Middle Green River Flow Investigation

Theme 1: A Retrospective Study of the Green River

Scope of Work

March 4, 2005 (Revised April 21, 2005)

Baseline Assumption:

The (Middle) Green River retains, in its present structure (e.g., channel shape and form, biological structure), a memory of hydrologic, geomorphic and biologic events that pre-date the construction of Howard Hanson Dam (HHD) in the early 1960s.

Hypotheses

Key Hypothesis: The closure and operation of HHD and the modifications in channel structure (e.g., construction of levees and revetments, channel straightening and dredging) for flood control purposes have altered the rates, magnitudes and spatial arrangement of ecosystem processes and functions compared to the pre-dam state.

Null Hypothesis : There is no change in structure or rate of change between pre- and post dam conditions in the Middle Green River study area below the dam.

The information we learn from addressing the key hypothesis above will be used to address a follow-up hypothesis regarding its applicability to salmonid populations.

Hypothesis 2: 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 the Green River at approximately river mile 88, downstream to the historic confluence with the now-diverted White River at approximately river mile 31.

The time frame covered by this study varies, but generally covers the period from approximately 1856 to the present day. Certain attributes will be examined for a more limited study period from 1936 to present (e.g., hydrologic/gauging data, photographic record), while other attributes may go back to 1856 (e.g., maps, written accounts, anecdotal information). The duration of the study is projected to be 18 months.

This project could include a reference river system if a suitable one is available. Alternatively, we might do an above the dam/below the dam study design. Additionally, we will examine alluvial systems below the dam that are both constrained and unconstrained. Specific components of the study design will be determined after the attributes are more clearly defined.

Study Objectives:

Overall objective: 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. Characterize geomorphic responses to pre and post-dam flow regimes in the Green River;
3. Develop a spatially explicit model of the flow/response relationship for the historical and current conditions at the reach scale;
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:

- historical 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), gravel conveyance, channel roughness, large woody debris distribution, log jam locations, morphologic sub-structure (pools and riffles); floodplain width, connectivity
- 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—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 analysis of variance (anova). 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 or sample differences between pairs of observations are significantly different from a hypothetical mean, which the null hypothesis sets as 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. The two-way anova may provide a clear distinction between 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.

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 (need to update based on more refined estimates of staff time for Tasks 1 through 8 below)

Senior staff: $120,000
Technicians: $ 50,000
Data acquisition: $27,000

Equipment and Supplies (including analytical programs): $12,000
Total: $209,000

Task 1: Complete a literature review of comparable studies or like components

This task involves a literature review of studies in the U.S. or other countries that examined affects of flow regime changes on physical, chemical or biological conditions at a river basin scale. This task will help define what has been done by others that may benefit our approach, attributes selected for analysis, and methods. It is assumed that some of the background literature review work done by the Normative Flows Project will greatly benefit this effort.

Deliverables:

Summary of studies reviewed, including annotated bibliography. Recommendations on attributes and methods that would be suitable for inclusion in MGFI study. Develop draft chapter on results of literature review for inclusion in draft and final report.

Assumptions:

Literature review of NFP as baseline; Information from other studies as presented at January 2005 meeting. Check on-line and peer review literature sources.

Schedule:

March – June 2005

Task 2: Compile existing information on Green River hydrology, geomorphology, and biological characteristics (according to the attributes and data noted above)

This task involves completing an inventory and collecting information from multiple sources and agencies. Data/information includes electronic files, maps, aerial photos, GIS data layers, reports, notes, etc.

Deliverables:

Reports and data on file in hardcopy or electronic form

Assumptions:

Collect existing data from available sources, including federal (COE, USGS, NOAA), state (WDFW, WDOE, WDNR), tribal (MIT), local (KC, TPU) and other sources (TNC, UW, etc.). Collect electronic files/data when possible. Aerial photo availability will influence analysis options.

Schedule:

March – August 2005.

Task 3: Examine key historical years to determine what available information and attributes could be evaluated for change across specific time periods (1856 – present; 1936 – present) and at what interval.

This task involves reviewing attributes and available information from Task 2 to determine which attributes can be evaluated from 1936 to present, or other time period. Constraints include length of flow record (before and after dam construction), climatic data, available aerial photographs or other picture sources, and maps.

Before 1936, construct the historical record from other sources, including any early COE studies, GLO maps, Bureau of Fisheries reports, railroad surveys, and old newspaper articles.

Deliverables:

Selection of key attributes/metrics (hydrologic, geomorphic, biologic) for change analysis. Determine which attributes can be accurately assessed from various available sources. Technical memorandum on recommended attributes/metrics.

Assumptions:

Attributes/metrics for the retrospective analysis will be limited by available data and information. Some may be easier than others to calculate or estimate from partial records.

Schedule:

May – August 2005

Task 4: Characterize the historical (pre-dam) and current (post-dam) flow regimes of the Green River for the period from 1936 to the present.

This task involves characterizing the historical and current flow regime in terms of peak (magnitude), frequency, duration, seasonality and variability of flows, bankfull flows, droughts (low flow events). Use the updated Indicator of Hydrologic Alteration (IHA) and Range of Variability Approach (RVA) with the new Environmental Flow Component parameters. Initially, the IHA will be run with the default settings in the program. After review of the first run with default settings, we may change these settings based on specific data from the Green River.

This task also involves examining and describing flow events of sufficient magnitude to cause channel change at three scales: segment, reach, and patch. Estimates of these habitat-forming flows will be based on predicted flow from literature values and evaluation of the photographic record in selected portions of the Green River and, if feasible, one or two other Puget Lowland rivers. Determine the mean interval between these events at each of the three spatial scales.

The IHA method uses a suite of relevant flow statistics to characterize variability of the hydrologic regime and quantifies hydrologic alterations caused by human impacts by comparing regimes with and without the dam in place. The data are then processed

into 34 parameters for each year for both with- and without-dam flow records. Parameters include monthly low flows, extreme low flows, high flow pulses, small floods, and large floods.

Deliverables:

- Flow statistics for the pre-dam (historical) and post-dam (current) flow regimes
- IHA and RVA output
- Information from the literature on habitat-forming flow events at different scales: segment, reach and patch

Assumptions:
Analysis will be run for available flow record (dating back at least to 1936). The Initial IHA analysis will be run by Ruth Mathews and Brian Richter.

Schedule:
May – August 2005

Task 5: Characterize and map the geomorphologic features of the river channel for different intervals between 1895 and the present

This task begins with the creation of a GIS database using based primarily on historical maps and aerial photos gathered in Task 2. Selected years of historical aerial photos will be put into digital format and orthorectified to a common coordinate system. For each selected year, a tiled, composite, orthorectified image of the entire study area will be created in GIS. Using this tiled aerial image, a GIS layer will be created for each year that identifies the following geomorphic features of the river channel: 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 between selected intervals (e.g., between available photo years). Source of available data include aerial photographs, maps, LiDAR, and survey data.

Map floodplain features such as side channels, oxbows, islands, and 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, if feasible.

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.

Characterize sediment size distribution for the current channel: evaluate both lateral longitudinal sediment profiles; Characterize large woody debris (LWD) size and distribution

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.

Deliverables:

- GIS data layers of river channel attributes for selected time periods dating back as far as 1895.
- Summary information for current channel conditions (use data from Corps of Engineers and other studies as available)
- Map showing classification system for channel patterns and characteristics by study segment and reach for each study year

Assumptions:
Digitized GIS data layers of channel location for numerous intervals are available from Green River Channel Migration Study (King County 1993). Aerial photos are available from King County or are readily available from other sources. Quality and decipherable information from aerial photographs may limit the identification of certain geomorphic characteristics.

Schedule:
July – December 2005

Task 6: Characterize and map the biological features of the Green River system and floodplain and evaluate rates of change of vegetation communities
This task involves identifying and mapping, where feasible, the following biological features of the river system and floodplain:

Using aerial photographs and General Land Office information, characterize the distribution and extent of riparian vegetation in the historical and current floodplain of the river at selected time intervals to reflect flood and drought events. Some of this work has been completed by Collins et al (2004) for the Green River from RM 45 to the mouth of the Duwamish (for circa 1860-1880), but lacks a serial perspective. 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. Determine the size and age classes of the cottonwood forests distribution. Identify vegetation patterns by segment, reach and patch.

Using historical data from the Bureau of Fisheries, literature information, the WRIA 9 Strategic Assessment and a reference system, characterize the fish communities of the historical river, as feasible. Characterize the fish communities of the current river.

Deliverables:

- GIS data layers of floodplain and riparian vegetation attributes for selected time

periods dating back as far as 1895 (including GLO notes and bearing trees) and for selected intervals based on aerial photos.
- Summary information for current floodplain and riparian conditions (use data from King County and WRIA 9 Strategic Assessment and other studies as available)
- Map showing classification system for floodplain and riparian vegetation by study segment for each study year
- Map showing the distribution of native fish assemblages in the Green River

Assumptions:
Aerial photos are available from King County or are readily available from other sources. Quality and decipherable information from aerial photographs may limit the identification of certain geomorphic characteristics. GIS data layers from Collins and Shiek (2004) are available from King County. Biological datasets are adequate to characterize current and historical fish assemblages in the Green River.

Schedule:
March – December 2005

Task 7: Synthesize information from the hydrologic, geomorphic, and biological information and analyses and develop a relational model of river and floodplain change in the Green River from historical conditions to the present
This task involves compiling and synthesizing information across Tasks 4 through 6 and calculating and comparing the following:

- 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 the key hypothesis.
- 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 historical, current, and reference rivers;
- Calculate patch turnover rates
- Determine if there is a relationship between fish assemblages and geomorphic features in both the pre and post-dam flow regimes

Derive rates of change for biologic attributes and disturbance regimes at the segment, reach and patch scale.

Develop a series of models using the Green River conceptual model as a basis to describe the linkages between the hydrologic, geomorphic and biologic components. Quantify rates and establish causal linkages between different components where possible and confirmed by significant correlations. Potential models include the following:

- Develop a model of geomorphic responses to distinct flow regimes;
- Develop a spatially explicit model of the flow/response relationship for the historical and current conditions;
- Develop a model of biologic response to the hydrologic and geomorphic relationships;
- 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. Not all ecologic processes will, or can, be identified but the dominant processes can be described.

Deliverables:

A series of models describing the relationships for various geomorphic responses to different flow regimes, and the subsequent biologic responses resulting from changes in hydrologic and geomorphic conditions. Relationships and correlations between hydrologic attributes and geomorphic and biologic responses will be evaluated.

Assumptions:

Coarse Green River conceptual model will be used as a starting point for examining relationships between ecosystem components. Relationships between hydrologic, geomorphic and biologic components will focus on attributes identified in Task 3 and refined in tasks 4 through 6.

Schedule:

November 2005 – April 2006

Task 8: Draft and Final Report

This task involves completing a draft and final report for the project detailing the findings from Tasks 1 through 7. A detailed table of contents will be prepared by King County and reviewed by the project team. The report will include an executive summary, introduction, literature review section, methods, and subsequent sections on results and discussion for the hydrologic, geomorphic and biologic components of the work. The final section will consist of conclusions and next steps.

Electronic copies of the draft report will be provided to the project team and outside reviewers for review and comment.

The comments from the project team and outside reviewers will be used to edit and finalize the report. The final report will also include a summary of GIS data layers and electronic files or maps generated as part of this project.

Deliverables:

Draft report in electronic form (pdf files) suitable for review by project team and outside reviewers. Final report, including figures, will also be available in electronic form, though it is expected that a limited number of hard copies will be produced.

Assumptions:

Reports will be distributed in electronic form for review. A limited number of hard copies will be produced.

Schedule:

Draft report: February – May 2006
Review period: June-July 2006
Final report: August-September 2006