Middle Green River Flow Investigation Study Plan
Planning Level Work Plans
October 19, 2004

<u>Theme 1: A Retrospective Study of the Green River</u>

Hypotheses

Hypothesis$_1$**:** The (Middle) Green River retains, in its present structure, a memory of hydrologic, geomorphic and biologic events that pre-date the construction of Howard Hanson Dam.

Hypothesis$_2$**:** The closure of HHD and the modifications in channel structure from flood control activities have altered the rates, magnitudes and spatial arrangement of ecosystem processes and functions compared to the pre-dam state.

Hypothesis$_0$ **:** There is no change in structure or rate of change between pre- and post development conditions in the Middle Green River.

Hypothesis$_3$ The flow regime during the post-dam period causes geomorphic and habitat variability (in functional, structural and process attributes) sufficient to sustain a viable salmonid population.

Study Design

This is a non-experimental study. It involves a comparison of channel conditions prior to significant human modification of the river ecosystem with those after construction of Howard Hanson Dam up to the present time.

The study encompasses the river and its valley from the upper limits of Eagle Gorge at approximately river mile 65, downstream to the historic confluence with the now-diverted White River at approximately river mile 23.

The time frame covered by this study varies but generally covers the period from approximately 1856 to the present day. The duration of the study is projected to be 18 months.

Study Objectives:

<u>Overall objective:</u> Characterize and compare the rates of change and spatial distribution of particular geomorphic and biologic processes and structure as they are influenced by the distinct flow regimes of the pre-dam and post-dam river.

1. Characterize the historic (pre-dam) and current (post-dam) flow regimes of the Green River;

2. Develop a model of geomorphic responses to these distinct flow regimes;
3. Develop a spatially explicit model of the flow/response relationship for the historic and current conditions;
4. Develop a model of biologic response to the hydrologic and geomorphic relationships;
5. Combine the models into an ecological response model. This model is intended to describe both the direction and relative magnitude of the relationships among hydrologic, geomorphic, and biologic processes at work in the Green River. Certainly, not all ecologic processes will, or can, be identified but the dominant processes as described above can be described.

The factors to examine are:

- historic and current flow regime: peak (magnitude), frequency, duration, seasonality and variability of flows, bankfull flows, droughts (low flow events);
- channel morphology: bar formation and distribution, bank erosion and channel avulsions, sediment characteristics (size and distribution), morphologic sub-structure (pools and riffles);
- Riparian recruitment: cottonwood stand distribution, age structure, recruitment
- Fish community structure: diversity, distribution, trophic structure.

Sampling and Statistical Design

This is primarily a characterization of river structure and rates of change between two distinct flow management periods in the river's history. It is descriptive rather than experimental and requires little more than descriptive statistics for the most part. However, when comparing the ecological responses to distinct flow regimes and assessing whether differences in rates and distributions are apparent—and related to the distinct flow patterns (H_1 and H_2)—tests for differences between the descriptors are necessary. In this case, we may consider the pre-development and post-development conditions as two "treatments"—a *before and after*--of the Green River and use the techniques for *paired comparisons* where various observations for one treatment are compared with the observations for the second treatment. Two techniques are available for testing the differences between the "treatments" in this situation. First, in such comparisons, we can legitimately arrange the data as a two-way anova (analysis of variance). Because we have only two treatments, this takes the form of a paired comparison test. The other method of analyzing paired comparisons designs is the *t-test for paired comparisons*. It is simple to apply and tests whether the mean od sample differences between pairs of observations is significantly different from a hypothetical mean, which the null hypothesis puts at zero. The standard error over which this is tested is the standard error of the mean difference.

For this work, a combination of the two tests should be used. While the paired comparison t-test is the common way of solving this type of problem, the two-way anova has the advantage of providing a measure of the variance component among the paired observations. For such ecological problems, the two-way anova might provide a clearer distinction among the pre and post treatment outcomes. However, these tests require a rather strict set of assumptions to be satisfied; these assumptions may not be met by the ecological variables to be evaluated. In that case, there are some non-parametric tests that can be used in this paired analysis in place of the analyses discussed above.

Logistics: Data Collection and Analysis

The Hydrologic Perspective

1. Examine the historic gage record and characterize the flow regime of the Green River from approximately 1850 to the present. Use IHA and RVA methods.
2. Examine and describe flow events of sufficient magnitude to cause channel change at three scales: segment, reach, and patch. Base the predicted flow on literature values and evaluation of the photographic record in selected portions of the Green River and at least two other Puget Lowland rivers;
3. Determine the mean interval between these events at each of the three spatial scales;
4. Using flow routing and budget techniques, develop a spatially explicit view of streamflow in the historic and current Green River

The Geomorphic Perspective

1. Using aerial photographs, maps, LiDAR, and survey data where they exist, map the following geomorphic features of the river channel, including channel location outline, low flow channel, active channel (including gravel bars, low flow and colonizing vegetation on gravel bars), and if possible, pools and riffles. Map geomorphic surfaces (e.g., stable, eroding, colonizing, depositional) for comparison from photo year to year.
2. Map floodplain features such as side channels, oxbows, floodplain sloughs to the extent possible. Identify approximate valley bottom boundary, adjacent terraces and landslide areas. Estimate distance of these features from the main channel;
3. Derive descriptive characteristics from the mapped data, such as main channel sinuosity, active channel width (e.g., as a percentage of floodplain width), channel edge length, area of geomorphic surfaces, side channel area, channel junction density, and floodplain occupation percentage of the active channel footprint for each year.
4. Characterize sediment size distribution for the current channel: evaluate both lateral longitudinal sediment profiles;
5. Classify the channel using an acceptable classification system such as Montgomery and Buffington or Forman et al. Describe general channel and floodplain patterns and characterize the dominant geomorphic processes by study segment and reach for each study year.

The Biologic Perspective

1. Using aerial photographs and General Land Office information, characterize the distribution and extent of riparian vegetation in the historic and current floodplain of the river at selected time intervals to reflect flood and drought events. Some of this work has been undertaken by Brian Collins of the River History Project for the lower Green River but lacks a serial perspective;
2. In particular, map the location and extent of cottonwood forests along the middle Green river; estimate the distance of these vegetation units from the main channel for both pre-dam and post-dam conditions;
3. Determine size/age classes of the cottonwood forests;
4. Using historic data from the Bureau of Fisheries, literature information, and a reference system, characterize the fish communities of the historic river as best as can be done;
5. Characterize the fish communities of the current river;
6. Using the hydrologic, geomorphic, and biologic information, develop a relational model of river and floodplain change in the Green River from historic to present;
7. Deriver rates of change for biologic attributes and disturbance regimes at the segment, reach and patch scale.

Sampling and Analysis

- From the data collected for each element above, create GIS layers that map channel and floodplain attributes: channel location over time, geomorphic surfaces, landslides, vegetation components;
- Identify channel patterns and vegetation patterns by segment, reach and patch;
- Calculate channel migration rates, vegetation growth rates, bar formation rates, and patch turnover rates for pool/riffle complexes;
- Compare and contrast pre-dam channel characteristics with post-dam attributes;
- Calculate rates and magnitudes of change and differential rates for major geomorphic processes and biologic processes;
- Characterize geomorphic channel change and associated biologic habitat conditions in response to the hydrologic regime during the post-dam period in enough detail to test Hypothesis 3.
- Conduct field work to verify channel units, vegetation units, and floodplain units in the current river;
- Establish at least two reference sites to compare rates of change in the current, flow-regulated river with unregulated systems;
- Calculate size, distribution , frequency and diversity of bio-geomorphic patch types in the historic, current, and reference rivers;
- Calculate patch turnover rates

Estimated Schedule/Personnel

The project should take approximately 18 months to complete. Investigation, gathering, and evaluation of potential data sources is estimated to consume approximately 6 months; analysis and evaluation of the data sources and mapping onto a base is estimated to take about 6 months; evaluation and interpretation of the results will take the remaining 6 months.

The project will be led by a senior ecologist and senior geomorphologist. In addition, the analytical team will consist of one senior hydrologist, investigative technician, one GIS technician, and one photogrammetric technician. The investigative technician will be responsible for the assembly, evaluation and preparation of the historic data; the hydrologist for assembly and analysis of the hydrologic record, the two technicians for data gathering from aerial photography and other map sources. The principle investigators will lead the analytical and interpretive tasks for the project. Each team member will be committed at ½ FTE for the 18 month duration of the project.

Estimated Cost

Senior staff: $120,000
Technicians: $ 50,000
Data acquisition: $27,000
Equipment and Supplies (including analytical programs): $12,000
Total: $209,000

Theme 2: Macrohabitat Analysis, High Flow Connectivity

Hypothesis

Scheduled releases of high flow and selected habitat improvement projects will increase the area and complexity of off-channel habitat for fish in the Middle Reach of the Green River. An increase in habitat area will depend on river stage, secondary channel density, and width of channel migration zone. An increase in usable habitat area will depend on timing of releases and concurrent life stage of fish species.

Study Design and Objectives

Flood storage behind Howard Hanson Dam has reduced high flows downstream. Flows in the Middle Reach of the Green River have not exceeded 12,000 cfs since 1962. Pre-regulation high flows ranged from 12,000 cfs (.50 probability), to 21,000 cfs (.10 probability), to 34,000 cfs (.01 probability) (King County, 1993). Flood storage has altered the hydrologic regime of the river and reduced the extent of overbank flows (connectivity) in floodplain and other off-channel areas.

The overall study design is to describe, map, and summarize off-channel habitat conditions at specified high flows on the Middle Reach of the Green River in King County, WA. Habitat assessment areas will include the floodplain at specified flows, historic channel locations, channel migration hazard areas, secondary channels, and associated landforms outside the main channel of the river.

Objectives of the study are to define and quantify potential fish habitat benefits of restoring flows greater than 12,000 cfs with overflows in off-channel areas on the river.

Sampling and Statistical Design

The MGFI study area extends 31 river miles from State Route 18 (SR18) upstream to Howard Hanson Dam. The Theme 2 Project Area (project area) extends 14 miles from RM 31.5 near SR18 upstream to RM 45.25 at Flaming Geyser Bridge. Green River Gorge, extending 16 miles upstream from Flaming Geyser State Park to the City of Tacoma diversion headworks, does not have much off-channel habitat due to geomorphic or topographic factors. The project area includes an area of extensive off-channel habitat and historic channel migration extending approximately 2 miles downstream of SR18.

The 100-year floodplain in the project area is about 865 acres (FEMA, 1996), as shown in the attached figure. It does not include some areas of historic channel changes.

The project area will be further divided into reaches based on geomorphic criteria; channel gradient, width of floodplain, historic channel pattern, and density of secondary channels.

Habitat areas will be separated into four classes: lotic systems with side channels, sloughs, and swales; lentic systems with wetlands and beaver ponds; contributing areas with tributary streams, wall-based channels, and hyporheic zones; and “high and dry” areas with islands, terraces, high banks, and valley walls.

Useable habitat areas will include juvenile rearing and foraging opportunities, juvenile and adult refuge during high flow periods, adult access to spawning areas, smolt outmigration, and adult holding and resting opportunities.

High flows perform other functions important to fish. They flush organic materials from the river and riparian areas, trigger certain insect behaviors, recruit large woody debris, stimulate plant growth in riparian areas, provide feeding areas for wading birds and waterfowl, and maintain and shape channels in the river (Postel and Richter, 2003). These processes will be described in general terms for the project area with recommendations for further study.

Logistics

Data compilation will include topography (5-ft contours) and hydrographics, orthophotography, floodplain boundaries (scale 1:24k), river cross-sections, historic channel locations, fish use surveys, flow records, and locations of man-made constraints on overflows.

Schedule/Personnel

Data compilation (Oct – Dec, 2004). Mapping and spatial analysis (Jan – Mar, 2005). Habitat assessment (Mar – May, 2005). Report review and publication (May – June, 2005). Project duration 1 year. Staff requirement 1.4 FTE combined: Hydrologist (.5 FTE), GIS analyst (.2 FTE), Fisheries biologist (.2 FTE), and Environmental scientist (.5 FTE).

Product

Report: Potential Increases in Off-channel Habitat for Fish at Specified High Flows on the Middle Reach of the Green River, WA.

References

King County. **Green River Channel Migration Study.** Department of Public Works, Surface Water Management Division. Seattle, Washington. December, 1993.

FEMA. **Q3 Flood Data Coverage**. Flood Insurance Rate Maps, King County, WA. Federal Emergency Management Agency. Washington, D.C. 1996

Postel, Sandra and Richter, Brian. **Rivers for Life**. Managing Water for People and Nature. Island Press. Washington, D.C. 2003

Theme 3: The Influence of Physical Processes on Aquatic Habitat

This theme involves the investigation of physical processes on aquatic habitat at the scale of channel forms (e.g., pools, riffles, runs). The results will be used to develop an understanding of how habitat conditions for these general types of channel forms will respond to human manipulations of streamflow, sediment load, channel morphology, and riparian vegetation.

Construction of Howard Hansen dam has reduced the supply of coarse (sand and gravel) sediment and wood from the upper Green River to the middle Green River while bank hardening and levees have reduced the local supply of sediment and wood and storage sites for these materials along the channel margins. Flood regulation has reduced the transport of sand and gravel, potentially limiting channel incision and armoring in response to dam construction, but also limiting turnover of floodplain habitats. The dynamics of sediment and wood transport must be well understood to assess the historical and future responses of the middle Green River to streamflow regulation and floodplain management activities.

Hypotheses

High flows can be managed to allow ecological functions (e.g., creating and maintaining off-channel habitat, recruitment of large woody debris, path turnover) without negative consequences including redd scour, depletion of limited sediment supply below Howard Hansen dam, and reducing large woody debris and instream habitat structure.   There are a number of important secondary hypothesis related to specific habitat responses. For example, the probability of chinook salmon redd scour increases with streamflow but can be reduced by limiting the frequency and duration of flows exceeding some threshold and managing flows when salmon are selecting spawning sites.

Study Design and Objectives

This study will examine the interactions between streamflow, sediment, and large woody debris (LWD) in the middle Green River.   It will require information about channel form and hydraulic conditions at representative sites within the Middle Green River. Hydraulic and sedimentological conditions would be analyzed at the sites to characterize sediment transport regime (e.g., threshold of motion, partial transport, equal mobility of all particles). The sediment transport investigation would include experiments using tracer cobbles in chinook salmon redd/non-redd locations to assess scour during winter. The investigation of LWD would include a retrospective assessment of in-channel LWD identified from historical aerial photos, US Army Corps of Engineers (USACOE) data on new wood placement, and multispectral aerial imaging. Remote inventorying would be verified and supplemented by field surveys of the location (relative elevation and location in channel) of selected pieces of LWD. The LWD investigation would quantify LWD retention time in selected reaches; quantify streamflow levels for distinct types of interactions (e.g., streamflow that transport key pieces for log jams, transport smaller debris, transport sediment around LWD; or provides cover or pools adjacent to LWD).

Sampling and Statistical Design

- stratify Green River by channel/valley morphology;
- select sites representing most common (and most important for salmon spawning) morphologies - 10 sites at least 5 sites with redds, at least 50 tracer cobbles per site;
- survey redd locations;
- place tracer cobbles and re-survey in late spring/early summer.

- stratify reaches by channel/valley type;
- randomly select jams/LWD pieces in selected reaches for field survey and hydraulic analysis;
- analysis of aerial photography/multispectral images could be comprehensive – no sampling required, could compare to other river (e.g., multispectral images for Puyallup River will be available).

Logistical Considerations

- field surveys of salmon redds and LWD;
- cross-sections surveyed with a boat;
- pebble counts on exposed bars;
- 1-D hydraulic analysis;
- obtain aerial photography;
- flight for multispectral imaging would need to be scheduled for summer.

Schedule/Personnel

- flight and field surveys in summer;
- analysis during winter/spring;
- report writing in summer/autumn;
- report reviewed in winter and published in spring.

Total project duration: 2 years. Staff requirements include a lead hydrologist (0.4 FTE); a lead ecologist (0.4 FTE); and technicians (1 FTE)

Estimated Cost

$320,000

Product

A report would be prepared that describes the hydraulic and sediment transport regimes at redd sites, analyzes the effects of dam on sediment transport regime in terms of both flood regulation and impoundment of coarse sediment, evaluates the current distribution of LWD, and identifies streamflow levels for the various forms of sediment transport and wood interactions.