Creating tools for assessing and restoring floodplain habitats in the Columbia River Basin

Abstract

We propose to develop and implement tributary floodplain assessments to evaluate the importance of geomorphic complexity, hyporheic connectivity and temperature patterns to salmon diversity and productivity in the Columbia Basin. This approach will use remotely sensed data sets to identify high quality floodplains on the John Day, Umatilla, Grande Ronde, Lochsa, Yakima, Swan, Bitterroot and Methow Rivers. Additionally, we will create restoration guidelines for the Mission floodplain on the Umatilla River. The Mission floodplain offers a unique opportunity to plan a well designed restoration effort – an upper portion of the floodplain has a diverse geomorphic, thermal and biological character while the lower floodplain is considerably simplified. Using information from diverse floodplains on several Columbia River Basin tributaries, we will quantify relationships between physical and biological habitat parameters that inform the Mission restoration design. This effort represents the culmination of a variety of past and ongoing research efforts that began in Umatilla Basin and would build upon existing facilities, stream databases, and remote-sensing imagery compiled by the Confederated Tribes of the Umatilla Indian Reservation. Also, this project continues an integrated collaborative effort between Tribal Government, university researchers, and small business. Expected benefits of this project include: 1) development of a rapid assessment techniques to document nodes of diverse floodplain habitats and help prioritize opportunities for habitat restoration; 2) a design to restore native aquatic diversity to the lower Mission floodplain on the Umatilla River; and 3) a means to link salmon habitats to dynamic physical environments. The proposed project will result in new types of information, innovative methods to evaluate this information and design criteria to further conservation and restoration plans in the Columbia River Basin.

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Problem Identification

Historically, habitat restoration efforts for salmonids have been focused on restoration of creeks and small rivers (~3rd order or smaller) through direct manipulation of in-stream habitat structure such as stabilizing stream banks and placing/securing large wood to create desired pool/riffle sequences (Platts and Rinne 1985; U.S.D.A. Forest Service 1988). More recently, however, there is general scientific consensus that in-stream structural manipulation is often ineffective (Frissell and Nawa 1992; Kondolf, Vick et al. 1996).

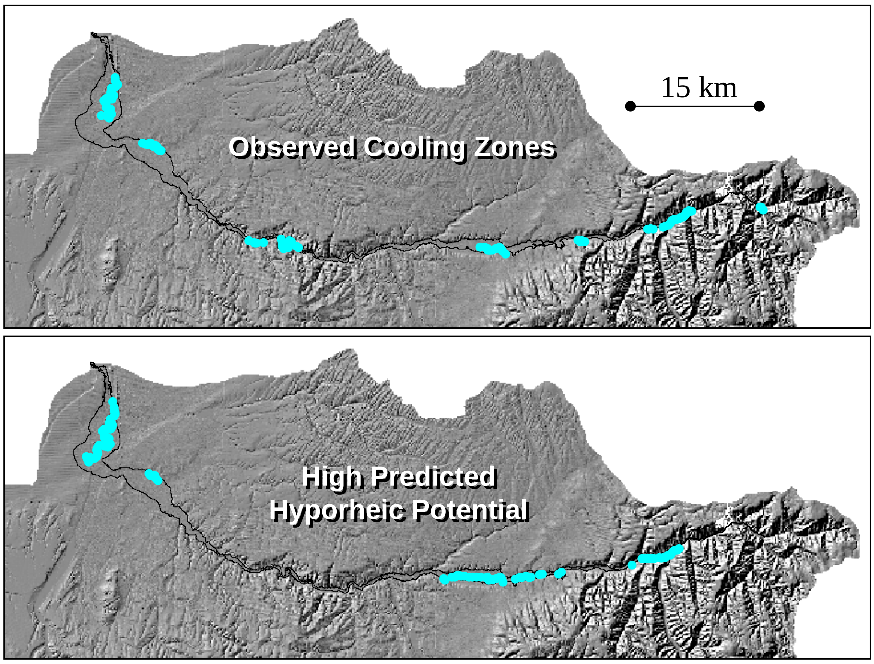

Figure 1: Correlation between observed cool-water areas in the Umatilla River and predicted zones of high potential for hyporheic flow based on geomorphic assessment. Black line is floodplain boundary (From O'Daniel and Poole, In preparation).

Instead, many argue that management focused on hillslope and in-stream hydrologic *processes* that create and maintain habitat will ultimately result in more effective stream rehabilitation and increase the likelihood of species recovery (Frissell, Liss et al. 1993; McIntosh, Sedell et al. 1994; Moyle and Yoshiyama 1994; 1996; Independent Scientific Group 1996; Stanford, Ward et al. 1996; Ebersole, Liss et al. 1997; Kauffman, Beschta et al. 1997; Poff, Allan et al. 1997; Wissmar and Beschta 1998; Beechie and Bolton 1999; Nemeth and Kiefer 1999; Williams, Bisson et al. 1999). Further, recent scientific literature highlights the importance of alluvial-bedded rivers in supporting robust fisheries and biological diversity (Independent Scientific Group 1996; Stanford, Ward et al. 1996; Brown 1997; Ward 1998; Ward, Tockner et al. 1999). Hyporheic processes represent an important dimension of river-floodplain connectivity that is important to the maintenance of overall physical complexity (e.g., thermal) and biological (e.g., salmonids) productivity in streams.

Region-wide, the effect of increased temperatures in Columbia River Basin (CRB) tributaries has dramatically reduced native fish populations. Since most stream systems are simplified, many large blocks of potential habitat in these mainstem Columbia tributaries are unavailable to salmonids due to human land-use activities (Frissell 1993; Moyle 1994; Independent Scientific Group 1996; National Research Council 1996). However, many of the same reaches contain, potentially, large blocks of high quality habitat. Although high stream temperatures are part of a complex system of feedbacks in stream systems, diverse stream temperatures are strongly associated with intact sections of floodplain habitat (Poole 2004). Functional alluvial floodplains moderate stream temperatures and provide a unique diversity of biological habitats (Junk 1990, Stanford and Ward 1993, Ward 1997, Naiman 1998).

Within alluvial river networks, floodplain segments are considered "hot spots" of biological diversity and productivity (Stanford 1998, Ward 1998). These floodplain segments possess essential physical habitat and the food webs that sustain various life stages of salmonids and other riverine fishes. Interactions between rivers and their floodplains create geomorphically complex habitat for fishes and other organisms. Recent research has shown that this geomorphic complexity can amplify connectivity between river water and the shallow alluvial aquifer beneath the channel and floodplain (Baxter and Hauer 2000, Poole et al. 2002). In turn, this hyporheic exchange can affect thermal heterogeneity in space and time, and may act as a buffer against temperature extremes in the main river (Fig. 1; O'Daniel and Poole, in preparation).

The thermal heterogeneity and buffering effect created by hyporheic exchange in geomorphically complex floodplains may have important consequences for different life stages of endangered salmonids in the CRB. For example, studies in the Columbia Basin by Baxter and Hauer (2000) and Geist (2000) showed reaches influenced by hyporheic upwelling were selected for spawning by bull trout and chinook salmon, respectively. By moderating stream temperature, hyporheic exchange can prevent occurrence of anchor ice in winter and create a more favorable environment for development of salmonid eggs and alevins (Benson 1953, Baxter and Hauer 2000, Baxter and McPhail 2000, Geist 2000). Similarly, Torgersen et al. (1999) found adult spring chinook salmon in the Middle Fork of the John Day River selected summer holding habitat in deep pools with cool-water patches influenced by hyporheic exchange. Likewise, Ebersole et al. (2001, 2003) demonstrated a strong association between abundance of juvenile steelhead and chinook salmon and the occurrence of channel margin and floodplain habitats whose summer temperatures were cooled by hyporheic upwelling, creating thermal refugia from the warm mainstem river. Such results from a few drainages highlight the need to assess the importance of floodplain habitat complexity, hyporheic connectivity, and thermal patterns to salmonids across the landscape of the CRB.

Although there is wide agreement that alluvial floodplains are zones of biological productivity (Brown 1997, Independent Scientific Group 1996, Stanford 1996, Ward 1998, Ward et al. 1999) there are no standard methods to assess floodplains. Floodplains are complex and dynamic ecosystems that are dependent on geomorphic and vegetation diversity tied to intra- and inter-annual cycles in river flow (Junk, 1989, Mertes 1997, Wiens 2002). Since the mainstem floodplains of Columbia River tributaries represent an integrated sum of the watersheds, understanding the processes that create and maintain floodplain diversity are likely to provide insight into other links between biological and physical processes. Although many floodplains are impacted by human activities, some contain a surprising amount of diversity (CTUIR 2003).

The processes that influence alluvial bedded floodplains include, hydrologic (delivery of sediment and large woody debris to channels and the movement of channels in response to flood events), chemical (nitrogen, phosphorus and carbon are routed in varying groundwater paths and contribute to high productivity in zones of hyporheic exchange, and biological (several critical salmon life history stages are linked to diverse hydrologic and chemical conditions). Therefore, it is important to identify and preserve the *processes* that contribute to functional floodplain environments. Because these processes are linked to widely varying spatial and temporal scales, it is also important to recognize the **context** or the spatial and temporal setting of normative floodplain functions.

Rationale

From our past work and based on comparable work cited above, we conclude that assessments and targeted restoration of complex interactions between river hydrology and floodplain morphology in alluvial floodplain rivers is critical to the restoration of native aquatic habitats. Increasing evidence shows that multiple scales of hyporheic exchange are common to the CRB (Baxter and Hauer 2000, (Mertes 1997), Ebersole et al. 2003, Kasahara and Wondzell 2003, Poole 2001, Poole 2004). Because of the important historical role of floodplain rivers as spawning areas, rearing habitat, and migration corridors for salmonids, we posit that a successful recovery strategy must include concerted effort to restore lateral ecological connectivity and habitat diversity in floodplain systems through targeted restoration of floodplain morphology and hydrologic processes. Considering both spatial and temporal aspects of this problem are crucial to defining the full range of processes (Lane and Richards 1997) necessary to maintain functional floodplains. Yet currently, the tools to identify, evaluate, and prioritize potential floodplain restoration projects are limited or non-existent.

To begin to fill this need, we propose to develop two suites of tools. The first set of tools includes remote sensing techniques to assess floodplain diversity, including channel and floodplain morphology, floodplain material spatial composition and geomorphic complexity (Figure 6). The techniques will be coupled with an innovative computer model (Figure 3) capable of tracking water movement in the channel, on the floodplain, and in the subsurface zone. Combined these results will identify restoration options in floodplains a range of model results will provide a detailed, mechanistic simulation of interactions between channel morphology and hydrologic regime that determine the locations, rate, timing and magnitude of water mixing between the river channel, floodplain, and hyporheic zone. These predictions will provide a direct indicator of ecological connectivity and the diversity of habitats critical to the life histories of Columbia River salmonids and other native aquatic biota.

The second set of tools is a combination of physical and biological monitoring centered on the Mission floodplain of the Umatilla River and the Wenaha floodplain of the Grande Ronde River. Field based instrumentation and investigation of the upper Mission site, the Minthorn area (Figure 3) began with the 2001 Innovative Project. In addition to application and analyses of remote sensing techniques, this geomorphically diverse area has been under hydrologic and hydrogeologic investigations to characterize the physical and geochemical exchange of water, temperature, and other geochemical components. In contrast, the lower Mission floodplain lacks the diversity represented by the Minthorn area and has not be studies previously. It is hypothesized that groundwater-river

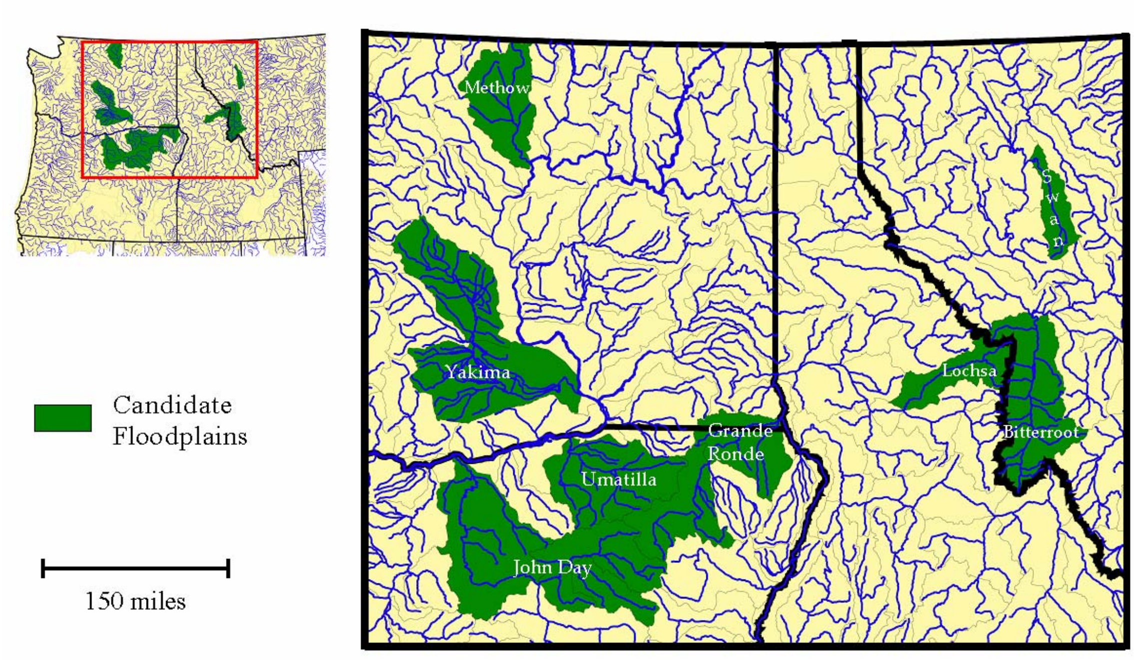

Figure 2: These candidate floodplains represent a broad range of geographic and biological expressions.

exchange rates, thermal regime and geochemical character of this less diverse area are degraded as is the fishery. This work will document the physical and biological conditions at this altered site and use these data in concert with remote sensing analyses and characterizations to plan and predict how stream restoration will alter aspects of this system. In addition, field investigations will be conducted on the natural floodplain of the Wenaha River in an effort to link the natural physical/geochemical/thermal systems with a continuing detailed fishery evaluations in this pristine environment.

The candidate floodplains (Figure 2) were selected from CRB tributaries with developed alluvial floodplains, without large mainstem dams and throughout a range of varying aquatic communities. Also, a range of floodplain land cover conditions was selected, from near pristine (Wenaha and Swan), rural development (Bitterroot), intensive and dryland agriculture (Yakima and Umatilla respectively).

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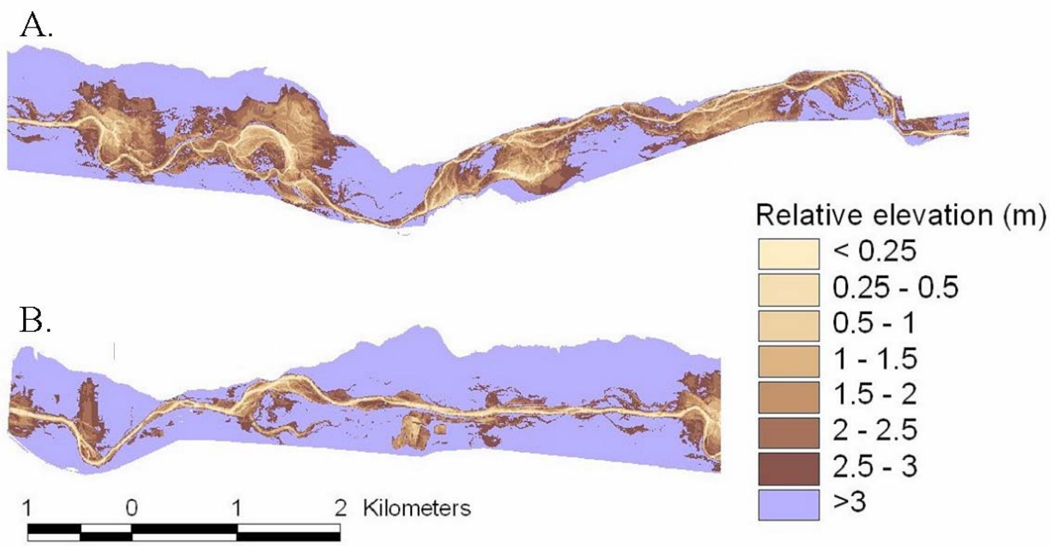

Figure 3: LIDAR data processed to relative elevation. The upper image (A). describes the section of the Umatilla River from Minthorn Springs to the Upper Mission floodplain. Channel connectivity is highest in the dark brown to light tan areas. The lower image (B) shows the middle and lower portion of the Mission floodplain that have been dredged and leeved.

the Minthorn area and has not been a focus of previously projects. It is hypothesized that groundwater-river exchange rates, thermal regime and geochemical character of this less diverse area is degraded as is salmon habitat (Contor 1997). This work will document the physical and biological conditions at this altered site and use these data in concert with remote sensing analyses and characterizations to plan and predict how stream restoration will alter aspects of this system. In addition, field investigations will be conducted on the natural floodplain of the Wenaha River in an effort to link the natural physical/geochemical/thermal systems while continuing detailed fishery evaluations in this pristine environment.

In a 2001 Innovative Grant, we identified areas on the Umatilla River that have a diverse mixture of floodplain waters and relatively high variation in geomorphic complexity. By applying novel methods we created a more complete understanding of the physical context of these diverse floodplains. Continuing this work, through other agencies, we have developed a hydrogeological characterization of the alluvial aquifer, a set of integrated remote sensing methods and a decision support system that enables the CTUIR to more effectively regulate water temperature.

While the Umatilla River, in northeast Oregon, has not been cited as an example of a river with functional floodplains, a relatively simple analysis of the geomorphic variation and stream temperature dynamics reveals that there are several diverse floodplains that significantly lower water temperatures (Figure 1). Patchiness or surface discontinuities associated with functional floodplain (figure 3). The upper portion of the Mission floodplain (Figure 3A) retains diverse geomorphic and thermal qualities, while the lower portion Figure 3B) of this floodplain has been leeved for the past forty years. Using LIDAR elevation data we have developed methods to classify hydrologic connectivity (Figure 3). Using other ancillary data we have made initial estimates of the potential range of surface water exchange in the lower Mission floodplain (Figure 5).

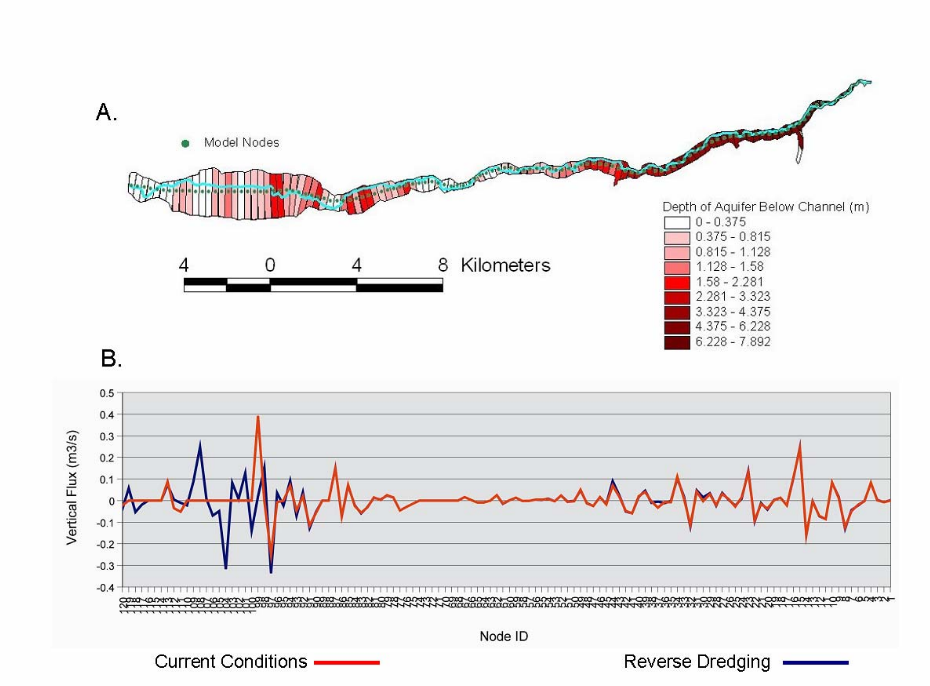

Figure 4: The upper images (A) is an estimate of the current depth of the alluvial aquifer is derived from well logs and associated with lateral sections of floodplain. The lower graph (B) is a first order estimate of vertical exchange rates for each of 120 nodes or approximately 40 miles along the Upper Umatilla River.

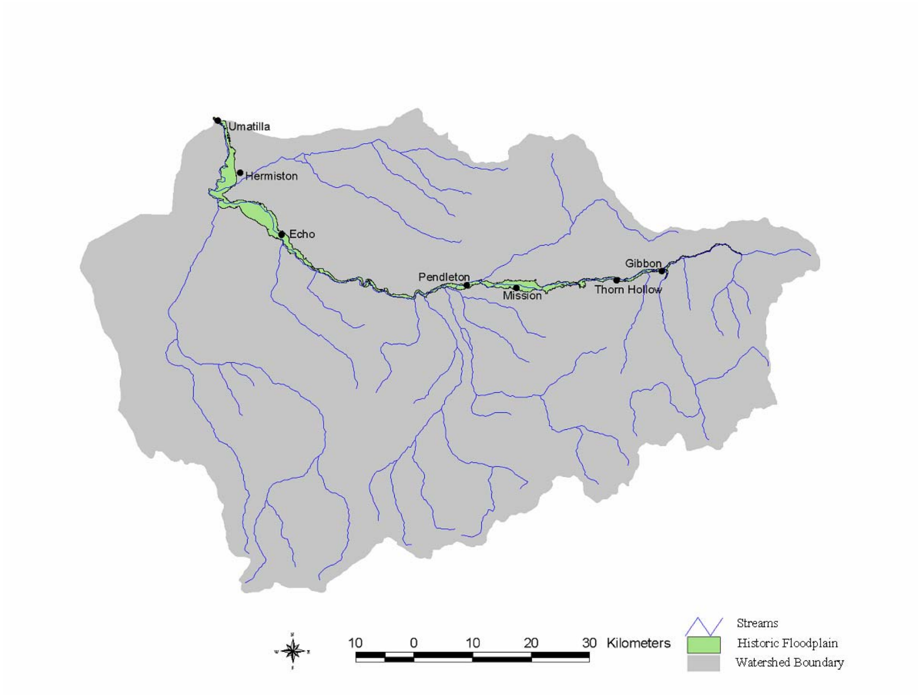

Figure 5. The historic floodplain of the Umatilla River floodplain is selected from a DEM using slope and an edge detection filter. This floodplain delineation method uses USGS 30 meter DEM data.

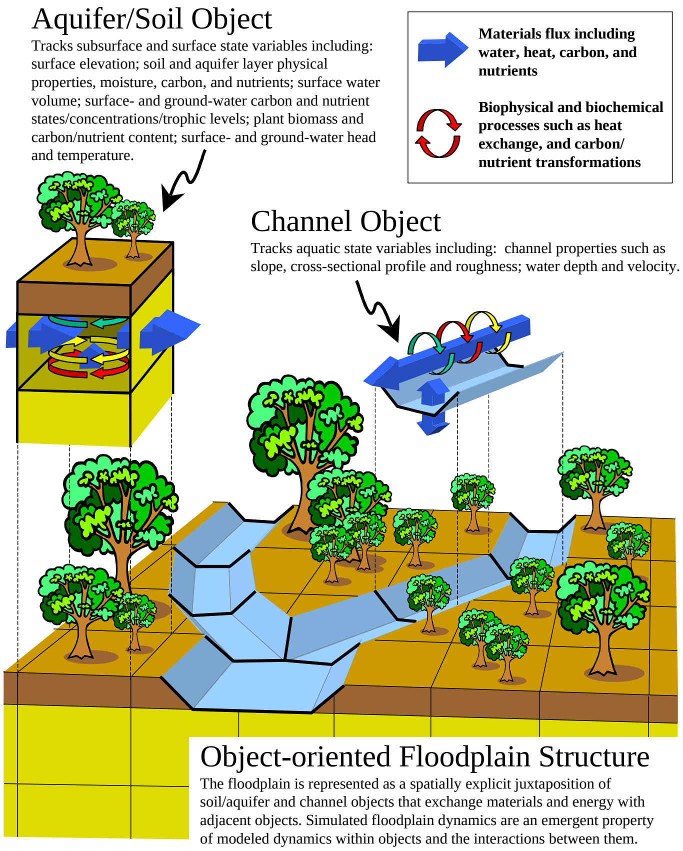

Figure 6: RIFLS-2, an on-going river ecosystem modeling effort based on the established model RIFLS (Poole 2000) is used to produce scenarios for the Mission floodplain.

The FLIR data show substantial variation in stream temperature along the Umatilla River at several spatial scales (O'Daniel and Poole). Fine-scale variation in stream temperature was explained by local heat flux dynamics such as unit-scale channel morphology, which enhances subsurface flow through gravel bars (Arrigoni – In preparation). However, the courser-scale variation in downstream warming was less easily explained; it does not correlate with expected drivers such as variation in shade (O'Daniel and Poole In preparation). Hyporheic flow (the two-way exchange of water between the stream channel and underlying alluvial aquifer) can be an important regulator of stream temperature (Figure 1). S. O'Daniel and G. Poole initiated research to test the hypothesis that hyporheic exchange could be responsible for the variation in downstream temperature. Additionally, Baxter (2000) investigated the role of multiple scales of hyporheic exchange on bull trout abundance and distribution. He found that bull trout used stream reaches influences by strong hyporheic upwelling for spawning and within these reaches redds were associated with local hyporheic downwelling zones. In this study, controls of geomorphology, hyporheic exchange and multiple scales and were necessary to characterize different life history stages of bull trout. By performing a remote-sensing geomorphic assessment of drivers of hyporheic flow, O'Daniel and Poole (In preparation) showed that cooling trends in the mainstem Umatilla River were associated with zones predicted to have high potential for hyporheic flow (Figure 1). Combined, the results from O'Daniel and Poole (In preparation) and Baxter (2000) suggest that floodplain morphology and associated hydrologic processes (such as hyporheic exchange) are critical determinants of habitat for salmonids.

Using methods piloted on the Umatilla River, we will assess a group of CRB tributaries (Figure 2) floodplains for cover type, geomorphic complexity, stream temperature distribution, biological productivity and interactions between these variables. We will extract the historic floodplain (Figure 5) as the extent of this analysis. Using a combination of remote sensing data sources (Figure 6) we will assess surface floodplain diversity (Table 1).

Outcomes of this work include successful acquisition of funds to purchase diverse floodplain parcels and recognition of the importance of geomorphic controls on stream temperature throughout Tribal government (CTUIR 2003). Based on past successes, we propose to extend this work to several floodplains in the Columbia River basin to further understand the possible regional implications of restoring greater connectivity between floodplain water types.

Outcomes of this project will include:

1) Increased understanding of the linkages between stream temperature, geomorphology and salmonid use;
2) Improved criteria to enable on-going projects to more effectively pursue geomorphic habitat restoration options;
3) Location of potential groundwater influenced segments in several floodplain in the Columbia River Basin;
4) Outputs from an agent-based floodplain model to describe 3-dimensional water dynamic through time to guide a restoration planning effort on the Mission floodplain;
5) A framework to draw inferences about floodplain character and productivity across multiple watersheds and spatial scales.

The tools introduced in the 2001 Innovative Project, enhanced through other parallel grants and further developed here, into a restoration planning design, contains the potential for broad systematic change in PNW river restoration. Where we can successfully identify problems in alluvial rivers, we can apply tools that will likely make a careful restoration effort very effective.

Significance to regional programs

Our project supports the goals and objectives of the 1994 Fish and Wildlife Program in a variety of ways that can be divided into five general categories: 1) evaluation of ecosystem integrity; 2) restoration of critical aquatic habitat; 3) facilitation of a watershed perspective; 4) tribal rights and responsibilities; and 5) coordination with ongoing projects. Each of these five general categories is listed below along with specific goals and objectives from the 1994 Fish and Wildlife Program. Each goal or objective is followed by a brief description of how our project supports the overall program. In the next section the Provisional Statements of Biological Objectives for environmental characteristics at the Basin scale are similarly addressed.

Evaluation of ecosystem integrity

2.1 System-wide Goal:

"The Council system goal is a healthy Columbia Basin, one that supports both human settlement and the long-term sustainability of native fish and wildlife species in native habitats..."

Our approach will facilitate a mechanistic understanding of ecological connectivity on floodplains along with the hydrologic processes that create and maintain connectivity and critical salmonid habitat diversity in the basin. The nested spatial framework will be useful for understanding drivers of habitat diversity and guiding management decisions for habitat restoration plans. Currently, the importance of connections between the stream channel, floodplain, and hyporheic zone is widely recognized, but there are few techniques to assess connectivity and habitat diversity.

3.3D Habitat database

"In developing and maintaining [the habitat database, we should] explore options to survey habitat conditions, such as analysis of aerial photographs, that could be more expeditious, less cumbersome and less costly than conventional methods."

Development of the proposed remote sensing techniques holds the promise for rapid, system-wide data collection techniques to evaluate ecological integrity on floodplains.

2.1 System-wide Goal:

"[W]here impacts have irrevocably changed the ecosystem, we must protect and enhance the ecosystem that remains."

Information generated from remote sensing techniques that characterize floodplain morphology and salmonid habitat will be useful for identifying floodplain locations where connectivity is high and for prioritizing degraded sites based on their potential for restoration.

2.2A Support Native Species in Native Habitat

"[R]emaining fish and wildlife habitat should be protected and restored to promote production of native species, especially habitat that supports weak populations of fish and wildlife"

Remote sensing assessments will help to provide a broad understanding of the geomorphic patterns that create salmon habitat in floodplain rivers. In the Umatilla River, this will facilitate development of restoration strategies for floodplain systems. Also, the Umatilla River supports a wild, native Steelhead population that is imperiled along with small Spring and Fall Chinook populations that have been re-established from hatchery stock after being locally extirpated.

7.8A.2 Implement State, Federal, and Tribal Habitat Improvements

"In streams where either water quality objectives or federal land management plan objectives for fish habitat and water quality are not being met, initiate actions needed for recovery."

Most CRB tributaries are not in compliance with water quality standards for temperature. Research on the importance of floodplain morphology and hyporheic flow for maintaining cool temperatures (O'Daniel and Poole In preparation) was initiated as part of an ongoing effort have resulted in a tribal TMDL for water temperature. To our knowledge, this TMDL is the first to explicitly incorporate groundwater influence on stream temperature. Results from the proposed project will be used to develop a renaturalization plan that would reduce summertime water temperature in the Umatilla River by improving floodplain connectivity and restoring natural hyporheic flows.

7.8B.1 Best Management Practices

"Establish best management practices under the Clean Water Act to maintain and improve salmon and steelhead production."

Currently there are no Best Management Practices that govern floodplain management. This project would provide information useful for developing BMPs for maintaining connectivity and habitat diversity on floodplains.

Appendix A: Recommendations Regarding Habitat Objectives and Funding Sources

"The Council recommends actions to improve stream morphology such as: 1) restoring floodplains by removing floodplain impacts (i.e. roads, riprap, and mining operations), 2) prohibiting channelization and channel armoring, and 3) meeting bank stability and sediment objectives."

Model results will be used to assess the hydrologic effects of targeted restoration projects and provide information to stakeholders regarding the specific expected benefits of restoration work.

Facilitation of a watershed perspective

4.1A Salmon and Steelhead Rebuilding Principles

"The region should approach habitat and production activities from a total-watershed perspective, not as activities that occur in isolation from land and water conditions in watersheds."

Combined remote sensing and mechanistic modeling techniques are especially well-suited to illustrating cumulative effects and placing individual projects in the context of the entire watershed.

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Combined remote sensing and mechanistic modeling techniques are especially well-suited to illustrating cumulative effects and placing individual projects in the context of the entire watershed. Ultimately, the proposed project will lead to techniques useful for understanding how individual projects can contribute to the overall restoration or degradation of watershed integrity.

4.2A Guiding Principles for the Columbia River Basin Salmon and Steelhead Research Program

"Research priorities are expected to reflect a systemwide analysis of the major uncertainties and problems associated with increasing runs in a biologically sound manner."

The mechanics of complex hydrologic interactions between channel, floodplain, and hyporheic waters remain largely unstudied from a "whole-system" perspective. While hyporheic flow is known to create a diversity of thermal habitats, the work of O'Daniel and Poole is among the first to document the potential influence of hyporheic flow on water temperature at the extent of an entire river. The proposed project is designed specifically to improve understanding of the region wide methods of water flow and mixing between channel, floodplain, and hyporheic zone, thus shedding light on the mechanisms of hyporheic influence on whole-stream temperature dynamics.

Tribal rights and responsibilities

4.1A Salmon and Steelhead Rebuilding Principle

"While the bulk of the region's attention is currently focused on threatened and endangered stocks, it is important not to lose sight of this region's obligations to fulfill Indian treaties and provide fish for Indian and non-Indian harvesters. Investments and adjustments should be made to provide harvest opportunities in tributaries or other areas and to facilitate rebuilding weak populations."

The proposed habitat analysis several CRB tributaries, and in particular rivers in the Umatilla Tribes ceded lands, will be extremely useful for the development of future management strategies to restore stocks, thus helping to fulfill tribal treaty obligations.

4.2A Guiding Principles for the Columbia River Basin Salmon and Steelhead Research Program

"[T]ribes should participate in development and oversight of the research program."

Previous and ongoing research that has lead to the development of this proposal was initiated and overseen by the Confederated Tribes of the Umatilla Indian Reservation. The proposed project will be overseen by the CTUIR and will integrate the skills and resources of tribal, university, and consulting scientists.

7.7 Cooperative Habitat Protection and Improvement with Private Landowners: Tribal Role

"Management of watersheds in a manner that continues to produce these resources is critical to tribal cultures and to obligations to comply with tribal rights. Therefore, the full involvement of tribes in developing and maintaining local and regional watershed approaches on reservation and ceded lands should occur."

The proposed project will help empower the CTUIR to develop effective strategies to manage floodplain land-use within the watershed such that ecological connectivity and salmonid habitat will be improved. The research will assist in the development of a nested scale approach to aquatic habitat management.

Coordination with ongoing research

4.2A Guiding Principles for the Columbia River Basin Salmon and Steelhead Research Program

"Research funded by Bonneville and the Corps [of Engineers] under this program is expected to be coordinated with research funded by other entities to ensure efficient use of funds and maximum return on research investments"

The proposed project is highly coordinated with other previous and on-going research. See the next section, *Relationship to Other Programs*, for more details on coordination efforts.

Additionally the proposed work is strongly connected to the Provisional Statements of Biological Objectives for environmental characteristics at the Basin scale. The following excerpts from the Fish and Wildlife Program, Appendix D are followed with a description of how our project supports the program.

2. Protect and restore freshwater habitat for all like history stages of the key species. Protect and increase ecological connectivity between aquatic areas, riparian zones and floodplains and uplands.

"Increase the connections between rivers and their floodplains, side channels and riparian zones."

Proposed work in the Mission floodplain will design the spatial and temporal context for a restoration action that seeks to return floodplain processes to a section of the Umatilla River. Additionally, this project identifies key floodplain segments in 8 CRB tributaries.

"Manage riparian areas to protect aquatic conditions and form a transition to floodplain terrestrial areas and side channels."

As a result of the 2001 Innovative Project "Habitat Diversity in Alluvial Rivers" and other parallel grants the CTUIR has pursued a program to acquire floodplain parcels. Currently, the CTUIR is managing > $500,000 in acquisition funds is target for floodplains in the Umatilla River watershed. The expenditure of these funds is informed by past, ongoing and proposed projects.

"Identify, protect and restore the functions of key alluvial river reaches."

Floodplain assessments in the candidate watersheds will yield an index of floodplain diversity, including relationships to temperature and biological productivity both within each watershed and among watersheds. The proposed assessment measures will provide an effective means to evaluate alluvial reaches in the CRB.

"Reconnect restored tributary habitats to protected or restored mainstem habitats, especially in the area of productive mainstem populations."

The proposed project builds on the established linkages between strong existing salmon populations and potential habitats identified through this teams work. Thermal and geomorphic diversity exhibited in the upper portion of the Mission floodplain (Minthorn Springs) of the Umatilla River were historically present throughout this floodplain. By initiating the design process we can both document a baseline to measure restoration success and consider temporal and spatial opportunities in the Mission floodplain.

3. Allow patterns of water flow to move more than at present toward the natural hydrographic pattern in terms of quantity, quality and fluctuation.

"Habitat restoration may be framed in the context of measured trends in water quality."

During the past six year the Umatilla River has had extensive water quality sampling through both field and remote methods. The resulting data set is one of the most extensive studies of riverine temperature dynamics. Through parallel, on-going work we are establishing daily (Arrigoni In Preperation) and seasonal trends of stream temperature at multiple spatial scales.

"Allow for seasonal fluctuations in flow. Stabilize daily fluctuations."

On-going work, from a parallel project, suggests that the continual exchange of river water through relatively short flowpaths may have a significant cooling effect on river segments (potentially >1 km). This work will be included in the planning and habitat evaluation for the Mission floodplain restoration.

"Increase the correspondence between water temperatures and the naturally-occurring regimes of temperatures throughout the basin."

Both the 2001 Innovative Project and the proposed work consider stream temperature variability a key element in water temperature management. By relating the fluctuations in the downstream temperature trends to measures of floodplain diversity we will identify geomorphic features (complexity) and multiple vegetation states (age structures) associated with normative temperature ranges.

Allow for biological diversity to increase among and within populations and species to increase ecological resilience to environmental variability.

"Expand the complexity and range of habitats to allow for greater life history and between species diversity."

Normative floodplain features including spring brooks, secondary flow channels and floodplain ponds are strongly associated with increased biological diversity. The design of the Mission Basin restoration plan will be based on comparative life history stages from other rivers with highly functional floodplain habitats.

"Manage human activities to minimize artificial selection or limitation of life history traits."

During the past several years, the CTUIR pursued a land acquisition plan that targets floodplain parcels. Additionally, the CTUIR is limiting land conversion in the near river environment (CTUIR 1996).

"Restoring habitat and access to habitat that establishes life history diversity is a priority."

Planning for the restoration of the Mission floodplain will link a potentially diverse, but currently simplified, floodplain with a functional upstream floodplain node (Figure 4). Comparisons of the several CRB floodplains will identify diverse and potentially diverse floodplains (Figure 2).

6. **Increase genetic connections and gene flow within the ecological system to facilitate development, expansion and protection of population structures.**

"Increase the abundance and range of existing habitats and populations."

By conducting life history assessments that combine many scales of floodplain data sets, we will gain a greater understanding of the potential ranges of salmon habitats and populations in the Mission floodplain.

"Expand and connect existing habitat pockets to facilitate development of resilient population structures for aquatic communities."

By identifying gaps in existing floodplain habitats we will identify local areas of diversity and potentially gain insight into systematic sources of floodplain degradation. The potential benefits of a more diverse Mission floodplain, connected to functional upstream areas, are not limited to salmonids. A range of native aquatic species including fresh water muscles, resident fish and invertebrates will increase with a carefully planned restoration effort.

Relationship to other Projects

The proposed project is consistent with the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program (FWP), Sections 7 and 10, and is one element in the comprehensive Basin Program, which includes artificial production, adult and juvenile passage improvements, instream flow enhancement, monitoring and evaluation, and watershed analysis. This project will complement the natural production and habitat programs already established in the Umatilla, Grand Ronde and John Day Basins and will integrate habitat efforts on private and public lands. Emphasis will be on a systematic assessment of geomorphic alterations and flow regulation to support efforts to restore salmon and protect dwindling numbers of summer steelhead and bull trout.

Many rivers in northeast Oregon have been the focus of work integrating remote sensing techniques and stream ecology research. The CTUIR, National Science Foundation, Bureau of Reclamation, US Forest Service, NASA and US EPA have all contributed to research integrating remote sensing techniques and stream ecology research in Northeastern Oregon [Li 1992, McIntosh 1995, Torgersen, 1999 #489; O'Daniel, In preparation #691]. This project will build critical links between floodplain and aquatic habitats, thereby refocusing regional restoration efforts on a more relevant suite of aquatic habitat states. Outcomes of this project will be directly coordinated with several projects in the Umatilla River Basin; specifically, Quantitative Assessment of Migrating Upstream Lamprey, Project #9402600, Umatilla Habitat Project, #8710002, Walla Walla Basin Habitat Enhancement, #9604601, North Fork John Day River Basin Anadromous Fish Habitat Enhancement, #200003100, Walla Walla Basin Natural Production Monitoring and Evaluation Project, #200003900 and Characterize Genetic Differences and Distribution of Freshwater Mussels, #200203700. In particular this project will be closely coordinated with Umatilla Basin Natural Production Monitoring and Evaluation, Project #9000501, to ensure a complementary effort to gather detailed fish habitat data in the Mission floodplain. Additionally, we expect that this collaboration will have lasting effects at the CTUIR in further developing critical links between tribal/state and university staffs and reexamining established monitoring and habitat roles.

Direct coordination with on-going NSF, EPA and BOR projects on the Umatilla River is considered in this proposal. These projects include “Flood and Human Response: Implications for Geomorphic Adjustment and Fish Habitat in the Pacific Northwest” (NSF), “Pesticide and Nutrient Fate on the Umatilla River Floodplain” (EPA) and Phase 3 of the Umatilla Basin Plan (BOR).

This project will benefit from a parallel, on-going efforts funded by NASA (NAG 13-02030). This work is complementary to the current proposal in that it further develops a more holistic view of stream temperature linked to remote sensing methods at each of the intensive study sites. Also, this parallel funding allows us to begin characterization of the alluvial aquifer through several geophysical methods. As a part of this project the intensive study sites have gained needed validation data including a weather station and the addition of 50 more monitoring wells.

Substantial cost sharing, as a part of this proposal, is possible through several parallel projects. These past and ongoing projects have contributed to a broad base of resources that enable us to leverage these data, collaborative relationships and ongoing method development to provide a highly efficient use of requested funds. To achieve the maximum benefit from on-going contributions, we request that this work begin at the start of FY 2005.

Relationship to on-going planning processes

a) Sub-basin Planning

This proposed project will provide new and relevant information into the Sub-basin planning process. Identifying varying stream temperature regimes and accompanying surface characteristics related to salmon life stage will give insight into the potential restoration strategies in several basins. Additionally, the continuous data products that this proposed project will use create will offer a more comprehensive treatment of floodplain environments.

b) BiOp

The proposed project will address critical uncertainties identified in the NMFS BiOp (listed below). While that are numerous references in the NMFS BiOp to aspects of this proposed work, the most general are address below.

-*"A two-pronged approach to habitat restoration action effectiveness research is recommended. The first approach is an extensive, watershed-scale top-down approach that monitors all treatment sites in a given geographic area. The second is an intensive, project-based bottom-up approach that monitors a large number of actions of the same class (e.g., riparian plantings or irrigation screening) across a broad, possible discontinuous region."*

This proposed project addresses both a "top-down" and a "bottom-up" approach to assessing the physical and biological character of CRB floodplains. In our past and on-going work, we have found that a combination of these approaches has lead to effective action to protect important habitats in the Umatilla River floodplain (see Rationale).

-*"Currently the region relies on an opportunistic approach to the implementation of project based monitoring – projects are not designed, implemented and monitored with in the context of a population, sub-basin or ESU. To be truly effective, restoration action implementation must be modified such that subbasin scale restoration planning is tightly integrated with the monitoring program."*

We propose to create tools within a scale specific framework (Figure 7) that have the potential to more closely relate monitoring and evaluation of productivity to habitat condition. We have outlined and piloted this strategy on the Umatilla River. Through a spatially extensive, functional approach to thermal variation and geomorphic complexity, we will identify previously unknown opportunity for habitat restoration.

-One of the stated goals for the restoration of stream habitat is "Complexity: To restore the complexity and range of habitat conditions for all life stages."

Numerous combinations of stochastic and deterministic processes drive riverine systems. Poole (2002) associates these attributes with complex systems and posits that hierarchical patch dynamics is an appropriate method to investigate these phenomena. We present metrics, thermal change and geomorphic complexity linked to biological productivity, to quantify multiple scales of change in floodplains across the CRB.

Proposal objectives

A primary goal of this study will be to evaluate the importance of floodplain geomorphic complexity, hyporheic connectivity and temperature patterns to salmon diversity and productivity in several rivers in the Columbia Basin. This investigation will be conducted across nested scales and address the multiple life stages and life history forms of salmonids that use these habitats (Figure 7). At the broadest scale, we will assess how distribution and characteristics of floodplain segments may affect salmon diversity and productivity among major tributaries of the Columbia Basin (Figure 2). Within these sub-basins, we will also assess spatial patterns to determine if floodplain segments represent hotspots for salmon diversity and productivity. In at least two selected sub-basins we will perform more in-depth investigations of the role of floodplain processes and habitats in sustaining multiple life stages and life history forms of salmon. We will evaluate how geomorphically and thermally complex habitats affects growth and survival of juvenile salmon by using existing productivity datasets. Together, this suite of approaches will identify relationships and elucidate mechanisms linking floodplain habitats and processes to salmon diversity and productivity, and will set the stage for more informed management and restoration of floodplains and salmon populations.

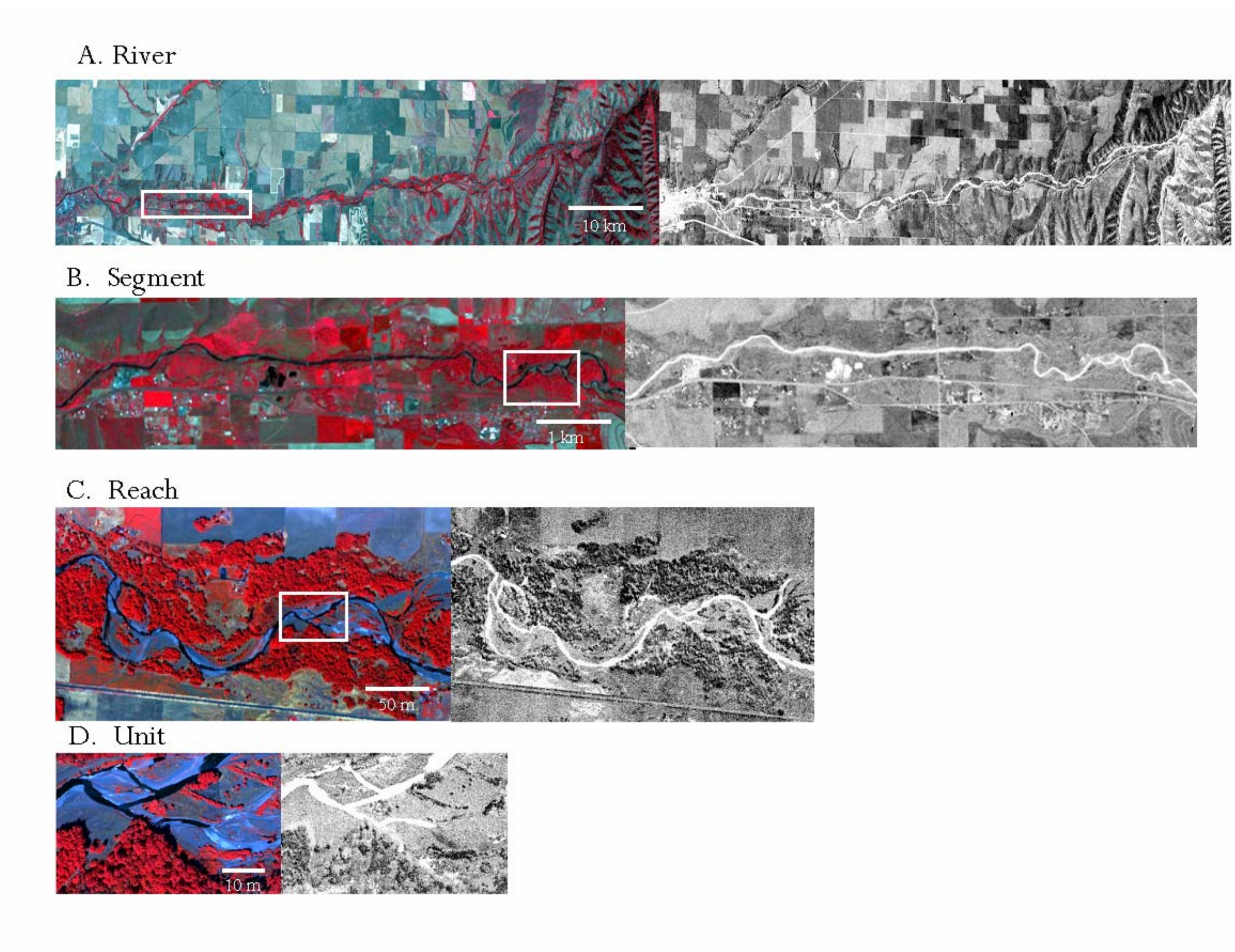

Figure 7: The image above, from the Umatilla River, shows multi-sensor, multi-resolution data sets. On the left side of each pair is a false color infrared image and on the right is an image, unmixed for water. All images are terrain corrected and intercalibrated. By creating data sets for several floodplains in the CRB, we will be able to measure the context and pattern of geomorphic complexity that controls stream temperatures and potentially salmon productivity. Additionally, this data set provide a physically meaningful (spectral and spatial) measures of floodplain diversity and function. Images are, A-Landsat, B-ASTER, C and D-CASI.

Table 2. Remotely sensed data to be used in the proposed CRB floodplain assessments.

Data Source	***Spatial Resolution***	***Importance***
ETM (Image A)	Moderate resolution (30 meter)	Landsat provides a synoptic view of all rivers in the CRB with a very large extent (185 km square). High temporal resolution (16 day cycle) allows within and between season comparisons.
ASTER (Image B)	Fine resolution (15-90 meter)	Provides finer spatial resolution and multiband thermal capabilities will yield additional information about thermal variation in floodplains. Fine temporal resolution (16 day cycle) allows within and between season comparisons.
Aerial Thermal and Optical data (Image C and D)	Fine resolution (1/2-5 meter)	Allows unit scale habitat unit mapping at limited extents. Fine spectral resolutions provide detailed information on floodplain materials, allowing separation of materials that are homogenous at moderate spatial resolutions.

Tasks and Methods

Objective 1: Define baseline floodplain characteristics

Further develop and implement a methodology using multi-resolution remote sensing data to assess floodplain diversity in several candidate CRB floodplains. Remote sensing data would be used to parameterize the model to assess water routing and mixing in the channel, floodplain, and hyporheic zone thus providing a mechanistic understanding of these complex hydrologic interactions and associated drivers of habitat diversity.

a) Make selections on image acquisition and obtain appropriate data.

Significant costs associated with obtaining imagery are ameliorated by this working groups' access to image resources. We will select a broad cross section of imagery that allows us to quantify floodplain diversity at a minimum of three separate spatial scales. We anticipate that cloud free imagery will be available for a majority of the floodplains to complete both a spring and fall image set allowing us to compare floodplains new inundation and at baseflows. Additionally, we will acquire imagery for the candidate floodplains from a variety of sensors (Table 1). Because several floodplain materials have similar temperatures, it is critical to identify the portion of the image that is exclusively water. Creating an appropriate resolution water mask is necessary to identify relic water bodies on the floodplain. Additionally, by masking out all other materials, except water, one can identify the edges of bars and river channels that characterize fine scale hyporheic buffering. Data of sufficient spatial resolution and radiometric quality that combines thermal and optical wavelengths is obtained through a parallel grant.

b) Process elevation datasets to create watershed and floodplain morphometry

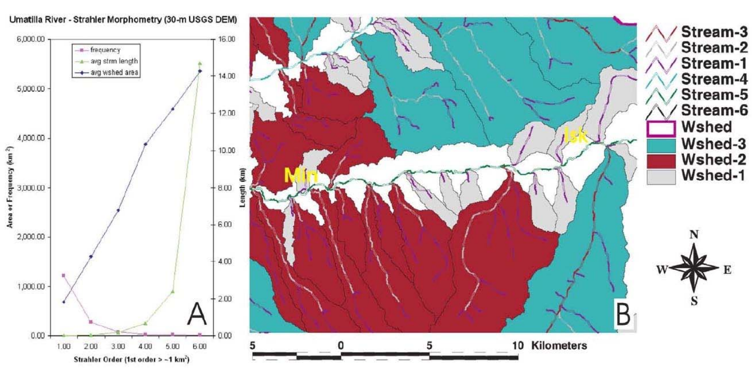

Figure 8: *Watershed structure for the Upper Umatilla River watershed derived from USGS 30 meter DEM data created from cell based flow modeling from Arc/Info GRID (Mertes, 2000, O'Daniel 2003).*

We will calculate watershed morphometry (Mertes 2001, Maidment 2000 and O'Daniel 2003) (Figure 8) for each candidate watershed. Techniques developed by this group (Mertes et. al. 1995, Mertes et. al. 2000 and O'Daniel 2003) demonstrate that topographic variability and inundation hydrology are highly correlated to the distribution of floodplain surface features. Morphometric parameters include stream length, bifurcation ratio, length ratio, drainage density, stream frequency, texture ratio, form factor, area perimeters, circularity ratio and elongation ratio and all the sub-watersheds in candidate watersheds. Further, we will investigate between 2 and 4 sets of LIDAR data for candidate floodplains. We expect to find a diverse set of patterns (Figure 8) that we can compare within and among candidate floodplains. Additionally, combining LIDAR and 30m DEM data represents a new opportunity for data integration into a spatially explicit model (RIFLS-2).

c) Identify and characterize geomorphically complex segments

In addition to the watershed characterization, the basin hydrologic and geologic foundation data sets will be established by reviewing available reports and papers, accessing state geologic and watershed data bases, and reviewing appropriate sets of drillers' logs. These data will be used to frame the candidate basins and supply addition breath to the remote sensing analyses. As stream segments are identified for further investigation, hydrologic data sets, the associated geology, floodplain material properties and sediment thickness will be developed. These basic geologic and hydrologic datasets will form the context for interpreting the surface geomorphic expressions.

Building on basic data we will identify surface floodplain segments that have complex character at nested scales. At the river segment scale we will use the Hyporheic Potential Index (HPI) (Figure 1). At the segment scale we will employ valley segment classification (Figure 9). We anticipate informing valley segment classification through a parallel geomorphic classification exercise. The result of this improvement to the valley segment classification will be, at minimum a semi-automated technique to generate this classification from standard (ETM, ASTER or DOQ data sets).

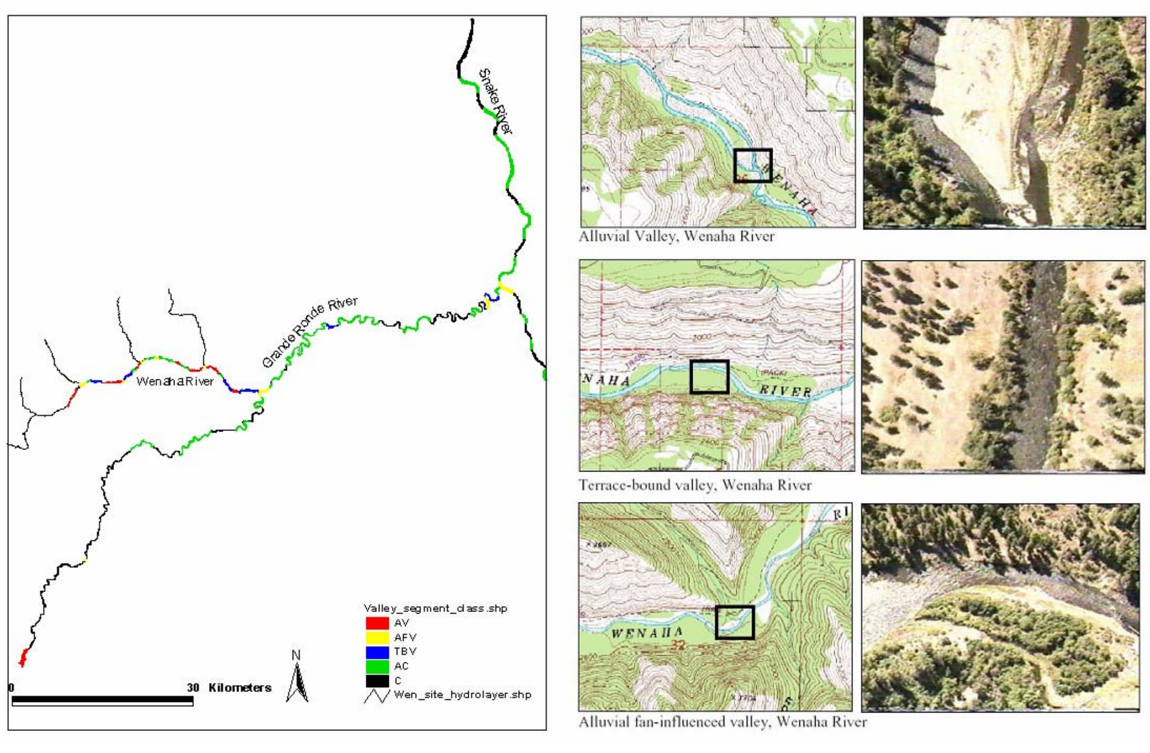

Figure 9: Map of valley segment types in the Wenaha River floodplain. AV = alluvial valley, AFV = alluvial-fan influenced valley, TBV = terrace bound valley, AC = alluviated canyon, C = canyon (from Baxter 2002).

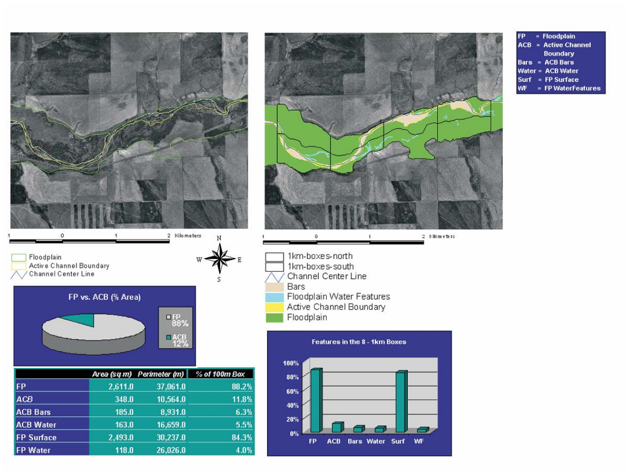

Figure 10: A stepwise feature-based tree is used to classify channel and floodplain elements. Examples of GIS based digitizing (above) in the Minthorn Springs area on the Umatilla River. These features are the basis for statistics on areal cover of the landforms and water types on the floodplain surface. Base data set is a Digital Orthoquadrangle - 5/6/94, 1:12,000.

At the scale of reach and unit we will use both DOQ and LIDAR data to measure floodplain complexity in several candidate floodplains. We have developed two methods of conducting geomorphic assessments, through analysis of digitizing (Figure 10) data and LIDAR (Figure 11). A detailed hierarchy of river features has been jointly developed with an NSF funded project (http://www.geog.ucsb.edu/~gna/umatilla/ and http://geography.uoregon.edu/mcdowell/Umatilla/), also working on the Umatilla River floodplain. These river features are nested at several scales in a detailed geomorphic classification system that is shared by both projects. Using this classification system we will compare topographic indices developed in basins with LIDAR (Yakima and Umatilla) and those without (Lochsa and Methow). Thus, we will develop and implement specific methods for "data rich" and "data poor" basins. We will use topographic indices developed as a part of Mertes' SRTM work to develop standard measures for comparison of floodplain geomorphic features both within and across floodplains. We anticipate an expanded range of geomorphic expressions on Yakima, John Day and Wenaha River floodplains to extend topographic/temperatures developed on the Umatilla River. These tools, developed with several cooperators, will facilitate a more complete understanding of the relationship of inundation hydrology and stream temperature.

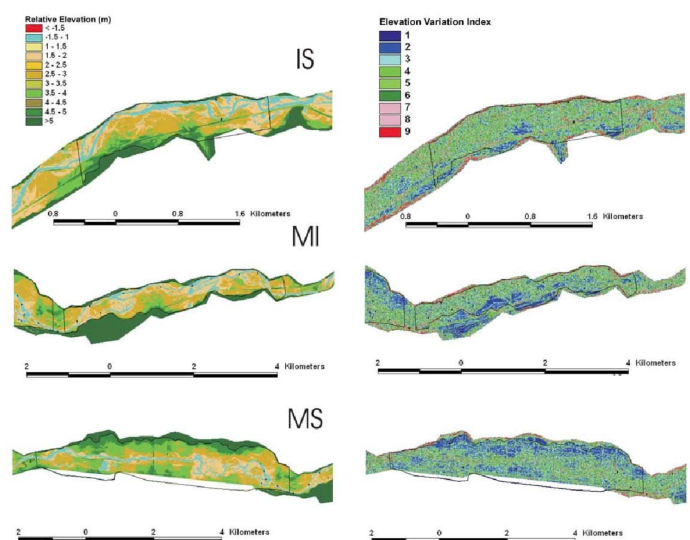

Figure 11: *Variability map derived from LIDAR 3 meter data using a 3 by 3 spatial filter. Black polygon outlines on image show location of sample areas: Mission (MS), Minthorn Springs (MI) and Iskuulpa (IS) areas (O'Daniel 2003)*

d) Relate temperature information to geomorphic complexity

Using FLIR longitudinal profiles, stream thermograph data and FLIR mosaics, we will relate the patterns of stream temperature to the floodplain features and water types. This project will use the extensive Forward Looking Infrared Radiometry (FLIR) datasets available for tributaries in the CRB. FLIR is an aircraft-based remote sensing technique that records data representing stream surface temperature by measuring thermal infrared (TIR) energy from the land/water surface. We will select FLIR imagery that is seasonally concurrent with optical data and other floodplain specific image data sets. In floodplains that do not have FLIR data available, stream thermograph data, collected from the inflow and outflow of appropriate floodplain reaches, will be used to assess temperature conditions. Combining temperature information with geomorphic data at multiple scales we will identify the geomorphic characteristics that constrain a more diverse expression of stream temperature.

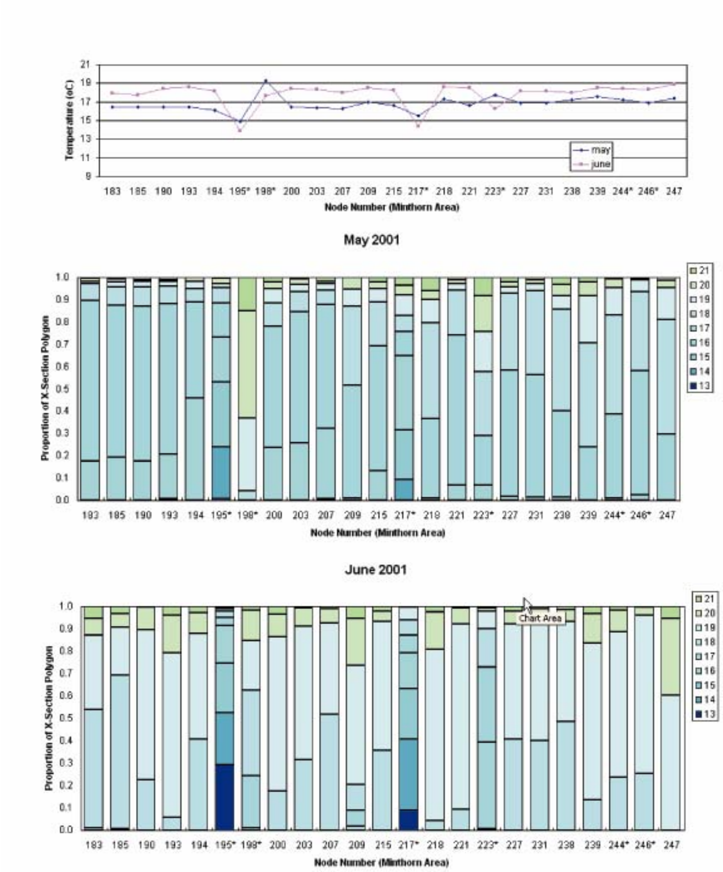

*Figure 10: Temperature data derived from FLIR showing distribution at model nodes for the Minthorn Springs are of the Umatilla River. Top figure shows median temperature variation. Next figures show the distribution of temperature for the months of May and June 2001. Nodes with a * indicate floodplain flow, all others are main channel.*

e) Compile and summarize available biological productivity datasets

We will evaluate the available data sets to identify an appropriate biological measure that is meaningful across a majority of the candidate floodplains (juvenile to adult ratios per segment). Further, we will investigate potential relationships between fish abundance, species and life history diversity, and river-floodplain characteristics for a suite of floodplain segments from throughout the Columbia Basin (Figure 2). We will create maps for each river system that describe the spatial distribution of salmon life stages and life-history forms for each species. By examining segments across a continuum that encompasses conditions from degraded to intact floodplains, we expect to identify relationships between fish productivity/diversity and river-floodplain habitat character. In addition, within these tributaries, we will also assess spatial patterns to determine if floodplain segments represent hotspots for salmon diversity and productivity.

Objective 2: Refine floodplain segment tools

a) Spectral and morphological classification of remote sensing imagery

Upon arrival, imagery will be terrain and atmospherically corrected. Then candidate tributary floodplains will be selected (ex. Figure 5) from the imagery. The ETM, ASTER and aerial remote sensing data will be analyzed with spectral mixture analysis tools (Adams 1986, Adams 1993) and/or standard classification techniques to produce maps of cover classes, active channel boundaries (O'Daniel 2003) and appropriate inundation areas (Mertes 1997). Additionally, we will decompose the spectral data into fraction images for vegetation, soil, and water types to develop a classification for floodplains that is landcover types along the river system. Variability statistics will be developed for water, geomorphic and landcover type. From this analysis we expect to produce for each floodplain, the zone of river-water influence, and surface cover complexity (Figure 7) and accompanying statistics that, in combination with the geomorphic assessment, provide substantially more information about the spatial patterns of CRB floodplains.

Also, we will use shape-based or morphological classification. We propose to use morphological classification in two ways, to measure domain shifts in rivers using power spectral density signal changes (Welsh 1967) and to classify the extent of compositional novelty on floodplains using a shape based classifier. Power spectral density function outputs will allow us to compare the resulting channel changes from inter-decadal flooding on a subset of the candidate watersheds. These changes in channel geometry will further allow us to validate the degree of channel stability in floodplains also providing a reliable measure of change associated with a single flood frequency cycle. Will use a morphological feature classifier to develop filters to classify floodplain water shapes (main channels, spring brooks, high flow channels and floodplain ponds). Results from both morphological and spectral classification techniques will be combined to create a detailed multi-resolution remote sensing index for CRB floodplains.

b) Instrument and develop data sets for key floodplain segments

Alluvial Aquifer

In addition to provide supporting physical data to characterize candidate basins, further investigation of the processes controlling gravel bedded stream temperature is planned. Two data sets will be derived for the main channel of the Umatilla River. One area has been previously investigated as part of an on-going study, the Minthorn Springs site, will have its monitoring program continued. The site has undergone geological, geophysical and hydrogeological investigation. It has been instrumented extensively with floodplain wells, temperature monitors and instream channel and bar temperature arrays. A floodplain weather station has been established and 1.5 years of groundwater behavior and temperature data have been collected. The continuation of this monitoring program will allow for not only a detailed understanding of how the stream-bar-floodplain system interface and this interrelation is propagated in the remote sensing analyses, but also how these interactions vary spatially and temporally. A second site downstream of the Minthorn site that includes a section of stream that has be modified such that stream complexity is reduced by channelization will also be instrumented to assess how the stream channel and floodplain interact. Work at this site will include developing a set of monitoring wells and piezometers, limited geochemical sampling, and floodplain and channel three-dimensional temperature monitoring.

Using this data base five additional sites will be selected for field instrumentation to more broadly characterize drivers diverse salmon habitat. The monitoring network will be scaled down from the scale used to monitoring the original sites in an attempt to collect a more broad based data set over a wider range of channel/floodplain conditions.
At sites selected from remote sensing and fish evaluations, vertical near channel and in channel temperature arrays installed by hand will form the foundation of the instrumentation. Inexpensive temperature monitors, Ibuttons, will be installed as described by Johnson et al. (2004). In addition, bar and bed sediment characterization as well as measurements of field hydraulic gradients associated with bar complexes will be undertaken in an attempt to related bar character/floodplain complexity to predicted and observed stream temperature buffering capacity.

This stream monitoring network will include multi-scale shallow well design, stream stage recorders and three-dimensional thermal and geochemical sampling. In addition, geophysical investigations including the use of ground penetrating radar and seismic refraction surveys, combined with recorded well log data and drilling as appropriate, will be used to assist in establishing alluvium-bedrock contacts and alluvium volumes. Installation of such a network and subsequent collection of 2 to 3 years of data is absolutely necessary in order to understand the influence of geomorphic conditions on fishery success.

Salmon habitat

Intensive monitoring of salmonid habitat use will not be a part of this project, rather we will rely on improved datasets generated from ongoing efforts by both state and tribal fisheries programs. Using existing data we will create coarse-scale maps of adult holding and juvenile rearing distribution (these data already exist for the Wenaha River, see Baxter 2002). This suite of biological maps will be spatially analyzed within the context of the valley segment maps (already in existence for the Wenaha-Grande Ronde system, see Figure 9) and remote-sensing imagery of geomorphic and thermal habitat that we generate for candidate river systems (see Objective 1b-1d above).

c) Relate floodplain surface features to hydrologic properties

Using the compiled data from geologic and hydrologic reports combined with surface and groundwater chemistry, hydraulic conductivity, temperature and outputs from floodplain elevation data sets (Figures 3 and 8), we will characterize the timing and sources of hyporheic exchange in several candidate floodplain segments. The Minthorn Springs site on the Umatilla River is an example where varying water temperature and chemistry associated with a normative floodplain feature. This springbrook has a dramatically different seasonal temperatures (Figure 12) and chemistry (Vitale In preparation) in tributaries originating from different water sources (hillslope waters and floodplain river water). To characterize several of the candidate floodplains we will combine geologic background information with remotely sensed data on watershed and local floodplain landforms (Objective 1b) with field data to explain the processes that are driving variations in water source.

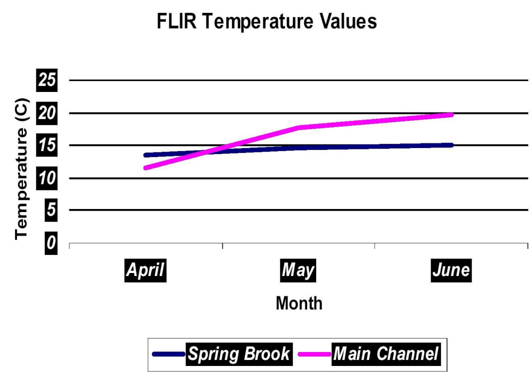

Figure 12: Main channel and springbrook temperatures at Minthorn Springs, Umatilla River. The mainstem Umatilla River varies over 10 degrees C. During the same period, the springbrook changes 3 degrees C. (O'Daniel 2003)

Planning and executing restoration of floodplains needs to be predicted on lessons learned from the multiple river/floodplain systems. Without these data, the probability of accomplishing set restoration goals would likely decrease, and our ability to assess the *reasons* for the success or failure of the restoration efforts would be compromised.

Objective 3: Assess biological productivity and floodplain diversity using the Rapid Assessment Tools

a) Create multi-scale metrics to quantify relationships between geomorphic surfaces, temperature

To differentiate processes that dominate an entire river from those controlling a particular reach, we will approach each candidate watershed as a set of nested processes. Using the basic geologic and watershed morphometry as a physical template we can monitor the seasonal and annual trends and variations in hydrology and stream temperature. Our initial results from the mainstem Umatilla River suggest that sinuosity and floodplain gradient control most of the hyporheic exchange. However, current research (Arrigoni In preparation) shows the number of short flowpaths that intersect bars dampens the diel temperature range and this lag has a substantial effect on local (unit or meters) temperature. We will use the combined datasets as a source for investigating emergent scales of temperature variation and geomorphic complexity. Using overlapping spatial filters of varying sizes, we will compare expressions of geomorphic complexity (Hyporheic Potential Index, valley segment classification) to temperature variation (FLIR profiles, mosaics and thermograph data). This task will result in a set of hierarchical relationships between geomorphology and stream temperature that can be directly related to salmon productivity at multiple spatial scales (river, segment, reach and unit).

b) Produce stream temperature scenarios using RIFLS-2

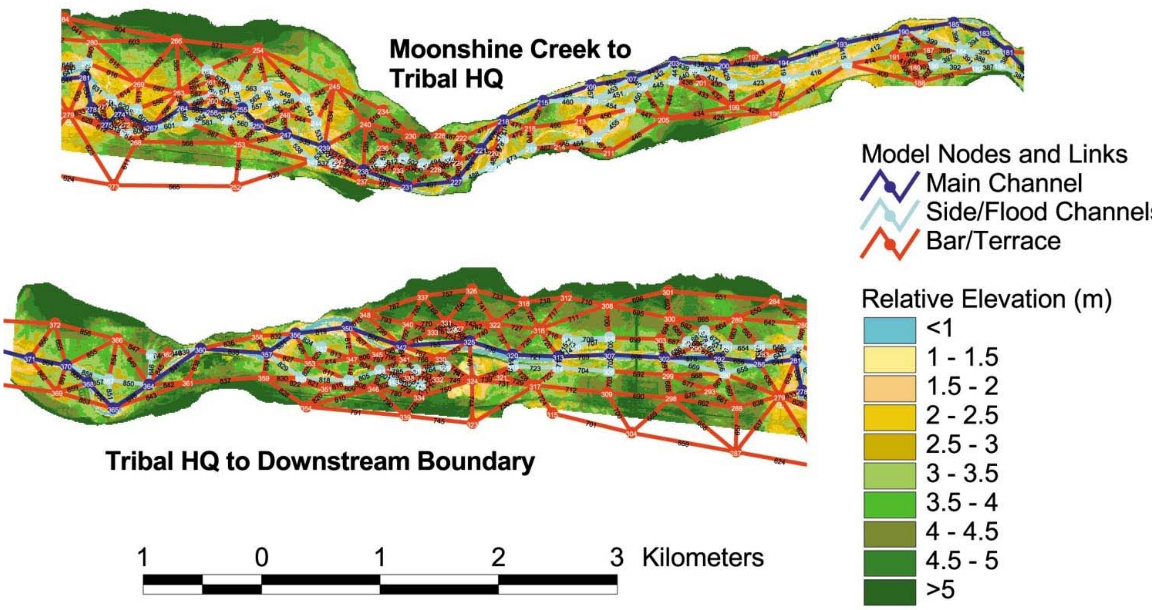

Figure 13: Resulting link and node locations used to parameterize a modified version of the Wetlands Dynamics Water Budget Model. Arbitrary numeric labels are shown for nodes (white) and links (black).

We will test RIFLS-2 using a generalized data set from the candidate floodplain segments, as well as completing runs for the Mission floodplain. Unlike other models of heat flux in rivers, RIFLS-2 tracks the heart and water budget of both river channel and the alluvial aquifer. Additionally, model dynamics are sensitive to changes in geomorphic conditions. RIFLS-2 is capable of simulating floodplain surface and subsurface hydrologic dynamics as river stage changes. Initial outputs from RIFLS-2 closely match field measurement (O'Daniel 2003). Along with several other field and remotely sensed data sets, outputs from RIFLS-2 will be used to investigate restoration guidelines of the Mission floodplain.

c) Compare biological productivity within and among CRB floodplains

Using the metrics developed in Objective 3a, we will spatially compare geomorphic and thermally diverse stream segments to salmon abundance, species and life-history types and stages. Conducting this analysis at multiple spatial scales, we expect to find specific relationships between spatial extent of habitats and salmon use. We expect to biological productivity to be greater in functional floodplain segments the spatial extent of habitats and salmon use. Further we will investigate spatial relationships between physical habitats and salmon use by incorporating multivariate and spatial statistics methods.

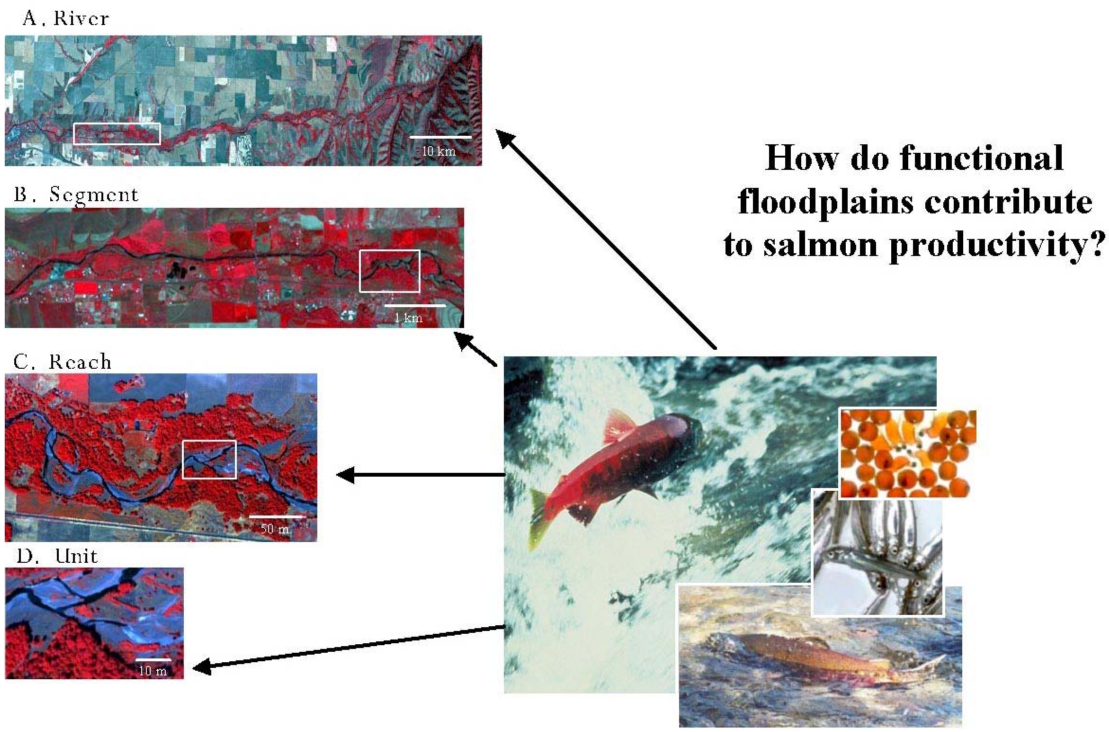

Figure 14: This study will evaluate how floodplain geomorphic complexity, hyporheic connectivity, and temperature patterns affect salmon diversity and productivity by conducting investigations across a hierarchy of scales to address the multiple species, life history types and life stages that use these habitats.

Summary

Completion of this project will: 1) further develop innovative techniques for structural and functional assessment of floodplain systems and associated salmon habitat; 2) implement tools for informing and guiding the management of floodplains to balance human activities against aquatic system health; 3) contribute toward an improved condition of salmon habitats; and 4) implement remote sensing techniques for rapid assessment of habitat diversity and ecological connectivity over several CRB floodplains.

Comparisons of geomorphic and cover complexity, thermal diversity and salmon survival will be conducted across eight basins in the CRB. The detailed maps and data describing the physical habitat of these floodplain segments (as described above) will set the context for these analyses. Overall patterns from the floodplain segments, and the basins as a whole, will be compared to one another. Thus, these analyses will allow us to evaluate one of the potential mechanisms by which use of geomorphically and thermally complex habitats may affect salmon productivity in the Columbia Basin.

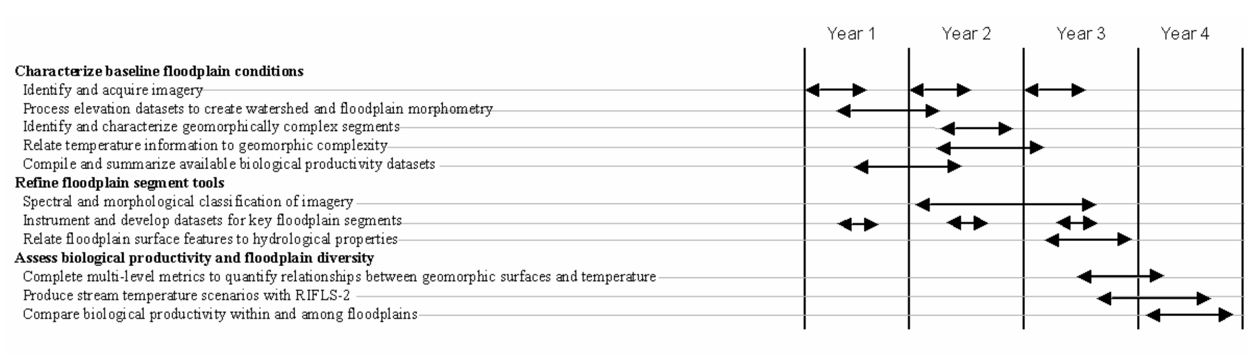

Figure 15: Timeline of the proposed project.

Facilities and Equipment

The Umatilla Tribes operate on a campus with > 30,000-sq. ft. of office space served by a high-speed telecommunication links (external T-1 connection and fiber optic internal connection). GIS, Fisheries, Water Resources and EPRP Programs possess several, professional quality, global positioning system (GPS) units, a significant amount of field measurement equipment, and share a fleet of field vehicles. The Umatilla Tribes GIS lab maintains a library of coverages for the Umatilla Indian Reservation, the lab has initiated and completed detailed research projects within the 6.4 million acres of CTUIR ceded lands in Oregon and Washington. Positions in the Lab include five full time employees. In addition to 15 seats of ARCGIS 8 and two seats of ERDAS Imagine, the Umatilla Tribal GIS program utilizes several statistical programs including CART, MARS, S plus and Cubist. Computer hardware includes a UNIX, Sun Sparc 20 workstation and 6 Windows workstations, 3 laptop computers and > 1TB of information storage space.

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Moyle, P. B. and R. M. Yoshiyama (1994). "Protection of aquatic biodiversity in California: A five-tiered approach." Fisheries **19**(2): 6-18.

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Nemeth, D. J. and R. B. Kiefer (1999). "Snake River Spring and Summer Chinook Salmon - The Choice for Recovery." Fisheries **24**(10): 16-22.

O'Daniel, S. and G. C. Poole (In preparation). "Hyporheic flow as a mechanism for variation in stream temperature along the Umatilla River, Oregon."

Platts, W. S. and J. N. Rinne (1985). "Riparian and stream enhancement management and research in the rocky mountains." North American Journal of Fisheries Management **5**: 115-125.

Poff, N. L., J. D. Allan, et al. (1997). "The natural flow regime. A paradigm for river conservation and restoration." Bioscience **47**(11): 769-784.

Stanford, J. A., J. V. Ward, et al. (1996). "A general protocol for restoration of regulated rivers." Regulated Rivers: Research and Management **12**: 391-413.

U.S.D.A. Forest Service (1988). Wildlife and Fisheries Habitat Improvement Handbook. Washington D.C., Department of Agriculture.

Ward, J. V. (1998). "Riverine landscapes: Biodiversity patterns, disturbance regimes, and aquatic conservation." Biological Conservation **83**(3): 269-278.

Ward, J. V., K. Tockner, et al. (1999). "Biodiversity of floodplain river ecosystems: ecotones and connectivity." Regulated Rivers: Research and Management **15**: 125-139.

Williams, R. N., P. A. Bisson, et al. (1999). "Scientific Issues in the Restoration of Salmonid Fishes in the Columbia River." Fisheries **24**(3): 10-25.

Wissmar, R. C. and R. L. Beschta (1998). "Restoration and management of riparian ecosystems: a catchment perspective." Freshwater Biology **40**(3): 571-585.

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Education and Professional Experience

2004 (expected): M.S.-University of California, Santa Barbara, Geography
1995: B.S.-Washington State University, Pullman, Landscape Architecture
1997–present: Geographer, Confederated Tribes of the Umatilla Indian Reservation, Pendleton, Oregon.
1996-1997: GIS/Remote Sensing Analyst, Pacific Meridian Resources, onsite contract to the U.S. Forest Service, Remote Sensing Lab, Region 5, Sacramento, California.
1995-1996: GIS/Remote Sensing Analyst, Pacific Meridian Resources, onsite contract to the U.S. Forest Service, Mendocino National Forest, Willows, California.

Research Interests

- Influence of geomorphic complexity on thermal regimes in alluvial rivers
- Advancing techniques of remote sensing using spectral mixture analysis and morphologic/shape based classifiers
- Use of GIS, spatial statistics, and data visualization techniques to conduct ecosystem research
- Application of complex systems and Resilience in fluvial systems

Publications Related to Proposal

O'Daniel, S., and G. C. Poole. In preparation. Interactions between Regional-Scale Variation in Geomorphology and Potential for Hyporheic Exchange along the Umatilla River, Oregon.
O'Daniel, S. 1999. Characterization of the Spatial Structure of Salmonid Habitats in the Umatilla River, Oregon. Proceedings of the 5th Annual World Congress of the International Society of Landscape Ecology, Snowmass, CO.
O'Daniel, S. J., Poole, G. C., Hyporheic flow as a mechanism for variation in stream temperature along the Umatilla River, Oregon, Eos Trans. AGU, 82(47), Fall Meet. Suppl., Abstract H21B-0295, 2002.
O'Daniel, S. J., Poole, G. C., Mertes, L.A. K. Final report to Bonneville Power Administration – Habitat Diversity in Alluvial Rivers. Portland, Bonneville Power Administration**:** 114.

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EDUCATION

B. A. – Biology & Geology, University of Oregon, Eugene, 1993; **M.S. – Ecology**, University of Montana, Missoula, 1997; **Ph.D. – Fisheries Science**, Oregon State University, Corvallis, 2002

EXPERIENCE

Assistant Professor, Department of Biological Sciences, Idaho State University, starting date December, 2004; **Postdoctoral research associate**, Department of Fishery and Wildlife Biology, Colorado State University, 2002-Present; **Graduate Research Assistant**, Department of Fisheries and Wildlife, Oregon State University, 1997-2002; **Graduate Research Assistant**, Flathead Lake Biological Station, University of Montana, 1994-1997.

PROFESSIONAL ACTIVITIES

Advisory Committee Member – Western Division of American Fisheries Society Advisory Committee on Bull Trout, 1998-Present; **Invited Reviewer –** U.S. Fish and Wildlife Service proposed Critical Habitat Rule and Draft Recovery Plan for Bull Trout, 2003; **Invited Reviewer –** Wallowa County-Nez Perce Tribe Salmon Habitat Recovery Plan and Hells Canyon National Recreation Area Management Plan, 2000; **Invited Reviewer –** Ecological Applications, Ecology of Freshwater Fish, Ecosystems, Hydrological Processes, Journal of the North American Benthological Society, Transactions of the American Fisheries Society, North American Journal of Fisheries Management, Northwest Science, 2000-2004.

HONORS AND AWARDS

Postdoctoral Fellowship, Japan Society for the Promotion of Science, 2002; **Thomas G. Scott Scholarship**, Department of Fisheries & Wildlife, Oregon State University, 2001; **Oregon Chapter American Fisheries Society Graduate Student Scholarship**, 2001; **Yerex Fellowship for Academic Excellence in Science**, Oregon State University, 1999; **Western Division American Fisheries Society Graduate Student Scholarship**, 1999; **Outstanding Geological Sciences Graduate**, University of Oregon, 1993; **Grace Morris full tuition academic scholarship to University of Oregon**, 1989-1993.

FIVE PUBLICATIONS RELATED TO THIS PROPOSAL

Baxter, C. V., K. D. Fausch, M. Murakami, and P. L. Chapman. In press. Fish invasion restructures stream and forest food webs by interrupting reciprocal prey subsidies. Ecology.

Baxter, C.V., F.R. Hauer and W.W. Woessner 2003. Measuring groundwater-stream water exchange: new techniques for installing mini-piezometers and estimating hydraulic conductivity. Transactions of the American Fisheries Society 132: 493-502.

Fausch, K.D., C.E. Torgersen, C.V. Baxter, H.W. Li. 2002. Landscapes to riverscapes: bridging the gap between research and conservation of stream fishes. BioScience 52: 483-498.

Baxter, C.V. and F.R. Hauer. 2000. Geomorphology, hyporheic exchange and selection of spawning habitat by bull trout (*Salvelinus confluentus*). Canadian Journal of Fisheries and Aquatic Sciences 57: 1470-1481.

Baxter, C.V., C.A. Frissell, and F.R. Hauer. 1999. Geomorphology, logging roads, and the distribution of bull trout spawning in a forested river basin: implications for management and conservation. Transactions of the American Fisheries Society 128: 854-867.

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EDUCATION

B. A. –Geology, College of Wooster, 1971 **M.S. – Geology**, University of Florida, Gainesville, 1973: **M.S. Water Resources Management**, University of Wisconsin-Madison, 1974; **Ph.D. Geology (Hydrogeology**), University of Wisconsin-Madison, 1978.

PROFESSIONAL EXPERIENCE
9/78 to 8/81, Assistant Research Professor, Water Resources Center, Desert Research Institute, U of Nevada, Las Vegas. 1981-present. Department of Geology, University of Montana, Missoula .Teaching and research in basic and applied hydrogeology. Teaching includes courses in Hydrogeology, Advanced Hydrogeology, Groundwater Modeling, Environmental Geology and Hydrogeology Field Camp. Groundwater research concentrates on quantifying flow systems in intermountain valleys, resource analysis, ground water - surface water interactions, characterization of hazardous wastes and contaminant transport including virus transport, and the use of groundwater flow models to evaluate conceptual models and make predictions.

RECENT HORRORS AND AWARDS
2005 Birdsall-Dreiss Distinguished Lecturer, Geological Society of America, Hydrogeology Section; 2003-2008 Candidacy on the Fulbright Senior Specialists Roster; 2004-2006 National Research Council Committee on River Science at the U. S. Geological Survey; 2003-present Acting Director of the University of Montana Center for Riverine Science and Stream Re-naturalization; 2001-04 Board of Directors, Association of Ground Water Scientists and Engineers, National Ground Water Association.

SELECTED PUBLICATIONS

Poole, G. C., J. A. Stanford, S. W. Running, C. A. Frissell, W. W. Woessner, and B. K. Ellis. In Press. A patch hierarchy approach to modeling surface and sub-surface hydrology in complex flood-plain environments. Earth Surface Processes and Landforms.

Loustaunau, P. K., W. W. Woessner and J. A. Kuhn, 2003. MTBE Fate near a Ground Water-Stream Interface. Proceedings 2003 Petroleum Hydrocarbons and Organic Chemicals in Ground Water, 20th Annual Conference, National Ground Water Association., Costa Mesa, CA. August 19-22., in press

Baxter, C.V., F.R. Hauer and W.W. Woessner 2003. Measuring groundwater-stream water exchange: new techniques for installing mini-piezometers and estimating hydraulic conductivity. Transactions of the American Fisheries Society 132: 493-502

Woessner, W. W., 2000, Stream and fluvial plain ground-water interactions: re scaling hydrogeologic thought. Ground Water, 38 (3), p. 423-429.

Huggenberger, P., E. Hoehn, R. Beschta, and W. Woessner. 1998. Abiotic aspects of channels and floodplains in riparian ecology. Freshwater Biology 40: 407-425.

Anderson, M.P. and W.W. Woessner, 1992, Applied Groundwater Modeling: Simulation of flow and advective transport. Academic Press, 372 pp.

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Education and Professional Experience

1980: B.S.-Stanford University, Biological Sciences and Geological Sciences
1985: M.S.-University of Washington, Geological Sciences
1990: Ph.D.-University of Washington, Geological Sciences
1991-1997: Assistant Professor-UCSB, Department of Geography
1997-2002: Associate Professor-UCSB, Department of Geography
2002-present: Professor-UCSB, Department of Geography

Research Interests

Dr. Mertes' research is to investigate the geomorphic and hydrologic processes responsible for the development of wetlands and floodplains in continental-scale river systems and across watersheds and to develop remote sensing techniques for analysis of wetlands and water properties. Because of training in geology, remote sensing, and biology this research includes continuum mechanics, sediment transport theory, limnology, computational hydrodynamics, GIS, and digital image processing, in addition to more traditional techniques of geomorphology and sedimentology. The nature of this work has led to the development of digital databases in Geographic Information Systems (GIS) for detailed spatial analysis of interaction of physical landscape properties with ecosystem properties at regional and watershed scales. Data from remote sensing and numerical modeling are combined with laboratory and field data.

Honors and Awards

2000: Invited Participant – National Academy of Sciences 3rd Annual Chinese-American Frontiers in Science

1998: Invited Participant – National Academy of Sciences 1st Annual Chinese-American Frontiers in Science

1996: Research Fellowship - Japanese Society for Promotion of Science

1987: J. Hoover Mackin Grant - Geological Society of America, Geomorphology Division

1984: Ferrel Fund Tuition Scholarship - Geology Department, University of Washington

1975-1980: Tuition scholarship - Stanford University

Professional & Public Service

2001-	Member, National Academy of Sciences BISO Board
1997-2001	Member, National Academy of Sciences International Advisory Board
1998-2000	Research Member, Sanctuary Advisory Committee, NOAA Channel Islands National Marine Sanctuary
1997-00	Panelist for NSF Hydrological Sciences Program Review Panel
1996	Panelist for NSF/EPA Water & Watersheds Review Panel

Publications Related to Proposal

Mertes, L. A. K., Dekker, A., Brakenridge, G. R., Birkett, C., and Létourneau, G., 2004, Rivers and Lakes, *in* Ustin, S. L., ed., Natural Resources and Environment: Manual of Remote Sensing: New York, John Wiley and Sons.

Mertes, L. A. K., 2002, Remote sensing of riverine landscapes: *Freshwater Biology* v. 47, p. 1-18.

Mertes, L. A. K., 2000, Inundation hydrology, *in* Wohl, E. E., ed., *Inland flood hazards: human, riparian, and aquatic communities*: New York, Cambridge University Press, p. 145-166.

Mertes, L.A.K., 1997, Documentation and significance of the perirheic zone on inundated floodplains: *Water Resources Research*, v. 33, p. 1749-1762.

Mertes, L.A.K., Smith, M.O., and Adams, J.B., 1993, Estimating sediment concentrations in surface waters of the Amazon River wetlands from Landsat images: *Remote Sensing of Environment*, v.43, p. 281-301.

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EDUCTATION

B.S. – Wildlife Science, Oregon State University, Corvallis, 1990
12 Semester Hours Fire/Land Management Graduate Credits, Colorado State University, Ft. Collins, CO 1993

EXPERIENCE

Wildlife Biologist, CTUIR DNR Wildlife Program, Start Date July, 1995; **Wildlife Biologist,** USDA Forest Service, Walla Walla, WA, Start Date September, 1990, End Date, April 1994; **Co-Operative Education Wildlife Biologist,** USDA Forest Service, Walla Walla, WA, Start Date June, 1987, End Date, September 1990.

HONORS AND AWARDS

Academic Achievement, Yakama Indian Nation Scholarship Committee, 1990.
Academic Excellence, College of Agricultural Sciences, Oregon State University, 1990.
Co-Operative Education Scholarship, USDA Forest Service, 1988 - 1990.

TRAINING

Introduction to ArcGIS, CTUIR Planning Program, 2003.
Government Contracting, Bill Helmich Associates, 2000.
US Fish & Wildlife Service Habitat Evaluation Procedures, 1998
Wetlands Identification, US Army Corps of Engineers, 1996
Technical Fire Management, Washington Institute, Duvall, Washington, 1993.
Applying the National Environmental Policy Act, USDA Forest Service, 1992.

PUBLICATIONS

Quaempts, Eric J. 2001. Wanaket Wildlife Mitigation Area Management Plan. Submitted to Bonneville Power Administration, Project No. 199209200.

Quaempts, Eric J. 2003. Habitat Evaluation Procedures Report – Iskuulpa Watershed Project. Baseline Mitigation Credits and Futures Analysis. Submitted to Bonneville Power Administration, Project No. 199506001.

Quaempts, Eric J. 2001. Protect and Enhance Iskuulpa Watershed. Proposal Submitted to Bonneville Power Administration, Project No. 199506001.

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Education and Professional Experience

1987: B.S.- Cornell University, Natural Resources
1989: M.S.- Utah State University, Forest Ecology
2000: Ph.D.-University of Montana, Aquatic Ecology/Hydrology

1990-1992: Staff Scientist, University of Washington
1992-1998: Staff Scientist, University of Montana
1998-2000: Landscape Ecologist, US EPA
2000: Systems Ecologist, Eco-metrics

Research Interests

- Cumulative impacts on forest/aquatic ecosystem structure and function resulting from interactions between land-use practices, natural processes, and geomorphology
- Use of statistical analysis, probability theory, computer modeling, and other quantitative methods in ecosystem research; integration of GIS with ecological models
- Application of Landscape Ecology principles across spatial scales in fluvial systems
- Forest/aquatic ecosystem conservation and restoration
- Application and limitations of ecological monitoring programs, ecosystem management, and adaptive management
-

Publications most closely related to the proposed project

Poole G.C., D. J., Keenan DM, Sauter ST, McCullough DA, Mebane C, Lockwood JC, Essig DA, Hicks MP, Sturdevant DJ, Materna EJ, Spalding SA, Risley J, Deppman (2004). "The case for regime-based water quality standards." BIOSCIENCE(54): 155-161

Poole, G. C., J. A. Stanford, et al. (2002). "Three-dimensional mapping of geomorphic controls on flood-plain hydrology and connectivity from aerial photos." Geomorphology **48**(4): 329-347.

Hauer, F. R., G. C. Poole, J. T. Gangemi, and C. V. Baxter. 1999. Large woody debris in bull trout (Salvelinus confluentus) spawning streams of logged and wilderness watersheds in northwest Montana. Canadian Journal of Fisheries and Aquatic Science 56: 915-924.

Poole, G. C., C. A. Frissell, and S. C. Ralph. 1997. In-stream habitat unit classification: Inadequacies for monitoring and some consequences for management. Journal of the American Water Resources Association 33: 879-896.

Poole, G. C. and C. H. Berman (2001). "An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation." Environmental Management **27**(6): 787-802.

Poole, G. C. (2002). "Fluvial landscape ecology: addressing uniqueness within the river discontinuum." Freshwater Biology **47**(4): 641-660.