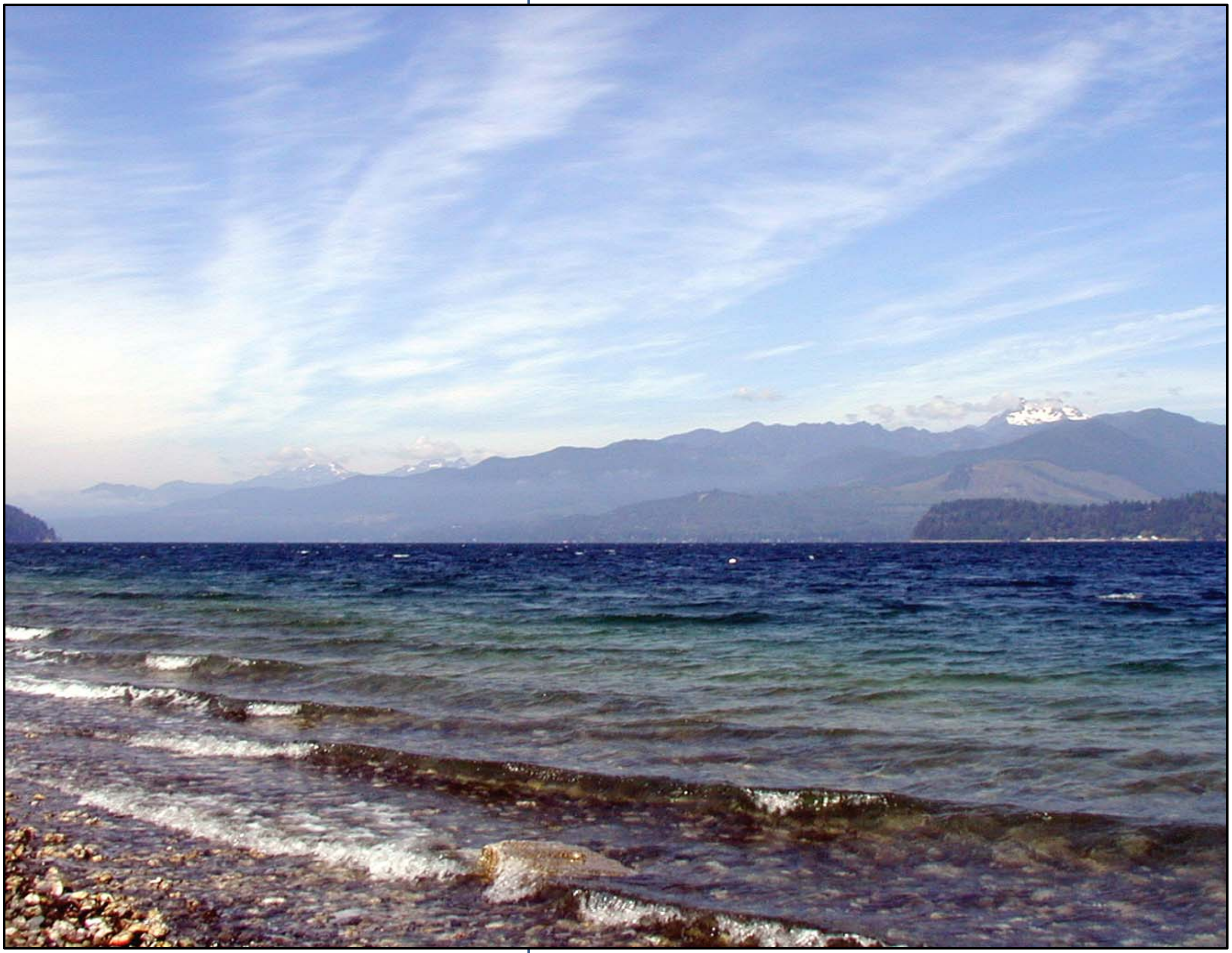
RIVER AND STREAM WATER QUALITY MONITORING PLAN FOR THE HOOD CANAL WATERSHED

PREPARED FOR
WRIA 16/14B PLANNING UNIT



PREPARED BY
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Prepared for

WRIA 16/14b Planning Unit

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Introduction

The Hood Canal region of Puget Sound is an ecologically sensitive area of particular cultural, economic, and recreational value to Washington State and tribal entities. Contamination at the mouths of freshwater streams has caused closures of commercial and recreational shellfish beds (Mason County Public Health 2007). High in-stream temperatures, degraded water quality, and poor habitat conditions seen in recent decades are believed to have caused the precipitous decline in Hood Canal salmon and steelhead runs seen in recent decades (Washington State Department of Fish and Wildlife 2010). Hood Canal has also seen increased frequency and duration of low dissolved oxygen events in marine waters, which resulted in significant fish kills (Hood Canal Dissolved Oxygen Program 2005). The Hood Canal region will also face significant future environmental changes caused by increased development and global climate change.

As documented in a recent monitoring inventory (Herrera 2010), several monitoring efforts (e.g., the Hood Canal Dissolved Oxygen Program and ongoing efforts of the Department of Ecology [Ecology], Kitsap County, Mason County and the Skokomish Tribal Nation) have produced valuable baseline water quality data and identified sources of impairment. Valuable information has also been gained from studies performed by Mason, Jefferson, and Kitsap counties and regional conservation districts, which examined specific water quality concerns related to fecal contamination and temperature.

However, many of these studies have been limited to subbasin-specific areas or specific problems. The long-term, multi-parameter studies conducted by Ecology and the Skokomish Tribal Nation are localized to specific areas and cannot support broad conclusions that can be applied to the whole watershed. Other studies have been too short-term or limited in the parameters measured to evaluate long-term trends.

Recognizing the limitations of these studies, the Water Resource Inventory Area (WRIA) 16/14b Planning Unit (Planning Unit) contracted with Herrera Environmental Consultants (Herrera) to develop a comprehensive, long-term monitoring strategy for streams that flow into Hood Canal. The purpose of this strategy is to provide a comprehensive evaluation of the current status of Hood Canal freshwater streams, and track trends in water quality over time. Through meetings and subsequent discussions, the Planning Unit selected the following primary objectives for this monitoring program:

- Develop a monitoring program to track long-term trends in water quality of selected area streams, to quantify how a range of stream metrics (chemistry, temperature, bacteria, and invertebrates) are changing over time in response to environmental alteration

- Develop a consistent, reliable, and accessible database, so that the full potential of the dataset (in terms of usability, accessibility, and robustness) can be realized

- Allow a range of monitoring intensity levels (tiers) that are easily customizable to promote valuable and efficient monitoring in several funding scenarios
- Acknowledge other critical monitoring needs that are not directly related to long-term water quality trend monitoring (e.g., investigative, research, and effectiveness monitoring)

Some of the identified uses of the data will include:

- Comparison of changes in pollutant (e.g., nutrients and bacteria) loads and yields over time at specific sites and between sites
- Evaluation of long term trends in stream flow and water temperature at basin and site specific scales
- This data, in combination with data collected through other programs (e.g., Ecology's Status and Trends monitoring program), will allow for a comprehensive assessment of the condition of Hood Canal streams and identification of site specific problems.

Though other water resource components such as groundwater, lakes, riparian habitat, and marine waters are important to the overall health of Hood Canal, the scope of this plan was limited to the evaluation of stream water quality. Stream water quality not only influences the biota (e.g., fish, plants, and invertebrates) present in these systems, it can also impact marine water quality of Hood Canal because streams are one of an important source of nutrients, sediments, and pathogens entering the canal. Establishing baseline conditions and evaluating long-term trends in water quality by implementing this plan will provide a basis for making future water management decisions. For example, deteriorating trends detected in all streams located in developed or developing basins would indicate that better basin-wide watershed management tools are needed, while those occurring at a site-specific scale would indicate that source identification or control work is needed. Changes happening across the entire watershed might indicate a more global change is occurring, such as those predicted by climate change models.

Stakeholder input was instrumental to the design and development of this monitoring strategy. Three meetings were held with the Planning Unit to shape the monitoring strategy to meet the needs of the stakeholders, and the plan was developed in steps. It began with agreeing on the main objective of the monitoring strategy (described above), discussion of various strategies for achieving the objective, and developing an inventory of existing monitoring efforts, then selection of key sites for monitoring. The following is a brief description of these steps. (A fifth step, development of a detailed Quality Assurance Project Plan [QAPP] for the monitoring strategy, is also underway.)

Other groups not well represented by the Planning Unit, such as Kitsap County representatives, University of Washington researchers, and Ecology staff, were contacted separately to discuss the monitoring approach, site selection and other concerns.

Strategy Development

Several approaches were considered for the development of this monitoring strategy; all would meet the primary objective of tracking long-term stream water quality trends. Each approach has been used for monitoring in the Hood Canal region and presents unique benefits and drawbacks. In an effort to reduce the total cost, special effort was made to try and choose an approach that integrates this plan with existing ongoing monitoring. The sections below present the monitoring approaches that were considered for this program.

Probabilistic Approach

A probabilistic approach to sampling, similar to the approach used by Ecology for its Status and Trends Program, was initially considered for this strategy. A probabilistic design requires that site selection be random. For example, each year approximately 10 stream segments would be randomly selected for monitoring. The next year, another 10 different stream segments would be randomly selected and monitored. Over time, there would be little or no overlap in the sites monitored except where this happens unintentionally through the randomization process. This design allows for making watershed-wide quantitative statements such as; “35% of all stream segments in Hood Canal are impaired in terms of fecal bacteria.” These quantitative statements can be easily compared between years to determine whether conditions are improving or deteriorating on a watershed-wide basis. The primary advantage of this method is that it eliminates sampling bias, which makes it possible to draw statistically valid conclusions about the entire watershed. In general, this is the most efficient method for assessing watershed wide trends, because less data (fewer sites and fewer sampling events) are required to draw conclusions.

However, several problems make the probabilistic approach unacceptable for this monitoring strategy. Probabilistic designs are not based on repeated visits to the same stream, so evaluating trends on a single stream is not possible. Sampling logistics would also be more complicated with this approach because stream segments are likely to be located far from easy access points. This would also involve obtaining access permission with new landowners every year; another important logistics consideration. The random site selection process also makes it difficult to incorporate existing monitoring.

Based on input from stakeholders and the Planning Unit, it was determined that the streams of highest interest to this plan are in developed or developing areas which are likely to be underrepresented by a probabilistic approach. Also, the Planning Unit was interested in obtaining information that could be used to focus efforts at site and basin scales.

Continuous Routine Monitoring

Continuous monthly monitoring is a widely-used strategy for assessing water quality trends and is already being used on several Hood Canal rivers and streams. This approach is well-suited to trend evaluation, because it provides a long-term record and can be used to evaluate year-to-year variability at the same site, and evaluating differences between sites and streams (assuming data from all sites was collected under the same conditions). Another benefit of this strategy is that the monitoring schedule is routine, making it easy to schedule and plan; an important consideration if multiple groups are involved in implementing the monitoring. It is also compatible with ongoing sampling efforts. Unlike a probabilistic approach, the inherent bias due to choosing streams non-randomly (e.g., because of existing concerns) means that it will likely take a longer time before statistically valid, watershed-wide conclusions can be made. Furthermore, continuous regular monitoring may be more costly if the goal is to obtain reasonable stream coverage over large sampling areas. Costs can be mitigated by visiting sites less frequently, but high water quality variability, especially during winter, may limit the utility of this approach. Also, routine monthly monitoring uses resources for monitoring time periods that provide less valuable data.

Another approach to continuous monitoring that addresses some of the above concerns is a seasonally stratified approach, where monitoring efforts are focused on critical time periods rather than being evenly spread throughout the year. This can be a quicker and more cost effective way of obtaining data that can be used for trend analysis. In the Puget Sound area, winter storms (between November and February) commonly result in high water quality variability, and the majority of nutrient and sediment loading occurs during this period. Higher frequency monitoring is needed during this time to capture the variability and estimate loads more accurately.

Conversely, as weather patterns stabilize into the spring and summer, water quality is less variable, and sampling can be reduced, relative to winter monitoring. Although water quality variability is lower in the summer, it is still a critical time period for Hood Canal streams because it is when temperatures are the highest and flows are the lowest, resulting in critical conditions for fish. The summer period also coincides with significantly increased population and recreational use of the watershed, therefore the contribution (load) of pollutants such as bacteria may increase. By monitoring only these critical time periods, more valuable data may be obtained through fewer samples than routine monthly monitoring.

One disadvantage of seasonally focused monitoring is that incorporating data from existing monthly monitoring programs is more complicated due to the misaligned sampling schedules. Furthermore, the high cost associated with routine, frequent monitoring likely allow monitoring of 10 to 12 sites at most. Although 10 to 12 sites would not provide a comprehensive evaluation of Hood Canal streams, these strategically targeted sites would provide valuable and consistent information which can stand alone or form the basis of a more comprehensive strategy.

Rotating Sub-Region Monitoring

Monitoring costs can be reduced by using a rotating sampling schedule where selected sites are sampled routinely for 1 year, but then not sampled again for 5 years. In the intervening years, a different set of sites is monitored. This approach allows greater spatial coverage for the same cost as continuous status monitoring of significantly fewer sites. Increased spatial coverage also allows for immediate land use and spatial comparisons.

The main disadvantages of this technique are that it takes a long time (decades) before trends can be assessed, and that results may be biased by annual weather variation rather than water quality variation, especially in the short term. There may also be a higher risk of losing funding for this type of program because it is not seen as providing an immediate benefit. This would jeopardize the value of all previously collected data. To make this type of monitoring feasible, the watershed would be divided into sub-regions and yearly monitoring designed around those sub-regions. Otherwise, sampling locations would be too dispersed to sample in a time-efficient manner.

Hybrid Approach

Hybrid approaches were also considered that included establishment of 'key' sites that follow the continuous routine monitoring approach, and establishment of 'secondary' sites that are either monitored following a rotating sub-region approach or following a probabilistic approach.

Selected Approach

The Planning Unit selected a hybrid approach that combines continuous, routine, seasonally-focused monitoring and the rotating subbasin strategy. This cost effective strategy reduces costs by limiting monitoring to only the highest priority streams in the watershed and to time periods of the greatest interest. Data gathered from monitoring at these sites is highly valuable because it provides a long-term, continuous data record that can be used for trend analysis after only a few years, and can potentially serve as an indicator of water quality in similar stream systems. Sampling a number of additional sites, from a given sub-region, every few years can serve to enhance spatial coverage, and augment the breadth and certainty of conclusions from routine monitoring.

This hybrid strategy lends itself to a tiered approach. For this monitoring strategy, Tier 1 will be routine monitoring that occurs every year at 10 to 12 sites in the watershed. This will form the foundation of this monitoring strategy by providing a long-term, continuous data record, and will provide invaluable long-term characterization data. Tier 2 will be the rotating sub-region approach.

For this plan, the Hood Canal Basin was divided into four sub-regions (Figures 4 and 5), which should allow for monitoring as many as 8 to 10 Tier 2 sites within a sub-region over a 1-day period. These sites would be monitored for a full year, and the next year a new sub-region would be selected for monitoring. This would allow for a 5-year rotating cycle so that sites in the original sub-region would be monitored again 5 years later. The rotating sub-region approach can use any sampling schedule, but a seasonally focused approach is recommended for Hood Canal for the same reasons it was recommended for Tier 1 monitoring. Tier 2 monitoring will greatly increase spatial coverage of the area while complementing the data gathered from regular monthly monitoring.

Inventory

An important step toward developing a new monitoring plan was to compile information regarding recent and ongoing monitoring efforts in the Hood Canal watershed. Federal, tribal, state, local agencies and other groups were contacted to develop inventory information on such details as the number and location of sampling sites, constituents measured, duration of data record, and future monitoring plans. This information was used to identify data gaps and concurrent monitoring efforts, and to determine the usefulness of existing data for evaluating baseline conditions in Hood Canal watershed streams. It became evident that while there have been (or are) a relatively large number and variety of monitoring efforts, the majority are short-term, targeted efforts to address specific problems. The few permanent water quality monitoring sites are concentrated in a few specific regions (Figure 4 and 5), so greater spatial representation of Hood Canal streams is needed.

Site Selection

Monitoring sites were selected based on geology, land use, level of impairment, degree of habitat degradation, flow concerns, and potential for future development. Figures 4 and 5 are maps of the watershed that show, among other attributes, salmonid presence, future consumptive water use concerns, and Category 5-listed waters (those defined by Ecology to "have data showing that the water quality standards have been violated for one or more pollutants, and there is no TMDL or pollution control plan").

Figures 2 and 3 depict current land use and development practices, and are included to provide context for site location selection. The goal was to choose a group of streams that span a range of the criteria listed above. There is a tendency to focus on the waterways that are currently the most impacted or already have impairment (e.g., Category 5) listings. However, because this monitoring plan aims to address trends in water quality, it is also important to assess some of the more pristine streams. The responses of these streams to environmental pressures, such as climate change, may provide more insight into the overall health of the Hood Canal watershed than the responses in the already impacted systems. Ultimately, it is most important to select a diversity of streams from a wide region to represent all watershed conditions.

Monitoring Strategy

The following strategy is meant to serve as a guide to direct long-term water quality monitoring in the Hood Canal basin. This strategy is intended to be implemented immediately and continue over the next several decades. It aims to provide enough data to evaluate trends in water quality in response to increased development in the Hood Canal watershed, and with climate change. This plan can be customized to meet specific budget constraints.

Different tiers, each representing greater monitoring intensity (and greater cost) have been identified to allow for flexibility with implementation. Tier 1 can stand alone as an independent monitoring program. Additional tiers build on Tier 1,and should be included in the plan as the budget permits. Each tier can also be tailored to meet specific budget guidelines by adding or subtracting components (e.g., parameters, number of sites, or frequency of sampling). Wherever reasonable, this strategy utilizes existing monitoring efforts to minimize duplicative monitoring, so that more funding is available for meeting priority monitoring objectives aimed at more comprehensive evaluation of the quality of surface water resources.

The majority of monitoring described in this strategy is referred to as long-term trend monitoring and is intended to establish a sound data record of standard water quality constituents. This plan also allows for targeted investigation of metals and organic pollutants, and evaluating biotic integrity through the sampling of aquatic macroinvertebrates. Research and effectiveness monitoring are also recognized as important long term needs. However, because these would be driven by a specific set of needs and objectives, they are mentioned, but not discussed in detail in this strategy.

Long-Term Trend Monitoring

The intention of this monitoring is to develop a long-term water quality record for examining between-season variability and long-term trends in surface water quality. There are three components or ‘tiers’ to long-term trend monitoring:

- **Tier 1**: Minimal coverage of the Hood Canal watershed, and would require continuous monitoring of flow and 10 sampling events to evaluate basic water quality parameters at 11 “key” sites, as described in more detail below.

- **Tier 2**: Adds a large number (10 to 40) of “secondary” sites which are sampled for a smaller set of basic water quality parameters on a rotating basis (i.e., 1 out of every 5 years). Within each tier there is the option to expand the set of parameters to broaden the scope of the study. Implementing both of these tiers would provide the best spatial and temporal coverage of water quality variables at the most reasonable cost.

- **Tier 3**: Assessment of stream riparian conditions, stream morphology changes, and habitat elements (large woody debris, pools and riffles, etc.) to form a broader, more qualitative assessment of stream and watershed health.

Tier 1 Monitoring

Site Selection

Tier 1 consists of long-term monitoring of selected "key" streams, chosen by the Planning Unit because they provide a good spatial distribution based on geology, land use, and vegetation, and represent varying levels of water quality and habitat degradation, in-stream flow concerns, and areas of future development. Appendix B lists all streams that were considered for this segment of the monitoring strategy and the evaluation criteria used to justify their selection. In total, 11 sites were identified for Tier 1 monitoring. The following explains why each site was selected. Figures 2 through 5 provide supporting information on topics such as land use, known water quality impairments, and potential water quantity concerns that were useful in making the site selections.

1. **Skokomish River:** The Skokomish River has the largest drainage area of any Hood Canal Stream and is, subsequently, the single largest freshwater input into Hood Canal. It has low residential growth potential due to a moratorium on development in the floodplain; however, it is affected by forestry activities, and the Skokomish River basin faces aggradation problems which pose concerns for future in-stream flows. The Skokomish Tribal Nation monitors water quality monthly at several sites. The US Geological Survey (USGS) and Ecology maintain flow gauging stations at a number of sites on the river.

2. **Jorsted Creek:** Jorsted Creek is representative of the many small- to medium-sized west shore drainages. There is currently development on Hamma Ridge within the Jorsted Creek watershed and moderate potential for development in the future. Jorsted Creek does not currently have any impairment listings, but fecal coliform may be of concern.

3. **Duckabush River:** The Duckabush River is one of the more pristine rivers in the Hood Canal watershed. It is also one of the larger drainages within the basin, with most of its drainage area in protected wilderness or Olympic National Park. Current land use is predominately forestry, with some rural residential development near the mouth. It is currently Category 5 listed due to elevated temperatures. Salmon habitat in the lower reaches is rated as poor (Aspect 2009).

4. **Big Quilcene River:** The Big Quilcene River is typical of the medium-sized drainages in Jefferson County on the Northwest shore of Hood Canal. There is a Category 5 temperature listing and fish passage may be of concern. Ecology has a permanent flow gauging station on the river.

5. **Big Beef Creek:** Big Beef Creek lies in one of the more developed watersheds in the Hood Canal region. Most of the land area is rural or suburban residential; only some of the watershed is forested. Residential growth potential in this region is high. There are currently Category 5 listings for dissolved oxygen and temperature in Big Beef Creek. Permanent flow gauging stations on Big Beef Creek are maintained by Ecology and USGS.

6. **Gamble Creek:** Gamble Creek is a small drainage with areas of dense development. It drains into the northern most region of this Hood Canal study area. This stream is representative of the small, developed streams throughout the west side of Kitsap County. Kitsap County Health District (KCHD) monitors fecal coliform bacteria monthly.

7. **Dewatto River:** The Dewatto River is a medium-sized, forested drainage in the central region of the Kitsap Peninsula. Timber harvest is ongoing within the watershed. Water quality in the Dewatto River is considered to be good, though it does have a Category 5 listing for fecal coliform. Ecology used to maintain a water quality monitoring site on the Dewatto River, which it has since abandoned. KCHD monitors the upper reaches for fecal coliform bacteria monthly.

8. **Union River:** The Union River is one of the largest drainages that flow into the north shore of the southern arm of Hood Canal. It is included in the list of impaired waters as a Category 5 stream due to low dissolved oxygen. There is a TMDL being implemented to control fecal coliform bacteria, but bacteria continue to be a concern. Development along the Union River is primarily rural residential, and is predicted to increase along with the Belfair urban growth area. Kitsap County Health District monitors a site on the Union River for fecal coliform.

9. **Tahuya River:** The Tahuya River is another large drainage that flows into the north shore of the southern arm of Hood Canal. It is Category 5 listed for dissolved oxygen. The watershed is fairly undeveloped, but has the potential for more development in the future. KCHD monitors the upper reaches for fecal coliform bacteria on a monthly basis.

10. **Big Bend Creek:** Big Bend Creek is typical of the small drainages on the south shore of the southern arm of Hood Canal. It is currently listed as a Category 5 stream due to fecal coliform contamination, and has the potential for increased residential development in the future.

11. **Trail's End Creek:** Trail's End Creek is listed as a Category 5 stream due to fecal coliform levels, and is a relatively undeveloped but developing south shore drainage of the southern arm.

Sampling sites on these streams are located at the mouths to capture the "end product" as the streams enter marine waters. Sites are identified in Figures 2, 3, 4, and 5. Ideally, river mouth sites would be sampled in conjunction with an upstream site to enable evaluation of changes in water quality conditions as the rivers flow through lower, more developed portions of the watershed. However, maintaining additional upstream sites on the 11 Tier 1 streams would be too costly for this tier of monitoring. The number of streams monitored in Tier 1 could be reduced so that paired upstream and downstream sites could be maintained for a reasonable cost. However, monitoring fewer streams than the 11 that have been selected would reduce spatial coverage to an unacceptable level.

The previous WRIA 16 surface water quality monitoring strategy suggested that upstream sites on the Duckabush and Dosewallips rivers could represent "background" conditions for all west side rivers. This strategy cannot be employed for the whole Hood Canal watershed because of significant variability in geology, climate, and land use between sites. Sampling exclusively on river mouth sites allows for the evaluation of whether water quality concerns exist within the watershed, even if it does not allow identification of specific pollutant sources.

Frequency and Parameters

Monitoring at Tier 1 sites will consist of six sampling events between November and February at approximately 2-week intervals, and three sampling events during July, August, and September at approximately monthly intervals. Once a specific schedule is established, it should be followed in subsequent years. The following is a list of the recommended parameters:

Field Parameters

- Temperature (via continuous data loggers)
- pH
- Dissolved oxygen (DO)
- Turbidity
- Conductivity
- Flow.

Lab Parameters

- Fecal coliform bacteria (FC)
- Total phosphorous (TP)
- Soluble reactive phosphorus (SRP)
- Total suspended solids (TSS)
- Total nitrogen (TN)
- Nitrate+nitrite nitrogen (N+N)
- Ultimate biochemical oxygen demand (BOD_{20})

Discharge (flow) measurement is critical to understanding water quality dynamics. Flow volume is vital for the productivity of salmon bearing streams in Hood Canal. Ideally, flow would be measured continuously at all Tier 1 sites, but high cost would likely prohibit it. A strategy for flow monitoring has been developed which capitalizes on existing efforts (Figure 6, Appendix A) and reduces the need to establish new gauging stations by relying on stream flow correlations with similar, nearby streams. Under this strategy, seven permanent and four temporary gauging stations would need to be maintained. Of the seven permanent stations, five are already gauged by USGS, Ecology, or Bremerton Public Works, so only two new permanent stations would need to be established. The four temporary stations would need to be maintained for a period of approximately 3 years while accurate correlations could be established. A detailed description on how such a strategy could be implemented is presented in Appendix A.

Monitoring basic water quality parameters at the 11 Tier 1 sites determines baseline conditions and provides insights into annual variability and long-term trends. Other measures of stream health besides water quality should be included in this tier of long-term trend monitoring, if funding allows. These components are listed below.

Aquatic Macroinvertebrate Sampling

Aquatic macroinvertebrate abundance and diversity estimates indirectly measure overall stream health and, therefore, can be good long-term indicators. Benthic Index of Biological Integrity (BIBI) scores are calculated from these assessments and can be used for tracking trends and making between-stream comparisons. Aquatic macroinvertebrate sampling could be scheduled to occur once every 2 years at Tier 1 sites. Though representative samples may not be gained by sampling invertebrates at only one site per stream, trends observed at that site presumably reflect changes that are affecting upstream and downstream areas.

Substantial changes in macroinvertebrate communities at the monitoring site could warrant a larger-scale investigative effort that targets several stream reaches. Sampling should be conducted between July 1 and October 15 to allow stream conditions to stabilize following spring floods. It also allows for macroinvertebrates to grow to a recognizable size, and the greatest percentage of invertebrates are in their pre-emergent form (Plotnikoff and Wiseman 2001). Data from these studies should be used to develop BIBI scores. BIBI scores use multiple metrics (e.g., taxa diversity, taxa distribution, and abundance) to evaluate stream health. King County Puget Sound Stream Benthos project has developed a BIBI scoring system specific to Puget Sound streams (King County 2009) that is recommended for use with this monitoring strategy.

Sediment Sampling

Metals and pesticides, though rarely concentrated enough to be measured directly in water samples, can accumulate in sediments where they can be taken up by shellfish and other invertebrates and enter the food chain. Urban and agricultural application is one way pesticides enter Hood Canal surface waters. Traffic and the associated roadway runoff is one of the largest sources of heavy metals in surface waters. As development of the region increases, it would be prudent to track trends in sediment metal and pesticide concentrations. Samples should be collected at each of the Tier 1 sites every 2 years unless there are indications of contaminants or contaminant increases, in which case annual monitoring should be implemented. Samples should be collected in summer when stream flows will have decreased enough to allow formation of good depositional areas for sediment sampling. This sampling may be coincident in time with macroinvertebrate sampling to optimize field monitoring.

Tier 2 Monitoring

Site Selection

Tier 2 monitoring is designed to produce data that augments the scope and breadth of Tier 1 monitoring. Tier 2 sites are selected to increase overall spatial coverage and allow for the determination of upstream conditions on several streams from Tier 1. The Hood Canal watershed was divided into four distinct sub-regions (Figures 4 and 5), defined to include 10 or more significant drainages while remaining small enough to sample in 1 day. Appendix C provides regionally grouped-sub-region lists of recommended sampling sites, some selection criteria, and ranking of priority for monitoring.

Special consideration was given to choosing secondary sites at upstream locations on Tier 1 streams. As discussed above, upstream sites will allow for the determination of anthropogenic impacts on water quality in the lower reaches. Establishing upstream sites on every Tier 1 stream is not necessary, but it should be ensured that at least one representative upstream site per sub-region, land use type, or geologic setting is chosen. When this plan is implemented, the number and identity of secondary sites is likely to deviate from the recommendations presented here. Appendix C should be consulted to aid the selection of additional sites.

Frequency and Parameters

Secondary sites selected for monitoring will be sampled concurrently with Tier 1 sites. The data gathered by this strategy will not be immediately useful for trend assessment because of the long time lapses between sampling years. However, within the first season, the data will be useful for making between stream comparisons. The parameters that will be measured are a subset of the parameters measured at Tier 1 sites and include; FC, TN, TP, TSS, Turbidity, DO, pH, temperature, and conductivity. Where secondary sites are upstream of a Tier 1 site, dissolved nutrients (N+N, SRP), and BOD should be measured so that datasets are comparable between upstream and downstream sites. Flow measurements should be taken at secondary sites whenever a sample is collected. Wherever convenient or financially feasible, continuous flow measurements are always preferred.

Optional Tier 2 Monitoring

Macroinvertebrate Sampling

Macroinvertebrate sampling as described for Tier 1 can be applied to Tier 2 sites as budget allows. The schedule for macroinvertebrate sampling would follow the same rotating sub-region approach so that sampling occurs once every 5 years at each site. As discussed above, the same data limitations due to sampling only one site per stream apply, however, where a Tier 2 site is upstream of a Tier 1 site, informal comparisons, especially regarding observed trends, between these sites may be made.

Tier 3 Monitoring

Habitat and Stream Morphology Assessment

Habitat and stream channel morphology assessment forms Tier 3 of this monitoring program. Stream habitat is created, maintained and changed through the dynamic interaction of natural hydrologic and upland processes, and human alteration. Habitat availability significantly impacts the productivity of a stream for salmonid reproduction and survival. Regular habitat evaluations are important, to identify problems and prioritize and implement appropriate restoration methods. Habitat evaluations can be performed on site, reach, or watershed scales. For this monitoring strategy, reach scale evaluation of the streams selected for long-term trend water quality monitoring would be appropriate. Habitat and stream morphology are typically not as dynamic as water quality, so infrequent assessments (e.g., every 3 to 5 years) should suffice.

There is also not the same need for temporally comparable data between streams, so habitat and morphology assessments can be completed during the summer when most streams are easily wadeable. Basic stream channel morphology measurements will already be made at 3- to 5-year intervals to calibrate flow monitoring equipment at all water quality monitoring sites. It may be most cost effective to combine more in depth habitat assessments with these efforts. Although it is a cost benefit that this monitoring does not need to occur annually, these types of programs have a greater risk of losing funding and continuity as organizations change and individual staff members priorities change.

WDFW (through their Intensively Monitored Watershed Project) and Ecology (through their Status and Trends program) are conducting some habitat assessments within the Hood Canal watershed. These efforts all use probability-based sampling designs, so routine assessments of the same stream location as proposed by this plan would complement the habitat data being collected by other agencies.

In addition to conducting typical habitat and stream morphology assessments, there may be added value in monitoring flow on a large number of streams during low flow periods. Appendix A details a program in which point flow measurements are taken in conjunction with evaluation of barriers to fish passage to determine the relationship between stream stage and fish passage problems. Results from these studies would be significant for individual streams and the Hood Canal watershed.

Even though habitat and stream morphology assessments are designated for Tier 3 monitoring, they are an important measure of stream and watershed health. Salmon usage and habitat condition were important selection criteria for choosing sites. Including habitat assessments on Tier 1 streams that currently support salmon runs, (Figures 4 and 5) should be considered before devoting resources to water quality monitoring at secondary sites. Though this strategy emphasizes water quality monitoring, the importance of salmon habitat condition as an important evaluator indicator of watershed health should not be overlooked.

Investigative, Research and Effectiveness Monitoring

The development and promotion of a long-term monitoring strategy does not imply that research and effectiveness monitoring is not equally important or necessary. Long-term trend monitoring, combined with other ongoing monitoring efforts, will likely result in discovery of water quality problems which merit additional study. Monitoring needs identified by the Planning Unit but not covered by the long-term strategy include:

- Evaluate the appropriateness of current impairment listings or the need for additional listings. Where key or secondary sites coincide with existing listings or new listing needs, the long-term strategy will be effective, but where they do not coincide, additional monitoring will be required.

- Evaluate the effectiveness of specific best management practices (BMPs) (e.g., low impact development, stormwater controls, agricultural BMPs, forest practices, and stream corridor BMPs) or new policies (e.g., wider buffers, reduced impervious area goals).

- Assess flow and water quantity limitations in streams where this information has not yet been developed. (Flow data collected under this strategy would certainly help to inform these studies.) Investigate pollution sources such as the targeted investigations of bacteria sources and effectiveness of source controls.

- Implement a stormwater sampling program to evaluate stormwater contributions of pathogens and nutrients into the marine waters of Hood Canal.

- Assess water quality of smaller surface water inputs (e.g., seeps, bulkhead drains, and runoff) along the shoreline of Hood Canal.

To the extent applicable, these monitoring efforts should follow the analytical methods and protocols laid out in the QAPP that is being developed for this strategy. It is also important that decisions about data management, specifically including a decision about whether data from these other monitoring efforts should be included in the watershed database, need to be made at the beginning of the study.

Roles and Responsibilities

While monitoring activities required for this plan may be performed by a combination of agencies and volunteers, it is crucial to identify a lead agency that has responsibility for implementing this monitoring plan and coordinating with other entities.

Data from existing monitoring efforts on Hood Canal is currently stored in multiple locations and formats, making it challenging and inefficient to acquire and organize data for evaluation. However, data storage and management for this project does not need to be a complicated or costly task. The existing Ecology Environmental Information Management (EIM) database lends itself well to this project as a data storage and management tool. The future ability to handle time series data, familiarity that many monitoring groups already have with EIM, and the fact that it already holds data for many Hood Canal sites, makes it the preferred choice. However, steps do need to be taken to insure that monitoring data are in fact- being accepted and uploaded to the EIM database. Having a dedicated data manager responsible for all data collected under this plan, regardless of who collected it, will make this process more efficient and more reliable. Using EIM and executing a reliable data management strategy will ensure the success of a long-term monitoring program for Hood Canal. It should be noted that EIM is only a data storage tool, and that the data must be downloaded to a spreadsheet or model to allow evaluation.

Data Evaluations

Data from the long-term trend monitoring portion of this plan will serve a variety of purposes. At a minimum the data should be used for regular reporting on the conditions of Hood Canal watershed freshwater resources. Following are the major data evaluation tasks that should be undertaken annually and described in a formal report. Details on these evaluations will be provided in the QAPP for this program.

- Calculate summary statistics to compare streams and seasons of interest.
- Identify water quality violations and improvements in monitored streams.
- Calculate pollutant load and yields to compare streams, as well as upstream and downstream sites on the same stream. As the database develops, comparison will be made between years for the same stream.
- Calculate the Water Quality Index (WQI) for each site and use this for comparison between sites and long term trend analysis.
- Calculate BIBI scores and subsequent trend analysis and comparison of trends between streams.
- Perform trend analysis for flow data for individual streams and compare to watershed wide trends, and extrapolate flows to ungauged streams in similar geo/climatic regions.
- Calculate 7-day maximum temperature and perform trend analysis to examine changes over time in individual streams.
- Compare sediment results to sediment quality standards.
- Compare long term changes in habitat and stream morphology (assuming Tier 3 habitat assessments are completed).

Resource Needs

This monitoring plan outlines an approach that specifies the number of sites, parameters, and frequency of sampling. These details are likely to change with the availability of financial and human resources. The tiered structure of this monitoring plan is intended to help prioritize monitoring efforts as funding specifics are defined. Tier 1 is the foundation of this strategy and will ideally be implemented in the full form that is presented in this strategy. Tier 2 and Tier 3 can be augmented in addition to Tier 1, and have been designed with flexibility so that specific components can be added to optimize efforts against funding constraints. The following is provided as a general summary of the resources that might be required for implementing this monitoring strategy.

Equipment

Implementing this monitoring strategy would require field meters (oxygen, pH, conductivity, turbidity, flow, and temperature), personal gear (waders, field vests, field notebooks), other miscellaneous equipment, and vehicle mileage costs. There is a wide range of costs associated with the initial purchase of this equipment, and similar variability in maintenance and calibration costs of field meters. Instead of making assumptions related to the cost to purchase and maintain this equipment, we have provided an estimated a daily use cost for rental of a "field pack" that includes all of this equipment and its maintenance needs. A rate of $100/day was used and should be enough to provide for long-term equipment replacement needs and calibration and maintenance needs for this equipment package. Continuous data-logging temperature sensors will also need to be purchased.

In sampling locations where flow gauging equipment (which continuously logs temperature) is installed, additional temperature probes will not be needed. A total of five temperature loggers will be needed to be placed at Tier 1 stations that will not be permanently gauged.

Analytic

Analysis of fecal coliform bacteria, nutrients, biochemical oxygen demand, and total suspended solid samples all require laboratory support and an analytical cost. Aquatic macroinvertebrate sorting and classification and sediment analysis require laboratory support as well. Table 1 summarizes analytical costs on a cost per sample and average annual basis for Tier 1 monitoring.

The estimated cost for water quality samples is $135 per sample, or $1,620 per event. Analysis of sediment metals and pesticides is estimated at $660 per sample, or $7,920 per event. Although costly on a per sample basis, since these samples are only collected once every 2 years the total additional annualized cost is less than $4,000 (Table 1). Macroinvertebrate identification costs are estimated at $300 per sample, and assuming a biennial sampling frequency, add $1,800 per year to the cost of the program. Other incidental costs such as field equipment rental and sample shipping are estimated at $4,000/year. Based on these costs the total annual analytical cost for

Tier 1 of this program is $25,960. Since analytical costs can vary, a planning level cost estimate of $35,000 has been assumed and used in cost summary below.

Table 1. Estimated costs for Tier 1 water quality monitoring.

Parameter	Cost Per Sample	Samples Per Event [a]	Events Per Year	Total Cost
Fecal coliform bacteria	$20.00	12	10	$2,400
Total suspended solids	$15.00	12	10	$1,800
Biochemical oxygen demand$_{20}$	$30.00	12	10	$3,600
Nitrate + nitrite nitrogen	$15.00	12	10	$1,800
Total nitrogen	$25.00	12	10	$3,000
Soluble reactive phosphorus	$15.00	12	10	$1,800
Total phosphorus	$15.00	12	10	$1,800
Water quality analysis cost [b]	$135.00	12	10	**$16,200**
Macroinvertebrates				
Macroinvertebrate	$300.00	12	0.5	**$1,800**
Sediments				
Metals	$200.00	12	0.5	$1,200
Organochlorine Pesticides	$165.00	12	0.5	$990
Organochlorine Herbicides	$260.00	12	0.5	$1,560
Total Organic Carbon	$35.00	12	0.5	$210
Sediment Analysis Cost	**$660.00**	**12**	**0.5**	**$3,960**
Other Expenses				
Sample Shipping [c]	$100.00	2	10	$2,000
Field Equipment Rental [d]	$100.00	2	10	$2,000
Total Annual Analytical Cost	**N/A**	**N/A**	**N/A**	**$25,960**
Planning Level Analytical Cost				**$35,000**

[a] There will only be 11 samples collected; however, an estimate of 12 has been used to account for field QA samples.

[b] Listed values are based on 2010 estimates from Aquatic Research Inc. in Seattle, Washington.

[b] This value reflects an estimate of $100 per day of sampling in shipping costs. This would cover use and a replacement plan for field meters and other field gear necessary for the monitoring. Cost estimates assume 2 days of usage per “event”.

[d] These values assume $100 field rental cost for each day of sampling.

Costs associated with Tier 2 monitoring have not been calculated since this program is optional and it is unknown how many sites might be sampled. However, based on the analytical costs in Table 1, a reasonable planning level cost of $125 per sample would apply to Tier 2 sites, based on not performing the biochemical oxygen demand or dissolved nutrient analyses. The cost of macroinvertebrate identification is still $300 per sampling event, but would not be averaged over 2 years, because invertebrates will be monitored in all years that water quality samples are collected. Monitoring Tier 2 sites will also require an additional day of sampling, which will incur another day of field rental and shipping charges. The annual analysis cost for a Tier 2 site, including macroinvertebrate sorting is estimated at $1,675. A planning level estimate of $1,800 would include 11 water quality monitoring events, 1 macroinvertebrate collection event, plus the additional shipping and field equipment rental and sample shipping costs.

Flow and Temperature Monitoring

There are two categories of cost associated with obtaining continuous streamflow (discharge) and temperature measurements: the initial cost of purchasing and installing the equipment, and the recurring cost of maintaining the station. There is a wide range of variability associated with both of these categories. The cost variability is dependent on the type of equipment used, and the number of times per year the site is visited for rating curve measurements. These costs partly depend on individual site needs (i.e., streams subject to higher flows require more rugged equipment; bedrock streambed requires less frequent rating curve calibration), but also depend on required reliability and longevity of the equipment. The information presented below represents a range of cost scenarios, and Table 2 presents a reasonable planning level estimate for the stream and temperature gauging portion of this monitoring program.

Table 2. Cost estimate for proposed Tier 1 Flow and Temperature Gauging Stations.

Station Type	Equipment & Installation Cost per Station [a]	Annual Maintenance Cost per Station [b]	Number of Proposed Stations	Total Installation Cost	Total Annual Maintenance Cost	Number of Years Operating	Lifetime Cost [d]
Flow							
Permanent	$17,000	$5,500	2	$34,000	$11,000	Indefinite	N/A
Temporary	$3,500	$5,500	4	$14,000	$22,000	3	$80,000
Temperature	$200	NA	5	$1,000	$100	Indefinite	
Total Cost	N/A	N/A	7	$49,000	$33,100[c]	N/A	N/A

[a] Installation cost per station is based on a $2,000 labor cost and $1,500 equipment cost for temporary stations, and $2,000 labor cost and $15,000 equipment cost for permanent stations.

[b] Maintenance cost per station is based on an average consulting cost from comparable projects, and assumes a 10% overestimate to cover infrequent replacement of damaged equipment.

[c] This estimate reflects maintenance of both temporary and permanent flow and temperature monitoring stations. This cost will be reduced to $11,100 per year when the temporary stations are abandoned.

[d] Lifetime cost of the temporary stations includes all equipment purchase, installation, and maintenance costs over their 3-year deployment.

Installation

USGS and Ecology maintain several gauging stations throughout the watershed (Figure 6). These stations use expensive equipment which is both rugged and highly accurate. The equipment cost of these stations is approximately $15,000. Less expensive pressure transducers are available at costs as low as $1,200. For the purpose of this cost estimate, a cost of $15,000 per site is assumed for the permanent gauging stations and $1,500 has been assumed for less expensive temporary units. These units generate accurate data; however, they are not designed to withstand the rigors of multi-year deployment, and cannot be expected to last more than a few years. In terms of this project it may be most cost effective to install the more expensive gauging equipment at the two new stations which will be monitored indefinitely, and rely on less expensive equipment at the temporary stations (Figure 6).

The labor cost associated with flow gauging station establishment is also substantial. Site accessibility and stream morphology can influence the effort required. A typical stream gauging site installation which includes site selection, equipment installation, and an initial discharge measurement, represents about 16 to 20 hours of work, or about $2,000. The temperature dataloggers are comparatively inexpensive to purchase and install. Assuming a cost of approximately $200 per unit and installation at five sites, the total equipment cost would be $1,000. A replacement cost of 10 percent per year should also be included, as part of the long term cost. Installation and calibration checks would be done simultaneous to flow gauging station installation and rating curve development.

Maintenance

Proper operation of flow gauging stations requires frequent, routine site visits. During these visits, equipment is inspected, data is downloaded, and true discharge is measured to maintain or establish a rating curve. USGS assumes an annual maintenance cost of nearly $17,000 per station and Ecology assumes a cost of $10,000 per station. These values include at least nine site visits for rating curve development and equipment maintenance and eventual equipment replacement costs. The cost of maintaining a flow gauging station is dependent on the number of site visits per year for scheduled equipment maintenance and rating curve development. The quality of the data generated improves with the number of rating curve points, and six rating curve points reflects the minimum that could still be expected to generate high quality data.

Previous stream gauging conducted on small streams within the Hood Canal watershed generated an annual maintenance cost of approximately $5,000 per site, which reflects six rating curve points (Lubischer, J. pers. comm.). An average annual cost per station of $5,500 is used to allow for periodic equipment replacement.

Flow Monitoring Cost Summary

The permanent and temporary monitoring sites proposed for the flow monitoring portion of this strategy each has specific equipment needs. More durable (and therefore more expensive) equipment is needed at the permanent stations, whereas less expensive equipment may be adequate for the temporary stations. The $17,000 (equipment and installation) per site for the two permanent stations, and a cost of $3,500 (equipment and installation) per site for the four temporary gauging stations results in an initial implementation cost of $48,000 plus $1,000 for temperature data loggers (Table 2.) The maintenance cost of each station, permanent or temporary, is $5,500. For the first 3 years of the project, when all six stations are being maintained, the annual maintenance cost will be $33,100. After approximately 3 years, when reliable correlations in discharge between temporary and permanent station have been established (as discussed in Appendix A), only the two permanent stations need to be maintained. Maintaining these stations will cost $11,100 per year (Table 2).

Personnel

Table 3 outlines the expected time investment and estimated cost investment for individual components of Tier 1 of this monitoring strategy. It does not include personnel time associated with flow monitoring, since that was included in the previous section, but does include time for evaluation of the flow data. The estimated personnel time required for routine sample collection for Tier 1 monitoring is 32 hours per event. This assumes two 10-hour field days, and two 6-hour periods for preparation and clean up. It is assumed that aquatic invertebrate samples could be collected by one person over a 4-day period, and sediment samples could be collected over a 2 day period. Tier 2 sample collection would add an additional 10 hours of labor time for routine sample collection.

Table 3. Estimated annual average personnel cost for Tier 1 water quality monitoring.

Task	Number of Hours Per Event	Cost Per Event [a]	Number of Events Per Year [b]	Total Cost
Routine Sample Collection	32	$3,200	10	$32,000
Macroinvertebrate Sampling	40	$4,000	0.5	$2,000
Sediment Sampling	20	$2,000	0.5	$1,000
Flow Data QA and Analysis [c]	200	$20,000	1	$20,000
Data Entry and QA	6	$600	10	$6,000
Data Management	60	$6,000	1	$6,000
Reporting	120	$12,000	1	$12,000
Ecology EIM Staff Time	10	$1000	1	$1,000
Total Personnel Cost	**N/A**	**N/A**	**N/A**	**$80,000**

[a] Cost per event is estimated assuming a fully-loaded $100 hourly rate. This rate covers direct salary plus indirect expenses (benefits, office space, administrative overhead, etc.).

[b] In cases where sampling is recommended on a biennial basis, a value of .5 events per year were used.

[c] Approximately 400 hours will be needed in the first year of flow monitoring for database and correlation model development.

There is a significant amount of time required for routine water quality data entry and QA, and annual reporting and database management. Analyzing continuously generated hydrologic data, is a time consuming task as well, and should be completed by a professional hydrologist. Since this program relies on stream flow correlations, a significant amount of time will be needed for a hydrologist to analyze data and model these correlations in addition to standard flow data management. 200 hours per year have been allocated for flow data management tasks. Assuming that EIM is used as a data management system, Ecology EIM support staff time needs to be budgeted, so it is also included in Table 3.

Assuming a fully loaded hourly labor rate of $100, the total annual cost of Tier 1 monitoring would be $80,000. This estimate includes associated QA and data management activities, but does not include the time spent establishing and maintaining flow gauging stations, conducting flow monitoring, or other support activities. However, flow gauging personnel costs are included in the flow monitoring estimates (Table 2).

Summary

Implementing this strategy will be a major step towards developing a comprehensive evaluation of the current water quality status of freshwater streams in the Hood Canal watershed. Previous monitoring conducted by the Planning Unit and the HCDOP have demonstrated the importance of water quality monitoring in this complex region, but also the ability of the diverse groups to cooperate and collaborate to reach a common goal. The data generated by this project will complement and enhance the findings of those previous studies. Ultimately, the findings of this and other complementary projects will aid in predicting and responding to changes in water quality and other biological indicators as the Hood Canal watershed responds to increased environmental pressures.

Specific details of this monitoring strategy are likely to change as funding availability and constraints are determined. However, the tiered structure of this plan ensures valuable and effective monitoring will occur under a wide range of funding scenarios. Overall, an annual cost for implementing the main component of this strategy (Tier 1) has been estimated at approximately $35,000 for sample collection and analysis, $80,000 for personnel time for field collection, data management and analysis, and between $11,100 and $33,100 for flow and temperature gauging station upkeep. An additional $49,000 will be needed at the start of this program to purchase and install flow and temperature gauging equipment.

There may be inherent scientific value beyond the primary goals identified for implementation of this surface water monitoring strategy. As the regional and global environment faces new changes, challenges, and stressors in the coming decades, a well-documented record of how these changes affect the water quality of the Hood Canal region may provide valuable insight into how similar systems respond.

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FIGURES

HERRERA ENVIRONMENTAL CONSULTANTS

Aspect CONSULTING

Project Location Map

DATE:	June 2010
PROJECT #:	090147
DRAWN BY:	PPW
REVISED BY:	PPW

FIGURE # 1

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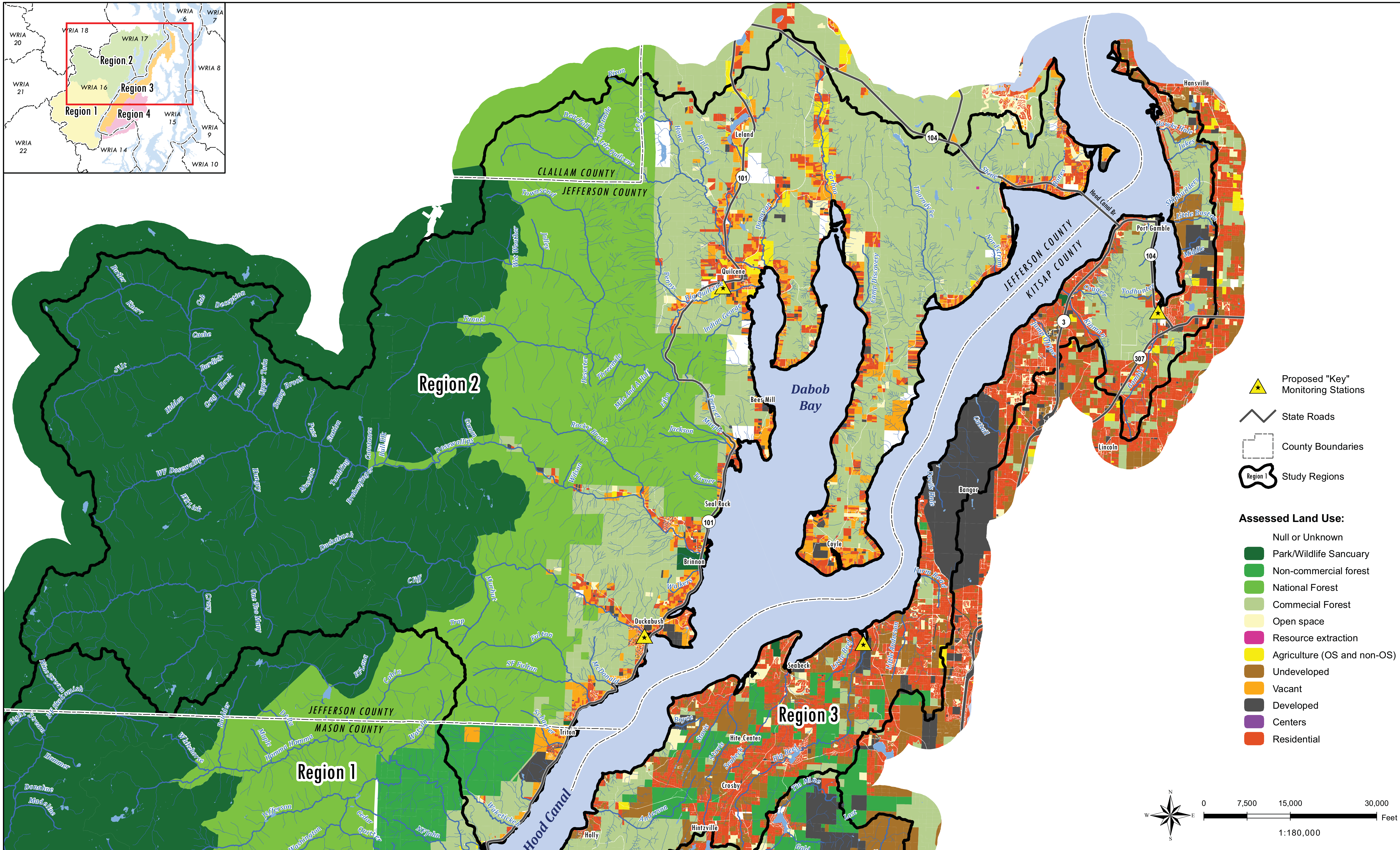

HERRERA ENVIRONMENTAL CONSULTANTS

Aspect CONSULTING

Land Use and Proposed "Key" Monitoring Stations
Northern Hood Canal Watershed

DATE: June 2010
PROJECT #: 090147
DRAWN BY: PPW
REVISED BY: PPW

FIGURE # 2

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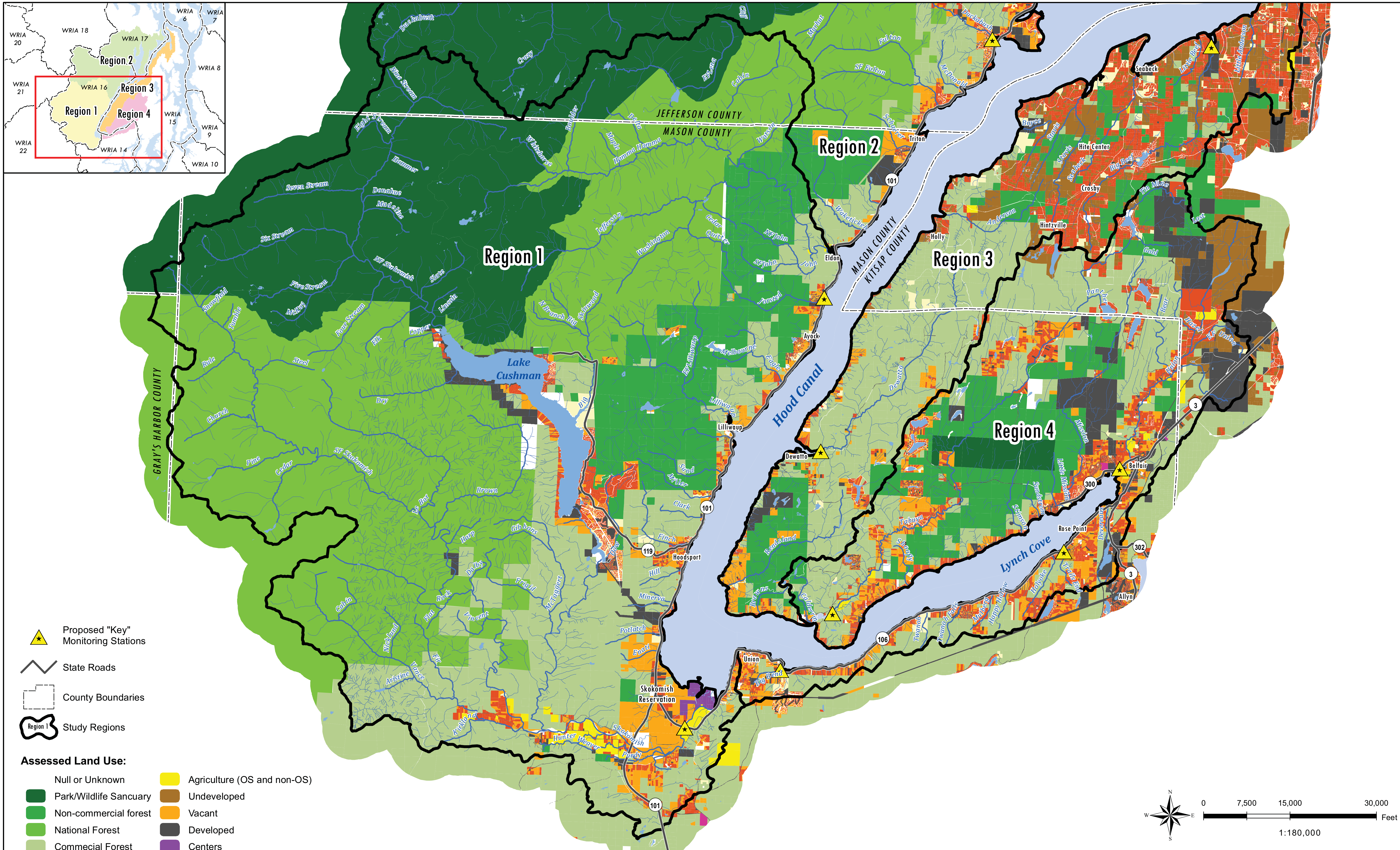


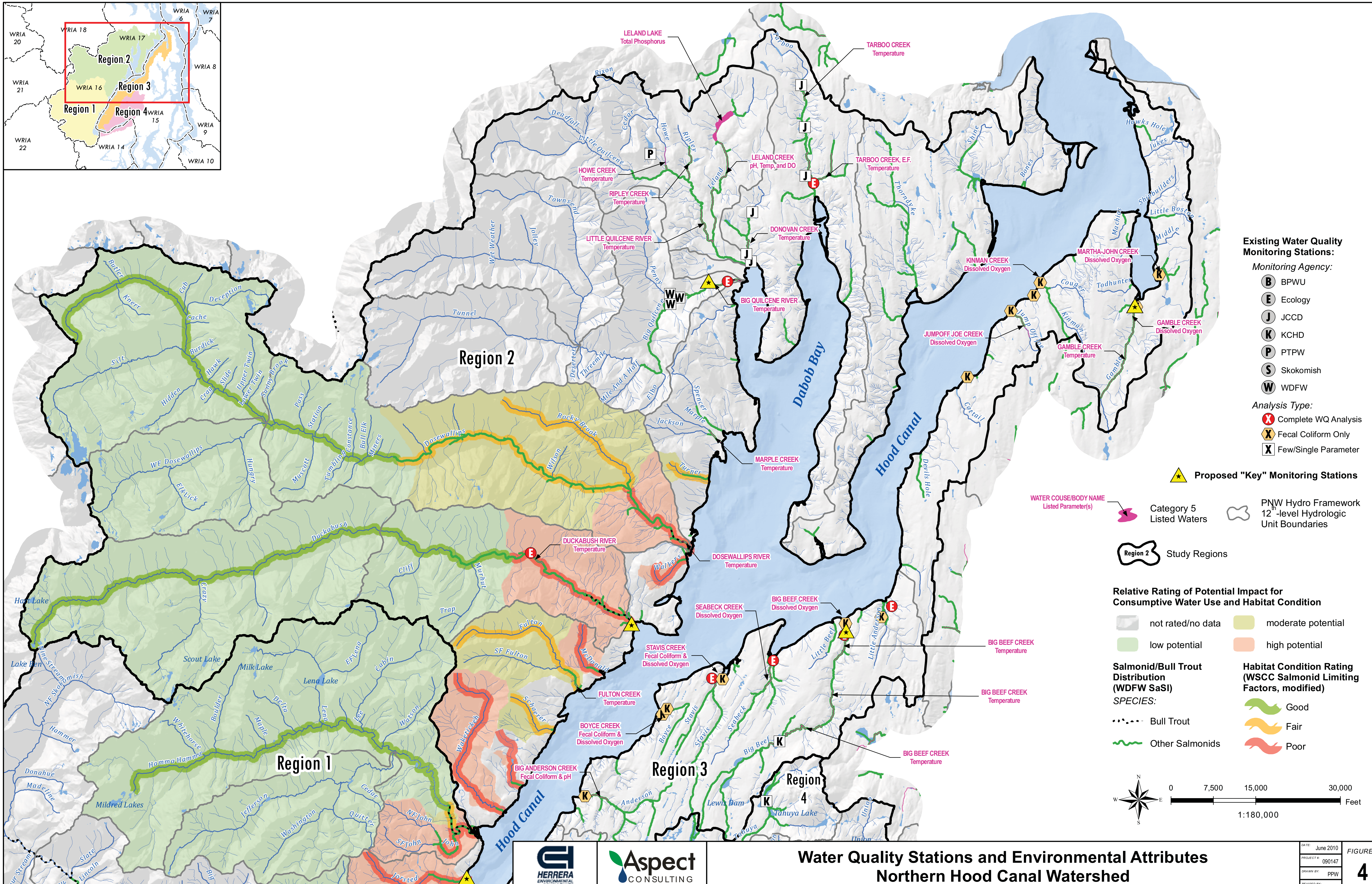
HERRERA ENVIRONMENTAL CONSULTANTS

Aspect CONSULTING

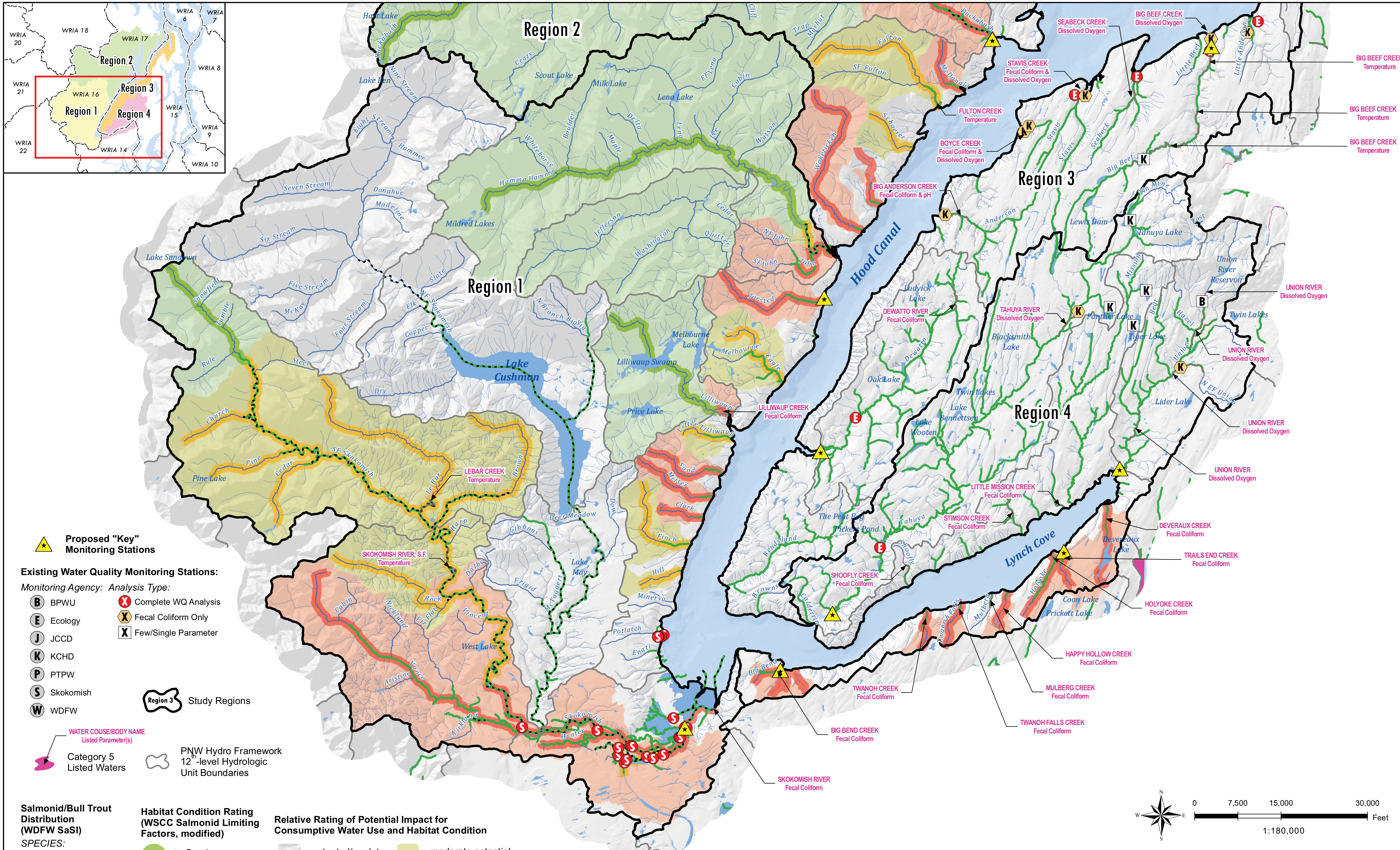
Land Use and Proposed "Key" Monitoring Stations
Southern Hood Canal Watershed

DATE: June 2010
PROJECT #: 090147
DRAWN BY: PPW
REVISED BY: PPW

FIGURE # 3



Water Quality Stations and Environmental Attributes
Northern Hood Canal Watershed



HERRERA ENVIRONMENTAL CONSULTANTS

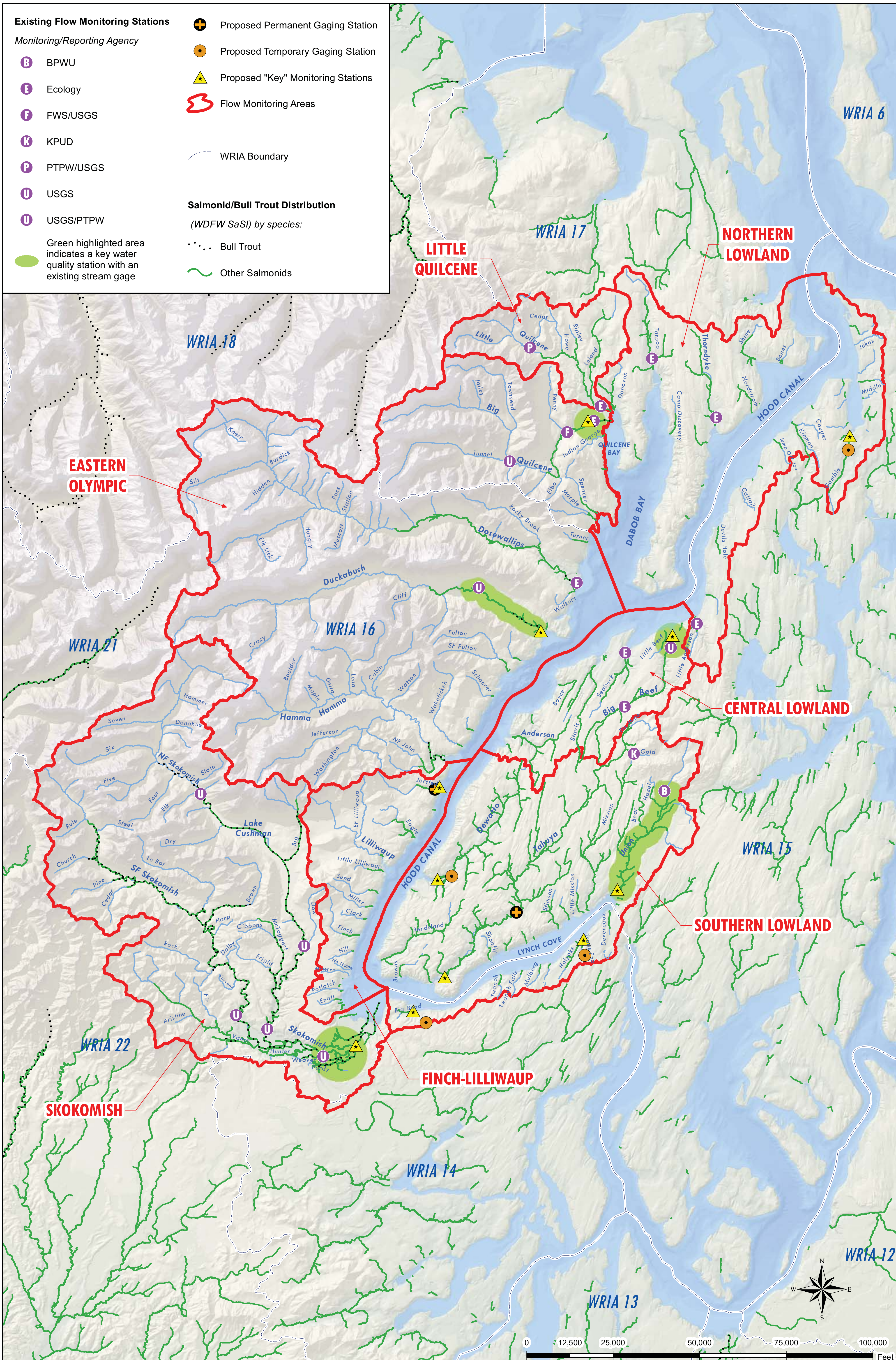
Aspect CONSULTING

Water Quality Stations and Environmental Attributes
Southern Hood Canal Watershed

DATE: June 2010
PROJECT #: 090147
DRAWN BY: PPW
REVISED BY: PPW

FIGURE # 5

T:\projects_8\WRIA16\HoodCanal_SW_Mon_Plan\Delivered\MonitoringStrategy\Bio_South.mxd



Geoclimatic Regions and Proposed Flow Gauging Stations

FIGURE # 6

APPENDIX A

Stream Flow Monitoring

Stream Flow Monitoring

1.1 Proposed Strategy

The proposed watershed level strategy for gauging stream flows in the Hood Canal watershed consists of the following elements:

- Maintain at least one permanent monitoring station in each of seven flow monitoring areas to serve as base stations for interstream flow correlations
- Installation of permanent staff gauges and temporary gauging stations at key water quality stations that are located on ungauged streams
- Development of interstream correlations for ungauged streams with key water quality stations
- Establishment of a pilot program to measure fall flows on multiple streams and determine whether instream flows can be correlated between streams

1.2 Flow Monitoring Areas

Figure 6 presents seven proposed geoclimatic areas where at least one gauging station should be permanently maintained. Delineation of these areas is based on general characteristics of discharge pattern, precipitation, slope, and surficial geology.

The **Eastern Olympic** area is characterized by a snowpack dominated discharge pattern, high precipitation (70 to 140 inches per year depending principally on elevation), steep mean slope (greater than 40%), and a high bedrock percentage. The **Skokomish** area has similar traits but is particularly impacted by logging and dam construction. The **Northern, Central, and Southern Lowland** areas are characterized by precipitation dominated discharge patterns, lower mean slope (less than 30%), and little near-surface bedrock. The lowland areas are distinguished by the approximate range of annual precipitation, i.e., 25-40, 40-60, and 50-70 inches per year for northern, central, and southern areas, respectively.

The remaining two areas may be considered intermediary. The **Little Quilcene** has a mixed discharge pattern that varies from year to year, sometimes showing a clear snowmelt signal and in other years presenting as precipitation driven discharge. Mean slope is similar to the Lowland areas, whereas mean elevation is intermediary between Eastern Olympic and Lowland areas, and the precipitation range of 40-120 inches per year is more similar to the Eastern Olympic area. The **Finch-Lilliwaup** area is generally similar to the Lowland areas, but has a significantly higher precipitation range of 60-100 inches per year.

1.3 Current Gauging Efforts

The following agencies are now conducting active flow monitoring in the Hood Canal watershed at 20 gauging sites (Figure 6):

- USGS (8 sites)
- Ecology (8 sites)

- Kitsap PUD #1 (1 site)
- Bremerton Public Works and Utilities (1 site)
- Port Townsend Public Works (1 site)
- U.S. FWS (1 site)

All sites are continuously monitored except for the Port Townsend and FWS sites on the Little and Big Quilcene Rivers, respectively. Continuous data is available from USGS, Ecology, and KPUD websites.

1.3.1 Flow Monitoring Agencies

USGS gauging locations are primarily in the Skokomish drainage, where 5 sites are monitored. Two additional sites in the Eastern Olympic area are on the Duckabush and Big Quilcene Rivers. The remaining station is at Big Beef Creek on the east shore of Hood Canal. The USGS also provides rating curves for the Port Townsend site on Little Quilcene and for the FWS on Big Quilcene.

Ecology's efforts are focused in two areas. There four stations in the southern portion of WRIA 17and three locations in the Intensively Monitored Watershed (IMW) on the east shore of Hood Canal. The IMW monitored streams include Little Anderson, Big Beef, and Seabeck creeks. Additionally, Ecology re-established a site at the mouth of the Dosewallips River.

Kitsap PUD monitors Gold Creek in the upper part of the Tahuya River drainage.

Bremerton Public Works and Utilities (BPWU) monitors flow downstream of Casad Dam on the Union River. Flow is measured primarily for the purpose of maintaining minimal flow and generation of hydrographs may involve aggregating data from different gauging structures.

Port Townsend Public Works and **FWS** contract with USGS to maintain rating curves for their sites on the Little and Big Quilcene Rivers, respectively. Staff gauge readings are made regularly, but this data may require processing to provide useful hydrographs.

1.3.2 Gauging in Flow Monitoring Areas

Except for the Southern Lowland and Finch-Lilliwaup areas, all other defined monitoring areas have long-term, continuous gauging stations. The Skokomish area is well monitored by five USGS stations. The Eastern Olympic area has four stations, located on Duckabush, Dosewallips, and Big Quilcene rivers. In the Little Quilcene area, the Little Quilcene River is gauged by Ecology.

Ecology maintains stations in the Northern Lowland area on Tarboo and Thorndyke creeks. The Central Lowland area is currently very well monitored for its size as part of the WDFW IMW program. Flow in that area is monitored on Little Anderson, Big Beef, and Seabeck creeks.

In the Southern Lowland area, Gold Creek and Union River are gauged. However, Gold Creek is only a minor contribution to the Tahuya River flow. The Union River data, if sufficiently continuous, may be useful for the key water quality station at the mouth, but the dam controlled flow would not be useful for interstream correlations.

No streams are monitored in the Finch-Lilliwaup area.

1.4 Proposed Gauging Stations

Additional permanent, continuous flow gauges are recommended for the Southern Lowland and Finch-Lilliwaup areas. Temporary stations are recommended at the five ungauged key water quality sites. Establishing temporary stations would consist of installing a pressure transducer, determining a rating curve, and collecting continuous data for correlation with a base station. One temporary site (Finch Creek) would require permanently maintaining a rating curve. A minimum period of three years is suggested for continuous monitoring, but this time period is dependent upon results and longer periods yield improved correlations.

Tentative locations for the proposed stations are presented in Figure 6. Actual locations would depend upon field inspections and landowner approval.

Specifically, new permanent gauges are suggested for one creek in the Finch-Lilliwaup area, such as Jorsted Creek, and either Dewatto or Tahuya River in the Southern Lowland area. Temporary stations and development of correlations with base stations are suggested for key water quality stations at Gamble Creek in the Northern Lowland area, and either the Dewatto or Tahuya River, Trail’s End Creek, and Big Bend Creek, the latter three being located in the Southern Lowland. A pressure transducer and rating curve will need to be maintained at Finch Creek in the Finch-Lilliwaup area.

In the Southern Lowland, previous stations were located on the Dewatto and Tahuya Rivers, which are also recommended as key water quality stations. Either river is a good candidate for a base station to be used for stream correlations. A new site may be located further upstream than previous installations to provide more stable bottom conditions and improved hydraulic control. A temporary gauge should be installed at the key station on the ungauged river and correlated to the base station. HCSEG has collected previous data and generated rating curves for both rivers. That information should be evaluated for use in determining correlations and, possibly, reducing the need for temporary gauging.

For the key water quality station on the Union River, it is assumed that flow data from Bremerton Public Works and Utilities can be leveraged to meet needs for water quality analysis. If this assumption proves incorrect, a temporary station would be needed.

Along the south shore of Lynch Cove, temporary gauges and interstream correlations with base stations would be required for both Big Bend and Trail’s End creeks.

For the Finch-Lilliwaup area, a permanent gauge could be reinstalled on Jorsted Creek, which would supplement previously acquired data (Aspect Consulting, 2005). Selection of another stream in the area would also be feasible. At Finch Creek, the hatchery at the creek mouth is fed by an upstream diversion. Therefore a staff gauge and rating curve will be required to measure the undiverted flow. As the creek cannot be correlated with a base station, a rating curve will have to be maintained over time.

In the Northern Upland, a temporary station and correlation with a base station is required on Gamble Creek.

1.5 Interstream Correlations

Three previous studies have provided information on interstream correlations. Aspect (2005) monitored six streams on the west side of Hood Canal for one year and provided initial interstream correlations. More recent data was collected on those streams by HCSEG. Paulsen (2006) used historic USGS stream flow data to develop estimated mean annual discharges of ungauged streams based solely on basin area. The HCDOP modeled discharges using the Distributed Hydrology Soil Vegetation Model (DHSVM) program. That work was not reviewed for this report, but results of the model may be leveraged to propose and evaluate interstream correlations.

Development of interstream correlations is a significant work element for supporting the key water quality stations, in particular, and different scientific analyses in the Hood Canal watershed, in general. Aggregating the flow data collected by USGS, Ecology, HCSEG, and Kitsap PUD presents an opportunity for leveraging these monitoring efforts. The required support for data management is discussed further below.

1.6 Instream Flow Correlations

Stream gauging and interstream correlations have historically focused on higher flows. However, the low fall flows—instream flows—are of particular interest for preserving and restoring salmonid runs. Therefore, a pilot program is suggested to determine if effective interstream correlations can be made at low flows. The pilot program would consist of point-in-time flow measurements throughout the watershed on approximately fifty streams, and be teamed with fish passage studies to interpret the significance of specific stage levels. Results are expected to be significant on both individual stream and Hood Canal wide levels.

A watershed low flow survey would be performed only once per year, but for meaningful results at least a five-year period of monitoring is suggested. Planning level program costs for the flow monitoring component are estimated at about $20,000 per year. Costs of the fish passage component will need to be estimated separately by a fisheries professional. Though stream flow monitoring is expensive, the proposed program of annual multi-stream measurements is expected to be relatively inexpensive as no capital costs are incurred and measurements would be made at low stages.

1.7 Data Management

At this time, there is no group that compiles and analyzes all the flow data available for the Hood Canal watershed. Rather, each individual analysis presently requires acquisition of data from source agencies and one-time processing, unrelated to past or future studies. Therefore, there is a clear opportunity (and need) to improve stream discharge analysis by combining data in a central database for analysis of interstream correlations and interstream low flow correlations. This aggregation of data would also create options for integrating stream flow analysis on a Hood Canal-wide basis with other data sets, such as from the proposed water quality effort.

It is recommended that Hood Canal stakeholders discuss the determination of the best structure for combining and analyzing flow data. In addition to deliberations within the WRIA 16 Planning Unit, data management should be part of the Hood Canal Integrated Watershed Plan currently being prepared by HCCC (2010).

APPENDIX B

Streams Considered for Monitoring

Streams Considered for Monitoring*

Monitoring Plan Region	Water Body	Size of Basin (S, M, L)	Concern for Future Instream Flow (High, Med, Low)	Known Water Quality Problem	Known Habitat Condition or Potential for Impairment	Salmon Run (SASI 2002)	Current Land Use	Growth Area (High, Med, Low)	Ongoing Water Quality / Flow Gauging?	Stream Included in HCDOP?
Southwest Shore										
West Side (South)	**Lower Skokomish River**	**L**	**High (aggradation)**	**Fecal Coliform 4A**	**High Potential for Stream Impairment**	**Several Species listed as Depressed**	**Forestry/Ag. Residential**	**Low**	**WQ: Skokomish Tribe Flow: USGS**	**Yes**
West Side (South)	**Jorsted Creek**	**S/M**			**Poor Habitat in Lower Reaches**		**Forestry Rural Residential**	**Low/ New devel. on Hama Ridge**		**Yes**
West Side (South)	Finch Creek	S	Medium	Fecal Coliform Category 2	Fair Habitat High Impairment Potential		Forestry	Medium	No	Yes
West Side (South)	Lower Hamma Hamma	L	Low	pH Category 1	High Potential for Stream Impairment	Most Runs Rated as Depressed Or Critical	Forestry	Low	Flow: Former USGS	Yes
West Side (South)	Lilliwaup River	M/L	High	Fecal Coliform Category 5/303(d)	Poor Habitat in lower reaches	Summer Chum Rated as Critical	Forestry	Low	No	Yes
West Side (South)	Hill Creek	S	Medium		Fair Habitat		Forestry	Low	No	Yes
West Side (South)	Miller Creek	S	High		Poor Habitat		Forestry Rural Residential	Low	No	Yes

Monitoring Plan Region	Water Body	Size of Basin (S, M, L)	Concern for Future Instream Flow (High, Med, Low)	Known Water Quality Problem	Known Habitat Condition or Potential for Impairment	Salmon Run (SASI 2002)	Current Land Use	Growth Area (High, Med, Low)	Ongoing Water Quality / Flow Gauging?	Stream Included in HCDOP?
West Side (South)	Sund Creek	S	High		Poor Habitat		Forestry Rural Residential	Low	No	Yes
West Side (South)	Potlatch Creek	S/M		Fecal Coliform	Poor Habitat		Forestry Rural Residential	Low		No
West Side (South)	Eagle Creek	S/M					Forestry Rural Residential	Low		yes
Northwest Shore										
West Side (North)	**Big Quilcene River**	**M**	**High**	**Temperature Category 5/303(d)**	**Not Rated**	**Summer Chum Rated as Depressed**	**Forestry / Rural Residential / Ag.**	**Low**	**Flow: Ecology City Monitors DW Quality**	**Yes**
West Side (North)	**Lower Duckabush**	**L**	**Low**	**Temperature Category 5**	**High Potential for Stream Impairment**	**Some Runs Rated as Depressed Or Critical**	**Forestry/ Rural Residential**	**Low**	**WQ: Ecology Flow: USGS**	**Yes**
West Side (North)	Tarboo Creek	M	High	Temperature Category 5/ 303(d)	Not Rated	Several Stocks Rated as Depressed	Forest/Ag.	Low	WQ: Ecology Flow: Ecology	Yes
West Side (North)	Little Quilcene River	M	High	Temperature Category 5/303(d)	Not Rate	Summer Chum Rated as Depressed	Rural Residential/Ag.	Low	Flow: Ecology	Yes
West Side (North)	Thorndyke Creek	M	Not Rated	Temperature Category 1	Fish Passage Problems		Forestry	Low	Flow: Ecology	Yes
West Side (North)	Fulton Creek	S/M	Not Rated	Temperature Category 5	Fair Habitat			Low		Yes

Monitoring Plan Region	Water Body	Size of Basin (S, M, L)	Concern for Future Instream Flow (High, Med, Low)	Known Water Quality Problem	Known Habitat Condition or Potential for Impairment	Salmon Run (SASI 2002)	Current Land Use	Growth Area (High, Med, Low)	Ongoing Water Quality / Flow Gauging?	Stream Included in HCDOP?
West Side (North)	Marple Creek	S/M	Not Rated	Temperature Category 5	Not Rated			Low		No
West Side (North)	Spencer Creek	S/M	Not Rated		Not Rated		Forestry/ Rural Residential	Med		No
West Side (North)	No Name Creek. N. Williams' Ct.	S/M	Not Rated		Not Rated		Forestry	Low		No
West Side (North)	McDonald Creek	S/M	Not Rated		Not Rated		Forestry	Low		No
West Side (North)	Waketickah	S/M	Not Rated		Poor Habitat		Forestry	Low		Yes
West Side (North)	Pierce Creek	S/M	Not Rated		Not Rated		Forestry	Low		No
West Side (North)	Rocky Brook Creek	S/M	Not Rated		Not Rated		Forestry	Low		No
Eastern Shore										
Kitsap Peninsula (West Shore)	**Big Beef Creek**	**S/M**	**Not Rated**	**Temperature Category 5/303(d)**	**Fair**	**Unknown (2002)**	**Forest/Rural Residential**	**High**	**Flow: USGS & Ecology** WQ: Kitsap Health Monitors FC	**Yes**
Monitoring Plan Region	Water Body	Size of Basin (S, M, L)	Concern for future instream flow (High, Med, Low)	Known water quality problem	Known Habitat Condition or Potential for Impairment	Salmon Run (SASI 2002)	Current Land Use	Growth Area (High, Med, Low)	Ongoing Water Quality / Flow Gauging?	Stream Included in HCDOP?

Monitoring Plan Region	Water Body	Size of Basin (S, M, L)	Concern for Future Instream Flow (High, Med, Low)	Known Water Quality Problem	Known Habitat Condition or Potential for Impairment	Salmon Run (SASI 2002)	Current Land Use	Growth Area (High, Med, Low)	Ongoing Water Quality / Flow Gauging?	Stream Included in HCDOP?
Kitsap Peninsula (West Shore)	**Gamble Creek**	**S**	**Not Rated**	**Temperature Dissolved Oxygen Category 5**	**Good**	**Not Rated**		**High**	WQ: Kitsap Health Monitors FC	**No**
Kitsap Peninsula (West Shore)	**Dewatto River**	**M**	**Not Rated**	**Fecal Coliform Category 5/303(d)**	**Fair**	**Some stocks Rated Healthy in 2002**	**Forestry**	**Low**	**WQ: Former Ecology**	**Yes**
Kitsap Peninsula (West Shore)	Lofall Creek	S	Not Rated	Fecal Coliform 4B	Degraded	Not Rated	Rural Residential	Low	WQ: Kitsap Health Monitors FC	No
Kitsap Peninsula (West Shore)	Jumpoff Creek	S/M	Not Rated	Fecal Coliform 4B	Degraded	Not Rated	Suburban Residential	Med/High	WQ: Kitsap Health Monitors FC	No
Kitsap Peninsula (West Shore)	Seabeck Creek	M	Not Rated	Dissolved Oxygen Category 5/303(d)	Good	Not Rated	Rural Residential	Med/High	WQ: Ecology & Kitsap Health Flow: Ecology	Yes
Kitsap Peninsula (West Shore)	Anderson Creek	S	Not Rated	pH/Dissolved Oxygen Category 5/303(d)	Good	Not Rated	Forestry/Rural Residential	Low	WQ: Kitsap Health Monitors FC	Yes
Kitsap Peninsula (West Shore)	Boyce Cr	S	Not Rated	FC/Dissolved Oxygen Category 5/303(d)	Good	Not Rated	Forest/Rural Residential	Low	WQ: Kitsap Health Monitors FC	Yes
Kitsap Peninsula (West Shore)	Stavis Creek	M	Not Rated	FC/Dissolved Oxygen Category 5/303(d)	Good / Excellent	Not Rated	Forest/Rural Residential	Med	WQ Monitored By Ecology and Kitsap Health	Yes

Monitoring Plan Region	Water Body	Size of Basin (S, M, L)	Concern for Future Instream Flow (High, Med, Low)	Known Water Quality Problem	Known Habitat Condition or Potential for Impairment	Salmon Run (SASI 2002)	Current Land Use	Growth Area (High, Med, Low)	Ongoing Water Quality / Flow Gauging?	Stream Included in HCDOP?
Kitsap Peninsula (West Shore)	Kinman Creek		Not Rated		Good	Not Rated		Low	WQ: Kitsap Health Monitors FC	No
Southern Arm										
Southern Arm	**Union River**	**M/L**	**High**	**Dissolved Oxygen Category 5/303(d)**			**Rural Residential**	**High (along Belfair UGA)**	**WQ: Bremerton Public Works**	**Yes**
Southern Arm	**Tahuya River**	**M/L**	**High**	**Dissolved Oxygen Category 5/303(d)**		**Stocks Rated as Depressed**	**Rural Residential**	**Medium**	**WQ: Kitsap Health Monitors FC**	**Yes**
Southern Arm	**Big Bend Creek**	**S**	**Not Rated**	**Fecal Coliform Category 5/303(d)**	**Poor**	**Not Rated**	**Forest/Rural Residential**	**Low**	**No**	**Yes**
Southern Arm	**Trail's End Creek**	**S**	**High**	**Fecal Coliform Category 5/303(d)**	**Poor Habitat**	**Not Rated**	**Rural Residential**	**Low**	**No**	**Yes**
Southern Arm	Happy Hollow Creek	S	High	Fecal Coliform Category 5/303(d)	Poor Habitat	Not Rated	Ag/Forest	Low	No	Yes
Southern Arm	Shoofly Creek	S	Not Rated	Fecal Coliform Category 5/303(d)	Not Rated	Not Rated	Forest/Rural Residential	Low	No	No

Monitoring Plan Region	Water Body	Size of Basin (S, M, L)	Concern for Future Instream Flow (High, Med, Low)	Known Water Quality Problem	Known Habitat Condition or Potential for Impairment	Salmon Run (SASI 2002)	Current Land Use	Growth Area (High, Med, Low)	Ongoing Water Quality / Flow Gauging?	Stream Included in HCDOP?
Southern Arm	Mission Creek	S/M	Not Rated		Not Rated	Not Rated	Forest/Rural Residential	High	No	Yes
Southern Arm	Little Mission Creek	S	Not Rated	Fecal Coliform Category 5/303(d)	Not Rated	Not Rated	Forest/Rural Residential	High	No	Yes
Southern Arm	Deveraux Creek	S	Not Rated	Fecal Coliform Category 5/303(d)	Poor	Not Rated	Forest/Rural Residential	Medium	No	Yes
Southern Arm	Alderbrook Creek	S	High		Poor Habitat	Not Rated	Rural Residential/ Golf Course	Medium	No	Yes
Southern Arm	Mulberg Creek	S	Not Rated	Fecal Coliform Category 5/303(d)	Poor	Not Rated	Forest/Rural Residential	Low	No	Yes
Southern Arm	Twanoh Falls Creek	S	Not Rated	Fecal Coliform Category 5/303(d)	Poor	Not Rated	Forest/Rural Residential	Low/Medium	No	Yes
Southern Arm	Dalby Creek	S	Not Rated		Poor	Not Rated	Forest/Rural Residential	Low	No	No

*__Bolded__ entries represent streams selected for Key monitoring stations.

APPENDIX C

Priority Sites for Tier 2 Monitoring

Table C-1. Region 1 potential secondary sites.

Water Body	Site Location (mouth, upstream)	Known Water Quality Problems	Current Land Use	Potential for Future Development	Ongoing Water Quality / Flow Monitoring	Ranking of Importance
South Fork Skokomish River	Upstream	Temperature	Forestry	Low	Skokomish Tribe Monitors WQ: USGS Monitors Flow	1
North Fork Skokomish River	Upstream		Forestry	Low	Skokomish Tribe Monitors WQ: USGS Monitors Flow	2
Liliwaup River	Mouth	Fecal Coliform	Forestry	Low	No	3
Jorsted Creek	Mouth		Forestry / Rural Residential	Low	No	4
Eagle Creek	Mouth		Forestry / Rural Residential	Low	No	5
Lower Hamma Hamma River	Mouth		Forestry / Rural Residential	Low	Former USGS Flow Monitoring Site	6
Potlatch Creek	Mouth	Fecal Coliform	Forestry / Rural Residential	Low	No	7
Sund Creek	Mouth		Forestry / Rural Residential	Low	No	8

Table C-2. Region 2 potential secondary sites.

Water Body	Site Location (mouth, upstream)	Known Water Quality Problems	Current Land Use	Potential For Future Development	Ongoing Water Quality / Flow Monitoring	Ranking of Importance
Big Quilcene River	Upstream	Temperature	Forestry / Rural Residential / Ag.	Low	Ecology Monitors Flow	1
Thorndyke Creek	Mouth	Temperature	Forestry	Low	Ecology Monitors Flow	2
Tarboo Creek	Mouth	Temperature	Forestry / Ag.	Low	Ecology Monitors Water Quality and Flow	3
Tarboo Creek	Upstream	Temperature	Forestry / Ag.	Low	Conservation District Monitors Temperature	4
Dosewallips River	Mouth		Forestry	Low	Ecology Monitors Flow	5
Fulton Creek	Mouth		Forestry	Low		6
Marple Creek	Mouth		Forestry	Low		7
Pierce Creek	Mouth		Forestry	Low		8

Table C-3. Region 3 potential secondary sites.

Water Body	Site Location (mouth, upstream)	Known Water Quality Problems	Current Land Use	Potential For Future Development	Ongoing Water Quality / Flow Monitoring	Ranking of Importance
Big Beef Creek	Upstream	Fecal Coliform	Forestry	Medium	WQ Monitored by Ecology and KCHD	1
Little Anderson Creek	Mouth	pH, Dissolved Oxygen	Suburban Residential	Medium	KCHD Monitors Fecal Coliform	2
Stavis Creek	Mouth	Dissolved Oxygen		Medium	WQ Monitored by Ecology and KCHD	3
Jumpoff Joe Creek	Mouth	Dissolved Oxygen	Suburban Residential	Low/Med	KCHD Monitors Fecal Coliform	4
Kinman Creek	Mouth	Fecal Coliform	Forestry / Rural Residential	Low/Medium	KCHD Monitors Fecal Coliform	5
Harding Creek	Mouth		Forestry	Low	KCHD Monitors Fecal Coliform	6
Anderson Creek	Mouth		Forestry	Low	KCHD Monitors Fecal Coliform	7
Seabeck Creek	Mouth	Dissolved Oxygen, Fecal Coliform	Rural Residential	Medium/High	KCHD Monitors Fecal Coliform	8

Table C-4. Potential secondary sites.

Water Body	Site Location (mouth, upstream)	Known Water Quality Problems	Current Land Use	Potential For Future Development	Ongoing Water Quality/Flow Monitoring	Ranking of Importance
Union River	Upstream	Dissolved Oxygen	Forestry / Rural Residential	High (along Belvair UGA)	No	1
Mission Creek	Mouth	Fecal Coliform	Forestry / Rural Residential	Low	No	2
Little Mission Creek	Mouth	Fecal Coliform	Forestry / Rural Residential	Low	No	3
Deveraux Creek	Mouth	Fecal Coliform	Forestry / Rural Residential	Medium	No	4
Mulburg Creek	Mouth	Fecal Coliform	Forestry / Rural Residential	Low	No	5
Twanoh Falls Creek	Mouth	Fecal Coliform	Forestry / Rural Residential	Low / Medium	No	6
Dalby Creek	Mouth	Fecal Coliform	Forestry / Rural Residential	Low	No	7
Alderbrook Creek	Mouth	Fecal Coliform	Forestry / Rural Residential	Low	No	8