BATTLE CREEK STREAM CONDITION MONITORING PLAN

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***Prepared by*:**
Michael B. Ward, Steve Tussing, Jeremy Moberg, and Pamela Nelle

Terraqua, Inc.
Wauconda, Washington

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INTRODUCTION

The purpose of this document is to describe a program for monitoring the condition of streams within the Battle Creek watershed that builds upon earlier work including, most importantly, a watershed assessment conducted in 2001 and 2002. This stream condition monitoring program is designed to be useful for status, trend, and restoration project effectiveness monitoring. This program is intended to be sensitive enough to promptly alert watershed managers to short-term, acute changes and to longer-term, chronic changes. This program is designed to be able to aggregate conditions at the watershed-scale but also be able to identify within-watershed variation.

To achieve this purpose, this document addresses each of the following objectives in separate sections:

- Background: The Battle Creek watershed is intensively monitored, in part because it is the focal area for major programs to restore populations of Chinook salmon and steelhead. The complicated history of monitoring in Battle Creek is briefly described to demonstrate the need for improved monitoring of stream conditions in this watershed.

- Stream Condition Monitoring Program Description: This section describes a program to monitor the conditions of streams within the Battle Creek watershed. Information in this section will aid future researchers in maintaining a statistically reliable, repeatable long-term monitoring program that measures stream condition. This section was built upon knowledge of existing data and on-going programs, which are presented in Appendix A, and a planning analysis of these data, which is presented in Appendix B.

- Existing Data and On-going Programs (Appendix A): This appendix compiles and summarizes existing data relevant to watershed-scale processes that affect stream conditions and describes on-going programs that measure indicators relevant to stream conditions. We attempt to draw upon and contribute to these programs and data sets without duplication of effort.

- Planning Analysis (Appendix B): Developing a successful monitoring program within the constraints of finite resources requires identifying a list of indicators relevant to the ecosystem process of interest, using an efficient sampling design, and employing a robust suite of protocols. We analyze existing data coupled with other research to recommend indicators, designs, and protocols for use in this stream condition program.

BACKGROUND

Ecosystem Processes: The Battle Creek watershed is the focal area for major programs to restore populations of Chinook salmon and steelhead. These populations of fish depend on a number of biological and physical (including chemical) processes within the Battle Creek watershed. Streams within the Battle Creek watershed are the conduits for the flow of water, sediment, nutrients, and energy that influence the productive capacity of local fish populations. The physical and biological condition of these streams can both influence and indicate how these ecosystem processes may affect Battle Creek fish populations. Therefore, an understanding of the condition of streams is important for understanding the status and trends of fish populations as well as the effectiveness of actions taken to restore these populations.

Geographical and Institutional Setting: Battle Creek drains a watershed area of approximately 370 square miles in central Northern California. The watershed includes the southern slopes of the Latour Buttes, the western slope of Lassen Peak, and the mountains south of Mineral, California. Nearly 350 miles of streams in the Battle Creek watershed drain land at elevations as high as 10,400 feet and cascade steeply down through basalt canyons and foothills to the confluence with the Sacramento River near Cottonwood, California, at an elevation of 335 feet. Approximately 250 miles of stream are fish bearing and 87 miles of stream were historically accessible to anadromous fishes such as Chinook salmon and steelhead. Land use in Battle Creek is predominately industrial timber harvest, livestock ranch lands, and agricultural development, with areas of dense residential development and undeveloped wilderness areas within Lassen National Park.

Battle Creek is widely recognized as a watershed critical to the survival and restoration of populations of Chinook salmon and steelhead, which are listed under state and federal endangered species acts. Restoration efforts in the Battle Creek watershed were initiated in 1997 by the Battle Creek Working Group (BCWG), and have resulted in the implementation (to begin in 2008) of the Battle Creek Salmon and Steelhead Restoration Project (Restoration Project). The Restoration Project is a multi-agency effort to improve fish passage conditions and habitat within the portion of the watershed encompassed by Pacific Gas and Electric (PG&E) Company's Battle Creek Hydroelectric Project.

Since its inception in 1997, the Battle Creek Watershed Conservancy (BCWC) has facilitated local participation in the development of the Restoration Project. The BCWC continues to support the goals of the Restoration Project by working to improve reach-scale and watershed-scale factors that might jeopardize the goal of restoring local runs of Chinook salmon and steelhead to Battle Creek.

The BCWC, with funds provided by the Anadromous Fisheries Restoration Project as part of BCWC's Stewardship Program, commissioned an assessment of conditions in the Battle Creek watershed in 2001. BCWC recognized the likelihood that in-channel stream conditions, in addition to the more widely recognized hatchery and hydropower-related limiting factors, may also influence the productive capacity of salmon and steelhead in Battle Creek. While the Restoration Project and other agency efforts have been mainly focused on hydropower-related limiting factors, the BCWC believed that it was critical to pay attention to stream conditions and their potential effects on the goals of the Restoration Project. To that end, the BCWC's watershed assessment 1) documented existing stream conditions and developed a baseline against which future conditions may be compared, and 2) identified, and prioritized for treatment, sediment sources within Battle Creek.

On behalf of the BCWC, Terraqua, Inc. conducted an assessment of the Battle Creek watershed in 2001 and 2002 (Ward and Moberg 2004). This assessment followed the field methodologies and reference criteria established by the U.S. Forest Service's (USFS) Aquatic and Riparian Effectiveness Monitoring Program (AREMP; Gallo et al. 2001). Ward and Moberg (2004) determined baseline conditions for selected biological and physical stream attributes present in the Battle Creek watershed through an intensive study of stream conditions by surveying at 50 randomly selected sites and concluded that:

- Fine sediment levels were high. In most cases, fine sediment levels were higher than levels favorable for salmonid production, higher than unmanaged California streams, and higher than USFS standards but were similar to other managed watersheds on USFS lands in California.
- A storm event in January 1997 was the primary sediment source factor affecting aspects of stream condition such as fine sediment levels, particle size, pool frequency, pool depth, and geomorphic channel conditions like bank erosion and channel avulsions.
- While roads or other land use factors were not ruled out as possible sediment sources, there was little direct evidence that road factors (density, near-stream density, road-stream crossing frequency) or other land-use factors (forest cover and near-stream meadow area) played a significant role in explaining the variability of three key stream condition indices at the watershed scale.

Ascertaining the status of biological and physical stream attributes in Battle Creek was an important product of the 2001 watershed assessment. However, the primary benefit of that work was to provide a reference against which to compare future conditions in order to understand trends in watershed-scale stream conditions. Understanding these trends, and comparing them to anticipated changes in fish populations during and after implementation of the Restoration Project, will magnify the power of the original 2001 work. The effectiveness of the Restoration Project will be determined largely by tracking trends in fish population levels. Unexpected results in fish population trends, which could result from problems in watershed conditions, will be fully explainable only through consideration of possible changes in the watershed's productive capacity as indicated by a time series of stream condition indicators. On the other hand, demonstrating that changes in fish population trends are a result of Restoration Project or adaptive management actions will require that changes in watershed conditions can be ruled out, which again requires a time series of stream condition information.

Restoration Project managers also recognized the important link between successful adaptive management of the Restoration Project and watershed conditions. The Adaptive Management Plan (AMP; Terraqua 2004) for the Restoration Project highlighted the role of

BCWC in monitoring watershed conditions, sediment processes, water temperature and climate. It also called for very close coordination of the BCWC's stream condition monitoring and the Restoration Project's adaptive management (Terraqua 2004).

The BCWC recognizes that the 2001 watershed assessment provides a robust and statistically valid baseline against which future changes in conditions can be compared through periodic, and statistically valid, monitoring. Therefore, BCWC's Stewardship Program applied for and was awarded a grant from Proposition 50 monies managed by the California State Water Resources Control Board (SWRCB) to design and implement a plan to monitor stream condition among other things. Terraqua, Inc. was hired by BCWC to accomplish these objectives and to produce the Stream Condition Monitoring Plan (SCMP). Terraqua has been assisted by a Technical Advisory Committee (TAC), comprised of private and public sector experts in fisheries and watershed processes, who closely overlap with the management of the Restoration Project that has advised on the development of this plan.

Initial implementation of the SCMP was also funded by Proposition 50/SWRQCB and began in 2006. In 2006, based on a draft of this plan and discussions with the TAC, stream-condition work was initiated. Terraqua conducted habitat sampling at 10 of the sites sampled in 2001-2002 and collected macroinvertebrates at all 50 sites sampled in 2001-2002. The results of the 2006 monitoring will be reported separately.

Climate Status and Trends: Recent climate change assessments for California provide guidance on which watershed attributes are likely to be impacted by the middle and later portion of this century. Climatic change is anticipated to alter the pattern of stream flow and water temperatures in Central Valley watersheds. While total precipitation is not anticipated to change, a shift in the form of precipitation from snow to rain will increase winter runoff, reduce snow pack, and reduce spring season runoff (Cayan et al. 2006; Hayhoe et al. 2004; Knowles and Cayan 2002, 2004).

The assumption that spring-driven streams, such as Battle Creek, have stable discharges at baseflow has led to the belief that these streams are buffered against changes to stream flows from climatic variability. However, recent research on deep groundwater dominated spring-fed streams within High Cascade basalt geologies, similar to the Battle Creek watershed, indicate that climatic change can reduce summer baseflows even if total yearly precipitation does not change. Tague et al. (2008) found that lower summer flows in spring-fed High Cascade streams will occur due to changes in the annual recharge and discharge hydrographs. With an increased proportion of precipitation falling as rain, groundwater recharge can increase in the winter and decrease in the spring, resulting in an earlier recession of the spring hydrograph and lower summer baseflows.

Lindley et al. (2007) and Williams et al. (2007) call for more focused research and monitoring to determine the effect that anticipated climate change will have on stream flows and stream temperatures in order to identify future impacts on threatened and endangered Central Valley anadromous salmonids. Anticipating the effects that climate change will have on Battle Creek streamflows and temperatures is an important component of adaptive management and the long-term success of the Restoration Project. Anticipating potential losses in summer baseflows and increases in stream temperatures will enable the determination of how flow releases can be managed to achieve the stream habitat goals of the Restoration Project and identify any potential loss to hydropower production capacity.

Rather than incorporating long-term climate change related monitoring into this plan in a piecemeal fashion, a short-term focused research approach would yield better answers. A focused research approach could identify how stream/spring flows and temperatures across the watershed are linked to precipitation and snowpack at various elevations to anticipate future changes. Furthermore, it could be efficiently designed to provide reach specific results that can feed directly into existing flow/temperature models that were used in Restoration Project assessment and design (e.g., Tu 2001). Terraqua is working with BCWC and other collaborators to design appropriate climate-change monitoring studies relevant to stream conditions in the Battle Creek watershed.

STREAM CONDITION MONITORING PROGRAM DESCRIPTION

This section describes the program recommended for monitoring the condition of streams within the Battle Creek watershed. This section was built upon knowledge of existing data and on-going programs, which are presented in Appendix A, and a planning analysis of these data, which is presented in Appendix B.

This SCMP is designed to be useful for status, trend, and restoration project effectiveness monitoring. This program should be sensitive enough to promptly alert watershed managers to short-term, acute changes and to measure longer-term, chronic changes. This program should be able to aggregate conditions at the watershed-scale but also be able to identify within-watershed variation.

This program is designed to work with other existing programs by filling data gaps necessary for understanding stream conditions and trends in Battle Creek. Knowledge of existing data and on-going programs, and their deficiencies, as well as sampling design and cost considerations, were taken into consideration when designing this program.

Appendix A describes the available data, relevant to watershed-scale processes affecting stream conditions, that is being produced by previous sampling or on-going programs that measure indicators relevant to stream conditions. For example, biological and physical aspects of the Battle Creek ecosystem are being monitored by on-going adaptive management monitoring conducted as part of the Restoration Project. Also, key physical indicators of stream conditions and macroinvertebrate population indicators that influence and reflect biological and physical stream conditions were first intensively researched in 2001-2002 by the BCWC. Furthermore, a number of programs measure chemical aspects (water quality) of streams in Battle Creek. Appendix A also briefly evaluates whether the existing data or on-going programs accomplish the goals of this document or whether additional work should be recommended.

Appendix B considers how to draw upon the existing body of information presented in Appendix A and how to contribute to those programs and data sets without duplicating effort. In Appendix B, we analyze existing data coupled with other research to identify remaining data gaps and we recommend indicators, protocols, and designs for use in this SCMP.

Elements of the SCMP

The SCMP is comprised of monitoring in four subject areas: biological monitoring through macroinvertebrate surveys and riparian condition surveys, physical stream condition surveys, water temperature monitoring, and monitoring of changes in land cover. The following sampling regimes describe how monitoring will proceed within these four subject areas.

1) Macroinvertebrate sampling: Conduct annual surveys of macroinvertebrates during the low-flow season at the 50 probabilistically-selected monitoring sites established during the 2001-2002 watershed assessment. Analyze macroinvertebrate community composition for acute (annual) changes and chronic (long-term, multiple year) trends.

2) Physical stream condition and riparian condition monitoring: Conduct annual surveys of physical stream conditions and riparian conditions at 20 of 50 probabilistically-selected monitoring sites established during the 2001-2002 watershed assessment to achieve monitoring of all 50 sites once every four years. This rotating panel design includes an annual panel of 10 “fixed-sites” and four rotating panels of 10 additional sites which will be sampled once every four years. In this manner, all 50 sites will be surveyed at least once every 4 years. Physical stream habitat and riparian condition data will be analyzed for long-term, multiple year trends.

3) Water temperature monitoring: Water temperature monitoring will be conducted at six locations in addition to the locations sampled by the U.S. Fish and Wildlife Service (USFWS) as part of on-going adaptive management of the Battle Creek Restoration Project area. Two of these locations will be located at the upper limit of the Restoration Project area on North and South Forks of Battle Creek. Additional sites include two in Digger Creek, upstream and downstream of water diversions near Manton, and two in the upper South Fork of Battle Creek, upstream and downstream of Battle Creek Meadows (see Appendix B for more detail regarding these sites).

4) Changes in land cover: Monitoring changes in land cover will be performed using the standards established by the California Land Cover Mapping and Monitoring Program (LCMMP). Land cover data will be re-analyzed every 4 years to detect changes, a timeline that coincides with the number of years it will take to cover all 50 physical stream and riparian condition monitoring sites using the rotating panel design.

Estimated Costs

Costs associated with all proposed stream condition monitoring elements are provided (Table 1). Costs were derived using the per site actual costs from prior monitoring and are more specifically described in Appendix B. Where actual costs are unavailable cost estimates are provided. Prior monitoring costs were available for the macroinvertebrate (50 sites) and physical stream surveys including riparian condition (10 sites) performed in 2006. Per site costs are extrapolated to arrive at a total annual cost for the work we are recommending. Greater detail on these costs and comparisons to costs from similar programs are provided in Appendix B.

Table 1. A summary of costs (in 2006 dollars) for elements of the Stream Condition Monitoring Program. See Appendix B for details.

Monitoring Element	***Number of Annual Sites***	***Cost Per Site***	***Annual Cost***
Macroinvertebrate Monitoring	50	$565	$28,250
Physical Stream / Riparian Condition Monitoring	20	$2,520	$50,400
Water Temperature Monitoring	6	$567	$3,400
Land Cover Change Monitoring	N/A	N/A	$3,613 *
Total Annual Cost:			**$85,663**

* Cost for land cover change monitoring is approximately $14,450 implemented once every four years which equates to $3,613 per year.

Data Storage and Management

Data collected as part of the SCMP will be stored and disseminated by the BCWC using the KRIS web-based database. Much of the data and reports associated with the Restoration Project and work by BCWC are already managed by the BCWC through this program.

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Personal Communications

Gerald Brown, Engineer, Tehama County Public Works.

Wease Bollman, Rhithron Associates, Inc., Missoula, MT. These personal communications with Bollman were supported by a 1996 unpublished manuscript by Leska Fore for which no additional citation material is available.

Dennis Heiman, State Water Resources Control Board, Redding CA.

Ken Roby, Fisheries Biologist, Lassen National Forest, Chester, CA.

APPENDIX A. EXISTING DATA AND ON-GOING PROGRAMS

Previous research and on-going monitoring programs provide data relevant to understanding certain aspects of stream conditions that are important to local fish populations. For example, biological and physical aspects of the Battle Creek ecosystem are being monitored by on-going adaptive management monitoring conducted as part of the Restoration Project. Also, key physical indicators of stream conditions and macroinvertebrate population indicators that influence and reflect biological and physical stream conditions were first intensively researched in 2001-2002 by the BCWC. Furthermore, a number of programs measure chemical aspects (water quality) of streams in Battle Creek.

This section describes the available data, relevant to watershed-scale processes affecting stream conditions, that is being produced by previous sampling or on-going programs that measure indicators relevant to stream conditions. This section also briefly evaluates whether the existing data or on-going programs accomplish the goals of this document or whether additional work should be recommended. Appendix B considers how to draw upon this existing body of information and how to build upon these programs and data sets to meet the goals of this SCMP without duplicating effort.

Biological Monitoring

Animals living in a stream may provide the best indicators of that stream's overall ecological condition. Changes in the natural processes of watersheds can have immediate and long-lasting effects on the animals that live in streams (Karr 1997; Fore 1998). Previous and on-going monitoring efforts in Battle Creek have investigated biological conditions relevant to stream conditions at the watershed scale. The most relevant of these efforts include the monitoring of populations of salmon and steelhead produced in Battle Creek (i.e., Restoration Project adaptive management monitoring) and macroinvertebrate surveys conducted in 2001 and 2002 as part of the Conservancy's watershed assessment. Other biological monitoring that may be relevant to stream conditions includes riparian vegetation monitoring and land cover monitoring.

Fish Population Monitoring of the Restoration Project

The movement of anadromous fish into and out of the Battle Creek watershed represents a large transfer of biomass, energy, and nutrients that can affect, and is affected by, stream conditions. The portion of the watershed that could support anadromous fish is relatively small (87 of 350 stream miles) compared to stream habitats that support resident fish (250 of 350 stream miles). While the magnitude of influence that anadromous stocks have on stream conditions at the watershed scale is unknown and still being studied (e.g., Stockner 2003), these fish populations are the most socially important or managed wildlife species in the watershed. Indeed, the status of these fish populations is the primary reason of concern regarding the condition of streams in the watershed as stream habitat conditions will directly affect these fish populations. Therefore, developing stream condition and fish population monitoring data sets, and the means to compare them, is a top priority.

Fish population monitoring in Battle Creek had been relatively intense within the last 50 years and has ramped up even more in the last 10 years in anticipation of the Restoration Project. In the future, as part of the implementation of the Restoration Project adaptive management program (Terraqua 2004), anadromous fish population monitoring will become more intensive and extensive (Table 2). The Restoration Project adaptive management monitoring will likely be sufficient for status, trend, and restoration project effectiveness monitoring. Likewise, this level of fish population monitoring should be able to detect short-term, acute changes (in some indicators) and longer-term, chronic changes. One possible drawback to the anadromous fish-centric approach of the Restoration Project is that factors affecting fish productivity at the watershed-scale could go unnoticed, yet still affect the anadromous populations and be confounded with other possible factors.

Table 2. A summary of fish population monitoring activities that will be conducted within Battle Creek under the Battle Creek Salmon and Steelhead Restoration Project adaptive management program (Terraqua 2004).

Monitoring Activity	*Location*
Estimate adult salmon and steelhead population sizes and distribution	Coleman National Fish Hatchery (CNFH) barrier weir, at hydroelectric project fish ladders, within spawning habitat, and in relation to hydroelectric project facilities and operations.
Estimate juvenile production	Upstream of CNFH and at the terminus of the Restoration Project in north and south forks.
Adult fish passage	Hydroelectric project fish ladders on north and south forks.
Juvenile habitat use	Nursery habitat in lower Battle Creek and cold-water refuges.
Salmon and steelhead life histories	Coleman National Fish Hatchery (CNFH) barrier weir (adults) and at downstream migrant traps within Project area (juveniles).
Fish communities/fish assemblages including changes in distribution	Throughout Project area.

Macroinvertebrate Communities

Macroinvertebrate communities are usually the most sensitive indicators of changes to chemical and physical stream conditions, and the usual threshold of significance for these physical and chemical changes is whether aquatic life is affected (Karr 1997). Therefore, macroinvertebrate communities are a relatively direct index of physical and chemical conditions that can be sampled cost-effectively and processed promptly enough to alert watershed managers to short-term, acute changes.

Steam macroinvertebrate communities are comprised of an enormous diversity of individual species, each with its own specific ecological requirements, and can illustrate the condition of a broad spectrum of ecosystem processes taking place within a watershed or stream. The relative abundance of specific taxa can indicate specific changes in stream conditions. Biological metrics and multimetric indices[1] that summarize the relative abundance of macroinvertebrate taxa have been linked with specific physical (Bollman 1998; Plotnikoff 1998), chemical and biological changes (Plotnikoff 1998; Fore 1998) in stream conditions.

Ongoing macroinvertebrate bioassessment monitoring within the Battle Creek watershed is limited, with few macroinvertebrate surveys performed prior to 2001. The Lassen National Forest (LNF) performs macroinvertebrate assessments as part of the Stream Condition Inventory Program (SCI). The current SCI methodology uses the River Invertebrate Prediction and Classification System (RIVPACS; Hawkins 2003) that enables interpretation of macroinvertebrate data at localized site to regional scales (USDA-Forest Service 2005). The LNF has established two reference sites within the Battle Creek watershed for long-term SCI monitoring. The South Fork Bailey and South Fork Digger Creek reference sites were first monitored in 1998 and 2005 respectively, and will receive ongoing monitoring every 5 years. The LNF also uses SCI monitoring to assess the effects of project implementation (e.g., restoration actions) on stream condition. Macroinvertebrate assessments are performed prior to and within 1 to 2 years after project implementation. Within the last 4 years, three project sites on LNF lands within the Battle Creek watershed have received pre-project assessments: Panther Creek (2002), Summit Creek (2003), and North Fork Battle Creek (2004) (K. Roby, LNF, pers. comm.). Summit Creek received post-project monitoring in 2006.

In 2001 and 2002 Terraqua performed sampling to characterize the aquatic macroinvertebrate diversity within the watershed to support the Watershed Assessment and the development of the SCMP (Terraqua and Kvam 2003). Terraqua and Kvam (2003) used the RIVPACS protocol, which is similar to the SCI methods, to sample and analyze macroinvertebrate communities at 44 sites, which can be used to generate at least 60 macroinvertebrate metrics or indices (Table 3). A number of these metrics or indices are affected by ecological conditions that are the subject of this monitoring plan, such as sedimentation, geomorphic channel processes, water temperature, and water quality (Table 4).

[1] Multimetric indices, such as those used in Terraqua (2003), like the B-IBI and ODEQ Biotic Index, are believed to be better at detecting habitat or macroinvertebrate community disturbances than single metrics (e.g., presence or absence of indicator species) because they use a number of biological attributes that integrate information from ecosystem, community, population, and individual levels (Barbour et al. 1999).

Table 3. A list of macroinvertebrate metrics or indices available from samples collected according to methods used by Terraqua and Kvam (2003).

Metric or Multimetric Index		
Air breather richness	Percent air-breather	Percent Trichoptera
Baetidae/Ephemeroptera	Percent burrrower	Percent univoltine
* B-IBI score	Percent clinger	Plecoptera richness
Burrower richness	Percent Coleoptera	Predator richness
Clinger richness	Percent Diptera	RIVPACS
Clinger taxa richness	Percent dominant (1 taxon, 3 taxa, or more)	Scraper richness
Cold stenotherm richness	Percent Ephemeroptera	* Sediment sensitive richness
Dominance (3 taxa)	Percent filterers	Sediment tolerant richness
Ephemeroptera richness	Percent gatherers	Semivoltine richness
EPT richness	Percent multivoltine	Sensitive taxa richness
Evenness	Percent parasites	Sensitive taxa richness
Filterer richness	Percent Plecoptera	Shannon H (ln)
Gatherer richness	Percent predators	Shannon H (log2)
HBI	Percent scrapers	Shredder richness
Long-lived taxa richness	* Percent sediment tolerant	Simpson D
Margalef D	Percent semivoltine	Taxa richness
Multivoltine richness	Percent shredders	Total taxa richness
* ODEQ – Biotic Index	Percent tolerant	Trichoptera richness
Parasite richness	Percent tolerant taxa	Univoltine richness

* - indicates a metric examined in detail in Terraqua and Kvam (2003).

Table 4. Ecological conditions demonstrated to affect selected macroinvertebrate metrics and indices.

Metric or Index	Ecological Condition	Reference
Clinger richness	Sedimentation	Bollman (pers. comm.)
Ephemeroptera richness	Particularly sensitive to chemical pollution, heavy metals, nutrients and fertilizers	Bollman (pers. comm.)
	Channel type, riparian vegetation, overall habitat score, pH, conductivity, gradient, canopy, temperature	Bollman (1998)
EPT richness	Embeddedness, flow/depth combinations, channel type, bank stability, riparian vegetation, overall habitat scores, pH, conductivity, gradient, canopy, temperature, percent fines	Bollman (1998), Plotnikoff (1998)
Percent dominant (3 taxa)	General stream condition	Bollman (pers. comm.)
Percent filterers	Embeddedness, water temperature	Bollman (1998)
Percent gatherers	Substrate particle size diversity	Bollman (1998)
Percent predators,	Riparian vegetation, conductivity	Bollman (1998)
predator richness	General stream condition	Bollman (pers. comm.)
* Percent sediment tolerant	Sedimentation	Terraqua and Kvam (2003)
Percent shredders	Riparian vegetation, canopy	Bollman (1998)
Percent tolerant	General stream condition	
Percent tolerant taxa	Embeddedness, flow/depth combination, channel alteration, channel type, riparian vegetation, overall habitat scores, pH, conductivity, gradient, temperature, percent fines, width:depth ratio	Bollman (1998)
Plecoptera richness	Flow/depth combinations, channel type, riparian vegetation, overall habitat, conductivity, canopy, temperature	Bollman (1998)
	Sedimentation, temperature, channel disturbance, canopy, dissolved oxygen	Bollman (pers. comm.)
* Sediment sensitive richness	Sedimentation	Terraqua and Kvam (2003)
Sediment tolerant richness	Sedimentation	Terraqua and Kvam (2003)
Semivoltine richness	Periodic, chronic, or multi-year disruptions	Bollman (pers. comm.)
Sensitive taxa richness	Embeddedness, flow/depth combination; channel type, riparian vegetation, overall habitat score, conductivity, gradient, canopy, temperature, percent fines	Bollman (1998)
Sensitive taxa richness	General stream condition	Bollman (pers. comm.)
Taxa richness	General stream conditions	Bollman (pers. comm.)
Total taxa richness	General stream conditions	Bollman (pers. comm.)
Trichoptera richness	Embeddedness, scour and deposition; channel type, bank vegetative stability, riparian vegetation, overall habitat scores, conductivity, gradient, canopy, temperature, percent fines	Bollman (1998)
	Channel simplification	Bollman (pers. comm.)

As no ongoing macroinvertebrate monitoring is currently being implemented within the Battle Creek watershed, additional recurrent surveys will be needed to fully meet the goals of the stream condition monitoring program. The combined biologic (macroinvertebrate) and physical monitoring protocols used to perform the watershed analysis (Terraqua and Kvam 2003; Ward and Moberg 2004) were chosen specifically to enable ongoing trend monitoring of stream conditions.

Riparian Vegetation

Riparian vegetation has many influences on the stream ecosystem, including: contributions of matter and energy in the form of leaf detritus and insect drop; shaping of channel morphology through roots, branches, and logs; and water temperature moderation through shading and wind interception (Murphy and Meehan 1991). Map-based approaches can be used to assess riparian vegetation and provide proxies for riparian habitat characteristics, canopy cover and large woody debris recruitment (Keithley 1999).

No comprehensive field studies of riparian vegetation have been conducted for the Battle Creek watershed. The previous watershed assessment (Ward and Moberg 2004) used remotely-sensed vegetation data derived from multi-spectral images taken by the Landsat satellite in 1996 to characterize forest cover at a one hectare (100 m) level of resolution. The Streamscape Inventory protocols (Lassen National Forest 2000, as amended in 2002) implemented along 25 miles of stream reaches on LNF lands in the upper watershed included the qualitative evaluation of existing riparian conditions. Riparian related attributes that were qualitatively estimated include riparian width, hardwood age structure, ground cover and large woody debris recruitment and recruitment potential (Lassen National Forest 2000, as amended in 2002; Lassen National Forest 2001). The SCI protocols used by LNF at several upper basin reference and project specific sites (a total of five) included the monitoring of stream shading by estimating average canopy cover using a Solar Pathfinder (Frazier et al. 2005).

The Restoration Project adaptive management program (Terraqua 2004) intends to monitor the response of riparian vegetation to increased instream flows within the anadromous portion of the watershed. These riparian studies will establish baseline conditions and then repeat assessments at 5 and 10 years after project implementation. Proposed riparian studies include repeat aerial photography, field-based monitoring and growth increment coring analysis (Terraqua 2004). None of these existing efforts fully meets the goals of this stream condition monitoring program.

Land Cover

Processes affecting stream conditions originate well beyond the riparian zones of stream networks. Aquatic ecosystems are maintained through temporal and spatial diversity driven by disturbance events which can be catastrophic in the short-term or chronic in the long-term. For example, natural disturbance processes (e.g., wildfire), land management (e.g., timber harvest, agriculture) and developmental practices can result in changes to vegetation, hydrology and sediment generation. Vegetation changes at the watershed scale may affect stream and riparian conditions and ultimately could threaten the success of the Restoration Project. Long-term land cover monitoring can provide the Restoration Project Adaptive Management Program insights into whether trends in stream conditions are attributable to natural disturbance processes such as wildfire or the consequence of anthropogenic activities that alter vegetation.

Regional changes in land cover were analyzed by the California LCMMP using Landsat Thematic Mapper satellite imagery, which has a spatial resolution of 30 meters (Levien et al. 2002, 2003). Changes in land cover for hardwoods, conifers, and shrub/chaparral and their causes were assessed by county and national forest between 1991 and 1996 for all public lands in the northeastern California project area. While the monitoring data is very reliable with an overall accuracy of 89% (Levien et al. 2002), the spatial scale and political delineation of the analyses (e.g., Tehama County and Lassen National Forest) are inappropriate for interpreting changes within the Battle Creek watershed. The LCMMP is currently an unfunded program and funding for future land cover change monitoring is uncertain.

The Ward and Moberg (2004) watershed assessment used remotely-sensed vegetation data as a proxy for canopy cover and prior timber harvest in the sediment source analysis. Vegetation data was derived from multi-spectral images taken in by the Landsat satellite in 1996 with a resolution of one hectare (100m).

Neither of these existing land cover related assessments in their current form are sufficient for long-term watershed monitoring relative to stream habitat conditions and trends. It may be possible to analyze LCMMP data at the watershed or sub-watershed scale in a way that could be sufficient to monitor land cover in Battle Creek. Ongoing monitoring using LCMMP standards would build upon prior monitoring efforts, though this work would need to be performed through a qualified contractor rather than the LCMMP.

Physical Monitoring

Physical monitoring of the Battle Creek watershed is necessary and complimentary to biological monitoring in determining the status and trends of stream networks and the effectiveness of restoration projects. Monitoring physical conditions can also aid in identifying the causal mechanisms driving changes in the status of fish and macroinvertebrates. Many historic and on-going physical monitoring efforts have been performed within the basin though few, with the exception of the recent watershed assessment (Ward and Moberg 2004), have attempted to characterize the conditions of fish bearing streams in the entire watershed. Physical monitoring efforts have included: the Battle Creek Watershed Assessment, Stream Condition Inventory Monitoring by the USFS, stream sediment monitoring, pool frequency monitoring, instream flow monitoring, and climate monitoring.

Battle Creek Watershed Assessment

Ward and Moberg (2004) conducted the Battle Creek Watershed Assessment in 2001 and 2002 using protocols and analyses developed by AREMP (Gallo et al. 2001). The methodology and structure of data collection for the watershed assessment was chosen to enable the detection of long-term trends in physical and biological condition. A benefit of the AREMP assessment approach (Gallo et al. 2001) is that statistical guidance on trend analysis has already been developed (Stevens 2002; Diaz-Ramos et al. 1996) and will be incorporated into future monitoring analyses.

Ward and Moberg (2004) selected sample reaches at 50 sites randomly located within the fish bearing waters of the Battle Creek watershed (Figure 1). One additional site was surveyed to provide stream condition comparisons to another nearby site. Stream conditions were characterized at each site (Ward and Moberg 2004). The physical attributes of sample sites were mapped (cross sections and longitudinal profiles), and stream bed particle size and presence of large woody debris were measured. These efforts yielded four variables that were used in the watershed analysis: percent fine sediment; median particle size (D_{50}); pool frequency; and frequency of large woody debris (Ward and Moberg 2004). Several other attributes of stream condition were also collected and can be used in future trend analyses.

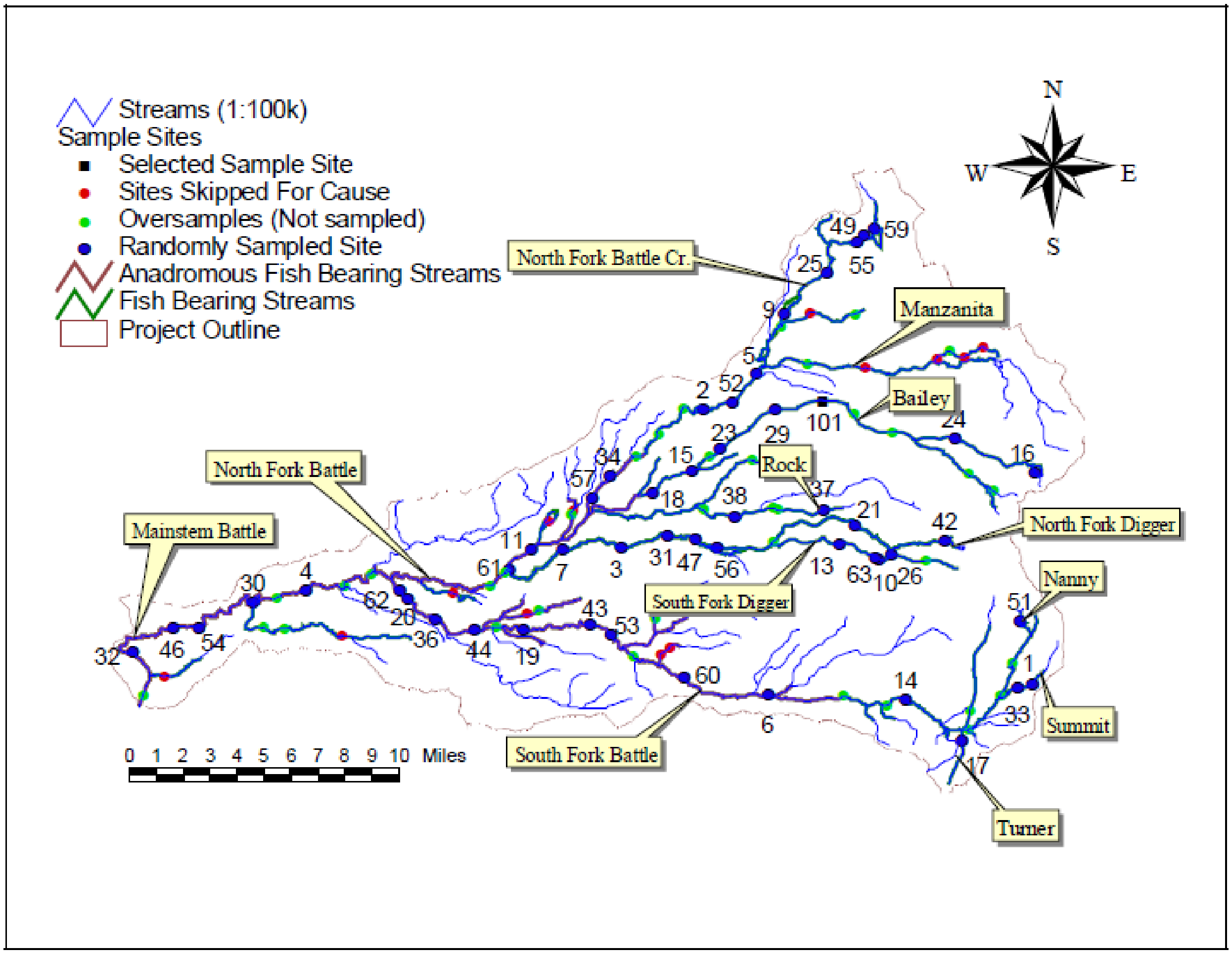

Figure 1. A map of the Battle Creek watershed depicting sample sites locations (blue and black), site numbers, and the names of streams with sites that were sampled. Oversamples (green) and sites skipped for cause (red) are also depicted. The depicted stream network is based on a 1:100,000 scale hydrography layer.

Continued monitoring of the sites first surveyed in 2001 and 2002 by Ward and Moberg (2004) will help determine stream condition trends across the watershed for an array of biological and physical attributes. Ward and Moberg's (2004) randomized sampling design allows trends observed during resurveying to be applied at the watershed scale. Ward and Moberg (2004) identified the floods of 1997 as the major contributor to the presence of high levels of fine sediment and low pool frequency and quality seen in the watershed. Trend monitoring (performed in 2006 and yet to be reported) will report how the stream conditions have recovered from those effects in the 5 years since they were initially measured and 9 years since the floods. Trend monitoring may also assess the influence of other contributing factors to high levels of fine sediment. Continued monitoring of fish bearing streams of the entire watershed will also aid in interpreting the trends in condition within the anadromous waters of the Restoration Project. If the Restoration Project fails to meet its goals of salmonid recovery due to limitations upstream watershed conditions or processes (e.g., fine sediment recruitment and routing through the stream network) then watershed-scale monitoring will assist adaptive management and threat detection and abatement.

Stream Condition Inventory Monitoring

The LNF has implemented two inventory and monitoring protocols that are important for the monitoring of stream conditions within LNF lands in the North and South Forks of the upper Battle Creek watershed (Lassen National Forest 2001). These include the more extensive (less intensive) Streamscape Inventory (Lassen National Forest 2000 (amended 2002)) and the more intensive (less extensive) SCI monitoring (USDA, Forest Service 2000).

The Streamscape Inventory evaluated existing stream and riparian zone conditions and was used to identify stream reaches that warrant more intensive assessment and monitoring with the SCI protocol (Lassen National Forest 2000 (amended 2002)). From 1999 through 2000 the Streamscape Inventory was performed for nearly 25 miles of stream reaches within LNF lands in the upper Battle Creek watershed (Lassen National Forest 2001). Within an analysis reach, quantitative measurements included: channel gradient; residual pool depth; channel width-to-depth ratios; counts of large woody debris; stream shading; water quality; discharge, and percent fines estimated with a grid. Several other attributes of the stream and riparian zone were more qualitatively estimated and included: large woody debris recruitment and recruitment potential; riparian width; hardwood age structure and ground cover; channel shape; confinement and bank stability; sediment sources and head cuts, and aquatic fauna (Lassen National Forest 2000 (amended 2002)). The LNF does not plan to resurvey the 1999 to 2000 Streamscape Inventory sites, though resurveys might be performed to detect changes in stream conditions due to future wildfires or projects implemented by LNF (K. Roby, LNF, pers. comm.).

The more intensive SCI monitoring (USDA, Forest Service, 2000, 2005) relies on measurements of attributes similar to the AREMP protocol used by Terraqua. The LNF SCI program can be used for effectiveness monitoring when surveys are conducted before and after restoration actions are taken. SCI monitoring has been performed on five sites within the Battle Creek watershed. Two of these sites, located on the South Fork Bailey Creek in Brokeoff Meadows above road 31N40 and on the South Fork Digger Creek just upstream of road 17 are considered “reference” sites as they are “unmanaged” by LNF and have not been affected by roads or logging. These sites are scheduled for re-sampling 5 years after the initial sampling. The reference reaches are compared to other managed sites to determine their condition and highlight any necessary restoration actions. The remaining three sites, located within the LNF on Summit Creek, Panther Creek, and North Fork Battle Creek, are considered impaired and will be re-sampled to monitor the effectiveness of restoration actions.

The attributes collected by the SCI protocol are similar to those collected under the AREMP protocol, although not always collected in the same manner: gradient; pool tail fines; pool frequency; residual pool depth; D_{50}; width-to-depth ratio, and large woody debris are collected by the SCI and AREMP methods and offer a point of comparison between the two monitoring efforts. For example, both stream condition assessments have found moderately high levels of fine sediments in pools (Ken Roby, LNF, pers. comm.). The LNF study identified road density and stream crossing as possible sources of fine sediment at the SCI sites. However, the SCI study was not designed to establish statistical relationships between sediment conditions and sediment sources outside of sampled reaches.

The SCI monitoring is a very important tool for identifying and treating adversely impacted streams in the LNF portions of Battle Creek. The LNF has been very active in identifying upper watershed sediment sources and developing restoration strategies and monitoring to reduce those sediment sources. Under the same Proposition 50/SWRCB grant that is funding this document, LNF is currently removing significant sediment sources on LNF property in Battle Creek by decommissioning 18 miles of roads, relocating approximately 2 miles of roads, decommissioning 10 acres of skid trails, improving up to 13 road crossings of streams, outsloping 12 miles of roads, and restoring 16 acres of aspen riparian vegetation stands (BCWC 2004). Relative to comprehensive watershed monitoring, a significant limitation with these monitoring efforts is their limited geographical scope confined to lands managed by LNF.

While stream condition monitoring by the USFS has provided valuable baseline comparisons with the watershed assessment and on-going monitoring, and adequately assists with effectiveness monitoring of a limited suite of USFS restoration projects, it is limited in geographic scope (i.e., USFS lands only), duration (the Streamscape Inventory is not scheduled to continue), and statistical power (which was not a design feature of this work). In light of these shortcomings, additional stream condition monitoring would be required to meet the goals of this SCMP.

Sediment Monitoring Focused Study

Sediment monitoring of the Restoration Project is proposed as a focus study within the Adaptive Management Plan to monitor the sediment dynamics at and downstream of the dam removal sites (Terraqua 2004). The monitoring and assessment of sediment dynamics and morphological responses will evaluate the effectiveness of dam removals to improve anadromous salmonid habitats and enable the adaptive management program to respond to changing physical conditions (Terraqua 2004). However, it is designated as a third tier program and will only be funded if the monitoring objectives in tiers 1 and 2 are adequately funded. No sediment monitoring of the Restoration Project has yet been performed.

The future implementation of this program alone would not meet all of the sediment monitoring needs to track trends in stream conditions upstream of and possibly within anadromous salmonid habitats. Additional stream condition monitoring would be required to meet the goals of this SCMP.

Pool Frequency

Excessive bedload or transported fine sediment can fill in pool habitats and depress pool frequencies (Montgomery and Buffington 1993; Rosgen 1996). When monitored over time, pool frequencies can provide a measure of how erosional processes and sediment inputs are impacting stream habitats and provide trends in habitat conditions and reach stability (Ward and Moberg 2004).

In 1988, Thomas R. Payne and Associates (TRPA 1998) mapped stream macrohabitat types for 52 miles of the Battle Creek watershed to estimate the response of fish habitats and populations to changes in instream flows. Stream reaches surveyed included the entire mainstem up to North Battle Creek Reservoir on the North Fork and up to the South Diversion on the South Fork (TRPA 1998). From this 1988 survey, the frequency of shallow (< 3 feet) and deep (> 3 feet) pools are available for the reaches mapped.

Pool frequencies were used to assess physical stream condition in both the Battle Creek Watershed Assessment and Stream Condition Inventory Monitoring (LNF) projects that were described above. The watershed assessment (Ward and Moberg 2004) performed habitat mapping and assessed pool frequencies for 50 randomly selected sites within fish bearing streams in the watershed. Within LNF lands, pool frequencies were characterized for 25 stream miles as a part of the Streamscape Inventory, though the ongoing monitoring of pool frequency (5 year recurrence) is limited to only two permanent SCI reference reaches (Lassen National Forest 2001). There are currently no existing monitoring programs established to provide trends in pool frequencies and stream reach stability over time for fish bearing waters in the Battle Creek watershed.

Due to the importance of pools to fish populations, we conclude that additional pool should monitoring be included in the SCMP to continue to build upon this previous work.

Instream Flows

Stream flow directly influences both the quantity and quality of coldwater fish habitats. Increases in instream flows are anticipated to result in increased anadromous salmonid habitats and populations in the Battle Creek watershed (Terraqua 2004; Ward and Kier 1999). Instream flows have been increased within the Battle Creek Hydroelectric Project under an agreement between PG&E and the resource agencies and will further increase with the implementation of the Restoration Project.

Battle Creek discharge is currently monitored by the U.S. Geological Survey and the Department of Water Resources (DWR) at a gauge downstream of Coleman National Fish Hatchery and by PG&E at their five hydroelectric power plants and eight diversion canals (Jones & Stokes 2005). Additionally, DWR has been monitoring flow at the mouths of both the north and south forks of Battle Creek since 2000. Planned monitoring identified in the Restoration Project's Adaptive Management Plan (Terraqua 2004) includes monitoring discharge below each dam, at all canal gates and spill channels, and at the mouth of the North and South Forks tributaries. Planned discharge monitoring at dam, canal and spill channel sites are largely mandatory monitoring requirements of the Federal Energy Regulatory Commission (FERC) license agreement regulated by FERC and Regional Water Quality Control Boards.

The discharge of significant springs throughout the watershed may decrease in magnitude or experience seasonal shifts in peak discharge in response to predicted changes in regional climate that could have significant impacts to stream conditions. The cool water temperatures of spring sources are directly related to the quality of anadromous salmonid habitats. Stream temperature modeling for Battle Creek (Tu 2001) assumes the discharge of these spring inputs do not vary year to year. Recent research of spring-fed stream networks in Oregon's High Cascade Mountains document significant losses of spring flows relative to losses in snowpack (Tague et al. 2008). Understanding the annual variability and future potential climate related changes in spring inputs is a critical data gap. Rather than the long-term monitoring of spring inputs, this document suggests that the relationships between precipitation, snowpack, and spring flow should receive focused research attention to better understand these important features of Battle Creek hydrology and their response to climate change.

Implementation of the Restoration Project Adaptive Management Program and related monitoring should address deficiencies in the monitoring of instream flows and should meet the goals of this SCMP.

Meteorological Monitoring

Air temperature, humidity, cloud cover, rainfall, snowfall, and other aspects of climate have direct influence on aspects of stream conditions such as flow and water temperature. Future management of the Restoration Project requires meteorological monitoring to address a number of scientific uncertainties as outlined in the Project's adaptive management plan (Terraqua 2004).

There are meteorological stations within or nearby the Battle Creek watershed at Red Bluff, Redding, Shingletown, Battle Ridge, Lassen Lodge, Manzanita Lake, and the city of Mineral (Table 5). Data collected from meteorological monitoring stations have previously been used to assess water temperature conditions within the Restoration Project area (Tu 2001). Common meteorological parameters required for temperature modeling include air temperature, humidity, solar radiation, wind speed, and atmospheric pressure (Deas and Lowney 2000). Snowpack monitoring sites within or near the Battle Creek watershed include: Lower Lassen Peak (LLP), Upper Lassen Peak (ULP) and Manzanita Lake (NMN) (Table 5). Many existing meteorological monitoring stations fall outside the Battle Creek watershed or occur at a range of elevations not directly comparable to much of the Battle Creek watershed (Table 5). The applicability of these meteorological monitoring stations to the objectives of this document is mixed.

Table 5. Meteorological monitoring stations within or near Battle Creek watershed.

Station	Elevation (feet)	Operator	Date of records	Latitude/Longitude
Redding (KRDD)	502	NWS	1897 to present	40.51500 /-122.29667
Redding (RRAC1)	502	USFS	2001 to present	40.5158 /-122.2906
Redding (47926)	580			40.35/-122.24
Red Bluff (KRBL)	348	USBR	1989 to present	40.15056 /-122.25222
Red Bluff (FSS, 047292)	350	CDWR	1933 to present	40.09/-122.15
Anderson (AP525)	430	USBR	1999 to present	40.43900 /-122.23950
Cottonwood (UP299)	425		1994 to present	40.39393 /-122.25905
Shingletown (AR225)	3,630		1989 to present	40.4767 /-121.9887
Battle Ridge (BTR)	3,399		1996 to present	40.3330 /-121.7500
Lassen Lodge (LSNC1)	4,100			40.3442 /-121.7136
Manzanita Lake (VIOC1)	5,660			40.54 / -121.5803
Snow Pack Monitoring Sites				
Lower Lassen Peak (LLP)	8,250	PG&E	1930 to present	40.4680 / 121.5070
Upper Lassen Peak (ULP)	8,500	unknown	1931 to 1971	40.4730 / 121.5070
New Manzanita Lake (NMN)	5,900	LNP	1950 to present	40.5330 / -121.5620

Meteorological data is an important part of the SNTEMP stream temperature model (Tu 2001) and is also an important tool for evaluating the effects of global warming on the Restoration Project goals and on the watershed as a whole. In the past, the Restoration Project used meteorological data from the Redding airport in the SNTEMP model (Tu 2001) to identify salmon habitat. Tu's (2001) modeling effort used Redding meteorological data for air temperatures, relative humidity, wind speed, and to rank year types (normal, warm, cold). Tu (2001) states that confidence in model predictions may be limited by the type of hydrologic and meteorological data that were used. The Battle Creek adaptive management plan also identifies the use of Redding meteorological data in the modeling of stream temperature as a key uncertainty (Terraqua 2004). Bartholow (1989) outlined two potential problems with meteorological data used in SNTEMP models: 1) the air temperature data used should adequately represent the study area; and 2) avoid the use of a single air temperature to represent all elevations in the study area. The Redding meteorological data used in the past does not satisfy either of these criteria.

The most significant and efficient addition to meteorological monitoring would be establishing meteorological data at elevations representative of the portions of the watershed that currently do, or potentially could, support anadromous fish. This would provide multiple meteorological data sets for use in the SNTEMP model, thereby greatly increasing the ability of the model to accurately predict water temperatures and available salmonid habitat. Recommended meteorological parameters to be monitored are those most commonly used to model stream temperatures and include: air temperature, humidity, solar radiation, wind speed and atmospheric pressure (Deas and Lowney 2000).

The average elevation of anadromous fish bearing waters within Battle Creek is 2,027 feet and the greatest gap for meteorological data is at these mid-elevations within the watershed (Table 5). To fill this data gap, the establishment of a meteorological monitoring station in the town of Manton (elevation 2,007 feet) is recommended. In 2007, the USFWS was funded through the Restoration Projects Adaptive Management fund to establish this meteorological monitoring station in Manton. When this monitoring station is installed it should fill the meteorological data gaps that exist within Battle Creek.

Water Quality Monitoring

Water quality is essential to aquatic ecosystems and other beneficial uses of water. Within the Battle Creek watershed, monitoring of influential water quality attributes could help establish trends in stream conditions and the effectiveness of watershed restoration efforts. Ongoing monitoring programs within the watershed include water temperatures within the restoration project area and the point source monitoring of effluents from multiple fish hatcheries.

Water Temperature

The effect of water temperature on metabolic processes influences both the productivity of aquatic ecosystems and the growth and respiration of aquatic organisms (Allan 1995). Water temperature is perhaps the most influential physical attribute of salmonid habitats in California's Central Valley (Myrick and Cech 2001). The warmest stream temperatures in Battle Creek occur June through September (Tu 2001) and can most adversely impact adult Chinook salmon and incubating eggs. Cold water temperatures driven by spring inputs is one of the primary attributes that makes Battle Creek one of the few restoration opportunities in the state for the endangered winter-run Chinook salmon (Ward and Kier 1999). Water temperature monitoring is important for tracking the effectiveness of the Restoration Project and instream flow releases to meet critical salmonid life history requirements.

Water temperatures have been periodically monitored at several sites in the Battle Creek watershed by the California Department of Fish and Game (CDFG) since 1988. In the years 1995 through 1997 more extensive temperature monitoring was implemented (approximately 12 sites) to depict existing conditions within the project-affected reaches of Battle Creek. Since 1998, water temperature has been measured by the California Department of Water Resources and USFWS at 21 stream and canal sites within and downstream of the Restoration Project area (Table 6). Ten new monitoring stations were added between 1999 and 2005. Between 2002 and 2004, monitoring was ceased at six of those sites leaving a current total of 25 stations collecting water temperature data (Table 6). The Restoration Project Adaptive Management Plan proposes the monitoring of longitudinal water temperature regimes at a network of locations within the project area. This includes "at least, the start and end of each stream reach (including diversion reaches and Panther and Keswick reaches downstream of the limit of anadromous fish distribution), major spring water sources and tributaries, the terminus of canals or power house tailraces as needed, and as needed elsewhere", (Terraqua 2004).

When fully implemented, this monitoring regime will be sufficient for monitoring stream conditions within the anadromous waters of the Restoration Project area. However, the goals of the goals of this stream condition monitoring program are not fully met by this monitoring regime because it is limited in geographical scope and misses sites necessary for capturing the status and trend of stream conditions in important stream reaches.

Table 6. U.S. Fish and Wildlife Service water temperature monitoring sites and duration.

Water source	Location	Duration
N.F. Battle Cr.	Below Battle Feeder Diversion Dam	03/27/98 to present
	Below Digger Cr. Confluence	08/08/01 to present
	Below Eagle Canyon Dam	03/27/98 to present
	Below Wildcat Dam	02/27/98 to present
	Mouth of N.F. Battle Cr.	02/27/98 to present
	End of Eagle Canyon Canal	01/23/98 to present
	End of Cross Country Canal	01/23/98 to 9/17/06
Digger Cr.	Mouth of Digger Cr.	09/08/01 to present
S.F. Battle Cr.	Below South Dam	01/23/98 to present
	Top of South Canal at Dam	9/05 to present
	Soap Cr.	6/05 to present
	End of South Canal	09/24/98 to 9/17/06
	Below Inskip Dam	01/23/98 to 9/17/06
	End of Inskip Canal	01/23/98 to present
	Below Coleman Dam	01/23/98 to present
	Near Mouth	02/27/98 to present
	Coleman Canal Before Forebay	02/27/98 to present
S.F. and N.F. Battle Cr.	Above South Powerhouse	10/27/98 to 9/17/06
	South Powerhouse tailrace	10/27/98 to 9/17/06
	Above Inskip Powerhouse	10/27/98 to present
	Inskip Powerhouse Tailrace	10/27/98 to present
Mainstem Battle Cr.	Darrah Springs above Baldwin Cr.	03/27/98 to present
	Darrah Springs below Baldwin Cr.	06/27/02 to present
	Above Coleman Powerhouse	03/26/98 to present
	Coleman Powerhouse Tailrace	10/27/98 to present
	Below Jelly's Ferry Road	08/05/98 to 01/16/02
	Mouth of Battle Cr.	03/24/99 to present
	Bottom of Reach 4	06/27/02 to present
	Top of Reach 6	08/23/03 to present
	Upper rotary screw trap	06/21/99 to present
	Lower rotary screw trap	06/21/99 to present

*Creeks with the same subscript have a common water source.

Point Source Pollution Monitoring Programs

Fish Hatcheries

Fish hatcheries can influence water quality through point source returns to stream networks. Effluent from hatchery production facilities can contain elevated levels of nutrients, solids (e.g., fecal matter, food, algae etc.), water temperature, aquaculture drugs (e.g., antibiotics), and chemicals (e.g., formalin etc.). Water treatment and/or monitoring programs are often required by regulatory agencies to ensure hatchery releases to streams do not impact other beneficial uses. Several private, state, and federal fish hatcheries operate within the Battle Creek watershed.

Fish hatcheries within the Battle Creek watershed include: Coleman National Fish Hatchery (operated by USFWS) 3 miles upstream from the mouth; Darrah Springs Fish Hatchery (operated by CDFG) located on North Fork Battle Creek; and five smaller hatcheries operated by Mt. Lassen Trout Farms, four within the North Fork and one within the South Fork of Battle Creek (Figure 1). The California Regional Water Quality Control Board (CRWQB) issues permits for these hatcheries and prescribes monitoring requirements for compliance with the National Pollution Discharge Elimination System. Monitoring requirements are similar for all the hatcheries and include the monitoring of influent (water source), effluent (hatchery discharge), and the receiving waters above and below the hatchery.

Perhaps most relevant to this report are the constituents monitored in the receiving waters and their frequency. In several cases the CRWQCB has determined that monitoring the receiving waters of some (three of five) of Mt. Lassen Trout Farm facilities is not feasible or appropriate due to effluent discharges onto agricultural lands (CRWQCB 2004c,e,f). In these cases all required constituents are instead monitored in both the influent and effluent (CRWQCB 2004c,e,f). Receiving water monitoring at all hatcheries include dissolved oxygen, turbidity, temperature and pH (CRWQCB 1996, 2004a,b,d) (Table 7).

Table 7. Receiving water monitoring constituents for fish production hatcheries within the Battle Creek watershed.

Constituent	Coleman Hatchery (USFWS)	Darrah Springs Hatchery (CDFG)	Mt. Lassen Trout Farms (Private)
Dissolved Oxygen	X	X	X
Turbidity	X	X	X
Temperature	X	X	X
pH	X	X	X
Conductivity		X	X
Hardness*		X	

* required only when copper sulfate solutions are added to facility waters

Newer permits specify that the monitoring of conductivity and monitoring hardness is required at the Darrah Springs Hatchery when copper sulfate is in use (CRWQCB 2004a). The required frequency of receiving water monitoring is either once per month at Coleman and Darrah Springs Hatcheries (CRWQCB 1996, 2004a), or once per quarter at Mt. Lassen Trout Farm facilities

(CRWQCB 2004b, d). While the receiving water monitoring at fish hatcheries may be appropriate to detect hatchery impacts, the limited spatial extent of this monitoring is inadequate to track the general trends in water quality and stream conditions at the watershed scale.

Effluent monitoring from the City of Mineral

The Tehama County Sanitation District No. 1 wastewater treatment plant for the City of Mineral is required by discharge permit to monitor discharges to streams within the Battle Creek watershed. As no discharges have been made for the last 5 years, no discharge related monitoring has been performed (Gerald Brown, Tehama County Public Works, pers. comm.).

Nonpoint Source Pollution Monitoring Programs

Irrigation, Agriculture, Grazing and Timber Harvest Program

There are currently no California state nonpoint source monitoring programs (irrigation, agriculture, grazing or timber harvest) ongoing in or planned for the Battle Creek watershed. While there are some possible concerns regarding nonpoint sources of pollution within the watershed, they are not watershed wide or significant enough to warrant a priority for funding and implementation (Dennis Heiman, SWRCB, pers. comm.). The Surface Water Ambient Monitoring Program is also not being considered for the Battle Creek watershed as there is already much interest and involvement by the State Water Resources Control Board in the current and planned monitoring activities in the watershed (Dennis Heiman, SWRCB, pers. comm.).

APPENDIX B. PLANNING ANALYSIS

Developing a successful monitoring program within the constraints of finite resources requires identifying a list of indicators relevant to the ecosystem processes of interest, using an efficient sampling design, and employing a robust suite of protocols. In this Appendix, we analyze existing data (presented in Appendix A) coupled with other research to identify data gaps, recommend indicators, protocols, and designs for use in this SCMP.

Data Gaps and Outstanding Stream Condition Monitoring Needs

Existing monitoring efforts within the Battle Creek watershed (Appendix A) are insufficient to assess ongoing trends in stream conditions at the watershed scale or to enable effective adaptive management of fish bearing waters. Based on the review of existing data in Appendix A, monitoring data gaps exist in several general areas including biological stream conditions, physical stream conditions, and water quality.

Biological monitoring data gaps include:

- Comprehensive, regularly recurring macroinvertebrate surveys.
- Regularly recurring surveys of riparian condition and trends.
- Documentation of changes in watershed land cover.

Physical monitoring deficiencies include:

- Regularly recurring physical stream condition surveys.

Water quality data gaps include:

- Stream temperature conditions above the Restoration Project and in the upper reaches of the Restoration Project (above Volta II Powerhouse on the north fork and South Diversion Dam on the south fork).

Recommended Indicators and Protocols

Based upon existing research and analyses of existing data, recommendations are made in this section regarding indicators and protocols to be used to fill the biological, physical and water quality data gaps in the Battle Creek watershed that were identified in the previous section.

Biological Monitoring

Macroinvertebrate Surveys

Invertebrate monitoring is an excellent surrogate for expensive and time-consuming physical metrics used to determine stream condition and water quality. Aquatic macroinvertebrates are versatile in that they can be easily and efficiently sampled to address changes in sediment delivery, point source and non-point source pollution, and climate change.

Invertebrate monitoring has been used by Ward and Moberg (2004) to monitor water quality and stream condition status and trends at the watershed level. Re-sampling of the sites previously sampled in 2001 and 2002 annually (Terraqua and Kvam 2003) are recommended to fill stream condition data gaps and establish trend analysis by using Benthic Invertebrate Indices (IBI) at the watershed level. The sampling design of Terraqua and Kvam (2003) is the only water quality and stream condition monitoring effort in Battle Creek that utilizes a randomized sampling approach that enables the assessment of the condition of the entire watershed. We recommend continuing this design for these reasons.

Continued use of AREMP RIVPACS protocols (Gallo et al. 2001, Gallo 2002) that were previously used by Terraqua and Kvam (2003) are also recommended. This protocol is sufficient to generate multiple IBI metrics (Table 3 and Table 4), is the same protocol used by LNF at SCI reference sites, and generates results that can be modified for comparison to results derived through California Stream Bioassessment Protocol (CSBP) protocols. A comparative study by Herbst and Silldorff (2006) in the eastern Sierra Nevada determined that RIVPACS methods performed similar to methods employed by either CSBP or the University of California-Sierra Nevada Aquatic Resource Laboratory methodologies for detecting impaired biological condition. Data from these three methods can potentially be used interchangeably for cross-validation (Herbst and Silldorff 2006).

Riparian condition and trends

As temperature is of significant concern to Battle Creek salmon and steelhead restoration efforts (Terraqua 2004), the monitoring of riparian condition, especially as it relates to canopy cover and stream shading, may be prudent. Field-based measures of canopy cover for fish bearing stream reaches could be efficiently incorporated into other recommended biological or physical stream condition monitoring efforts. Watershed-wide canopy cover estimates at existing randomized monitoring sites may also be helpful to refine the canopy shading variable in future water temperature models. The USFS AREMP protocols (Gallo 2002) do not have a field based riparian canopy cover monitoring component. The Pacific Southwest Region SCI protocols (Frazier et al. 2005) previously used by LNF to monitor SCI reference sites call for the use of a Solar Pathfinder to estimate stream shading. We recommend measuring riparian canopy cover along physical habitat mapping transects using a densiometer following the canopy cover protocol of the EPA's Environmental Monitoring and Assessment Program (EMAP) (Peck et al. 2001) because it is easier to use and cost-effective. The state of California's Surface Water Ambient Monitoring Program also uses a similar densiometer approach for monitoring riparian canopy cover at monitoring site transects.

Changes in watershed land cover

Watershed-scale land cover monitoring is an important adaptive management component to explore causal relationships between vegetational changes and stream condition trends. It will be important to discern between highly variable natural disturbance events such as wildfires that maintain aquatic ecosystems and anthropogenic impacts that may require an adaptive management response. We recommend the analysis of existing California LCMMP satellite imagery data (Levien et al. 2002, 2003) at an appropriate watershed or sub-watershed scale to monitor land cover in Battle Creek. As the LCMMP program is not currently active, we recommend future land cover mapping and change detection be implemented every 4 years using standards established by the LCMMP program to support trend analysis. A 4-year recurrence will align land cover change monitoring with the 4-year period it will take to cover all physical stream and riparian condition monitoring sites using the rotating panel design (see Sample Timing).

Physical Monitoring

Physical stream condition surveys

Regularly recurring physical stream condition surveys are needed to assess the effects of watershed-scale trends on stream conditions within the Restoration Project. The continued use of AREMP monitoring protocols (Gallo et al. 2001) is recommended for the long-term monitoring of trends in stream channel condition. These protocols were previously implemented in 2001 and 2002 for the Battle Creek watershed assessment (Ward and Moberg 2004) and include the following components: physical habitat mapping (e.g., width-to-depth ratios, pool frequencies, etc.), measuring stream bed particle size (e.g., D_{50}), estimating the percentage of fine sediment, and the frequency of large woody debris. Ongoing repeat sampling of initial randomized sites sampled in 2001 and 2002 would enable the assessment of status and trends in physical stream conditions of fish bearing streams of the entire watershed.

The AREMP monitoring protocols (Gallo et al. 2001) have been shown to perform as-well-as or better-than several other protocols commonly used for monitoring physical stream conditions. For example, the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) conducted a "side-by-side" comparison test of seven commonly used habitat monitoring protocols[2] in a study designed to compare the repeatability and equivalence of protocols for measuring physical stream attributes (Lanigan et al. 2006). During the summer of 2005 each of 12 stream reaches in the John Day River basin of Oregon was evaluated by seven different state and federal monitoring groups. Group means and variability (standard deviation, coefficient of variation, and Root Mean Squared Error) were compared both within and among all monitoring groups where attribute means for each crew within a protocol (monitoring group) served as replicates for the reach. The accuracy of each group, relative to estimates of "true" values of the indicators being measured derived from much more intensive surveys of the same variables, was also performed.

[2] The seven monitoring protocols tested included those used by the Aquatic Riparian Effectiveness Monitoring Program (AREMP; Reeves et al. 2004), the PacFish InFish Biological Opinion Monitoring Program (PIBO; Kershner et al. 2004), the Northwest Indian Fish Commission, the Upper Columbia Monitoring Program (UC; Hillman 2006), the Oregon Department of Fish and Wildlife (ODFW; Moore et al. 2007), the California Department of Fish and Game's North Coast Watershed Assessment Program (NCWAP; Downie 2004), Environmental Protection Agency's EMAP program (EMAP; Kaufman et al. 1999).

Water Quality Monitoring

Stream temperature monitoring outside the Restoration Project area

Water temperature is a key factor in assessing the suitability of streams to support salmonid production. The SNTEMP model relies heavily on water temperature data to predict the available habitat for different life stages of Chinook salmon and steelhead under the different flows prescribed in the Restoration Project's Environmental Impact Report/Environmental Impact Statement (Jones and Stokes 2005). While ongoing monitoring efforts provide comprehensive temperature monitoring within the Restoration Project area, data gaps exist for resident fish bearing waters and stream reaches that feed the Restoration Project area.

The design adopted to monitor water temperatures in the upper watershed will be driven largely by the limited funding available to deploy remote water temperature sensors. Under current funding limitations, it does not appear feasible to monitor water temperature conditions using a randomized sampling approach that would allow for the description of water temperature on a watershed scale. Unmonitored tributaries and/or reaches thought to contribute significantly to water temperature increases should be prioritized for focused monitoring. Water temperature monitoring protocols should follow those already established by USFWS for the existing network.

When fully implemented, this monitoring regime will be sufficient for monitoring stream conditions within the anadromous waters of the Restoration Project area. However, the goals of this stream condition monitoring program are not fully met by this monitoring regime because it misses sites necessary for capturing the status and trend of stream conditions in important stream reaches and is limited in geographical scope.

Two of the water temperature monitoring sites specified in the Adaptive Management Plan that are most useful to capturing the status and trends in stream conditions, at the upstream ends of the Keswick (on the North Fork Battle Creek) and Panther (on the South Fork Battle Creek) reaches, are not currently being monitored (Table 6). We recommend that water temperature monitoring be initiated at these two reaches as soon as possible to maximize the time series of information regarding the temperature of water being delivered to these two important reaches of the Restoration Project area. Possible failure of the Restoration Project to meet its goals and objectives based on possible water temperature limitations in these reaches will be difficult to discern without this information.

Furthermore, water temperature monitoring under the Adaptive Management Plan is limited in geographical scope to anadromous waters only. This does not adequately capture trends in stream conditions that may be influenced by conditions upstream of the Restoration Project area. While current funding limitations make it not feasible to monitor water temperature conditions using a randomized sampling approach that would allow for the description of water temperature on a watershed scale, we recommend that two areas upstream of the Restoration Project area be monitored more intensively for water temperature conditions. This would provide information about non-Restoration Project influenced stream conditions in the Battle

Creek watershed and elucidate mechanisms that may be affecting water temperatures outside of the Restoration Project area.

We recommend that water temperature be monitored in the South Fork Battle Creek upstream and downstream of Battle Creek Meadows (near the city of Mineral) to elucidate water temperature effects of this unique part of the Battle Creek watershed. Ward and Kier (1999) recognized the possible influence of these meadows, including affects of past land-use practices and current restoration efforts, on water temperature in the South Fork Battle Creek. Little or no additional information has been collected since that report to determine if, or how much, conditions within Battle Creek Meadows affect water temperatures in the South Fork Battle Creek upstream of the Restoration Project area. We believe that processes occurring in the Battle Creek Meadows may have a significant influence on water temperatures in the South Fork Battle Creek and should be examined scientifically. The location of these monitoring sites could be on public or private lands depending on landowner willingness to participate. We recommend that the BCWC continue discussions with public or private landowners to determine willingness to participate in monitoring and to select specific monitoring sites.

Likewise, water diversions for agricultural and residential uses from Digger Creek, and restoration efforts being considered in that stream (e.g., Terraqua 2002), may influence the temperature of water within Digger Creek and water delivered to the Restoration Project area by Digger Creek. Therefore, we recommend that water temperatures be monitored at two locations on Digger Creek upstream and downstream of the reaches affected by local water diversions. Again, the location of these monitoring sites could be on public or private lands depending on landowner willingness to participate. We recommend that the BCWC continue discussions with public or private landowners to determine willingness to participate in monitoring and to select specific monitoring sites.

Sampling Design and Parameter Power

Several aspects of sampling design are explored in this section using information derived from literature and from data collected in the original 2001 watershed assessment, including: selection of the proper target population; sample selection; sample sizes for assessing status; sample sizes for detecting trends, and tools that optimize sample selection to balance between competing objectives of characterizing status and detecting trends.

The SCMP's primary objective is to detect trends in stream condition through the repeat sampling of various parameters at randomly selected monitoring sites. However, detecting trends is complicated by the cumulative effect of variance, such as observer and temporal and spatial variance, on a sampling design (Roper et al. 2002). Sampling to be carried out by the SCMP is intended to detect trends across the entire watershed using watershed averaged conditions as well as detecting trends for individual sites. In the rest of this section, attributes proposed for monitoring are analyzed for their power to overcome variance and detect small changes in stream conditions.

Target Population

The target population used in the original 2001 watershed assessment, which included all fish bearing waters of the Battle Creek watershed, meets the goals of this stream condition monitoring program to describe status and trends at the watershed scale (Ward and Moberg 2004). In light of this historical precedent and its continuing usefulness, we recommend continuing with this target population for future site selection.

Sample Selection and Location

Randomization of sample sites should be used whenever there is an arbitrary choice to be made of which units will be measured in the target population (Hillman 2006). The intent is that randomization will remove or reduce systematic errors (bias) of which the investigator has no knowledge that could occur if sample sites were to be intentionally or opportunistically selected. If randomization is not used, then there is the possibility of some unseen bias in selection or allocation.

Roper et al. (2003) examined the usefulness of permanent sites to reduce the number of sites required to show changes in stream habitat attributes. They found that using permanent sites greatly reduced the amount of samples required to detect changes at sites. Larsen et al. (2004) found similar results for detecting trends in stream habitat attributes. Yearly random selection of sampling sites was deemed the "worst-case" scenario as the site component of variation is 80% to 90% of total variation. Instead, initial random selection of a collection of permanent sample sites was found to be most useful. Roper et al. (2003) also found that relocating sites using GPS, maps, and photos was sufficient to resample permanently located sites.

The sampling sites used in the original 2001 watershed assessment were randomly selected using an unequal probability random tessellation stratified survey design for a continuous linear network population (Olsen 2001). This design remains the standard in selecting randomized locations for ecological sampling based on geographical considerations and continues to meet the goals of this stream condition monitoring program to describe status and trends at the watershed scale (Ward and Moberg 2004). Therefore, we recommend adopting the 50 sample sites studied in the original watershed assessment as the permanent collection of sample sites.

A way to examine the potential to detect change in two groups of attributes (e.g., year-to-year change) is to conduct a power analysis of the parameters of interest (Roper et al. 2002). Roper et al. (2002) evaluated the variance of parameters used to measure stream characteristics and recommended attributes that have a low observer variation (i.e., within year variance) (Table 8). The same power analysis was conducted for the physical habitat attributes (Table 9) and biological macroinvertebrate indices (Table 10) studied in the 2001 and 2002 watershed analysis (Ward and Moberg 2004). Table 8 through Table 10 illustrate how many samples are required to detect a 5%, 10%, 20%, 30%, or 50% change in the attribute of interest. Green colored cells identify the degree of change that can be detected for each attribute if re-sampling of the 50 existing monitoring sites was implemented.

Generally, the number of sites required to show change are similar between the Roper et al. (2002) analysis and Ward and Moberg's (2004) analysis. All the parameters used by Ward and Moberg (2004) can detect a 50% change in stream conditions by re-sampling 50 or less sites with the exception of percent sediment tolerant macroinvertebrates. However, if ongoing monitoring efforts are limited to 10 resample sites, only sinuosity, entrenchment ratio, and less than half of the significant macroinvertebrate indices could detect a 50% change in condition (Table 9 and Table 10).

Table 8. Power analysis by Roper et al. (2002) showing the number of sample sites needed to detect different degrees of change for various attributes. The green colored cells identify the percent change detectable for each attribute with a 50 site re-sampling effort.

	Sample Sizes required to Detect Percent Change				
Stream Attribute	5 percent	10 percent	20 percent	30 percent	50 percent
Stream Slope	3,611	903	226	101	37
Sinuosity (length/length)	198	50	14	7	3
Ave. Bankfull Width	1,054	264	66	30	12
Bankfull Width: depth	1,266	314	66	30	12
Substrate d50	3,081	771	193	86	31
Percent fines	3,165	792	198	88	32
Pool frequency (all pools)	243	61	17	8	4
Pool residual depth (all pools)	405	102	27	13	6

Table 9. Parameter power analysis for physical habitat attributes in Battle Creek sampled in 2001 and 2002 showing how many samples are required to detect different degrees of change. The green colored cells identify the percent change detectable for each attribute under a 50 site re-sampling effort.

	Sample Sizes required to Detect Percent Change				
Stream Attribute	5 percent	10 percent	20 percent	30 percent	50 percent
Stream Slope	2,315	579	146	65	24
Sinuosity (length/length)	31	9	3	2	1
Ave. Bankfull Width	1,839	461	116	52	19
Bankfull Width: depth	1,071	268	68	31	12
Substrate d50 (algae ignored)	3,301	826	207	93	34
Percent fines (skipping algae-obscurred points)	1,846	462	116	52	19
Pool frequency (all pools)	2,592	649	163	73	27
Pool residual depth (all pools)	1,108	278	70	32	12
Pool frequency (only scour pools)	2,505	627	157	70	26
Pool residual depth (only scour pools)	1,168	293	74	33	13
Entrenchment ratio	750	188	48	22	8
Wood frequency (#/1000m)	2,990	748	188	84	31

Table 10. Parameter power analysis for macroinvertebrate metrics and indices generated from 2001 and 2002 sampling (Ward and Moberg 2004) showing how many samples are required to detect different degrees of change. The green colored cells identify the percent change detectable for each attribute with a 50 site re-sampling effort.

	Sample Sizes required to Detect Percent Change				
Stream Attribute	5 percent	10 percent	20 percent	30 percent	50 percent
Total taxa richness	337	85	22	11	5
EPT richness	712	179	46	21	8
Sensitive taxa richness	4,807	1,203	302	135	49
Cold stenotherm richness	4,651	1,164	292	130	48
Sediment sensitive richness	2,824	707	178	80	30
Percent sediment tolerant	14,078	3,520	881	392	142
Percent dominant (1taxa)	1,077	270	69	31	12
ODEQ score	145	37	10	5	3
B-IBI score (sum)	182	46	13	6	3

The objectives of the SCMP are not limited to detecting changes between two groups of samples (e.g., comparing two years) but are primarily focused on detecting trends in stream conditions. Larson et al. (2004) provides guidance to determine the minimum number of monitoring sites needed to attain the desired level of confidence in trends. In detecting 1% and 2% trends in physical stream attributes per year with 80% likelihood, Larsen et al. (2004) found that varying the number of sites sampled annually (from 10 to 50) made relative little difference for some stream attributes. Most significant for detecting trends was the duration of the monitoring program. With 50 sites sampled per year, nearly all 1% to 2% trends in stream attributes can be detected in 10 to 20 years (Larsen et al. 2004). Larsen et al. (2004) recommend that 30 to 50 sites be sampled annually if studies are designed to estimate conditions at the regional scale. The greatest decrease in the numbers of years it will take to accurately detect trends in stream attributes occurred when the number of annual monitoring sites were increased from 10 to 20 (Larsen et al. 2004).

Sample Timing

One way to reduce annual costs of monitoring and to design a sampling strategy that meets multiple objectives is to allocate samples over time in a rotating panel design. For example, the Environmental Protection Agency's EMAP program relies on a survey design that was developed to describe current status and to detect trends in a suite of indicators. These two objectives have conflicting design criteria; status is ordinarily best assessed by including as many sample units as possible, while trend is best detected by repeatedly observing the same units over time (Overton et al. 1990, Roper et al. 2003). EMAP addresses this conflict by using rotating panels (Stevens 2002). Each panel consists of a collection of sites that will have the same revisit schedule over time. For example, sites in one panel could be visited every year, sites in another revisited every 5 years, and sites in still another revisited every 10 years.

In Battle Creek, funding limitations and multiple objectives may similarly restrict the number of sites that can be annually re-sampled to monitor biological and physical attributes. However, wide variation in costs suggest that some stream condition indicators could be cheap enough to sample annually while more expensive indicators might be allocated over a longer time period. For example, macroinvertebrate sampling is generally more sensitive to changes in biological and physical conditions and requires considerably less effort than re-sampling of attributes based on physical stream measurements. Annual re-sampling of macroinvertebrates at all 50 sites would be an affordable way to detect smaller changes in stream condition and water quality watershed-wide. On the other hand, physical stream condition sampling is more costly but better suited for studying long-term stream condition trends.

For these reasons, we recommend that a split rotating panel design be used for long-term stream condition monitoring.

- Macroinvertebrate sampling at all 50 sample sites every year.

- Physical stream condition surveys at 20 sites per year to achieve monitoring of all 50 sites once every 4 years. This rotating panel design would include an annual panel of 10 "fixed-sites" and four rotating panels of 10 additional sites each that would be sampled once every 4 years (Figure 2). In this manner, all 50 sites would be surveyed at least once every 4 years.

	Year															
Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
2	10				10				10				10			
3		10				10				10				10		
4			10				10				10				10	
5				10				10				10				10

Figure 2. Rotating panel design for status/trend monitoring within Battle Creek. Shading indicates the years in which sites within each panel are sampled and the number indicates the number of sites to be sampled. For example, sites in panel 1 are visited every year, while sites in panel 2 are visited only in years 1, 5, 9, 13, and 17, assuming a 20-year sampling frame.

Recommendations from the analysis of sampling designs and parameter power

- Conduct sampling within the same target population (all fish bearing waters of Battle Creek) to ensure that monitoring results can be compared with the 2001-2002 watershed analysis.

- Randomly select sites from the target population to ensure that no bias can be introduced through the site selection process.

- Use permanent randomly selected monitoring sites, located by GPS and monumented with survey stakes, as opposed to sampling new sites each year.
- Expect that year-to-year changes on the order of 50% of the measured value can be detected for nearly all biological and physical metrics used by Ward and Moberg (2004) if 50 sites are sampled annually. Expect that detection of finer year-to-year changes would require additional sample sites.
- Expect that trends of 1% to 2% change per year can be detected in 10 to 20 years using 50 annual sampling sites.
- Anticipate that funding limitations will restrict the number of sites that can be re-sampled to monitor biological and physical attributes.
- Sample 50 sites annually for macroinvertebrates to ensure that fine-scale trend detection will be possible within the time-scales relevant to managing the Restoration Project.
- Use a rotating panel design for physical stream condition monitoring at 20 sites annually (i.e., at all 50 sites over a 4-year period; Figure 2).

Cost Considerations

One of the most important factors influencing the design of any monitoring program is cost. To understand how cost would affect the monitoring that we recommend in this plan, we analyzed the actual costs in 2006 to sample macroinvertebrates at 50 sites and physical stream surveys (including riparian condition) at 10 sites. Per site costs are extrapolated to arrive at a total cost for the work we are recommending. These costs are compared to costs from similar programs. Where actual costs are unavailable we provide cost estimates.

Biological Monitoring

<u>Macroinvertebrate Surveys</u>

In 2006, Terraqua, Inc. collected macroinvertebrate samples at 50 sites in the Battle Creek watershed and Rhithron Associates, Inc. performed laboratory analysis and identification of these samples. The per-site cost of this work was about $565 and includes all costs associated with collection, shipping, processing, and data entry. Costs from similar work that Terraqua has conducted or coordinated are useful for comparison (Terraqua 2006).[3] In 2006, Terraqua (again using Rhithron Associates for sorting/identification, but at a higher rate) sampled macroinvertebrates at 52 sites in north central Washington State for an average per-site cost of $390. At the same time under the same program, Washington Department of Ecology (with Rhithron Associates) sampled macroinvertebrates at 52 sites in north central Washington State for an average per-site cost of $535. In both of these Washington examples, macroinvertebrates

[3] The work referred to here "that Terraqua has conducted or coordinated" was part of the Integrated Status and Effectiveness Monitoring Program which is funded by the Bonneville Power Administration (see http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/index.cfm).

were collected at sites being visited for habitat surveys, which is why our costs were significantly lower in Washington compared to Battle Creek.

Several aspects of this work should be considered to properly understand the total costs. Most importantly, most of these samples (40 of 50) were collected during field trips with the sole purpose of collecting macroinvertebrates. However, savings can be realized if macroinvertebrates are collected at sample sites in conjunction with physical habitat surveys, as travel time to and from sites comprises the bulk of the per-site cost. Also, costs to sort and identify macroinvertebrate samples can vary depending on several factors, most importantly the laboratory and the taxonomic level at which the samples are identified. In our case, based on a long working relationship with this laboratory, the fact our client is a non-profit organization, the lower taxonomic specificity (midges to family) that we required, and our willingness to allow the laboratory to schedule our work after their busy season, we were able to secure per-sample rates at a much reduced rate ($195/sample) compared to industry-standard rates that averaged about $275/sample.

Based on this analysis, we estimate that future costs of sampling macroinvertebrates in Battle Creek may range from about $450 to $650 (in 2006 dollars) per sample depending who does the collection, which laboratory is used, and whether site-trips are for multiple purposes or for the single purpose of collecting macroinvertebrates.

Riparian condition and trends

Riparian shading (canopy cover) indicators are sampled at the same time as physical habitat sampling using the same established transects. The additional cost of performing densiometer measurements during physical habitat site visits is minimal and is included in the overall costs estimated for physical habitat surveys.

Changes in watershed land cover

As the California LCMMP program is not currently active, continued monitoring using LCMMP standards that build upon prior monitoring efforts will need to be performed through a qualified contractor. Several private contractors have worked closely with the LCMMP program in developing the standards, methods and performing change detection analyses. An estimate from one of these contractors (Sanborn Solutions, Sacramento CA) anticipates that costs associated with performing ongoing land cover change assessment once every 4 years would be approximately $14,450. This mapping and change detection product is consistent in resolution to the LCMMP program (minimum mapping unit 2 acres, classification to 12 classes, 85% accuracy). Additional costs of generating an initial land cover baseline to coincide with the 2001-2002 watershed assessment and correlated with the LCMMP results are estimated to be $4,596.

Other projects within the Battle Creek watershed are anticipated to rely on GIS-based mapping products, such as the riparian monitoring component of the Restoration Project and watershed-scale fire management planning. Coordination among projects prior to implementing land cover change monitoring is warranted as there would certainly be cost share benefits if a single mapping product at an appropriate level of resolution for all projects was identified. Finer scale mapping products, though more expensive, may better meet the needs of anticipated projects. Estimated costs (Sanborn Solutions) for using a higher resolution 1:24,000 "Standard Land Cover" mapping product (minimum mapping unit of 0.5 acre, classification to 12 classes, 85% accuracy) for land cover change detection would be approximately $22,109 for a single date change detection once every 4 years. If imagery were not publically available, imagery would also need to be purchased for approximately $12,000 (5 meter imagery). This finer scale mapping product (0.5 acre minimum mapping unit) would also provide an improved capacity to detect land cover changes that occur within the watershed of less than two acres which is the minimum resolution of Landsat-based mapping products generated by programs such as the LCMMP.

Physical Monitoring

Physical stream condition surveys

In 2006, Terraqua, Inc. surveyed physical stream conditions and riparian conditions at 10 sites in the Battle Creek watershed. Per-site costs were about $2,520 including all the costs associated with mobilization/demobilization, physical stream condition surveying, and data entry. Costs from similar work that Terraqua has conducted or coordinated are useful for comparison (Terraqua 2006). From 2004 through present, Terraqua has conducted physical stream condition surveys at approximately 30 sites (varies depending on year) in north central Washington State for an average per-site cost ranging from about $750 to $2,500. At the same time under the same program, Washington Department of Ecology conducted physical stream condition surveys at approximately 50 sites (varies depending on year) in north central Washington State for an average per-site cost ranging from about $2,600 to $3,200. However, the protocols used in these Washington examples are less rigorous than those we have been using in Battle Creek (where the use of electronic survey equipment to topographically map sites requires additional time and expense) thereby accounting for most of the difference in price between this Washington work and the Battle Creek work. Additional reasons for the Terraqua cost differences have to do with economies of scale: per-site costs are naturally lower the more sites that are sampled due to efficiencies in mobilization/demobilization and efficiencies in work processes in the field and office.

Based on this analysis, we estimate that future costs of surveying physical stream conditions and riparian conditions in Battle Creek will be approximately $2,500 (in 2006 dollars) per site but could range as high as $4,500 per-site depending primarily on who does the surveying.

Water Quality Monitoring

Stream temperature monitoring outside the Restoration Project Area

Based upon actual USFWS costs to perform similar ongoing stream temperature monitoring in Battle Creek, per-site costs are approximately $567 per year with monthly data downloads. This would be approximately $3,400 per year to monitor six additional stream temperature monitoring sites.

Terraqua cost estimate for six additional monitoring sites (monthly downloads) would range from $6,480 to $10,320 annually for a per-site cost ranging from $1,080 to $1,720 depending on which personnel are available.

The USFS in the Entiat River, Washington, monitored 30 stations (four year-round, 26 for between 6 and 9 months) with 30-minute data and monthly downloads for $4,227 in 2006.

Based upon this cost analysis, we estimate that the annual cost of stream temperature monitoring will range from $567 to $1,720 per site depending upon who does the monitoring.