Project Number	New Project, no existing project number (New BPA 200847100)
Proposer	John Jorgensen, Yakama Nation Fisheries
Short Description	This project will assess and characterize nutrient availability, and if needed will perform controlled experimental addition of limiting nutrients to enhance natural production of anadromous salmonids and their supporting ecological functions and limnological conditions in rivers in the Methow Subbain.
Province(s)	Columbia Cascade
Subbasin(s)	Methow
Contact Name	John Jorgensen
Contact email	john@mid-columbia-coho.net

10.A Abstract

Pacific salmonid populations have declined dramatically across the Columbia River Basin. These population declines are often due to cumulative effects of multiple factors affecting production in freshwater and marine environments. An important result of these population declines is the concurrent nutrient, productivity, and ecosystem function losses associated with significantly reduced marine derived nutrient (MDN) loading rates from the loss of salmon carcasses. Anadromous salmon carcasses provide significant amounts of MDN, which historically provided the basis for primary productivity in stream systems, especially in the interior areas of the Columbia Basin that are naturally oligotrophic. Lower MDN loading from diminished salmon runs results in negative feedback through reduced juvenile rearing capacity for Pacific salmon systems. Recent research has indicated that MDN loading rates as low as 6 to 15% of historical levels currently exist among anadromous salmon spawning streams in the Pacific Northwest.

This project will quantify and evaluate nutrient status and availability in two watersheds of the Methow River Basin (Twisp and Methow rivers), under current conditions of diminished anadromous salmon runs. More specifically, this project will conduct a rigorous multi-trophic level sampling program to quantify and evaluate baseline water quality and nutrient availability, primary, secondary, and tertiary productivity rates including algal, periphyton, and benthic macroinvertebrate, and fish communities. A stratified random sampling design will be used to select study sites in each of the upper, middle, and lower reaches of the study area river(s). The goal is to develop a comprehensive pre- and any post-treatment biological assessment of experimental nutrient addition. Finally, this project provides the necessary adaptive management framework to determine if nutrient limitation and/or imbalance currently exist, and to generate empirically-based recommendations for restoring ecological processes needed to increase natural production of anadromous salmonids, with additional unquantified benefits to anadromous Pacific lamprey, resident fish, riparian ecosystems, and wildlife populations.

10.B Problem statement: technical and/or scientific background

Problem statement - The problem addressed by this project is the continued low level of natural production of anadromous Pacific salmonids (*Onchorynchus spp*.) in the Methow River Basin in North Central Washington (Upper Columbia Basin, Figures 1 and 2) and the potential relationship with diminished marine derived nutrients (MDN) inputs to the system. The Methow River historically supported multiple viable anadromous salmonid populations as well as Pacific Lamprey (*Lampetra tridentata*), resident trout, and numerous other fish and wildlife populations. Population abundance of these species have declined dramatically from historical levels. Numerous factors are associated with these declines, stemming from in- and out-of-basin sources of mortality. Although significant measures have been implemented to reverse this trend during recent decades, there is little realized improvement in numbers of salmon returning to this region of the Columbia River Basin.

In fact, depressed natural production due to reduced MDN inputs is a chronic problem across the Columbia River Basin. The Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan calls for nutrient enhancement as a restoration strategy, but also points out the need for a better understanding of why, where, and how much nutrients may be needed (UCSRB 2007). A more holistic approach to understanding and resolving underlying conditions that limit productivity in our aquatic systems in general can be a critical step in salmon restoration. By characterizing nutrient availability, trophic status and potential nutrient limitation related to reduced MDN levels in the Methow River Subbasin (Twisp and Methow rivers), it may be possible to specifically mitigate identified anthropogenic nutrient, productivity, and ecological function losses to restore higher levels of natural productivity.

In addition to nutrient limitation, we understand that loss and deterioration of physical habitat may also limit natural production of salmonids to varying degrees in different parts of the study area (Methow Subbasin). Large efforts are underway to preserve, rehabilitate, and restore river processes and physical habitat conditions throughout the Methow Basin and the Upper Columbia (UCSRB 2007; NPPC 2004). Recovery criteria have been established and desired increases in natural production, if co-limited by habitat quantity, quality, and food availability, would require coordinated efforts, to restore both nutrient availability and physical habitat. In this context we are currently pursuing collaborative efforts with local and regional researchers and managers. This integrated approach appears to provide the best chance of improving natural production in the study area by working to restore the biological and physical habitat conditions required for survival of early life history stages of salmonids.

Technical and Scientific Background/Justification

Factors limiting natural production of Pacific salmonids - Current low levels of natural production of anadromous Pacific salmonids in the Columbia River Basin and other west coast North American river systems are the cumulative result of multiple factors in the freshwater and marine environments. Reduced natural production in the freshwater environment can occur at various life stages and can be caused by physical and biological limitations. These can include degradation of spawning, incubation, and rearing habitats, effects of invasive species through competition and predation, passage restrictions to and from critical habitats, climate change, and nutrient limitation and resulting cascading trophic effects (NRC 1996; Ruckelshaus et al. 2002; Williams 2006). Mortality in the Columbia River, the estuary, and in marine environments can also occur at multiple life stages, and may be affected by physiological acclimation, competition, predation, harvest, passage and migration success, and other immediate or delayed artificial and natural factors (Ruckelshaus et al. 2002; Williams 2006). One estimate suggested recent salmon escapement levels may only provide 6-7% of historical MDN inputs to salmon rivers in the Pacific Northwest (Gresh et al. 2000). Another analysis suggested < 2% of historical marine-derived P is currently returning to the Snake River (Scheuerell et al. 2005), and that, under some circumstances, there could even be a net export of nutrients when adult escapement is extremely low (Moore and Schindler 2004).

Roles of marine-derived nutrients – Nutrient availability is central to natural productivity in aquatic systems in general, and for Pacific salmonids in particular (e.g. Gende et al. 2002; Naiman et al. 2002; Wipfli et al. 1999). Historically, anadromous Pacific salmonids provided significant inputs of MDN to freshwater streams (Cederholm et al. 1999, 2001; Gresh et al. 2000), likely serving as a metabolic driver for interior systems otherwise characterized as oligotrophic or ultraoligotrophic (nutrient-poor). This nutrient input can affect ecosystem metabolism from the bottom up, enhancing biological productivity at all trophic levels (Wipfli et al. 1998).

Kline et al. (2007) reported two main pathways by which nutrients make their way from salmon carcasses to the environment: (1) the *direct pathway*, where salmon spawn and carcasses are directly consumed, by bears, birds, fish (young salmon and resident species), and stream invertebrates; and (2) the *remineralization pathway*, where nutrients are released back into the water by microbes during the decomposition of salmon carcasses. Increased nutrient availability from decomposing salmon carcasses, in the forms of N, P, and C, provides the basis for increased algal and periphyton production and microbial growth in streams (Bothwell 1989; Peterson et al. 1993; Yani and Kochi 2004). This in turn can enhance productivity and diversity of the invertebrate community and production of juvenile salmonid forage (Johnson et al. 1990; Mundie et al. 1991; Quamme and Slaney 2003; Yani and Kochi 2004; Holderman et al. 2008). In addition, carcasses can significantly increase substrate surface area available for microbial and invertebrate productivity and diversity. Increased secondary production can enhance in-stream growth, condition, and survival for juvenile resident and anadromous fish populations and may ultimately contribute to increased numbers of out-migrating salmonids and survival due to higher fitness (Peterson et al. 1993; O'Keefe and Edwards 2003).

Numerous studies suggest broad cycling of salmon-derived nutrients into multiple trophic levels in riparian and terrestrial ecosystems (Gende et al. 2002; Reimchen et al. 2003). MDN has been identified in the hyporheic zone and in riparian and adjacent terrestrial forest soils, vegetation, invertebrate, and vertebrate communities associated with Pacific salmonid ecosystems (Ben-David et al. 1997; Cederholm et al. 2000; Hildebrand et al. 1999a, 1999b; Bilby et al. 2003). The preponderance of evidence has made it clear that current discussions on restoration efforts must include the role of MDN in restoring salmon populations and the systems on which they rely (Peery et al. 2003; Stockner 2003, and references therein).

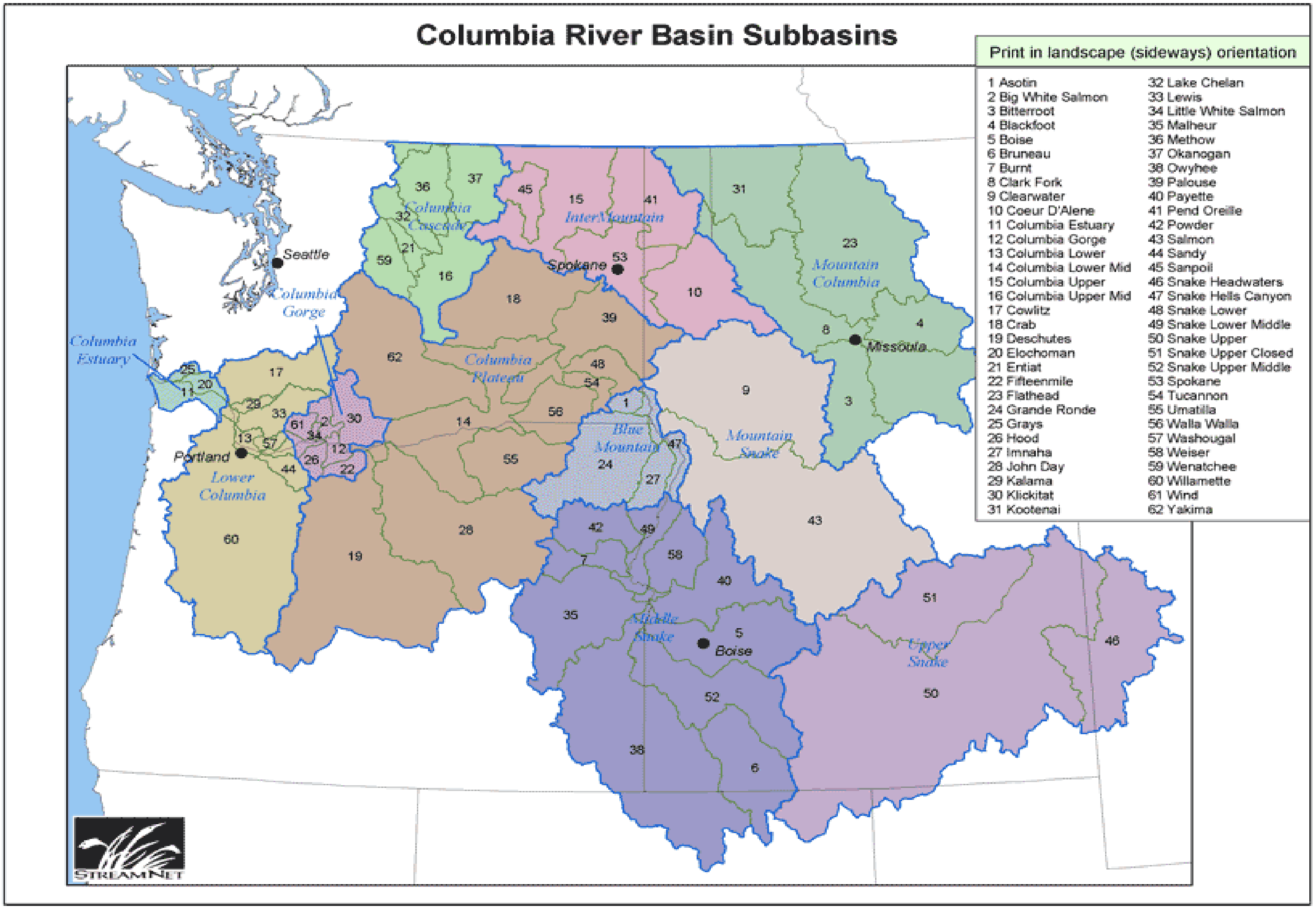

Figure 1. **Columbia River Basin map showing all Subbasins, including the Methow River Subbasin (#36) in the upper (Northwest) corner of the Columbia Cascade Ecological Province, bounded on the north by the US-Canada border.**

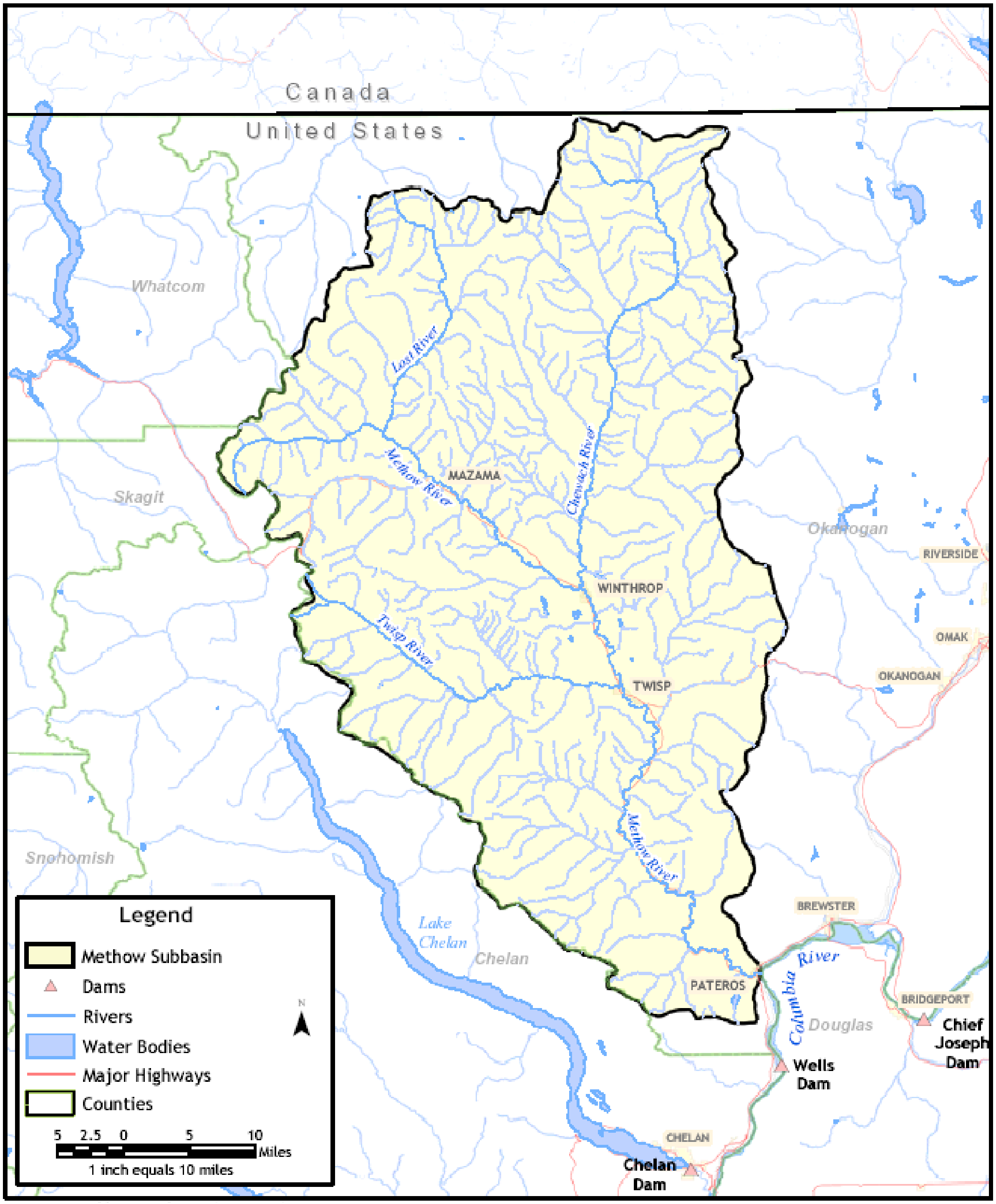

Figure 2. **Map of the Methow River Subbasin (shaded) showing the Twisp and Methow rivers, which serve as study areas for this project.**

Justification for proposal - This proposal directly addresses nutrient availability and its potential limitation for natural production of Pacific salmonids in the Methow River Subbasin, specifically in the Methow and Twisp rivers. We believe an assessment of nutrient availability and the potential to test experimental nutrient augmentation is justified for the following reasons:

(1) Salmon habitat in the Twisp and Methow rivers does not appear to be critically limiting, but it's acknowledged that physical habitat improvements may also be beneficial and needed in these systems to improve natural production and compensate for additional anthropogenic limitations downstream;

(2) Non-native species do not occur in significant numbers;

(3) Efforts to improve out-of-basin survival (hydrosystem passage) and instream production of salmon and steelhead (hatchery programs) have generated little improvement in the abundance and productivity of natural origin fish;

(4) Current MDN loading from anadromous salmonid carcasses is significantly reduced from historical levels; and

(5) The Twisp River has very low egg-emigrant survival rates (e.g. ~1% vs. ~12% in Chiwawa, Wenatchee basin; [see Hillman et al. 2007]), indicating a production bottleneck that could be addressed with experimental nutrient addition if nutrients are found to be limiting.

10. C Rationale and significance to regional programs

This section describes the relation of this proposed project to the: 1) objectives in the Columbia River Basin Accords, 2) objectives, strategies, and hypotheses identified in the Methow River Subbasin Plan, 3) objectives of the 2000 Fish and Wildlife Program (Program), and 4) the 2003 Mainstem Amendments. This section also describes applicable relationships between the proposed project and Biological Opinions, recovery plans, Habitat Conservation Plans, and other relevant regional or local plans.

10.C.1 Columbia River Basin Accords – As with Columbia River Basin Fish and Wildlife Program projects proposed in the past, the ISRP will conduct scientific review of proposed Columbia River Basin Fish Accords projects using criteria established by the Act. These criteria include whether projects:

1. Are based on sound scientific principles;
2. Benefit fish and wildlife;
3. Have a clearly defined objective and outcome;
4. Include provisions for monitoring and evaluation of results; and
5. Are consistent with the Council's Fish and Wildlife Program.

This proposed project is consistent with project requirements under the Columbia River Basin Accords by being based on sound scientific principles and by providing direct benefits to fish and wildlife populations within and beyond the project area, and increased nutrient and food availability within the immediate project areas (see Section 10.B, “Technical and scientific background/Justification”). This project also meets project requirements under the Accord by providing clearly defined objectives, outcomes, and monitoring and evaluation (see Sections 10.F.1.”Biological /physical objectives, 10.F.4 “Metrics”, and 10.G “Monitoring and Evaluation”), and by addressing goals and objectives of the Council’s Fish and Wildlife Program (see Section 10.C.3. “Objectives of the 2000 Fish and Wildlife Program”).

10.C.2 Objectives identified in the Methow River Subbasin Plan (Page numbers provided below refer to printed Subbasin Plan pages, not electronic page numbers)

This proposed project is justified by and directly addresses the following limiting factors, strategies, objectives, and hypotheses from the Methow Subbasin Plan:

- Limiting factor: Nutrient availability (Table 54, Page 300 of Methow Subbasin Plan)
- Salmon Carcasses (Table 54, Page 300 of Methow Subbasin Plan): (low abundance of salmon/steelhead and their nutrients contribution to stream ecology including benthic macroinvertebrates and fish growth)
- Management strategy (Table 54, Page 300 of Methow Subbasin Plan): Increase or maintain artificial production capacity at levels necessary to meet management needs, maintain new and existing acclimation sites, and support existing and new scatter plantings. Program is intended to support conservation, reestablishment of natural broodstock and interim harvest opportunities.

Section 5.5 (Subbasin Plan Assessment, Unit summaries; Page 301)

- Hypothesis 4 (Page 310) - Increasing food availability within the AU (assessment units)* will increase survival for spring Chinook, steelhead, and bull trout in the following life stages: a) fry colonization (spring Chinook, steelhead, and bull trout), and; b) rearing (spring Chinook, steelhead, and bull trout). Westslope cutthroat trout survival will increase for migration and overwintering.
- Objective 3 (Page 310) - Conduct productivity analysis (invertebrate sampling and organic/inorganic constituent sampling/analysis), and determine appropriate nutrient supplementation program.
- Objective 4 (Page 310) - Supplement nutrients as needed and determined from Objective 3 of Hypothesis 4 of this proposal. One example provided in the Methow Subbasin Plan was to: “Achieve 125 salmon carcasses/mile as an interim target, based on estimates of historic run size” (Mullen et al. 1992 distributed in areas of current spawning and rearing; WDFW unpublished data). However, no empirical linkage currently exists between the relevance of this 125 kelt/mile estimate and current nutrient availability in the proposed study area. (NOTE: For this project it is currently unclear whether or the degree to which project waters are nutrient limited, and/or unbalanced. Therefore, kelt addition is currently unwarranted due to this lack of quantification. However, if experimental nutrient addition is found to be warranted following baseline assessments described in this proposal, kelts, time-released nutrient briquettes (i.e. carcass analogues), or liquid

inorganic fertilizer(s) will be reviewed and compared in terms of appropriateness for this project.

- Strategy 1 (Page 311) - Restore nutrients through salmon carcass or analogue distribution.

*Note: Similar language was used for most of the Methow River Subbasin AUs (assessment units), indicating broad support for the need for increasing food availability. Repetitive language was avoided in the interest of brevity. Likewise, nutrient addition and studies to determine the appropriate locations, quantities, and methods of nutrient additions were also identified in the Salmon and Steelhead Recovery Plan.

10.C.3 Objectives of the 2000 Fish and Wildlife Program (Program)

The Program's goals, objectives, scientific foundation and actions are structured in a "framework", which is an organizational concept for fish and wildlife mitigation and recovery efforts that the Council introduced in the 1994-1995 version of the Program. The 2000 program, organized with the framework concept, is intended to bring together, as closely as possible, Endangered Species Act requirements, the broader requirements of the Northwest Power Act and the policies of the states and Indian tribes of the Columbia River Basin into a comprehensive program that has a solid scientific foundation. The Program also explicitly states the Northwest Power and Conservation Council's the (Council's) goals and links the Program to a specific set of objectives, describes the strategies to be employed, and establishes a scientific basis for the program. Thus, the program guides decision making and provides a reference point for evaluating success.

The Northwest Power Act directs the Council to develop a program to "protect, mitigate, and enhance" fish and wildlife of the Columbia River and its tributaries, including related spawning grounds and habitat affected by the development and operation of the federal hydrosystem. In support of this programmatic vision, the Council has stated four overarching biological objectives for this program:

- A Columbia River ecosystem that sustains an abundant, productive, and diverse community of fish and wildlife;
- Mitigation across the basin for the adverse effects to fish and wildlife caused by the development and operation of the hydrosystem;
- Sufficient populations of fish and wildlife for abundant opportunities for tribal trust and treaty right harvest and for non-tribal harvest; and
- Recovery of the fish and wildlife affected by the development and operation of the hydrosystem that are listed under the Endangered Species Act.

This proposed project addresses all four of the Council's above programmatic biological objectives. Nutrient assessment and potential enhancement in project watersheds will enable monitoring and restoration of ecological functions and process, promoting improved levels of biological productivity from the bottom up. The proposed project also directly assesses and if needed experimentally treats (mitigates) anthropogenic nutrient deficiency to counteract the adverse effects of development and operation of the hydrosystem and other downstream limitations. Ultimately this project is designed to address the Council's programmatic objectives of recovery and the provision and maintenance of sufficient fish and wildlife populations to support opportunities for tribal trust and treaty right harvest and for non-tribal harvest.

10.C.4 The Northwest Power and Conservation Council's 2003 Mainstem Amendment plan includes the following objectives relating to:

- the protection and enhancement of mainstem habitat, including spawning, rearing, resting and migration areas for salmon and steelhead and resident salmonids and other fish;
- system water management;
- passage spill at mainstem dams;
- adult and juvenile passage modifications at mainstem dams;
- juvenile fish transportation;
- adult survival during upstream migration through the mainstem;
- reservoir elevations and operational requirements to protect resident fish and wildlife;
- water quality conditions; and
- research, monitoring and evaluation.

This proposed project directly addresses three of above Mainstem Amendment objectives (the first and the last two), by enhancing spawning and rearing habitats for salmon, steelhead, resident salmonids, and other fishes identified as nutrient-limited. If experimental nutrient addition is deemed appropriate based on project bioassessment, it will improve water quality conditions, in terms of biological productivity. Furthermore, iterative, adaptive experimentation as part of the project design will generate valuable information, data, and protocol evaluations to inform future RM&E programs.

10.C.5. Applicable relationships to Biological Opinions, recovery plans, Habitat Conservation Plans, or other plans.

The Biological Strategy of the Upper Columbia River Technical Team (UCRTT 2008) lists "nutrient enhancement" as a critical uncertainty in the upper tributaries of the Methow Basin. As a recommendation, the UCRTT stated that: "An assessment is needed to determine the location and magnitude for potential nutrient enhancement projects "Within current and historic ranges, consistent within individual stream capacity and recovery objectives." These recommendations are consistent with our project goals.

The Methow Implementation Schedule (MIS) from the Upper Columbia Salmon Recovery Board (UCSRB document in review) lists "depleted nutrients" as a limiting factor in all reaches of the main-stem Methow and for most of its anadromous tributaries. Specific recommended actions include "fertilizer, carcass analog and carcass placement". Recommended timelines for specific actions include, for 2008-2010: "evaluate approach, identify appropriate methods and obtain permits and approval", for 2011-2013: "add nutrients" and for 2014-2017: "continue to add nutrients to make up the difference between annual escapement and needed abundance for recovery". This sequence of steps

needed to get to the appropriate actions defined in the MIS is consistent with the proposed project's goals and timeline.
Data Gap Prioritization analysis (unpublished UCRTT 2008 document) stated: "Understand the need and magnitude of adding nutrients s part of an ESU wide plan to determine where, how, and how much nutrient supplementation is needed" as a Tier 1 data gap.

10.D Relationships to other projects

Methow Subbasin Projects - The Yakama Nation is a contributing member to the Methow Restoration Council, the basin's Watershed Action Team. Members of the MRC include WDFW, USGS, USFWS, USFS, BOR, DOE, Methow Conservancy, Washington Rivers Conservancy and Wild Fish Conservancy. Projects among the different groups include hatchery monitoring and evaluation programs, habitat restoration projects, flood plain protection, and habitat effectiveness monitoring.

Project personnel work collaboratively with the WDFW hatchery monitoring and evaluation program. The locations of their rotary screw traps provide valuable sampling sites for measuring condition factor population attributes of resident and anadromous fish in the study areas. Data collected at the traps, including, survival, egg to emigrant, and SAR rates will give us good estimates of pre- and post- fertilization production. We are also pursuing collaborations with the Wild Fish Conservancy and DOE as part of a basin-wide water quality evaluation program.

USGS effectiveness monitoring – Initial discussions confirmed that BOR, USGS (Pat Connelly, Cook WA) and Dr. Colden Baxter (ISU, Pocatello) will be collaborating on evaluations of physical habitat improvements and operating instream PIT tag stations within the Methow Basin to assist in monitoring juvenile and adult production and addressing potential project treatment (experimental nutrient addition) effects. Collaborative discussions between key project personnel and these within-basin cooperators are ongoing and are undertaken to provide mutually beneficial monitoring, evaluation, and analytical outcomes among all parties.

Kootenai/y fertilization projects - Most key personnel (Drs. Anders, Ashley, Shafii, Smith, Ward, and Yassien) have been involved with many aspects of the Kootenay Lake and Kootenai River nutrient assessment and subsequent fertilization projects and their development since 1990. Interaction of key project personnel with those of other pioneering, long-term successful nutrient evaluation and addition projects in North America and elsewhere provide invaluable project design, implementation, monitoring, evaluation, and analytical attributes for this project. These scientific and management networks also provide logistical efficiencies required for successful long-term scientific and management collaborations.

British Columbia Projects – Several key project personnel (e.g. Drs. Ashley, Ward and Yassien) have also been instrumentally involved in the design, implementation, evaluation, and analysis of numerous successful nutrient evaluation and nutrient addition projects from conceptual design through implementation of experimental phases through implementations phases as ongoing management phases. Several examples of such project in B.C. involving key proposed project personnel include nutrient assessment and enhancement projects on the: Adams River, Mesilinka and Keogh rivers, Big Silver Creek, and the Salmo and Chilliwack rivers.

10.E Project history (for ongoing projects)

Because this is a new project it is exempt from a response in this project history section.

10.F Biological/physical objectives, work elements, methods, and metrics

10.F.1 Biological/physical objectives

This project has four sequential, complementary objectives, to:

1) Determine whether nutrient availability and/or imbalance significantly limit natural production of anadromous salmonids in the Methow River Basin (e.g. the Twisp and Methow rivers) (Years 1-3);
2) If significant nutrient limitation is confirmed by work funded under Objective 1, quantify changes in natural production of juvenile anadromous salmonids in response to experimental nutrient addition (Years 3-8);
3) Implement and evaluate ongoing nutrient management (Years 9-10 and beyond as needed); and
4) Determine if results can be successfully scaled up to larger geographic areas, and applied to other rivers in the Columbia Basin.

10.F.2 Work Elements

Several BPA work elements (WE) are needed to satisfy Objective 1:

WE-157	Collect/Generate/Validate Field and Lab Data
WE-160	Create/Manage/Maintain Database
WE-162	Analyze/Interpret Data
WE-132	Produce (Annual) Progress Report
WE-183	Produce Journal Article

An additional work element will be implemented under Objectives 2 and 3 if Objective 1 and 2 confirm significant nutrient limitation and show desirable ecological response to experimental nutrient addition respectively:

WE-44	Add Nutrients Instream

10.F.3 Methods

This section describes methods needed to successfully address each project work element. For more details regarding specific BPA project work elements see: www.efw.bpa.gov/contractors/statementsofwork.aspx

WE 157 - Collect/Generate/Validate Field and Lab Data

A stratified random sampling design will be used to select a minimum of three study sites in each of the upper, middle, and lower reaches of the Twisp and Methow rivers. Sampling at these sites will involve a minimum of three replicates, with adjustments made based on sample size and power analysis of empirical project data as needed. For example, if statistical power resulting from a given sampling regime is insufficient to identify or separate nutrient addition treatment effects from background variability for critical metrics, the associated variability will be analyzed and partitioned into spatial and temporal components to assess required increases in spatial and/or temporal sampling to provide the adequate statistical representation for a given level of statistical confidence. These standard sites will be used for sampling water quality, estimating primary productivity, and characterizing the algal/periphyton and benthic macroinvertebrate communities. This project is organized by these trophic level categories.

A standardized multi-trophic level bio-assessment is proposed for all years of the 10-year study. Biomonitoring during the first three consecutive years will establish baseline conditions (depending on inter-annual variation and power and sample size analysis results). Continued implementation of this bio-assessment will be used to evaluate experimental nutrient addition if Objective 1 confirms significant nutrient limitation. Nutrient limitation and nutrient availability targets will be defined through collaborative regional group efforts supported and coordinated through this project, including development of decision pathways for evaluating nutrient addition options.

The assessment will include water quality, nutrient availably, Chlorophyll *a*, and total chlorophyll (*a* + *b*) concentration and accrual, aquatic benthic macroinvertebrate, and fish community sampling, analysis, and evaluation. Benthic macroinvertebrate sampling will include stationary Hess samplers to quantify and characterize the invertebrate community occupying the substrates and the interstitial space in the underlying hyporheic zone. Invertebrate drift will also be sampled with standard gear and techniques to assess the relative contribution of invertebrate drift, including terrestrial taxa and their potential benefit to the fish community as prey. Specific fish analysis will include at least standard growth, length, weight, condition factor and age class structure analyses. Furthermore, any community data from other collaborative, sympatric projects will be incorporated into the ecological assessment. We will coordinate with other projects that collect fish stomach content data (e.g. the ISU and USGS study in the Methow Mainstem) and to assess effects of nutrient addition. However, for this project it may be necessary to consider stomach content analysis on exclusively non-threatened (unlisted under ESA) indicator fish species such as mountain whitefish (*Propospium williamsonii*), coho, and cutthroat trout and the literature to assess diet item availability shifts and cascading trophic effects in response to experimental nutrient addition.

More specific methodological information by trophic level is provided below:

Water Quality - Water samples will be collected weekly from the right bank, mid-channel, and left bank sections at each site to measure ambient nutrient concentrations as river conditions permit. Water quality sampling will occur from April through October. As with all sampling in this project, sample size and power analyses will be performed as soon as adeq1uate amounts of empirical data are collected to optimize sampling regimes based on sample representation and the associated empirical temporal and spatial variability. All samples will be collected in 250 mL bottles pre-rinsed with de-ionized water. All samples will be stored on ice and shipped to Aquatic Research Incorporated Laboratory in Seattle for analysis within 24 hours.

Water samples will be analyzed for standard metals, soluble reactive phosphorous (SRP), total phosphorous (TP), total dissolved phosphorous (TDP), NO3+NO2, N:P ratios, and ammonia. Minimum detection limits for TP and TDP were 2 μg·L-1, 1 μg·L-1 SRP, 10 μg·L-1 for NO3+NO2, and 5 μg·L-1 ammonia. Some samples will also be analyzed for total organic carbon (TOC, with the minimum detection limit being 0.25 mg/l).

Periphyton Analysis (algal accrual and Chlorophyll a) - At each site 4 to 6 algal accrual tiles will be deployed to assess primary productivity. Tile arrays will be run perpendicular to the riverbank to ensure consistent provision of monthly data across variation in river stage throughout the annual field season. Algal/periphyton accrual on artificial substrate plates (mg/m^2/month), species composition, biomass, diversity, and Chlorophyll *a* and total chlorophyll concentrations and accrual rates will be measured, calculated, and analyzed. For taxonomic identification and enumeration of periphyton, samples will be collected two times over the duration of the experiment, with one sample collected per site per sample date. The periphyton samples will be collected from the top of the cement tiles and preserved with Lugols solution and 10% formalin. Algal community composition reflects local nutrient availability, balance, and ecological river conditions. Algae will be classified as Cyanophyta (blue-greens), Chlorophyta (greens) Bacillariophyta (diatoms), Chrysophyta (goldens), with further taxonomic identification at least to genus where possible and beneficial.

Algal Biomass - Algae will be collected from standard punch cores sampled from the Styrofoam glued to the cement tiles monthly from April through September (n=6) during each annual field season. Sample cores will be placed in Whirl-paks, stored in brown plastic bottles, and frozen at -20°C until shipped for total chlorophyll and chlorophyll a. Chlorophyll analysis will be performed by the University of Idaho Analytical Sciences Laboratory, Holm Research Center, (Moscow, ID) using the Winterman/DeMots method for extraction and analysis.

Benthic macroinvertebrates - At each site, 4 to 6 replicate invertebrate samples will be collected monthly with standard Hess samplers (or other gear as substrate conditions dictate) from April through October as flow conditions permit. Sampling adjustments will be made as necessary, based on sample size and power analysis of empirical project data as needed.

In addition, invertebrate drift may also be sampled at these same sites and times to assess the relevance of this component of potential food supply. The following summary of aquatic invertebrate drift sampling was summarized from Bode et al. (1991):

Site Selection: Invertebrate drift sampling sites should include riffle habitat with a substrate of rubble, gravel, and sand. Depth should be one meter or less, and current velocity should be at least 0.4 meters per second. Sites should have comparable current velocity, visible flow field characteristics substrate type, embeddedness, and canopy cover to both upstream and downstream sites characteristic of pre-determined sampling reaches to the degree possible.

Sampling: Macroinvertebrates are sampled using the standardized traveling kick method. An aquatic net, Surber sampler, or other appropriate drift sampler is positioned in the water at arms' length downstream and the stream bottom is disturbed by foot, so that the dislodged organisms are carried into the net. Sampling is continued for a specified time and for a specified distance in the stream. (Rapid assessment sampling specifies sampling 5 minutes for a distance of 5 meters. Extended or reduced time and area can be standardized as a function of invertebrate density or sample requirements; An extended passive drift sampling methods could also be employed to increase probability of terrestrial invertebrate capture in the drift.). Net contents are emptied into a pan of stream water and examined, and the major groups of organisms are recorded, usually at the ordinal (taxonomic order) level (e.g., stoneflies, mayflies, caddisflies). Larger rocks, sticks, and plants may be removed from the sample if organisms are first removed from them. The contents of the pan are poured into a U.S. No. 30 sieve and transferred to a quart jar. Smaller jars can be used with smaller sample contents loads. The sample is then preserved by adding 95% ethyl alcohol to the jar, to which Rose Bengal stain has been added. Seal the jar tightly and slowly rotate it from the upright to an inverted position several times until the Rose Bengal stain is thoroughly mixed throughout the sample. Invertebrates in the sample are selectively stained (compared to woody debris) enabling efficient removal of invertebrate specimens from woody debris and detritus during subsequent sample sorting).

Sample Sorting and Subsampling: In the laboratory the sample is rinsed with tap water in a U.S. No. 40 standard sieve to remove any fine particles left in the residues from field sieving. Sample contents are then transferred to a white or light colored enamel pan and distributed homogeneously over the bottom of the pan. A small amount of the sample is randomly removed with a spatula and placed in a Petri dish with alcohol. This portion is examined under a dissecting stereomicroscope and 100 organisms are removed from the debris. As they are removed, they are sorted into major groups, placed in vials containing 70 percent alcohol, and counted. (Sparely population samples may required sorting of entire samples to collected adequate numbers of specimens for quantitative statistical analysis). Following identification of a subsample, if the results are ambiguous, suspected of being spurious, or do not yield a clear water quality assessment, additional sub sampling may be required based on invertebrate density in the sample.

Taxonomic Identification: All organisms are identified to the genus and family levels and to the species level when possible and warranted. Most hard-bottomed benthic macroinvertebrates are identified as whole specimens using a dissecting stereomicroscope. The number of individuals in each species (or other appropriate taxon), and the total number of individuals in the sample are recorded on a data sheet. All organisms from the subsample are archived in 70% alcohol.

Subcontracts to specialty invertebrate taxonomy labs (e.g. Invertebrate Ecology Inc, Moscow ID.) will be considered if needed to resolve critical taxonomic and ecological uncertainties. In addition to enumeration, taxonomic analysis, biomass determination (using standard wet weight and preservation techniques), and community attributes will be analyzed and reported. Invertebrate community attributes could include structural or function guild analyses, taxonomic and temporal and spatial analyses of other ecological metric (diversity, richness, and others).

Fish community – This project will integrate fish data currently being collected by WDFW to evaluate Chinook salmon and steelhead production within the Methow and Twisp rivers. WDFW operates rotary screw traps in the Methow and Twisp rivers and estimates smolt production using mark-recapture methods. Adult spawners are indexed in the two rivers. Numbers of adults returning to the Twisp River are also counted at a weir used to collect hatchery broodstock. These data are used to calculate smolt per redd, smolt per spawner, and recruit per spawner indices of production (See Snow et al. 2007; 2008). Fish datasets will include numbers of juveniles collected, collection method, collection sites, fish size (length, weight), condition (K), estimated age class, numbers marked (PIT-tagged), PIT tag codes, all recapture histories. PIT tag files will be loaded to the PTAGIS database. Recaptures of PIT tagged fish will be retrieved from PTAGIS. Adult datasets will include numbers of fish of each species, fish size, recaptures of marked fish, and index redd counts for study areas.

In addition to enumeration by routine snorkeling survey techniques, more specific information on numbers, distribution, and size measurements of summer parr (sub-yearlings) will be collected using baited minnow traps and/or beach seining. Minnow traps baited with salmon eggs have been used to successfully collect YOY salmon and trout in streams throughout the Columbia and Snake basin (C. Peery, USFWS, Cramer Fish Sciences, pers. comm. 2009). Mark-recapture techniques will be used to estimate summer rearing densities. Snorkel surveys during summer may be a good approach to estimate fish numbers/densities. However, fish size and condition cannot be accurately estimated from snorkel surveys, whereas seining and trapping will provide size data of adequate resolution to calculate growth and condition.

Annual salmon and steelhead outmigrant (smolting) data will also be available through the WDFW operated rotary smolt trap on the Twisp River. All fish collected at the screw trap will be PIT tagged to assist downstream survival estimates. A portion of these fish will be released upstream so they may be recaptured in the screw trap to estimate capture efficiency and total smolt production. Adult abundance and distribution data will be collected at the Twisp Weir site and through spawning ground surveys. Adult information will be used to estimate productivity metrics of smolt per spawner ratios and smolt-to-adult ratios (SARs). Fish data will be correlated with empirical project water quality, nutrient availability, primary and secondary productivity data and metrics to assess effects of the project and to characterize system effects on salmonid status and productivity

The primary analytical method will be multivariate analysis of variance (MANOVA, PROC GLM, SAS Institute Inc., Carey, NC) in which response variables (juvenile densities, growth rates, smolt-spawner ratios) will be related to environmental and productivity variables. Canonical variate analysis (PROC CANCOR) will be used to identify which response variables were associated with differences when they occur. Single variable analysis of variance (ANOVA) will be used to better define relationship between important fish production variables and environmental data.

This study design covers a 10-year period, conducting baseline sampling during phase (Objective) 1, years 1-3, and evaluating nutrient supplementation evaluation during years 4-10. This temporal scale will allow collection of three years of pre-treatment and six years of post-treatment juvenile productivity. Adult return information will be available from three pre-treatment and four post-treatment year classes (if experimental nutrient addition is warranted based on analysis of empirical project data analysis).

WE 160 - Create/Manage/Maintain Database

Data quality issues are especially important when conducting long-term multifaceted studies involving several teams of researchers. Without the use of a standardized protocol, independent data collection is often carried out by separate research efforts, all too commonly leading to inconsistencies, confusion, and errors throughout the larger project.

A database management system will be used to help avoid the aforementioned problems. The centralization of data into a common relational unit (i.e. a relational database) shifts the responsibility for data quality and maintenance from multiple individuals to a single database manager, thus allowing data quality issues to be assessed and resolved in a timely manner. The proven relational database system proposed also provides a convenient, efficient mechanism for standardizing data components, such as variable names and values uniformly across all segments of a project. This is particularly important when data are collected from a variety of locations, times, and by different personnel.

For the database user, the efficiency of database functions is maximized by using data formats based on familiar software products such as Excel or Quatro Pro. For the project manager, the database facilitates monitoring and evaluating data quality and data collection. Project and identified cooperating resource managers can track all aspects of data collection as they happen and can pinpoint areas that need attention.

In sum, the proposed relational online, secured database system will integrate all segments of a large, multidisciplinary ecological study into one organizational and functional unit at one location, while providing oversight and accessibility to the data collection process. The quality of all data collected is uniformly maintained and compatibility among research efforts is thus ensured. While the physical database would exist in a central location, access will not be physically limited. Database interfaces can be created to operate over the internet, allowing project members to access their data from virtually anywhere. These interfaces provide users with the ability to upload, download, edit, and search data remotely, creating a dynamic system that is continually updated with the most recent information. At the same time, data are protected through user access restrictions. For example, researchers might be able to read any data, but only edit data from their own project. This accessibility could be set to any combination of read/write/edit abilities from an administrator capacity with full access to all data, to a highly restricted public access capability limited to general project information. Generation of customized summary reports, such as graphs or tables, will also be easily obtained through a web based interface. Using this type of feature, users can track trends over time or location, compare results from various disciplines and evaluate, for example, average responses. Exploration of data in this manner will help users define and clarify their research goals as well as provide a means of integrating the various disciplines of a larger research project.

In terms of data warehousing and archiving, project crews will collect data, produce and proof an Excel database. This will get backed up electronically and in hard copy form, and will be archived separately on site and off site. These data (in spreadsheet form) will then be sent electronically to Statistical Consulting Services Inc (SCS). After receiving them, SCS will back them up on and off site locally, and if necessary will repeat this process after any and all proofs and edits/modifications are completed. Data will then be uploaded onto the web-based relational database, which is also backed-up electronically on a dedicated machine.

Furthermore, construction and maintenance of a centralized database management system will be monitored and updated by a designated database manager to address data quality assurance and maximize efficiency in dissemination of information. Periodic upgrades and enhancements to this system will ensure availability of quality data in real time, and validity of statistical analyses and interpretations for which such data are will be utilized. Additionally, housing all databases for related basin projects in one central, accessible, protected location will allow for consistency and efficient use of data among projects.

We will incorporate all project data into the relational database as they are collected and become available. System enhancements may include full text data descriptions for all incorporated components, implementation of data availability matrix for every component of the project, implementation of various mapping formats including topographic, GIS, etc, addition of data censoring options for all trophic level data, restructuring and enhancement of graphic capabilities (line plots, bar plots, pie charts), incorporation of multi-trophic/multi-year plotting routines, and implementation of more advanced security features.

WE 162 - Analyze/Interpret Data

Data analysis for each tropic level will include summary and quantitative statistics.

Summary statistics - Numerous biological and ecological response variables or metrics will be evaluated by site and by year for all sites and periods of data availability. These are discussed in the next section (10.F.4 Metrics). Response variables will include:

Water Quality (Including nutrient availability and primary productivity/chlorophyll accrual rates): Water samples will be analyzed for standard metals, low level soluble reactive phosphorous (SRP), total phosphorous (TP), low level total dissolved phosphorous (TDP), NO3+NO2, N:P ratios, and ammonia. Minimum detection limits for TP and TDP were 2 µg·L-1, 1 µg·L-1 SRP, 10 µg·L-1 for NO3+NO2, and 5 µg·L-1 ammonia. Some samples will also be analyzed for total organic carbon (TOC, with the minimum detection limit being 0.25 mg/l).

Chlorophyll/Primary production: Chlorophyll a concentration (mg/m^2) and chlorophyll a accrual rate (mg/m^2/ 30 days), and total chlorophyll (chlorophyll a + b; mg/m^2) and total chlorophyll accrual (mg/m^2/ 30 days) will be calculated.

Algae/Periphyton: abundance, biomass, total richness (# of species), richness by taxa, taxa composition represent a standard suite of algae and periphyton metrics. Numerous additional metrics could be used and evaluated using Principal Components Analysis (PCA). A series of over a dozen additional metrics was compiled and recently implemented using this approach as part of the Kootenai River Experimental Fertilization Project (e.g. taxonomic composition metrics, richness, abundance, Shannon-Weaver and other diversity indices, nitrogen uptake, oxygen tolerance, trophic status measures, or abundance by morphological type (e.g. erect, stalked, prostrate, unattached, filamentous, and variable (Van Dam et al. 1994; Holderman et al. 2009),

Benthic macroinvertebrates: numerical and percent richness by feeding ecology functional group (e.g. filterer, gatherer, predator and scraper).

Juvenile fish data: summer parr abundances, density, size, growth rates, smolt abundances, estimated population size (from mark-recapture calculations), fish size, condition factor (K), growth, estimated survival.

Adult fish data: numbers returning to weirs, size, condition factor (K), growth rates, estimated survival (requires estimate of ocean and downstream harvest rates), redd and carcass counts in river study reaches.

Quantitative statistics - Sample size, power analysis, Principal Components Analysis (PCA) and Analysis of Variance (ANOVA) tests will be performed using data from each trophic level or community.

A minimum of two and preferably three years of statistically adequate pre-treatment biomonitoring are required to produce a reasonable baseline condition for the study rivers. Empirical data from the first year will be used to provide data for the sample size determination and power analyses needed to ensure an adequately rigorous sampling design for subsequent pre- and post-treatment years. PCA will be performed to reduce the dimension of biological community data and to determine which taxonomic groups and metrics are contributing significantly to observed variation. Data for all PCA runs will be selected to represent taxonomic orders and biological or ecological metrics that were common in samples from all dates at those sites or site combinations. ANOVA will be performed annually using data from each and all years to investigate the average algal/periphyton and macroinvertebrate abundance, biomass, and richness, to test for site or time effects on these metrics, and to assess effects of experimental nutrient addition if experimentally implemented based on results from Objective 1. Abundance and biomass responses may be logarithmically transformed to meet statistical requirements of the analyses. Analysis of variance tables, least squares means tables, and a table of predetermined contrasts for reach (site) effects will provided as analysis output. All ANOVA and PCA tests will be performed using the SAS package. These analyses will be rerun annually before and after experimental nutrient addition (if that is warranted and implemented) to determine and characterize treatment effects in terms of water quality, nutrient availability and composition, and all response variables in the algal/periphyton, invertebrate, and fish communities.

We intend to characterize current productivity of fish communities in the Methow and Twisp systems, focusing on chinook salmon and steelhead, and if warranted, to test if productivity improves with experimental nutrient addition. Primary metrics of productivity include: (1) juvenile outmigrant abundance, a nominal measure of smolt production, as determined from catch-per-unit effort (numbers of fish collected per hour of trap operation), (2) estimated total outmigrant abundance (calculated from mark-recapture methods), (3) smolts per spawner and, for later years, (4) smolt-to-adult ratios (SARs). Secondary measures of productivity will include (5) summer parr (subyearlings) abundance indices (catch-per-unit-effort), (6 & 7) juvenile and adult fish condition (K), (8) mean growth rate, and (9) survival between key life stages.

Differences in productivity associated with nutrient supplementation will be tested using analysis of covariance (ANCOVA), using adult escapement (nutrient source) as the covariate, and multivariate analyses (MANOVA) to determine if multiple responses are occurring. We will also use stepwise multiple regression to evaluate what independent variables are best associated with the variability in production metrics. Independent variables to be included in the analyses include year, amount of nutrient added and nutrients added adjusted by flow to account for dilution, mean flow and temperature during winter, spring and summer, and spawner abundance. Best fit model(s) will be determined using Akaike Information Criteria (AIC

Objectives 2 and 3 only

Initial responses to nutrient addition – Analysis of Variance (ANOVA) will be used to assess aggregated algal/periphyton, and invertebrate and fish abundance and biomass, richness, and taxonomic order composition were evaluated in the zone of maximum expected response with analogous testing at control sites upriver from nutrient addition to assess treatment effects with adequate statistical rigor.

Expected results - We anticipate that pre-treatment sampling will indicate nutrient deficiency as reflected in low algal abundances, low macroinvertebrate (density and diversity, low juvenile densities, low fish condition factors and growth rates, low smolt-adult ratios, and potentially premature emigration by juvenile salmonids. Nutrient additions may have the greatest influence on primary productivity in terms of increase algal and periphyton biomass, with commensurate increases seen in grazers and tertiary predators. Higher food availability may increase summer parr fish condition and translate to higher juvenile abundances in late summer and possibly as outmigrants the following spring.

WE 132 - Produce (Annual) Progress Report

This work element covers written reports of results that typically are submitted to BPA at the end of a contract period for dissemination to the public. Previously called "Annual" reports, these progress reports may cover less than a year or multiple years. They are not required or appropriate for all contracts in all years, but are particularly important when useful results are not captured by standard Pisces metrics or status reports, or prior to project-based publications in the peer-reviewed literature.

WE 183 - Produce Journal Article

This work element applies to manuscripts being submitted for publication. Preliminary analyses towards the publication of a journal article can be covered by WE# 132 (above): Produce (Annual) Progress Report.

WE 44 - Enhance Nutrients Instream

This work element addresses possible actions for Objectives 2 and 3 if satisfaction of Objective 1 confirms significant nutrient limitation. This section will be further developed if and when baseline monitoring data for water quality, nutrients and the algae, periphyton, and invertebrate and fish communities indicate nutrient limitation during pre-treatment years.

For project planning purposes most nutrient enrichment programs will be adequately described by characterizing the following seven variables as recommended by Ashley and Stockner (2003), after quantifying baseline conditions in all project trophic levels.

1. Desired nutrient concentrations;
2. Formulation of nutrient source;
3. Seasonal timing of application;
4. Frequency or duration of nutrient addition;
5. Location of application;
6. DIN:TDP ratio of nutrients to be added; and
7. Application techniques.

10.F.4 Metrics

A large series of metrics are involved in the multiple trophic level bio-assessment program proposed for implementation in this project.

Water quality and nutrient metrics will include: standard metals and water chemistry parameters, soluble reactive phosphorous (SRP), total phosphorous (TP), total dissolved phosphorous (TDP), NO3+NO2, N:P ratios, NH4, total organic carbon (TOC) and Chlorophyll a.

Metrics for the algae/periphyton community may include: abundance, biomass, species richness, diversity indices (e.g. Shannon Weaver), nitrogen uptake, oxygen tolerance, trophic state, richness by trophic state, and morphological type.

Metrics for the benthic macroinvertebrate community may include up to 19 variables provided in the following table.

Metrics	Units
Abundance	Numbers/m^2
Biomass	g/m^2
Richness	Overall number of species sampled
EPT_Richness	Number of species in the Orders Ephemeroptera, Plecoptera and Trichoptera
E_richness	Number of species in the Order Ephemeroptera
P_richness	Number of species in the Order Plecoptera
T_richness	Number of species in the Order Trichoptera
Filterer_richness	Number of species in "Filterer" functional group
Gatherer_richness	Number of species in "Gatherer" functional group
Predator_ richness	Number of species in "Predator" functional group
Scraper_richness	Number of species in "Scraper" functional group
p_ Ephemeroptera	% of Order Ephemeroptera
p_ Plecoptera	% of Order Plecoptera
p_ Trichoptera	% of Order Trichoptera

p_ Filterers	% of “Filterer” functional group
p_ Gatherers	% of “Gatherer” functional group
p_ Predator	% of “Predator” functional group
p- Scraper	% of “Scraper” functional group
Shannon	Shannon’s index of diversity

The following fish metrics will be used to assess fish condition and system productivity for this project: biomass, abundance, density, and condition factor (*K*) for parr, smolts and returning adults, and survival estimates through various early life stages found in the freshwater spawning, incubation and early rearing environments. Data for these analyses will come from local cooperative fish studies from the study area waters in the Methow River basin and from original sampling efforts where needed. Ongoing studies include: 1) smolt monitoring by WDFW using rotary screw trap and adult escapement estimates from the weir on the Twisp River and spawner surveys, and the local USGS research, (Martens and Connolly 2008) that involves PIT tagging and tracking juvenile chinook salmon in the Methow River. We will coordinate field activities and share data collection efforts with these and other groups.

10.G Monitoring and evaluation

The objectives of this project are to:

(1) Determine the nutrient status of the Methow and Twisp rivers, and if productivity is nutrient limiting. If found to be limiting then:

(2) Conduct an experimental manipulation to supplement nutrients and evaluate the effectiveness to increase primary, secondary and tertiary productivity in the system, with the ultimate goal of restoring ecological processes to something approaching historical levels. Finally, we propose to:

(3) Use results from the first two objectives to evaluate the feasibility of scaling up these methods to larger geographical areas and/or applying them to additional rivers within the Columbia River Basin.

Data from Objective 1 of this study will be used to determine if the Methow basin is currently nutrient deficient. This determination can be difficult since there is little in the way of historical information with which to compare. Baseline measures of water nutrient constituents, algal and macroinvertebrate abundance will be compared to literature values from systems similar to the Methow basin but with relatively healthy salmon production (e.g. B.C. populations). Other indications of nutrient limitation we will look for may be low algal and insect diversity indices and relatively slow growth rates and low smolt per spawner rates for salmon and steelhead as compared to literature values. Alternatively, the Methow Subbasin Plan suggested that an interim loading rate for nutrient supplementation may be 125 carcasses per mile of river, “based on estimates of historic run size” (Objective 4, Page 310). Thus, if adult escapement is of a level to produce a loading rate significantly lower than 125 carcasses per mile of accessible habitat, we may infer that the Methow River is under seeded for MDN. This, in combination with water quality and trophic sampling, may be sufficient evidence to determine the current nutrient condition of the system.

Alternatively, a large body of implemented research and management involving nutrient enhancement has identified a general range of target nutrient concentration values, ranging from 3 to 5 ug/L phosphorus, with accompanying nitrogen concentrations consistent with a targeted 20:1 atomic N: P ratio (Ashley and Stockner 2003; Stockner 2003). This project will evaluate approaches and criteria for defining nutrient limitation for salmonid productivity and define measurable values and thresholds as the central benchmarks for recommended actions.

Appropriate null hypotheses to test include:

$H_{o1.1}$: Algal abundance is within acceptable limits for salmon systems not considered to be nutrient limited.

$H_{o1.2}$: Macroinvertebrate abundance and diversity indices are within acceptable limits for salmon systems not considered to be nutrient limited.

$H_{o1.3}$: Fish production, growth rates, and adult escapement numbers are within acceptable limits for salmon systems not considered to be nutrient limited.

The second phase (Objective 2) of the proposed study involves evaluating the effectiveness of nutrient supplementation to improve system productivity. This evaluation would involve comparing data from pre- and post-treatment time periods using inferential statistics. Appropriate null hypotheses include:

$H_{o2.1}$: Water nutrient levels are not significantly different between pre- and post-treatment periods.

$H_{o2.2}$: Algal and periphyton abundance and diversity are not significantly different between pre- and post-treatment periods.

$H_{o2.3}$ Primary productivity rates are not significantly different between pre- and post-treatment periods.

$H_{o2.4}$: Benthic macroinvertebrate abundance and diversity are not significantly different between pre- and post-treatment periods.

$H_{o2.5}$: Salmon productivity metrics are not significantly different between pre- and post-treatment periods.

Comparisons between sites or grouped sites upstream and downstream from an experimental nutrient addition site could also be performed within years to further characterize effects of nutrient addition.

Finally;

$H_{o3.1}$: Results from Objectives 1 & 2 cannot be scaled up to large geographical areas or applied to other subbasins of the upper Columbia River.

Sampling, collecting and storing data will be done using existing tribal field office resources (vehicles, computers, microscope, waders, Hess samplers etc.)

Stored samples needing furthers lab analysis will be sent to appropriate contractors. Proposed contractors include: Aquatic Research Institute, the Holm Center, University of

Idaho and Eco Analyst. Further Statistical analysis and database development will completed by Statistical Consulting Services. These contractors will be responsible for the equipment to complete their tasks.

If after the assessment period has been completed (up to 3 years) and a nutrient prescription is needed, additional contractors may be needed to complete those specific tasks. Tribal facilities will grow to meet the need of the project at that time.

10.H Facilities and equipment

Sampling, collecting, and storing data will involve existing tribal field office and program resources (vehicles, computers, microscope, waders, Hess samplers etc.).

Stored samples needing further lab analysis will be sent to appropriate contractors. These contractors are Aquatic Research Institute, the Holm Center, University of Idaho and Eco Analysts, both in Moscow, ID. Further Statistical analysis and database development, operations, and maintenance will be performed by Statistical Consulting Services, in Clarkston WA.. These contractors are responsible for the necessary equipment to complete their tasks.

After the assessment period has been completed (up to 3 years), if a nutrient prescription is needed, additional contractors may be needed to complete those specific tasks (Ward and Associates, other key personnel (see Section 10.J, “Key Personnel”). Associated tasks may include cost-benefit analysis, site selection, and interaction with the regulatory agencies. Some of these activities could occur during the first three years of the project as directed by empirical data analysis. For example, if study waters are found to be nutrient limited or imbalanced, forecasting approximate experimental nutrient addition loads (by weight/volume) and assessing requirements of holding and dosing site facilities could be required. Tribal facilities may need to be expanded as needed to meet all the needs of this project as future data analysis warrants.

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10.J Key Personnel

The following key personnel are influential for the successful design, implementation, and evaluation of this project. Their resumes are provided below.

Key Personnel	Affiliation	Project Role(s)
John Jorgensen	Yakama Nation Fisheries, Twisp WA	Project Leader
Kraig Mott	Yakama Nation Fisheries, Twisp WA	Field Technician
Chris Peery, Ph.D.	Cramer Fish Sciences, Moscow ID	Project design, coordination, and evaluation, scientific advisor
Paul Anders, Ph.D.	Cramer Fish Sciences, UI, Moscow ID	Project design, coordination, and evaluation, scientific advisor
Bahman Shafii, Ph.D.	Statistical Consulting Services, UI, Moscow, ID.	Statistical design, oversight, and analysis
Ken Ashley, Ph.D.	BC Ministry of Environment, Ashley and Associates, Vancouver BC	Project design, oversight, scientific advisor
Peter Ward, Ph.D. Hasssen Yassien, Ph.D.	Ward and Associates, Vancouver BC.	Design, installation, and operational oversight of nutrient dosing systems
David Smith, Ph.D.	USACE, ERDC, Vicksburg MS.	Project design, salmonid cognitive ecology, and scientific oversight
Tim Hatten, Ph.D. Russ Bingham Rod Sprague	Invertebrate Ecology Inc., UI, Moscow ID	Invertebrate taxonomic identification and ecological characterization

John Jorgensen

Education:

B.Sc.	1997	Fish and Wildlife Biology, Montana State University

Employment:

2001- Present	Fisheries Biologist III, Yakama Nation, Methow Field Station, Twisp, WA
1999-2000	Fisheries Technician, Alaska Department of Fish and Game, King Salmon, AK
1997-1998	Fisheries Technician, Idaho Department of Fish and Game, Powel, ID
1995-1997	Fisheries Technician, Montana State University, Bozeman, MT

Experience:

Responsible for multiple projects in the Methow Basin, projects include coho reintroduction and habitat restoration. Responsibilities include project development, implementation, monitoring and evaluation, analysis and report writing.

Kraig Mott

Education:

B.Sc.	2005	Biology, Eastern Washington University

Employment:

2005- Present	Scientific Technician, Yakama Nation, Methow Field Station, Twisp, WA
2003-2005	Fisheries Technician, Eastern Washington University & WDFW, Spokane, WA

Christopher A. Peery, Ph.D.

A. Professional Preparation

Linfield College, OR	Biology	B.A. w/honors, 1986
College of William and Mary, VA	Biological Oceanography	M.S., 1989
University of Idaho, Moscow	Fisheries Resources	Ph.D., 1995
University of Idaho, Moscow	Fisheries Ecology	Postdoc, 1995-1996

B. Professional Appointments

2008-Present	Fisheries Scientist, Cramer Fish Sciences, Moscow, ID
2004-2008	Assistant Research Professor, Department of Fish and Wildlife, University of Idaho
2001-2003	Research Scientist, Idaho Cooperative Fish and Wildlife Research Unit, Department of Fish and Wildlife, University of Idaho
1996-2001	Research Associate Idaho Cooperative Fish and Wildlife Research Unit, Department of Fish and Wildlife, University of Idaho

C. Publications Most Relevant to the Proposed Project

(*) see http://www.cnr.uidaho.edu/uiferl/Reports.htm for .pdf of abstracts

Peery, C.A, K. Kavanagh, and J.M. Scott. 2003. "Pacific salmon in aquatic and terrestrial ecosystems": Setting biological defensible recovery goals. Bioscience 53:622-623.

Keefer, M.L., C.C. Caudill, C.A. Peery, and S.R. Lee. *In press.* Which way home? Unintended consequences of transporting juvenile anadromous salmonids expressed during adult migration. Ecological Applications.

Keefer, M.L., C.A. Peery, and C.C. Caudill. 2008. Migration timing of Columbia River spring Chinook salmon: effects of temperature, river discharge, and ocean environment. Transactions of the American Fisheries Society 137:1120-1133.

Keefer, M.L., C.A. Peery, and M.J. Heinrich. 2008. Temperature-mediated en route migration mortality travel rates of endangered Snake River sockeye salmon. Ecology of Freshwater Fishes 17:136-145.

Peery, C. A., and T. C. Bjornn. 2000. Summer dispersal and growth of hatchery chinook salmon parr following release into four Idaho streams. North American Journal of Fisheries Management. 20:19-27

Peery and Bjornn. 2004. Interactions between hatchery and natural chinook salmon juveniles in an artificial stream channel. Fisheries Research 66:311-324.

Keefer, M.L., C.A. Peery, and C.C. Caudill. 2006. Long-distance downstream movements by homing adult Chinook salmon. Journal of Fish Biology 68:1-7.

Keefer, M.L., C.A. Peery, W.R. Daigle, M.A. Jepson, S.R. Lee, C.T. Boggs, K.R. Tolotti, and B.J. Burke. 2005. Escapement, harvest, and unknown loss of radio-tagged adult salmonids in the Columbia-Snake River hydrosystem. Canadian Journal of Fisheries and Aquatic Sciences 62: 930-946.

Keefer, M.L, C.A. Peery, T. C. Bjornn, M.A. Jepson, and L. Stuehrenberg. 2004. Hydrosystem, dam and reservoir passage rates of adult Chinook salmon and steelhead in the Columbia and Snake rivers. Transactions of the American Fisheries Society 133:1413-1439.

Paul J. Anders, Ph.D.

A. Professional Preparation

Ph.D. Natural Resources (Conservation Biology of White Sturgeon), U. of Idaho, 2002.
M.S. Biology (Fisheries), Eastern Washington University, 1991
B.S. Natural Science (Limnology), Saint Norbert College, 1983.

B. Professional Appointments

1. Associate Consultant, Fishery Scientist, Cramer Fish Sciences (Formerly S. P. Cramer and Associates) Moscow, ID. (10/05-Present)
2. Affiliate Faculty, University of Idaho, College of Natural Resources, Fish and Wildlife Department (9/03-present)
3. Senior Fisheries Consultant, S. P. Cramer and Associates, Moscow, ID. (10/02-10/05)
4. Fisheries Scientist (0.5FTE) Columbia River Inter-Tribal Fish Commission, Steelhead kelt reconditioning project (Fall 01 – Fall 02)
5. Research Support Scientist II, University of Idaho, Center for Salmonid and Freshwater Species at Risk Aquaculture Research Institute, Fish Genetics Lab, Moscow, ID. (1/00-10/02)
6. Research Associate, University of Idaho, Center for Salmonid and Freshwater Species at Risk Aquaculture Research Institute, Fish Genetics Lab, Moscow, ID. (1/99-1/00)
7. Independent Fisheries Consultant (1/99-10/02)
8. Doctoral Research Assistant, University of Idaho, Aquaculture Research Institute, Fish Genetics Lab, Moscow, ID. (7/96-12/98)
9. Fisheries Biologist/Administrator, Kootenai Tribe of Idaho, PO. Box 1269, Bonners Ferry, ID. (5/94-7/96)
10. Fisheries Biologist, Kootenai Tribe of Idaho, PO. Box 1269, Bonners Ferry, ID. (2/93-5/94)
11. Fisheries Biologist (GS-9-482), U.S. Fish and Wildlife Service, Columbia River Field Station, Cook WA. (8/90 - 2/93)

C. Publications Most Relevant to the Proposed Project

Holderman, C., G. Hoyle, R. Hardy, P. Anders, P. Ward and H. Yassien. Libby Dam Hydro-electric Project Mitigation: Efforts for Downstream Ecosystem Restoration. 2009. Pages - *In:* Environmental and Water Resources Institute of American Society of Civil Engineers Conference: "*An International Perspective on Environmental and Water Resources*". Thailand, 2009. http://www.fishsciences.net/reports/2009/holderman_et_al_2009_ EWRI_Conference.pdf

Holderman, C., P. Anders, B. Shafii, and G. Lester. 2008. Characterization of the Kootenai River aquatic macroinvertebrate community before and after experimental nutrient addition, 2003–2006. Report to the Kootenai Tribe of Idaho and Bonneville Power Administration. 53 pp.

Idaho Department of Fish and Game, Kootenai Tribe of Idaho, Cramer Fish Sciences, and Ward and Associates. 2008. Best Management Plan for Kootenai River Nutrient Dosing System. Report prepared for U. S. EPA, Region 10, Seattle WA.

Anders, P., Editor. 2007. Kootenai River Nutrient Restoration Project-Annual Implementation Report prepared by Cramer Fish Sciences for the Kootenai Tribe of Idaho, Idaho Department of Fish and Game, and the International Kootenai/y Ecosystem Restoration Team. 69 pgs. http://www.fishsciences.net/reports/2007/KOO04_2007-implementation-report_2008-0400.pdf

Anders, P.J. and K.I. Ashley. 2007. The Clear-water Paradox of Aquatic Ecosystem Restoration. Fisheries 32 (3):125-128. http://www.fishsciences.net/reports/2007/Fisheries0405-Anders_and_Ashley_2007.pdf

Since 1995, Dr. Anders has authored and co-authored over 100 papers, reports, and articles on fisheries and aquatic ecology topics. For a detailed list see: ttp://www.spcramer.com/content/docs/anders_paul.doc

Bahman Shafii, Ph.D.

A. Professional Preparation

B.S. Agronomy/Agricultural Engineering, Rezaeyeh University, 1977.
M.S. Agricultural Economics, University of Idaho, 1980.
M.S. Statistics, University of Idaho, 1982.
Ph.D. Forest Biometrics, University of Idaho, 1988.

B. Professional Appointments

Lecturer, Department of Management and Systems, Washington State University, Pullman, Washington, 1984-1988.
Professor, Plant Science, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow, Idaho, July 2004-present.
Director, Statistical Programs, College of Agricultural and Life Sciences, University of Idaho, Moscow, Idaho, January 1988-present.
Adjunct Full Professor, Department of Statistics, College of Science, University of Idaho.
Adjunct Full Professor, Department of Business, College of Business and Economics, University of Idaho.

C. Publications Most Relevant to the Proposed Project

Mahler, Robert L., B. Shafii, S. Hollenhorst, and B. J. Andersen. 2008. Public perceptions on the ideal balance between natural resource protection and use in the Western USA. *Journal of Extension, 46(1): 1RIB2*

Smith, David L., E. L. Brannon, B. Shafii, and M. Odeh. 2006. Use of the average and fluctuating velocity components for estimation of volitional Rainbow Trout density. Transactions of the American Fisheries Society 135: 431-441.

Shafii, Bahman and W.J. Price. 2005. Bayesian analysis of dose-response calibration curves. *Applied Statistics in Agriculture*, J. E. Boyer (Ed.). Kansas State University, Manhattan, Kansas, pp. 126-136.

Dr. Shafii has authored and coauthored over 100 peer reviewed papers. For more information see: http://www.uidaho.edu/ag/statprog

Ken I. Ashley, Ph.D.

A. Professional Preparation

University of British Columbia	Zoology	B.Sc., 1972
University of British Columbia	Zoology	M.Sc., 1981
University of British Columbia	Civil Engineering	M.A.Sc., 1989
University of British Columbia	Civil Engineering	Ph.D. 2002

B. Professional Appointments

2009-Present	Manager, Special Projects, Fish and Wildlife Branch, BC Ministry of Environment
2005-2008	Senior Engineer, Environmental Management, Greater Vancouver Regional District
1999-2005	Section Head, Bioengineering, Fisheries Research and Development Section, BC Ministry of Environment
1979-1999	Limnologist, Fisheries Research Section, Ministry of Environment

C. Publications Most Relevant to the Proposed Project

Lawrence, G.A., K.I. Ashley, N. Yonemitsu and J.R. Ellis. 1995. Natural dispersion and the fertilization of small lakes. Limnology and Oceanography 40:1519-1526.

Ashley, K.I., L.C. Thompson, D.C. Lasenby, L. McEachern, K.E. Smokorowski and D. Sebastian. 1997. Restoration of an Interior Lake Ecosystem: The Kootenay Lake Experiment. Water Qual. Res. J. Canada (32):295-323.

Rae, R., F.R. Pick, P.B. Hamilton and K.I. Ashley. 1997. Effects of fertilization on phytoplankton in Kootenay Lake, British Columbia. Lake and Reservoir Management 13(1):57-66.

Johnston, N.T., M.D. Stamford, K.I Ashley and K. Tsumura. 1999. Responses of rainbow trout (Oncorhynchus mykiss) and their prey to inorganic fertilization of an oligotrophic montane lake. Can. J. Fish. Aquat. Sci. 56:1011-1025.

Sterling, M.S., K.I. Ashley and A.B. Bautista. 2000. Slow-release fertilizer for rehabilitating oligotrophic streams: a physical characterization. Water Quality Res. J. Canada 35(1): 73-94.

Stockner, J.G. and K.I. Ashley. 2003. Salmon nutrients: Closing the circle. Pages 3-16 In: J.G. Stockner, editor. Nutrients in salmonid ecosystems: sustaining production and biodiversity. American Fisheries Society, Symposium 34, Bethesda, Maryland.

K.I. Ashley and J.G. Stockner. 2003. Protocol for applying limiting nutrients to inland waters. Pages 245-260. In: J.G. Stockner, editor. Nutrients in salmonid ecosystems: sustaining production and biodiversity. American Fisheries Society, Symposium 34, Bethesda, Maryland

Perrin, C.J., M.L. Rosenau, T.B. Stables and K.I. Ashley. 2006. Restoration of a montane reservoir fishery using biomanipulation and nutrient addition. North Amer. J. Fish. Management 26:391-407.

Anders, P.J. and K.I. Ashley. 2007. The Clear-water Paradox of Aquatic Ecosystem Restoration. Fisheries 32 (3):125-128.

Matzinger, A., R. Pieters, K. I. Ashley, G. A. Lawrence, and A. Wüest. 2007. Effects of impoundment on nutrient availability and productivity in lakes. Limnology and Oceanography 52(6):2629-2640.

Peter Ward, Ph.D.

A. Professional Preparation

- B.Sc (Hons), Physics & Mathematics, University of London, 1961
- M.Sc, Physics, University of London, 1967
- Ph.D., Engineering Science, University of California, Berkeley, 1972.

B. Professional Appointments

- Adjunct Professor (1987-present), Department of Civil Eng., University of British Columbia.
- Member of six engineering and scientific professional organisations, including the Association of Professional Engineers and Geoscientists of British Columbia, Canadian Water Resources Association, American Geophysical Union and American Society of Civil Engineers.
- Dr. Ward has spent thirty eight years working in hydrology and water resources engineering, including full-time engineering teaching at university level, consulting work for government with emphasis on water flows and water quality, developing, installing and monitoring nutrient addition systems, and work for the private sector with a focus on conceptual design, installation and monitoring.

C. Publications Most Relevant to the Proposed Project

P.R.B. Ward, H A Yassien, February 1995. Flow Proportional Liquid Fertiliser Injector. Prepared for Fisheries R & D Division, Ministry of Environment. Vancouver, B.C.

P.R.B. Ward, W.G. Dunford, April 1995. Design of Prototype Flow Proportional Liquid Fertilizer Injector. Prepared for Fisheries R & D Division, Ministry of Environment, Lands and Parks. Vancouver, B.C.

P.R.B. Ward, H A Yassien, November 1995. Construction & Field Testing of Flow Proportional Liquid Fertilizer Injector. Prepared for Fisheries Research and Development Section, Ministry of Environment, Lands and Parks. Vancouver, B.C.

P.R.B. Ward, H A Yassien, June 1996. Gravity Fed Liquid Fertilizer Injection for Fish Habitat Improvement: Error Analysis & Prototype Testing. Prepared for Ministry of Environment, Lands & Parks Fisheries Research. Vancouver, B.C.

P.R.B. Ward, H A Yassien, August 2004 . Sheep Creek Nutrient Dosing Pump Design and Installation. Prepared for BC Hydro Environmental Department. Burnaby, B.C.

P.R.B. Ward, H A Yassien, October 2004. Kootenai River Proposed Nutrient Dosing Equipment Ideas and Layout. Prepared for Kootenai Tribe of Idaho. Bonners Ferry, Idaho.

P.R.B. Ward, H A Yassien, December 2005. Kootenai River Nutrient Dosing: As Built System and Performance for 2005 Summer Season. Prepared for Kootenai Tribe of Idaho. Bonners Ferry, Idaho.

P.R.B. Ward, H A Yassien, December 2005. Transverse Mixing Characteristics of Kootenai River Downstream of Dosing Site: Medium Flow Regime. Prepared for Kootenai Tribe of Idaho. Bonners Ferry, Idaho.

Charlie Holderman, Ryan Hardy, P.R.B. Ward, H A Yassien, March 2006. Equipment for Liquid Nutrient Dosing in Small and Large Rivers in the Northwest. For American Fisheries Society 42nd Annual Meeting – 2006. Sunriver Resort, Oregon.

P.R.B. Ward, H A Yassien, July 2006. Dosing System for Chilliwack River 2006. Prepared for British Columbia Conservation Foundation, Surrey, B.C.

P.R.B. Ward, H A Yassien, December 2006. Kootenai River Nutrient Dosing System and N-P Consumption: Year 2006. Prepared for Kootenai Tribe of Idaho. Bonners Ferry, Idaho.

P.R.B. Ward, H A Yassien, January 2008. Kootenai River Nutrient Dosing System and N-P Consumption: Year 2007. Prepared for Kootenai Tribe of Idaho. Bonners Ferry, Idaho.

Hassen Yassein, P. Eng.

Citizenship:	Canadian
Profession:	Civil Engineer
Specialisation:	Water Resources Engineering and Operation Research
Contact information:	9460 Pinewell Cres, Richmond, BC, V7A 2C6, Canada
	Email - hassen@telus.net
	Phone (604)218-8887

A. Professional Preparation

B.Sc. in Civil Engineering, Addis Ababa University, Ethiopia.
Diploma in Hydrology, Free University of Brussels, Belgium, 1984.
M. S., in Hydrology, Free University of Brussels, Belgium, 1985
Ph.D. in Water Resources Management, Civil Engineering Department, UBC, Vancouver.

B. Professional Appointments

Twenty three years professional experience in Water Resources and Hydrology, setting up and running of a technology institute and water works construction. Experience includes: Establishing hydrological stations, data collection and hydrological data analysis. Estimating and computing floods and water surfaces levels in rivers and lakes. Writing technical reports for engineering firms, government offices and the public. Served in a research team working for the development of new technology to improve fish habitat in lakes and rivers. Taught at higher education institute, administered workshops and oversaw operation of hydraulic and water treatment laboratories. Designing and constructing of rural water supply systems, pump testing of deep wells and spring developments. Supervised water supply systems, spring developments and drilling water wells. Directed and supervised surveyors, draftsmen and construction technicians.

C. Publications Most Relevant to the Proposed Project

Publications most relevant to the proposed project include reports on design, development, installation and monitoring and maintenance of nutrient addition systems from the following nutrient addition projects.

See relevant publication list above for Peter Ward and Ward Associates

David L. Smith, Ph.D.

A. Professional Preparation

Washington State University, WA	Environmental Science	B.S., 1990
Washington State University, WA	Environmental Science	M.S., 1996
University of Idaho, Moscow	Natural Resources	Ph.D., 2003
University of Idaho, Moscow	Civil Engineering	Postdoc, 2003-2004

B. Professional Appointments

2006-Present	US Army Engineer Research and Development Center, Ecohydraulics and Cognitive Ecology Team, Vicksburg, MS
2006-present	Adjunct Faculty, Department of Biological Systems Engineering, University of Idaho
2006-2004	Senior Scientist, Crammer Fish Sciences, Moscow, ID
1997-1996	Senior Field Engineer, Bechtel Hanford, Inc, Richland, WA
1996-1994	Field Engineer, IT Hanford Inc, Richland WA
1994-1990	Project Engineer, Westinghouse Hanford Inc, Richland, WA

C. Publications Most Relevant to the Proposed Project

Smith, D.L., M. Allen, and E.L. Brannon. 2008. Characterization of velocity gradients inhabited by juvenile chinook salmon by habitat type and season. Pages 53-70 *in* S.V. Amaral, D. Mathur, and E.P. Taft, III, editors. Advances in fisheries bioengineering. American Fisheries Society, Symposium 61, Bethesda, Maryland.

Nestler, J.M., R.A. Goodwin, D.L. Smith, J.J. Anderson, and S. Li. 2008. Flow Field Distortion, Sensory Biology, Hydrogeomorphology, and Cognitive Ecology: Elements Describing Juvenile Salmon Movement Behavior and Passage. River Research and Applications. 24(2): 148-168

Smith, D.L. and E.L. Brannon. 2007. Influence of cover on mean column hydraulic characteristics in small pool riffle morphology streams. Rivers Research and Applications 23: 125–139.

Smith, D.L. E.L. Brannon , B. Shafii, and M. Odeh. 2006. Use of the average and fluctuating velocity components for estimation of volitional rainbow trout density. Transactions of the American Fisheries Society 135: 431-441.

Smith, D.L., E.L. Brannon, and M. Odeh. 2005. Response of juvenile rainbow trout to turbulence produced by prismatoidal shapes. Transactions of the American Fisheries Society 134: 741-753.

Russell C. Biggam

A. Professional Preparation

University of Idaho, ID, Entomology and Biology, B.S., 1973

B. Professional Appointments

1981-Present	University of Idaho, Division of Plant, Soil and Entomological Sciences, aquatic labs under Drs. Brusven and Johnson
1973-1981	University of Idaho, Division of Plant, Soil and Entomological Sciences, aquatic labs with multiple faculty
1968-1972	University of Idaho, Division of Plant, Soil and Entomological Sciences

C. Expertise

- Identifications of larval and adult aquatic and terrestrial invertebrates
- Aquatic sampling techniques
- Biology and ecology in invertebrates
- Data input, formatting and basic analyses

D. Selected Publications

Eigenbrode, S.D., J.D. Andreas, M.G. Cripps, H. Ding, R.D. Biggam, M. Schwarzlaner. 2008. Induced chemical defenses in invasive plants: a case study with *Cynoglossum officinale* L. Biological Invasions 10: 1373-1379.

Bruvsen, M.A. and R. Biggam. 1996. Trend changes in aquatic habitat and benthic macroinvertebrate bioassessment conditions in upper Hangman Creek and tributaries. Project Completion Report.

Bruvsen, M.A. and R. Biggam. 1995. Ecological-economic assessment of a sediment-producing stream behind lower granite dam on the lower Snake River, USA. Regulated Rivers: Research & Management 10:373-387.

Hoiland, W.K., F.W. Rabe and R.C. Biggam. 1994. Recovery of macroinvertebrate communities from metal pollution in the south fork and mainstream of the Coeur d'Alene River, Idaho. Water Environment Research 66: (1)84-88.

Bruvsen, M.A., W.R. Meehan and R.C. Biggam. 1990. The role of aquatic moss on community composition and drift of fish-food organisms. Hydrobiologia: 196:39-50.

Biggam, R.C. and M. A. Brusven. 1989. The Gerridae (water striders) of Idaho (Hemiptera: Gerridae). The Great Basin Naturalist 49:(2) 259-274.

Biggam, R.C. and M.W. Stock. 1988. Pronotal stripes and wing length in *Gerris incurvatus* Drake and *Hottes* (Hemiptera: Gerridae). Pan-Pacific Entomologist. 64(4) 359-363.

Rabe, R.W., R. C. Biggam, R.M. Breckenridge, R.J. Naskali. 1985. A limnological description of selected peatland lakes in Idaho. Journal of the Idaho Academy of Sciences. 22(2) 63-90.

Bruvsen, M.A. and R.C. Biggam, and K.D. Black. 1976. Ecological strategies for assessing impact of water fluctuations on fish food organisms. Project Completion Report, National Marine Fisheries Service Contract No. 03-4-208-243.

Timothy D. Hatten, Ph.D.
President, Invertebrate Ecology Inc., Moscow, ID

A. Professional Preparation
- University of Idaho, Postdoc Entomology, 2007-2009; President Invertebrate Ecology Inc., Moscow, ID.
- University of Idaho, Entomology Ph.D., 2006
- Washington State University M.S., Entomology, 2003
- University of Arizona, B.S. Natural Resources, B.S., 1984

B. Professional Appointments

2006-Present	President, Invertebrate Ecology Inc. Moscow, ID
2007-2009	Postdoctoral Researcher, UI, Moscow, ID
2005	Fellow, NSF Integrated Graduate Education and Research Traineeship Program (IGERT), Moscow, ID
1994-1999	Liaison, Environmental Protection Agency and USDA-NRCS, CA
1988-1993	Conservationist, USDA-NRCS, CA
1986-1988	Peace Corps, Niger, Africa

C. EXPERTIZE
- Landscape and community ecology with emphasis on invertebrate fauna
- All aspects of sampling, collecting, processing and identifying invertebrates, terrestrial and aquatic
- Analysis of parametric, nonparametric, fine- and coarse scale data

D. PUBLICATIONS

Hatten, T.D., S.D. Eigenbrode, N.A. Bosque-Pérez, S. Gebbie, F. Merickel, and C. Looney. 2006. Influence of matrix elements on prairie-inhabiting Curculionidae, Tenebrionidae and Scarabaeidae in the Palouse. Pp. 101-108, *In:* Egan, D. and J. Harrington [eds.], Proceedings of the Nineteenth North American Prairie Conference. August 8-12, 2004, Madison: University Communications, Madison, WI.

Hatten, T.D., N.A. Bosque-Pérez, J.R. LaBonte, S.O. Guy and S. D. Eigenbrode. 2007. Effects of tillage on the activity-density and diversity of carabid beetles in spring and winter crops. Environmental Entomology 36 (2): 356-368.

Hatten, T.D., S. D. Eigenbrode, J. Johnson-Maynard, K. Umiker, J.R. LaBonte and N.A. Bosque-Pérez. 2009. Effect of crops, tillage and soil organic carbon on carabid beetles in commercial agricultural fields of the Inland Pacific Northwest, USA. Agricultural and Forest Entomology (In review).

Umiker, K., J. Johnson-Maynard, T. D. Hatten, S. D. Eigenbrode and N. Bosque-Pérez. 2009. Soil properties and earthworm density as influenced by cropping practices on farms of the Palouse Region, Idaho. Soil and Tillage Research (In press).

Roderick Sprague IV
Taxonomist, Invertebrate Ecology Inc., Moscow, ID

A. Professional Preparation

University of Idaho, B.S. Entomology, 2008

B. Professional Appointments

2008	Taxonomist, Invertebrate Ecology Inc., Moscow, ID
2002-2004	Taxonomist, University of Idaho, Division of Plant, Soil and Entomological Sciences, multiple labs, Moscow, ID
1993-2001	Custodian, University of Idaho, Moscow, ID
1979-1983	Museum Curator, W. F. Barr Insect Museum, University of Idaho, Moscow, ID

C. Expertise

- Identifications of aquatic and terrestrial invertebrates
- Specimen curation and storage, dry or wet