Green River
Fish Habitat Analysis Using the
Instream Flow Incremental Methodology

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Green River
Fish Habitat Analysis Using the
Instream Flow Incremental Methodology

by
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Olympia, Washington 98504

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IFIM Technical Bulletin
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ABSTRACT

A study of the Green River was conducted using the Instream Flow Incremental Methodology. This study provides fish habitat versus flow relationships for use in streamflow management by Ecology. In addition, the study can be used by the Corps of Engineers to examine the downstream effects on fish habitat from increasing water storage behind Howard A. Hanson Dam and the present management of existing storage.

Five study sites, involving a total of 31 transects, represent fish habitat in 40 miles of the Green River. Fish habitat is defined in this study as water depth, velocity, substrate, and cover. Habitat measurements for the computer models were collected at three different flows.

The five site models indicate peak habitat for spawning steelhead at flows ranging from 550 to 700 cfs, spawning chinook 525 to 700 cfs, spawning coho 240 to 375 cfs, spawning chum 260 to 400 cfs, juvenile steelhead 300 to 400 cfs, juvenile chinook and coho 140 to 240 cfs, adult holding chinook 220 to 450 cfs, and adult holding steelhead 300 to 600 cfs.
This publication provides fish habitat versus flow relationships for the Green River. These habitat relationships can be used to help determine how to manage the flow in the river. There is no one flow at which habitat for fish is optimum. The different fish species and lifestages exist simultaneously in the river and each has a different optimum flow requirement. Providing an optimum habitat flow for one lifestage will usually result in habitat loss for another lifestage.

Peak habitat flow does not necessarily equate with peak fish production. Flows higher than peak habitat flows are needed for juvenile fish at certain times of the year to maintain existing production levels.
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<tr>
<td></td>
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<tr>
<td>cfs</td>
<td>cubic feet per second</td>
</tr>
<tr>
<td>COE</td>
<td>Corps of Engineers</td>
</tr>
<tr>
<td>Ecology</td>
<td>Washington Department of Ecology</td>
</tr>
<tr>
<td>fps</td>
<td>feet per second</td>
</tr>
<tr>
<td>HAH</td>
<td>Howard A. Hanson</td>
</tr>
<tr>
<td>HABTAT</td>
<td>Computer program that combines IFG4 with habitat-use curves</td>
</tr>
<tr>
<td>IFG4</td>
<td>Instream Flow Group’s hydraulic model</td>
</tr>
<tr>
<td>IFIM</td>
<td>Instream Flow Incremental Methodology</td>
</tr>
<tr>
<td>IRPP</td>
<td>Instream Resource Protection Program</td>
</tr>
<tr>
<td>NMFS</td>
<td>National Marine Fisheries Service</td>
</tr>
<tr>
<td>PHABSIM</td>
<td>Physical Habitat Simulation computer model</td>
</tr>
<tr>
<td>RM</td>
<td>river mile</td>
</tr>
<tr>
<td>VAF</td>
<td>Velocity Adjustment Factor</td>
</tr>
<tr>
<td>WAC</td>
<td>Washington Administrative Code</td>
</tr>
<tr>
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<td>Washington Department of Fisheries</td>
</tr>
<tr>
<td>WDW</td>
<td>Washington Department of Wildlife</td>
</tr>
<tr>
<td>WUA</td>
<td>Weighted Usable Area</td>
</tr>
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<td>USFWS</td>
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I. PROJECT BACKGROUND

Study Objectives

One of the main objectives for this Instream Flow Incremental Methodology (IFIM) study is to provide the Washington Department of Ecology (Ecology) with information to review its Green River minimum instream flows. Additionally, the Corps of Engineers (COE) can use this IFIM study to evaluate present water releases from Howard A. Hanson (HAH) reservoir and alternative flow regimes if HAH reservoir storage is increased.

Ecology’s Instream Resource Protection Program

Ecology has conducted IFIM studies since 1983 for setting minimum instream flows through its Instream Resource Protection Program (IRPP). Minimum instream flows for the Green River were set by Ecology under its IRPP in 1980 by regulation (Chapter 173-509 Washington Administrative Code, see Table 1). The minimum instream flows for the Green River were set at 150 cfs for the summer and at 300 cfs for the winter at U.S. Geological Survey (USGS) gage 12106700 near Palmer, and at 300 cfs for the summer and 550 cfs for the winter at gage 12113000 near Auburn.

A study conducted on the Green River (Swift 1979) was an important basis for the minimum instream flows. The USGS methodology used for determining salmon-spawning flows was essentially the same as IFIM except substrate and cover was not included. Other methodologies were used as a basis for salmonid-rearing flows. These methods involved correlations between low, summer flows and adult salmon and steelhead returns. Final minimum flows proposed by the agencies were modified by professional judgment of fish biologists. Ecology’s adopted spawning flow of 550 cfs was intended to protect 95 percent of the spawning habitat.

Participants

Project participants included the Washington Department of Fisheries (WDF), Washington Department of Wildlife (WDW), COE, City of Tacoma, Trout Unlimited, Muckleshoot Indian Tribe, National Marine Fisheries Service (NMFS), and U.S. Fish and Wildlife Service (USFWS).

River Description

The Green River begins in the Cascade Mountains near Stampede Pass and flows west through the Snoqualmie National Forest. Thirty miles downstream from its source the river encounters HAH Dam at river mile (RM) 64.5 and then the Tacoma Water Diversion Dam at RM 61. The river continues downstream to the town of Kanasket and the start of the Green River Gorge (RM 58). The 300-foot deep gorge continues for 12 miles to Flaming Geyser State Park (RM 46). Two major tributaries, Newaukum Creek (RM 4.7) and Big Soos Creek (RM 33.7), join the
Table 1. Minimum Instream Flows for the Green River adopted 6/6/80 (Ch. 173-50 WAC).

INSTREAM FLOWS FOR FUTURE WATER RIGHTS IN THE GREEN-DUWAMISH RIVER BASIN (in Cubic Feet per Second)

<table>
<thead>
<tr>
<th>Month</th>
<th>Day</th>
<th>Gage 12113000 Normal Year</th>
<th>Gage 12106700 Normal Year</th>
<th>Gage 12106700 Critical Year</th>
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<tr>
<td></td>
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<td>Green River Near Auburn</td>
<td>Green River Near Palmer</td>
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<tr>
<td>Jan.</td>
<td>1</td>
<td>550</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>550</td>
<td>300</td>
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<tr>
<td>Feb.</td>
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<td>300</td>
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<td>15</td>
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<td>300</td>
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<td>Apr.</td>
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<td>300</td>
<td>300</td>
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<td>550</td>
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<td>Sept.</td>
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<td>300</td>
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<td>Oct.</td>
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<td>190</td>
<td>150</td>
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<tr>
<td></td>
<td>15</td>
<td>350</td>
<td>240</td>
<td>150</td>
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<tr>
<td>Nov.</td>
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<td>300</td>
<td>190</td>
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<td></td>
<td>15</td>
<td>550</td>
<td>300</td>
<td>240</td>
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<tr>
<td>Dec.</td>
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<td>550</td>
<td>300</td>
<td>300</td>
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<td>15</td>
<td>550</td>
<td>300</td>
<td>300</td>
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For a definition of “critical year” see Ch. 173-509-303 WAC.
Green River upstream of Auburn (RM 32). Here the river turns northward and flows past Kent (RM 26) and Tukwila (RM 14), becoming the Duwamish River at RM 11. The river flows into Elliott Bay on Puget Sound. Tides affect the lower 12 miles of the river.

Hydrology

The Green River has 483 square miles of drainage area fed by snowmelt, rain, and ground water. The median flow at Auburn (USGS gage 12113000 at RM 31.3) ranges from 1900 to 1400 cubic feet per second (cfs) from December through May and is about 300 cfs during August, the normal low flow month (Figure 1). The median flow at the Purification Plant near Palmer (USGS) gage 12106700 at RM 60.3) ranges from 1400 to 800 cfs from December through May, but is only 150 cfs during August (Figure 2). The Purification Plant gage is just downstream from the City of Tacoma’s 113 cfs year-round diversion.

Figures 1 and 2 portray the annual exceedence-frequency hydrographs for both gages. The 90-percent-exceedence flow is equaled or exceeded 90 percent of the time. It can also be thought of as a 1-in-10-year low flow. The 50 percent exceedence flow is the median flow and gives the closest approximation to being the “normal” flow. The exceedence hydrographs are based on a 10-day-average flow thus eliminating some of the variation from daily flows.

History and Water Rights

The Green River was radically altered between 1900 and 1916. Once a tributary of the White River (which was a tributary of the Duwamish River), the Green River was diverted to flow directly into Puget Sound (Figure 3). The lowering of Lake Washington and a major flood in 1906 were the primary causes of this diversion. The lower part of the river retained the name Duwamish River.

The City of Tacoma built the Tacoma Water Diversion Dam on the Green River in 1911. The dam, at RM 61, blocks all upstream migration of salmonids. Presently, no spawning occurs upstream of the diversion dam, but juvenile salmonids are outplanted into tributaries upstream of HAH dam. Tacoma diverts 113 cfs or the natural flow, whichever is less, under a vested water claim (water was diverted before the 1917 Water Code). This claim is not subject to Washington State’s 1980 minimum instream flows. An adjudication has not been held to determine if the claim is valid.

In 1985, Tacoma was granted a water-right permit by Ecology for an additional 100 cfs. That water right cannot be certified until a second pipeline is built and the water is put to beneficial use. The additional 100 cfs diversion is subject to Washington State’s 1980 minimum instream flows for the Green River.
Figure 1. Exceedence-frequency hydrograph of the Green River at Auburn (RM 31.3).
Figure 2. Exceedence-frequency hydrograph of the Green River at the Purification Plant (RM 60.2).
Figure 3. Configuration of the Duwamish basin prior to 1900 and after 1916 (from Grette and Salo, 1986).
Operation of HAH Dam

A second dam, HAH Dam, was built at RM 64.5 by the COE and began filling December 5, 1961. It was authorized by Congress for flood control and conservation storage to augment low summer/fall flows for over 12,000 cfs at Auburn and to provide a minimum flow of 110 cfs with 98 percent reliability. The COE actually releases a minimum flow of 223 cfs to ensure that 110 cfs passes Tacoma’s diversion. Overall, the operation of the dam since 1962 has changed flows at Auburn by decreasing high flows in April, May, and June and increasing low flows in July, August, September, and October (Figure 4).

The COE monitors the weather, snowpack, and reservoir inflow to decide whether to start filling the reservoir in April, May, or June to ensure a 110 cfs instream flow. Filling of the reservoir is delayed as late as possible in the spring to allow downstream passage out of HAH reservoir of coho, chinook, and steelhead smolts. But reservoir filling often starts during the peak of smolt outmigration, and the smolts are prevented from migrating to the ocean. However, if reservoir filling is delayed just one week too late, HAH reservoir can run out of water storage before the expected October rain. Flow is then so low with fall chinook spawning is severely disrupted.
Figure 4. Pre- and post-HAH reservoir median flows for the Green River at Auburn.
II. METHODS OF STUDY

IFIM was selected and used in this study as the best available methodology for predicting how fish habitat is affected by incremental changes in streamflow.

Description of the Instream Flow Incremental Methodology

IFIM, as described by Bovee (1982), was derived by the U.S. Fish and Wildlife Service’s Instream Flow Group in the late 1970’s. IFIM is a process where certain variables affecting fish habitat are chosen for in-depth analysis. However, the term IFIM is often used when referring to PHABSIM (Physical Habitat Simulation) or IFG4 (hydraulic model). PHABSIM is a collection of computer models in IFIM (Milhous et al 1984). IFG4 is the most commonly used hydraulic model in PHABSIM.

The IFIM process involves several planning steps undertaken with interested groups. First, a “scoping” meeting is held with interested groups to discuss the entire scope-of-work including possible study-site locations. Next, field trips are coordinated with interested groups to select study sites and transect locations. Then field data (water velocities and depths, substrate, and cover) is collected at different flows. The field work should include observations from the study river on the habitat preferred by the fish. A hydraulic model is built and calibrated. The hydraulic model gives a representation of the velocities and depths (associated with substrate and cover) available for fish over a range of flows. Meetings are held with interested groups to reach agreement on the method of calibration of the hydraulic model, the method of transect weighting, and the habitat-use curves to be used with the hydraulic model. Finally, fish biologists from the interested agencies and tribes use professional judgment to interpret the habitat-versus-flow curves to arrive at a flow regime for the fish.

IFG4 uses data from multiple transects to predict the depths and velocities in a river over a range of flows. IFG4 creates a cell for each measured point along the transect or cross section (Figure 5). Each cell is assigned an area, an average water depth, and a velocity associated with a type of substrate and/or cover for a particular flow. Fish habitat is defined in the computer model by the variables of velocity, depth, substrate, and cover.

After the hydraulic model, IFG4, is calibrated, PHABSIM combines IFG4 output with a biological model. The biological model consists of habitat-use curves describing the preference of each fish species for depth, velocity, substrate, and cover. The habitat-use curves for each fish species are defined further for various lifestages, such as adult spawning, juvenile rearing, and adult holding (See Appendix H4).
Figure 5. Top view looking down on placement of transects and measurement verticals used to define the distribution of aquatic habitat in an IFIM site (from Bovee, 1982).
The habitat for each cell on a transect is calculated by multiplying the habitat-preference factor by the area. The habitat preference factor is calculated as in this example. A velocity preference of 1.0 multiplied times a depth preference of 0.9 times a substrate/cover preference of 0.8 equals a preference factor of 0.72 for that cell. This preference factor is multiplied by the number of square feet of area in that cell. All cells for all transects are summed to arrive at the total number of square feet of preferred habitat at a specified flow. The final result is a listing of fish habitat-values called Weighted Useable Area (WUA). WUA is in units of square feet of habitat per 1,000 feet of stream.

WUA is an index of fish habitat. Transforming WUA into a fish population estimate requires assumptions not considered in the PHABSIM model. To use WUA for a fish population estimate requires assumptions such as: 1) the number of fish that would use a square foot of habitat (averages from streams differ naturally by a factor of 200), 2) that no other factors are affecting the population (such as fishing pressure or disease), and that the population of one lifestage does not limit the population of the following lifestage over time (assumes there will always be enough juvenile fish to fully seed all of the adult-fish habitat).

Interagency Participation in Scope-of-Work

A detailed work plan and river segmentation map for an instream flow study on the Green River was presented by Ecology at a COE, WDF, WDW, City of Tacoma, Muckleshoot Indian Tribe, NMFS, USFWS, Trout Unlimited, and others. Participation was sought from these groups by Ecology for an IFIM study of the Green River. Assistance was given by the groups listed above in field work, site and transect selection, hydraulic-model calibration, and selection of habitat-use curves.

Study Site and Transect Selection

Preliminary sites were selected for the IFIM study by reviewing topographic maps, a draft copy of The Status of Anadromous Fishes of the Green/Duwamish River System (Grette and Salo 1986), and A Catalog of Washington Streams and Salmon Utilization, Volume 1, Puget Sound Region (Williams et al 1975). Further site selection was done during two field surveys. A helicopter survey from Kent to HAH dam was made by Brad Hall (COE), Lance Meyer (COE), and Brad Caldwell (Ecology). A survey by boat from Kent on upstream through Flaming Geyser State Park was performed by Jean Caldwell (WDF), Will Sandoval (Muckleshoot Indian Tribe), and Brad Caldwell (Ecology).

Five study sites were selected and all interested state, federal, tribal, municipal, and environmental groups were invited for a ground tour on two separate occasions to ensure agreement on site and transect selection. Approximately 40 miles of the Green River are represented by the five sites. The lower 12 miles of the Green/Duwamish were not included in the study because of tidal influence. The Green River gorge reach, RM 46 through RM 58, also was excluded because of inaccessibility and time constraints.
Figure 6 shows the IFIM sites with the number of river miles the site represents, gradient of the reach, names we gave the sites, approximate river mile locations of each site, number of transects used to represent the habitat, and a short description of the habitat found in each reach. Figures 7, 8, and 9 are site and transect maps of all five sites.

One site, the Hosey site (just downstream from the Tacoma Water Diversion Dam), was not included initially in Ecology’s field work plans and its transects are based on preliminary work by the City of Tacoma. The City of Tacoma had hired Hosey and Associates to conduct an IFIM study on this reach. Agency and tribal scoping on transect selection had been completed and the consultant was ready to collect field measurements. Ecology was informed on June 19, 1986 that the IFIM study on this site was cancelled. Although the site wasn’t included in Ecology’s initial work plan, we decided that the habitat the site represented was important enough to add the site to Ecology’s study.

Field Procedures

IFIM measurements were initiated on June 17, 1986 for the five sites:

1. Kent.
2. Nealy Bridge.
3. Car Body.
4. Flaming Geyser.
5. Hosey.

Measurements of water depth, water velocity, substrate composition, and cover were made along each transect. A temporary gage at each site verified steady streamflow during flow measurement. Water velocity was measured with calibrated Swoffer, Pygmy, and Gurley velocity meters mounted on top-set wading rods. Deep water required the use of a USGS boat-mounted apparatus involving a Swoffer velocity meter attached to a 30 lb. weight connected by a cable to a reel mounted on a cross-piece and boom on a boat. The boat was accurately positioned in the river by sliding the boat along a cable marked with beads at five-foot intervals. The beaded cable was strung between fence posts using cable clamps and tension was applied with a winch.

Water-surface elevations and stream-bank profiles were surveyed with a tripod-mounted transit level and stadia rod. Survey points were referenced to an arbitrary, fixed benchmark. Substrate composition and cover were assessed by visually estimating the percent of the two main particle size classes and type of cover according to a scale recommended by WDF and WDW (Appendix H5).
<table>
<thead>
<tr>
<th>RIVER REACH</th>
<th>% GRADIENT</th>
<th>SITE NAME</th>
<th>RIVER MILE</th>
<th>NO. OF TRANSECTS</th>
<th>HABITAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-32</td>
<td>0.08</td>
<td>KENT</td>
<td>27.2, 30.5</td>
<td>6</td>
<td>WIDE, SLOW, Diked, Silted Bottom, Some Spawning in Riffles, Mostly Pool–Glide.</td>
</tr>
<tr>
<td>32-36.7</td>
<td>0.1</td>
<td>NEALY BRIDGE</td>
<td>35</td>
<td>7</td>
<td>WIDE, MEDIUM VELOCITIES, OFTEN ONE SIDE Diked, GRAVEL BOTTOM, EXCELLENT SPANNING, LONG GLIDES.</td>
</tr>
<tr>
<td>36.7-40</td>
<td>0.2</td>
<td>CAR BODY</td>
<td>39.6</td>
<td>7</td>
<td>WIDER, MEDIUM VELOCITIES, UNDiked, LARGE COBBLE BARS, GRAVEL BOTTOM, EXCELLENT SPANNING, POOL–Riffle.</td>
</tr>
<tr>
<td>40-46</td>
<td>0.3</td>
<td>FLAMING GEGYER</td>
<td>40.6, 43.6</td>
<td>5</td>
<td>WIDE–FAST VELOCITIES IN COBBLE GLIDES, NARROW–FAST RIFFLES, MEDIUM VELOCITY GLIDES/POOLS WITH GOOD SPANNING, GRAVEL/COBBLE.</td>
</tr>
<tr>
<td>46-58</td>
<td>1.5</td>
<td>NO SITE</td>
<td>60.6</td>
<td>6</td>
<td>GREEN RIVER GORGE</td>
</tr>
<tr>
<td>58-64</td>
<td>0.7</td>
<td>HOSEY</td>
<td>60.6</td>
<td>6</td>
<td>NARROW CANYON, DEEP POOLS, COBBLE BOTTOM, SOME FAST RIFFLES/CASCADES, SOME GOOD SPANNING.</td>
</tr>
</tbody>
</table>

Figure 6. GREEN RIVER IFIM SITES LISTING RIVER MILES REPRESENTED, GRADIENT, SITE NAME, RIVER MILE LOCATION OF SITES, NUMBER OF TRANSECTS, AND HABITAT DESCRIPTION.
Figure 7. SITE AND TRANSECT MAP OF KENT AND NEALY BRIDGE SITES.
Figure 8. SITE AND TRANSECT MAP OF CAR BODY AND FLAMING GEYSER SITES.
Figure 9. SITE AND TRANSECT MAP OF THE HOSEY SITE.
Site Description and Conditions During Measurements

**Kent Site (RM 27.2 and 30.5)**

The Kent site represents the river from RM 12 through RM 32. The river gradient in this reach is approximately 0.08 percent, as determined by topographical maps. The river is diked, wide, slow, has a silted bottom, and is mostly pool and glide habitat. Some spawning occurs in the riffles.

Six transects were used to represent the Kent site. Transects 1, 2, and 3 were near RM 27.2 and transects 4, 5, and 6 were near RM 30.5. Transect 1 was a deep pool/glide; transects 2 and 3 were glides; transect 4 was a shallow, fast glide; transect 5 was a deeper glide; and transect 6 was a pool/glide. Field measurements were collected at the Kent site at flows of 262 cfs on 8-8-86, 538 cfs on 6-18-86, and 950 cfs on 11-12-86. The flows were steady during measurement and no significant bed shifts occurred between the low-, medium-, and high-flow measurements on the six transects.

**Nealy Bridge Site (RM 35)**

The Nealy Bridge site represents the river from RM 32 through 36.7. The gradient in this reach is about 0.1 percent. The Nealy Bridge site is characterized by long glides with gravel and cobble bottom substrate. The river in this reach is wide, with one or both sides diked, and is an excellent salmonid spawning reach.

Seven transects were used to represent the Nealy Bridge site. Transects 1, 2, and 3 were downstream of Nealy Bridge (RM 35) and transects 4 through 7 were upstream of the bridge. Transect 1 was a fast chute; transects 2 and 3 were shallow glide/riffles; transect 4 was a shallow riffle; transect 5 was a glide; transect 6 was a deeper glide; and transect 7 was a narrow, fast glide with a gravel bar. Field measurements were collected at the Nealy Bridge site at flows of 238 cfs on 8-7-86, 425 cfs on 6-17-86, and 887 cfs on 11-11-86. The flows were steady during measurement and no significant bed shifts occurred between the low-, medium-, and high-flow measurements on the seven transects.

**Car Body Site (RM 39.6)**

The Car Body site represents the river from RM 36.7 through 40. The gradient is about 0.2 percent. The Car Body site is characterized by large cobble-bars, gravel/cobble substrate, and is an excellent salmonid spawning reach. The river is undiked, wider than the other reaches, and has more pool/riffle sequences.

Seven transects were used to represent the Car Body site. The transects were centered around RM 39.6 Transect 1 was a shallow glide; transect 2 was a fast riffle with a large, calm backwater on the right bank; transect 3 was a shallow glide; transect 4 was a deep glide; transect 5 was a deep, fast glide; and transect 6 was a glide. Transects 4 through 6 had a large cobble bar on the
right side. Transect 7 had a split channel, with a fast chute on the right side and a riffle on the left. The left side of transect 7 was dry at the two lower measured flows. Field measurements were collected at flows of 234 cfs on 8-5-86, 410 cfs on 6-20-86, and 1048 cfs on 11-14-86. The flows were steady during measurement and no significant bed shifts occurred between the low-, medium-, and high-flow measurements on the seven transects.

Flaming Geyser Site (RM 40.6 and 43.6)

The Flaming Geyser site represents the river from RM 40 through 46. The river gradient is about 0.3 percent. The Flaming Geyser site is a sequence of fast glides; wide, fast riffles; and glide/pools with high-quality gravel/cobble substrate for spawning salmonids.

Five transects were used to represent the Flaming Geyser site. Transects 1 and 2 were at RM 40.6 and transects 3, 4, and 5 were at RM 43.6. Transects 1 and 2 were shallow, fast riffles; transect 3 was a fast chute; and transects 4 and 5 were glides. Field measurements were collected at flows of 220 cfs on 8-6-86, 301 cfs on 6-24-86, and 966 cfs on 11-10-86. The flows were steady during measurement, and no significant bed shifts occurred between the low-, medium-, and high-flow measurements on the five transects.

Hosey Site (RM 60.6)

The Hosey site represents the Green River from RM 58 through RM 64. The river gradient in this reach is about 0.7 percent. The Hosey site is generally a narrow canyon with deep pools and cobble bottoms. Fast riffles and cascades are in this reach. Salmonid spawning occurs in the few riffles and tails of the pools.

Six transects were used to represent the Hosey site. The transects were centered around RM 60.6. Transect 1 was a wide riffle, transects 2 and 3 were deep pools, transect 4 was a cascade, transect 5 was a shallow glide, and transect 6 was a pool/glide. Field measurements were collected at flows of 140 cfs on 8-4-86, 194 cfs on 6-25-86, and 768 cfs on 11-13-86. The flows were steady during measurement and no significant bed shifts occurred between the low-, medium-, and high-flow measurements on the six transects.

HAH flow releases were held steady all summer and fall and then were increased quickly to high flow in November. A higher medium flow could have been measured before 6-25-86, but Ecology was not notified that the City of Tacoma was dropping this study site until 6-19-86.

Only the water surface elevation was measured on transect 4 during high flow measurement. Measurement of water depths and velocities at this transect was judged to be too dangerous due to high velocities in the rapids.
III. HYDRAULIC MODEL

Calibration Philosophy

Calibration of the hydraulic model involves checking the velocities and depths predicted by the model against velocities and depths measured in the field. This includes examining indicators of the model’s accuracy such as mean error and Velocity Adjustment Factor (VAF). Velocities and depths predicted at very high and low flows are examined to determine if they are within an acceptable range.

Calibration of the IFG4 model is done cell by cell for each transect to decide whether the accuracy of the predicted cell velocities is adequate. Generally, if the predicted cell velocity at the calibration flow is within 0.2 feet per second (fps) of the measured cell velocity, the predicted velocity is considered adequate. The calibration philosophy is to change data or use a computer calibration option only when doing so would improve the model’s ability to extrapolate without significantly changing the accuracy of depths and velocities predicted at the measured flows. Change to a calibration velocity is limited to 0.2 fps. The 0.2 fps limit is reasonable considering the normal range of velocity measurement error. All cell velocities are reviewed at the highest and lowest extrapolated flows to ensure that extreme cell velocities are not predicted.

Indicators of Model Accuracy

Two indicators of the IFG4 model’s accuracy in predicting depths and velocities are mean error and the VAF.

The mean error is the average of the ratio of the measured discharges to the predicted discharges for one transect. As a rule of thumb, the mean error should be less than 10 percent.

The VAF for a three-flow IFG4 model indicates whether the flow predicted from the velocity/discharge regressions matches the flow predicted from the stage/discharge regression. This is done for each transect. The velocities predicted from the velocity/discharge regressions for a transect are all multiplied by the same VAF to match the flow predicted from the stage/discharge regression. This comparison of flows predicted from two different methods gives an indication as to whether or not the model’s assumptions of linear relationships between velocity and flow and stage and flow are valid. A VAF of 1.0 means both methods are predicting the same discharge.

A VAF in the range 0.9 to 1.1 is considered good, 0.85 to 0.9 and 1.1 to 1.15 fair, 0.8 to 0.85 and 1.15 to 1.20 marginal, and less than 0.8 and more than 1.2 poor (Milhous et al 1984). The extrapolation range of the model is usually limited when two or more transects have VAFs which fall below 0.8 or above 1.2. Model results are generally considered accurate for extrapolating to a 0.4 times the lowest measured flow and 2.5 times the highest measured flow (Milhous et al 1984).
The VAFs for the one-flow IFG4 model do not have the same meaning as with the three-flow UFG4 model. (All sites used a three-flow model, but the Hosey site required the additional use of a one-flow model just for transect four.) The VAF range listed above does not apply to one-flow model VAFs. Instead of predicting velocities from a velocity/discharge regression (three-flow IFG4), the velocities are predicted from Manning’s equation using a constant roughness factor (N). The bottom roughness factor is highest at low flow and becomes progressively lower as flow increases. Since the N value calculated by the computer is constant, the N value used to predict velocities at a flow higher than the measured flow is usually too high. The VAF corrects this problem by changing the predicted velocities to achieve the flow predicted from the stage/discharge regression. The VAF in the one-flow model will be nearly one at the measured flow and usually less than one at lower flows and more than one at higher flows.

Normal empirical values for bottom roughness do not apply to these Manning’s Ns. These Ns are used only for calibrating the velocities in the IFG4 hydraulic model.

**Options in IFG4 Model**

Several options are available in the IFG4 hydraulic model (see Milhous et al 1984). The standard method is to set all the options to zero except for option eight which is set at two. The only nonstandard option used in our hydraulic models was option 14 set at three. This was only done for the Kent site.

**Site Specific Calibration**

The extrapolation ranges of the Green River IFG4 models were held to within the standard range of 0.4 times the lowest measured flow to 2.5 times the highest measured flow. The depths, velocities, VAFS, and mean errors were found to be acceptable within the standard range for all models.

**Kent Site Calibration**

A three-flow IFG4 model was run for this site using the standard options except option 14 was set at three, the upper BMAX limit option. A BMAX of 1.3 was found by trial and error to improve velocity prediction at high flows without significantly affecting the measured velocities. Option 14 set at three meant the beta coefficients on all velocity/discharge regressions were limited to the specified maximum. BMAX cannot be used on a single transect and must be applied to all transects in the model. Limiting the slope of the velocity/discharge regression improved the extrapolation range of the model, but not at the expense of the accuracy of predicted velocities at the measured flows. Each individual cell velocity on each transect was reviewed after application of the BMAX to determine if any significant changes occurred.
The IFG4 input file, a summary of the calibration details, data changes, a table showing which velocities on each transect were affected by the BMAX option, and the VAFS are included as Appendix B.

The mean errors of the stage/discharge regressions range from 0.26 to 5.77 percent. All are less than the 10 percent calibration guideline mentioned previously.

At 100 cfs the worst VAF is 0.84, and at 2500 cfs the worst VAF is 0.93. The velocity and depth predictions are adequate for the extrapolation range of 100 to 2500 cfs.

**Nealy Bridge Site Calibration**

A three-flow IFG4 model was run for this site using the standard options.

The IFG4 input file, a summary of the calibration details, data changes, and VAFS are included as Appendix C.

The mean errors of the stage/discharge regressions range from 0.81 to 9.32 percent. All are less than the 10 percent error guideline.

The worst VAFs are 1.12 at 100 cfs and 0.92 at 2000 cfs. The velocity and depth predictions are adequate for the extrapolation range of 100 to 2000 cfs and could possibly be extended higher and lower if necessary.

**Car Body Site Calibration**

A three-flow IFG4 model was run for this site using the standard options.

The IFG4 input file, a summary of the calibration details, data changes, and VAFS are included as Appendix D.

The mean errors of the stage/discharge regressions range from 0.53 to 5.18 percent. All are less than the 10 percent error guideline.

Two cells had Manning’s Ns specified by us. The Ns calculated by the model were too low and causing predicted velocities to be too high. N’s were corrected by trial and error with repeated computer runs to achieve correct velocities.

The worse VAFs on transects 1 through 6 are 0.84 at 100 cfs and 0.84 at 2500 cfs. Transect 7 has a VAF of 0.74 for 100 cfs and 0.76 for 2500 cfs. The velocity and depth predictions are adequate for extrapolation from 100 to 2500 cfs.
Flaming Geyser Site Calibration

A three-flow IFG4 model was made for this site using the standard options. The IFG4 input file, a summary of calibration details, data changes, and VAFS are in Appendix E.

The mean errors of the stage/discharge relationships range from 0.29 to 4.0 percent and are less than the 10 percent error guideline.

The worst VAFs are 0.89 at 80 cfs and 0.95 at 2000 cfs. The IFG4 hydraulic model velocity and depth predictions are adequate for the extrapolation range of 80 to 2500 cfs.

When measured velocities were changed for calibration, a limit of 0.2 fps was used, except on transect 3 where a 0.6 fps velocity was changed to 2.6 fps at high flow. Cell velocities adjacent to this vertical were on the order of 2.5 to 3 fps at the measured flow. This data-point anomaly was due to velocity-meter placement in a small standing wave. The resultant steep velocity/discharge regression slope in this cell caused all other cells to have significantly lowered predicted velocities. This one data point was modified to improve the accuracy of all the other predicted cell velocities.

Hosey Site Calibration

A three-flow IFG4 model was run for this site using the standard options for transects 1, 2, 3, 5, and 6.

A one-flow IFG4 model was also run for this site using the standard options with the medium flow velocity measurements for transect 4. Transect 4 could not be measured at high flow because of dangerously high velocities on the transect.

The mean errors of the stage/discharge relationships range from 0.27 to 5.86 percent. All were within the 10 percent error guideline.

The worse VAFs for the three-flow model were 0.74 for 60 cfs and 0.82 for 2000 cfs.

The input file for the one-flow model has a duplicate transect labeled 4.5. Because the one-flow model requires more than one transect to calculate habitat, a duplicate transect was necessary, but the duplicate receives no weighting in the model.

One Manning’s N was specified in the one-flow model.

The velocity and depth predictions are adequate for an extrapolation range of 60 to 2000 cfs.
Transect Weighting

Appendix G lists the percent weighting each transect received relative to the whole site. The model automatically determines weighting for each transect by using the distance between the transects. Transect weight can be set to pre-determined levels by specifying distances between the transects (this is composite weighting). Sometimes composite weighting is done when the transects are physically far apart and the distances between the transects would create incorrect weighting. Some sites received composite weighting while other sites received a combination of actual distances between transects and composite weighting.

Agency and Tribal Approval of the Hydraulic Model

A meeting was held March 7, 1988 by Ecology to judge the adequacy of the Green River hydraulic models. Those in attendance were Hal Beecher (WDW), Paul Hickey and Jean Caldwell (Muckleshoot Indian Tribe), Ken Bruya (WDF), and Steve Hirshey and Brad Caldwell (Ecology). All agreed that the Green River hydraulic models were calibrated adequately, and that the normal extrapolation range of 0.4 times the low measured flow and 2.5 times the high measured flow was appropriate. Attendees also agreed that transect weighting, using a combination of the distances between transects and composite weighting, was appropriate.
IV. HABITAT-USE CURVES

Selection and Verification of Habitat-Use Curves

IFIM requires a biological model of water depths, velocities, substrate, and cover preferred by fish be compared against the same variables predicted by the IFG4 hydraulic model. This biological model is described as habitat-use curves.

Habitat-use curves for salmon were selected from WDF’s and Ecology’s standard set of “river” curves (Caldwell and Caldwell, 1987, unpublished). Habitat-use curves for trout were from WDW (Hal Beecher, 1987).

Verification of the habitat-use curves was done by observing fish species in the Green River. Snorkel surveys were done at all sites on species of fish present, fish distribution, and abundance (Appendix H1). A periodicity chart is included in Appendix H2 to show which months each fish species and lifestage is present. Field observations of depths and velocities used by spawning chinook and spawning steelhead were collected and summarized into histograms. (Appendix H3).

Agency and Tribal Approval of Habitat-Use Curves

A meeting was held March 7, 1988 by Ecology to get agreement on the habitat-use curves to be used in the Green River IFIM model. The meeting was attended by Hal Beecher (WDW), Paul Hickey and Jean Caldwell (Muckleshoot Indian Tribe), Ken Bruya (WDF), and Steve Hirschey and Brad Caldwell (Ecology).

Standard WDF salmon “river” curves were chosen by the above group except for changing the depth curve to unlimited depth for adult, holding chinook; juvenile chinook; and juvenile coho. These lifestages were observed to utilize deep pools throughout the Green River. The standard trout curves were also chosen. These habitat-use curves are in Appendix H4. The substrate/cover code was chosen with cover use by juvenile salmon included (Appendix H5).
V. FISH SPECIES AND OPTIONS USED IN HABTAT PROGRAM

Fish Species Used in HABTAT

The HABTAT program combines the depths and velocities predicted from the IFG4 hydraulic model with the depths and velocities from the habitat-use curves. The program calculates WUA (fish habitat) versus flow relationships.

Habitat-use curves were run for steelhead trout, and chinook, coho, and chum salmon because these are the predominant species in the river. Pink and sockeye salmon were not included because their numbers are few.

Options Used in HABTAT

There are several options available in the HABTAT program. The standard method was used with options 1, 8, and 10 set at one with all other options set at zero (Milhous et al 1984).
VI. RESULTS

WUA-vs.-Flow Curves

The WUA (Fish habitat)-versus-flow results are presented in Appendix A. The figures are grouped by site; downstream site first (Kent) followed by the next upstream site (Nealy Bridge), etc. Each group of figures is arranged by area, and then by species: steelhead, chinook, coho, chum.

The area-versus-flow graphs indicate that most sites have flat, rectangular channel cross sections. The average wetted widths at 500 cfs are 124 feet at the Kent site, 155 feet at the Nealy Bridge site, 124 feet at the Car Body site, 128 feet at the Flaming Geyser site, and 93 feet at the Hosey site. The Kent and Nealy Bridge sites have little loss of wetted width until the flow drops below 200 cfs.

All of the sites, except the Hosey site, have higher quantities of spawning habitat than rearing habitat. Spawning habitat is limited in the Hosey site by the large amount of deep pools with bedrock and boulder substrate.

The WUA curves are bell-shaped at all sites except the Car Body site. At the Car Body site the habitat curves have two peaks instead of one. The first peak indicates at what flow velocities and depths are optimum in the low-flow channel. The second peak indicates at what flow velocities and depths are optimum over the wide cobble bars which are normally dry except during high flow. This double hump is typical of rivers with large, exposed gravel/cobble bars.

Summary and Comparison of Flows Which Provide Peak Habitat

Table 2 lists the peaks from the WUA (fish habitat) curves from Ecology’s study sites. Many of the peak habitat flows are quite similar throughout the river.

Table 3 lists Chapman’s (1984) optimum flows for the Green River based on his two-flow IFIM study. The details of his study were not available for a complete comparison, however, his results at river miles 30 and 43 agree well with our results.
Table 2. Flows Which Provide Peak Habitat from WUA-vs.-Flow Results.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Steelhead Spawning</th>
<th>Steelhead Holding</th>
<th>Chinook Spawning</th>
<th>Chinook Holding</th>
<th>Chinook and Coho Juveniles</th>
<th>Coho Spawning</th>
<th>Chum Spawning</th>
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Determining a minimum instream flow for a river requires more thought than choosing the peak WUA flows from an IFIM study. Setting a minimum instream flow for the Green River requires ranking the importance of each river reach, fish species, and lifestage. This ranking requires a consensus on long-range management plans for the fishery resource from several state and federal natural-resource agencies and the Muckleshoot Indian Tribe.

In addition, a minimum instream flow must include flows necessary for incubation of fish eggs, smolt out-migration, fish passage to spawning grounds, and prevention of stranding of fry and juveniles. Other variables which have to be considered include water temperature, water quality, sediment load, and added flows from tributaries and ground water. Significant inflows to the Green River occur from Big Soos Creek, Newaukem Creek, and ground water (Appendix I).

A flow which provides peak habitat for fish may not necessarily provide optimum fish production. At low flows other hard-to-quantify variables not included in this study may be of overriding importance for fish production. Flows higher than peak habitat flows may be needed to provide: (1) water velocity sufficient for downstream transportation of aquatic insect drift needed for food; and (2) more water depth for less competition between fish species, less predation by birds and larger fish, less poaching by humans, and less 4-wheel drive vehicle crossings over spawning salmon and steelhead nests.
Appendix A

WUA VS FLOW GRAPHS
AREA VS. DISCHARGE
GREEN RIVER KENT SITE, TRIBUTARY TO THE DUWAMISH RIVER

Discharge vs Area
Green River Kent Site RM 30.5
Date and Flow Measured
08-08-86 262 cfs
06-18-86 550 cfs
11-12-86 950 cfs

Discharge Area
100 105985
110 106440
120 106864
130 107262
140 107683
150 108285
160 108889
170 109480
180 110036
190 110596
200 111037
220 111870
240 112951
260 113904
280 114213
300 114436
325 114701
350 114940
375 115163
400 115371
450 115758
500 116112
550 116444
575 116601
600 116752
625 116900
650 117042
700 117300
750 117544
775 117661
800 117772
825 117885
850 117992
900 118199
950 118398
1000 118589
1200 119259
1500 120126
2000 121246
2500 122138
COHO SALMON HABITAT
GREEN RIVER KENT SITE, TRIBUTARY TO THE DUWAMISH RIVER

SPAWNING

JUVENILE

WEIGHTED USABLE AREA (SQUARE FEET)

DISCHARGE (CFS)

COHO Salmon in the Green River
Kent Site RM. 30.5
Date and Flow Measured
08-08-86 262 cfs
06-18-86 530 cfs
11-12-86 950 cfs

Flow Spawning Juvenile
100 24204 23986
110 26006 25111
120 27621 26030
130 29163 26794
140 29922 27423
150 30547 27974
160 30975 28501
170 31372 28965
180 31702 29261
190 31915 29653
200 32080 29879
220 32426 30248
240 32910 30733
260 33519 30342
280 33931 30198
300 34286 29939
325 34321 29505
350 34230 28983
375 33940 28430
400 33669 27820
450 32896 26519
500 31556 25066
550 30689 23598
575 30581 22909
600 30572 22303
625 30600 21730
650 30685 21148
700 30231 20042
750 28315 18991
775 26803 18464
800 24964 17932
825 23176 17412
850 21473 16899
900 18991 15901
950 17159 14966
1000 16190 14052
1200 14325 10829
1500 11273 8069
2000 6461 6175
2500 3449 5558
AREA VS. DISCHARGE
GREEN RIVER NEALY BRIDGE SITE, TRIBUTARY TO THE DUWAMISH RIVER

Discharge vs. Area
Green River Nealy Bridge Site
Date and Flow Measured
08-07-86  239 cfs
06-17-86  425 cfs
11-11-86  887 cfs

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STEELHEAD HABITAT
GREEN RIVER NEALY BRIDGE SITE, TRIBUTARY TO THE DUWAMISH RIVER

WEIGHTED USABLE AREA (SQUARE FEET)

DISCHARGE (CFS)

SPAWNING

JUVENILE

ADULT

Steelhead in the Green River Nealy Bridge Site RM. 35.0
Date and Flow Measured
08-07-86 239 cfs
06-17-86 425 cfs
11-11-86 887 cfs

Flow  Spawning Juvenile Adult
100  32304  26615  1533
110  34995  27510  1729
120  37481  28348  2059
130  39859  29127  2444
140  42122  29942  2749
150  44590  30797  3104
160  47066  31635  3505
170  49609  32458  3811
180  52197  33257  4155
190  54690  34174  4432
200  57256  35043  4605
220  62851  36620  5070
240  68213  37954  5849
260  73397  39154  6301
280  78364  40100  6551
300  82875  40770  6693
350  91058  41716  7794
375  97076  41862  8068
400  99896  41916  8245
425  102331  41859  8370
450  104437  41730  8043
500  107728  41296  6910
550  109554  40784  5835
575  110640  40463  5466
600  111014  39985  5240
625  109981  39347  4992
650  109600  38527  4865
675  109070  37719  4829
700  108323  36728  4864
725  107476  35743  4773
750  106566  34745  4584
800  104056  33173  4331
900  97791  30398  3916
1000  90654  27109  3218
1200  76366  21505  2985
1500  57555  18253  3031
2000  34812  16406  2511
COHO SALMON HABITAT
GREEN RIVER NEALY BRIDGE SITE, TRIBUTARY TO THE DUWAMISH RIVER

SPAWNING
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JUVENILE

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Date and Flow Measured
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06-17-86 425 cfs
11-11-86 887 cfs

Coho Salmon in the Green River
Nealy Bridge Site HM. 35.0
CHINOOK SALMON HABITAT
GREEN RIVER CAR BODY SITE, TRIBUTARY TO THE DUWAMISH RIVER

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**CHINOOK SALMON IN THE GREEN RIVER**
*Car Body Site: RM. 39.6*

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#### Chart

- **Spawning**
- **Juvenile**
- **Adult**

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CHINOOK SALMON HABITAT
GREEN RIVER FLAMING GEYSER SITE, TRIBUTARY TO THE DUWAMISH RIVER

SPAWNING

JUVENILE

ADULT

Chinook Salmon in the Green River
Flaming Geyser Site RW. 43.6
Date and Flow Measured
08-06-86 220 cfs
06-24-86 301 cfs
11-10-85 966 cfs

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Appendix B

KENT SITE CALIBRATION INFORMATION
Appendix B1  IFG4 Input File  Kent Site

Green River at Kent  Split site, Lower at RM 27.2, Upper at RM 30.5
Q/DATE MEASURED  950 cfs on 11-12-86,  538 on 06-18-86, 262 on 08-08-86
IOC  0000000200000300000

BMAX   1.3
QARD 100
QARD 262
QARD 538
QARD 950
QARD 2500
XSEC 1.0  0.001.00  85.10
1.0  -5.0 97.4  0.0 93.4  3.0 91.9  5.0 90.7 10.0 88.6 15.0 87.0
1.0  20.0 86.6  25.0 86.2  30.0 86.0  35.0 85.7  40.0 85.4  45.0 85.3
1.0  47.5 85.1  50.0 85.3  52.5 85.3  55.0 85.3  57.5 85.4  60.0 85.4
1.0  65.0 85.8  70.0 86.0  75.0 86.7  80.0 87.4  85.0 88.4  90.0 89.0
1.0  95.0 89.5  100.0 90.0 105.0 90.2 108.4 91.7 110.0 93.0 114.0 94.9
  1.0  124.0101.3

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NS  1.0  0.0  65.8  0.0  65.9  0.0  56.7  0.0  36.8  0.0  61.5
NS  1.0  0.0  61.5  0.0  16.7  0.0  0.8  0.0  0.8  0.0  0.8
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VEL1  1.0  0.7  0.6  0.3
CAL2  1.0  91.02  538.00
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2.0  20.0 87.8  25.0 87.7  30.0 87.7  35.0 87.6  40.0 87.4  45.0 87.4
2.0  50.0 87.3  55.0 87.3  57.5 87.3  60.0 87.3  62.5 87.4  65.0 87.4
2.0  67.5 87.5  70.0 87.6  72.5 87.6  75.0 87.4  77.5 87.4  80.0 87.2
2.0  82.5 87.1  85.0 86.9  90.0 86.5  95.0 86.3 100.0 86.5 105.0 87.1
2.0  110.0 88.0  115.0 89.3 120.3 93.5 121.3 95.2 126.3100.2
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Appendix B2  Summary of Calibration Details  Kent Site

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Appendix B3  Data Changes  Kent Site

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Appendix C

NEALY BRIDGE SITE CALIBRATION INFORMATION
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Q/DATA MEASURED  887 cfs on 11-11-86, 425 on 06-17-86, 238 on 08-07-86  
IOC  000000020000000000  
QARD  100.0  
QARD  238.0  
QARD  425.0  
QARD  887.0  
QARD  2000.0  
XSEC  1.0  0.0000.50  86.10  
<p>| 1.0 | -5.0 | 98.2 | 0.0 | 93.2 | 5.0 | 91.2 | 10.0 | 88.7 | 12.5 | 88.5 | 15.0 | 88.6 |
| 1.0 | 17.5 | 88.6 | 20.0 | 88.7 | 22.5 | 88.5 | 25.0 | 87.8 | 27.5 | 87.3 | 30.0 | 87.0 |
| 1.0 | 32.5 | 87.1 | 35.0 | 87.1 | 40.0 | 86.9 | 42.5 | 86.8 | 45.0 | 86.8 | 47.5 | 86.7 |
| 1.0 | 50.0 | 86.6 | 52.5 | 86.8 | 55.0 | 86.7 | 60.0 | 86.3 | 62.5 | 86.2 | 65.0 | 86.1 |
| 1.0 | 67.5 | 86.3 | 70.0 | 86.6 | 72.5 | 87.2 | 75.0 | 87.6 | 80.0 | 88.8 | 82.5 | 89.1 |
| 1.0 | 85.0 | 89.8 | 87.5 | 89.9 | 90.0 | 90.5 | 100.0 | 91.4 | 150.0 | 94.0 | 200.0 | 91.5 |
| 1.0 | 228.0 | 93.4 | 258.0 | 94.7 |
| NS | 1.0 | 0.0 | 0.8 | 0.0 | 45.8 | 0.0 | 45.8 | 0.0 | 45.8 | 0.0 | 54.8 | 0.0 | 54.8 |
| NS | 1.0 | 0.0 | 54.9 | 0.0 | 56.9 | 0.0 | 56.9 | 0.0 | 64.8 | 0.0 | 64.6 |
| NS | 1.0 | 0.0 | 56.6 | 0.0 | 65.7 | 0.0 | 63.7 | 0.0 | 63.7 | 0.0 | 64.6 |
| NS | 1.0 | 0.0 | 64.6 | 0.0 | 64.6 | 0.0 | 64.6 | 0.0 | 64.5 | 0.0 | 64.5 |
| NS | 1.0 | 0.0 | 46.6 | 0.0 | 46.6 | 0.0 | 46.5 | 0.0 | 46.9 | 0.0 | 46.9 |
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| NS | 1.0 | 0.0 | 56.8 | 0.0 | 56.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAL1 | 1.0 | 90.46 | 887.00 |
| VEL1 | 1.0 | 2.3 | 2.9 | 4.6 | 5.0 | 5.1 | 5.3 | 4.0 | 4.8 | 4.9 | 4.9 | 4.6 | 4.6 |
| VEL1 | 1.0 | 4.4 | 4.6 | 4.6 | 3.7 | 2.2 | 2.0 | 0.9 | 0.7 |
| VEL1 | 1.0 |
| CAL2 | 1.0 | 89.78 | 425.00 |
| VEL2 | 1.0 | 1.8 | 1.8 | 2.7 | 3.0 | 3.2 | 2.7 | 2.7 | 3.1 | 3.0 | 2.9 | 2.8 |
| VEL2 | 1.0 | 2.8 | 2.6 | 2.2 | 2.0 | 1.0 | 0.7 | 0.0 |
| VEL2 | 1.0 |
| CAL3 | 1.0 | 89.17 | 239.00 |
| VEL3 | 1.0 | 0.8 | 1.3 | 1.3 | 2.1 | 2.2 | 2.2 | 2.3 | 1.8 | 2.1 | 2.4 | 2.3 | 2.2 |
| VEL3 | 1.0 | 2.1 | 2.2 | 1.9 | 1.6 | 1.2 | 0.7 |
| VEL3 | 1.0 |
| XSEC | 2.0 | 298.0000.50 | 89.20 |
| | 2.0 | -7.0 | 97.3 | 0.0 | 94.7 | 2.0 | 93.7 | 4.0 | 92.0 | 5.0 | 91.0 | 10.0 | 89.2 |
| | 2.0 | 15.0 | 89.7 | 20.0 | 89.7 | 25.0 | 90.0 | 30.0 | 90.3 | 35.0 | 90.6 | 40.0 | 90.8 |
| | 2.0 | 50.0 | 91.1 | 60.0 | 91.5 | 70.0 | 91.5 | 80.0 | 91.4 | 90.0 | 91.3 | 100.0 | 91.2 |
| | 2.0 | 110.0 | 91.2 | 120.0 | 91.1 | 130.0 | 91.0 | 140.0 | 91.0 | 150.0 | 90.9 | 160.0 | 90.5 |
| | 2.0 | 170.0 | 90.6 | 180.0 | 90.8 | 190.0 | 91.3 | 200.0 | 91.6 | 205.0 | 91.3 | 210.0 | 91.4 |
| | 2.0 | 215.0 | 93.4 | 217.0 | 95.4 | 219.0 | 97.4 |
| NS | 2.0 | 0.0 | 0.8 | 0.0 | 0.8 | 0.0 | 0.8 | 0.0 | 88.5 | 0.0 | 88.5 | 0.0 | 53.6 |
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Appendix C2  Summary of Calibration Details  Nealy Bridge Site

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Appendix C3  Data Changes  Nealy Bridge Site

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CAR BODY SITE CALIBRATION INFORMATION
Appendix D1  IFG4 Input file  Car Body Site.

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## Appendix D1 IFG4 Input File Car Body Site Continued

| NS | 7.0 | 0.0 64.8 | 0.0 64.8 | 0.0 64.8 | 0.0 64.8 | 0.0 64.8 | 0.0 74.6 |
| NS | 7.0 | 0.0 74.6 | 0.0 74.6 | 0.0 74.6 | 0.0 56.8 | 0.0 56.8 | 0.0 56.8 |
| NS | 7.0 | 0.0 64.9 | 0.0 22.5 | 0.0 26.9 | 0.0 26.9 | 0.0 26.9 | 0.0 22.5 |
| NS | 7.0 | 0.0 22.5 | 0.0 12.5 | 0.0 26.7 | 0.0 26.6 | 0.0 26.6 | 0.0 64.7 |
| NS | 7.0 | 0.0 74.6 | 0.0 74.6 | 0.0 74.6 | 0.0 74.6 | 0.0 64.8 | 0.0 64.8 |
| NS | 7.0 | 0.0 64.8 | 0.0 64.8 | 0.0 65.7 | 0.0 65.7 | 0.0 65.7 | 0.0 65.7 |
| NS | 7.0 | 0.0 65.7 | 0.0 65.7 | 0.0 65.7 | 0.0 66.5 | 0.0 8.0 | 0.0 8.0 |
| CAL1 | 7.0 | 94.74 | 1048.00 |
| VEL1 | 7.0 | 2.8 | 3.3 | 3.0 | 2.9 | 2.5 | 2.2 | 0.0 | 0.0 | 0.3 |
| VEL1 | 7.0 | 0.3 | 0.7 | 1.9 | 3.8 | 4.4 | 5.8 | 5.1 | 5.6 | 5.3 | 5.1 | 5.5 | 5.8 |
| VEL1 | 7.0 | 5.8 | 6.3 | 5.8 | 6.0 | 5.7 | 4.1 | 3.2 | 2.4 | 2.2 |
| CAL2 | 7.0 | 93.78 | 410.00 |
| VEL2 | 7.0 | 0.0 | 0.0 | 0.0 | 0.5 |
| VEL2 | 7.0 | 0.4 | 0.5 | 0.6 | 0.7 | 0.5 |
| VEL2 | 7.0 | 0.1 | 0.2 | 0.1 | 1.0 | 1.9 | 2.2 | 2.0 | 2.8 | 2.8 | 2.7 | 3.6 | 3.6 |
| VEL2 | 7.0 | 3.4 | 3.5 | 3.1 | 3.1 | 3.4 | 3.3 | 2.8 | 2.3 | 1.4 |
| CAL3 | 7.0 | 93.39 | 234.00 |
| VEL3 | 7.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.9 | 1.1 | 1.3 | 1.6 | 2.5 | 2.0 | 2.9 |
| VEL3 | 7.0 | 2.8 | 3.0 | 3.1 | 3.0 | 2.9 | 2.9 | 2.6 | 2.3 | 0.9 |
| ENDJ |
Appendix D2  Summary of Calibration Details  Car Body Site

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Appendix D3  Data Changes  Car Body Site

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## Green River at Flaming Geyser  RM 43.6

**Q/DATE MEASURED**  
966 cfs on 11-10-86, 301 on 06-24-86, 220 on 08-06-86

**IOC**

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Appendix E2  Summary of Calibration Details  Flaming Geyser Site

Flaming Geyser Site Calibration Information for Calculated Discharges

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B coefficient log/log discharge/stage relationship

|     | 3.28 | 2.62 | 3.08 | 3.17 | 3.01 |
Appendix E3  Data Changes  Flaming Geyser Site

Cell velocities changed for calibration

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### Appendix E4  Velocity Adjustment Factors  Flaming Geyser Site

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Appendix F

HOSEY SITE CALIBRATION INFORMATION
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QARD 140.0
QARD 194.0
QARD 768.0
QARD 2000.0
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1.0 20.0 94.0 25.0 94.1 30.0 94.2 35.0 94.3 40.0 94.9 45.0 95.2
1.0 50.0 95.4 55.0 95.2 60.0 95.3 65.0 95.4 70.0 95.4 75.0 95.3
1.0 80.0 95.2 85.0 95.0 90.0 94.7 95.0 94.8 100.0 94.6 105.0 94.4
1.0 110.0 94.5 115.0 94.4 120.0 93.8 125.0 93.5 130.0 93.1 135.0 93.6
1.0 140.0 93.8 145.0 93.7 150.0 94.3 155.0 95.9 160.0 97.0 162.0 99.2
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NS 1.0 0.0 45.5 0.0 45.7 0.0 45.7 0.0 55.5 0.0 64.5 0.0 64.5
NS 1.0 0.0 65.7 0.0 56.6 0.0 65.6 0.0 65.6 0.0 65.9 0.0 65.9
NS 1.0 0.0 76.6 0.0 56.6 0.0 56.6 0.0 56.5 0.0 56.5
NS 1.0 0.0 65.5 0.0 65.5 0.0 88.5 0.0 88.5 0.0 88.5 0.0 88.5
NS 1.0 0.0 8.0 0.0 8.0 0.0 8.0 0.0 8.0 0.0 8.0 0.0 8.0
CAL1 1.0 96.88 768.00
VEL1 1.0 0.2 1.4 2.9 3.8 3.5 3.6 3.6 3.4
VEL1 1.0 2.8 2.3 2.1 2.2 1.4 1.4 1.6 2.6 3.0 3.4 3.6 3.8
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VEL3 1.0
XSEC 2.0 29.4000.40 93.10
2.0 -7.0 101.2 -6.0 100.3 0.0 97.3 2.5 95.6 5.0 95.7 7.5 95.5
2.0 10.0 93.4 15.0 91.7 20.0 90.4 25.0 89.7 30.0 89.3 35.0 89.1
2.0 40.0 88.6 45.0 88.5 47.5 88.1 50.0 88.1 52.5 88.3 55.0 88.4
2.0 57.5 88.7 60.0 88.8 65.0 88.7 70.0 89.1 75.0 90.0 80.0 90.8
2.0 85.0 92.2 90.0 93.9 95.0 95.7 96.0 97.2 100.3 97.5 105.0 100.5
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NS 2.0 0.0 76.5 0.0 86.6 0.0 75.6 0.0 76.5 0.0 57.6 0.0 57.6
NS 2.0 0.0 57.6 0.0 57.6 0.0 78.5 0.0 27.6 0.0 24.7 0.0 21.9
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### Green River at Hosey Site Transect 4 RM 60.6

**Q/date measured**: 190 cfs on 06-25-86

**IOC**: 00000002000000000000

**QARD**: 60.

**QARD**: 140.

**QARD**: 190.

**QARD**: 768.

**QARD**: 2000.

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93
Appendix F2   IFG4 Input File for One-Flow Model   Hosey Site

VEL1  4.5
VEL1  4.5
CAL2  4.5   91.70  190.00  171.00
VEL2  4.5   0.0  0.3   1.0  1.6   1.4  2.1  2.5  1.8
VEL2  4.5   2.8  1.1   2.0  28   4.4  1.2   0.7  4.5   2.4  0.6   1.6  2.1
VEL2  4.5   1.3  1.1   0.5  1.5
CAL3  4.5   91.59  144.00  160.00
VEL3  4.5
VEL3  4.5
VEL3  4.5
ENDJ
Appendix F3  Summary of Calibration Details  Hosey Site

Hosey Site Calibration Information for Calculated Discharges

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<td>1.23</td>
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<td>.6570</td>
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*Transect Four was run as a one-flow model.
Appendix F4  Data Changes  Hosey Site

Cell velocities changed for calibration

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<th>Changed</th>
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<td>Vertical 12</td>
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<td>0.6</td>
</tr>
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<td>VEL3</td>
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<td>0.5</td>
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<td>Changed</td>
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<td>Specified Mannings N of 0.3</td>
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## Appendix F5  Velocity Adjustment Factors  Hosey Site

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<td>.995</td>
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<td>.960</td>
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<td>3.00</td>
<td>768.0</td>
<td>.998</td>
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| 4.00     | 60.0   | .822 *|
| 4.00     | 140.0  | 1.000 *|
| 4.00     | 194.0  | 1.096 *|
| 4.00     | 768.0  | 1.744 *|
| 4.00     | 2000.0 | 2.556 *|
| 5.00     | 60.0   | .735 |
| 5.00     | 140.0  | .980 |
| 5.00     | 194.0  | 1.020|
| 5.00     | 768.0  | 1.008|
| 5.00     | 2000.0 | .857 |
| 6.00     | 60.0   | 1.011|
| 6.00     | 140.0  | 1.006|
| 6.00     | 194.0  | 1.007|
| 6.00     | 768.0  | 1.003|
| 6.00     | 2000.0 | .989 |

* A one-flow IFG4 model was used for transect 4.
Appendix G

TRANSECT WEIGHTING
### Appendix G  TRANSECT WEIGHTING

Transect weight as a percent of each site.

<table>
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<th>Site</th>
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<td>Nealy Bridge</td>
<td>8.34</td>
<td>15.34</td>
<td>15.34</td>
<td>20.82</td>
<td>18.19</td>
<td>13.82</td>
<td>8.11</td>
</tr>
<tr>
<td>Car Body</td>
<td>7.89</td>
<td>16.26</td>
<td>15.59</td>
<td>17.15</td>
<td>22.49</td>
<td>16.57</td>
<td>3.92</td>
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<td>Flaming Geyser</td>
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<td>15.00</td>
<td>10.00</td>
<td>30.00</td>
<td>30.00</td>
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<tr>
<td>Hosey</td>
<td>10.00</td>
<td>25.00</td>
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<td>15.00</td>
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Appendix H

FISH HABITAT USE
Appendix H1  Snorkel Surveys of Fish Distribution and Use

ECOLOGY SNORKELING OBSERVATIONS

RIVER:  Green River                 DATE:  April 23, 1986

DISCHARGE OF RIVER:  895 cfs at Purification Plant gage  
                     1280 cfs at Auburn gage

REACH OF RIVER SURVEYED: at RM 60.9, 100 ft. downstream of footbridge

VISIBILITY:  8-10 ft.

SPAWNING STEELHEAD OBSERVATIONS

<table>
<thead>
<tr>
<th>Depth</th>
<th>Velocity</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.7 ft.</td>
<td>2.07 fps</td>
<td>large gravel 60%, small cobble 40%</td>
</tr>
<tr>
<td>3.5 ft.</td>
<td>3.4 fps</td>
<td>large gravel 50%, small cobble 30%, and large cobble 20%</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: The redds were in the center of the channel. Though there were many redds we saw active fish on only two redds.

OBSERVATIONS BY: Brad Caldwell and Jim Farley (WDF)
Appendix H1  Snorkel Surveys of Fish Distribution and Use  Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER:  Green River  DATE:  May 9, 1986

DISCHARGE OF RIVER:  450 cfs at Purification Plant gage
833 cfs at Auburn gage

REACH OF RIVER SNORKELED:  RM 60.3 to 60.9. Snorkeled from the footbridge just below diversion (RM 60.9) to the pipe bridge upstream of the control station (RM 60.3). The COE had reduced the river flow to 450 cfs about a week ago. No redds were observed in the 3 to 15 foot depths. Redds were observed at three sites: just below the footbridge, at gravel bar on roadside; ¾ of the way down from the footbridge to the pipe bridge (below largest tributary on north side); and immediately underneath and slightly downstream from the pipe bridge. Two redds were observed on the north edge of the river on transect two. Six dark steelhead were near two large, fresh redds at the footbridge spawning bar.

VISIBILITY:  15 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
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</thead>
<tbody>
<tr>
<td>Steelhead adults (by foot bridge)</td>
<td>6</td>
</tr>
<tr>
<td>Steelhead adults (dark, by pipebridge)</td>
<td>20</td>
</tr>
<tr>
<td>Whitefish (12-15 in.)</td>
<td>12</td>
</tr>
<tr>
<td>Trout juvenile (5 in.)</td>
<td>1</td>
</tr>
</tbody>
</table>

SPAWNING STEELHEAD OBSERVATIONS

<table>
<thead>
<tr>
<th>Depth</th>
<th>Velocity</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6 ft</td>
<td>4.02 fps</td>
<td>small cobble 60%, large gravel 40%</td>
</tr>
<tr>
<td>2.0 ft</td>
<td>3.32 fps</td>
<td>small cobble 50%, large gravel 50%</td>
</tr>
<tr>
<td>2.0 ft</td>
<td>2.59 fps</td>
<td>small cobble 50%, large gravel 50%</td>
</tr>
<tr>
<td>2.6 ft</td>
<td>1.97 fps</td>
<td>large gravel 60%, small cobble 40%</td>
</tr>
<tr>
<td>1.8 ft</td>
<td>2.40 fps</td>
<td>large gravel 70%, small cobble 30%</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: Good-quality spawning gravel was observed in the pools, but there was no evidence of the dark, brown algae having been being disturbed by fish. Heavy concentrations of caddis larvae were observed at densities of 12 to 25 per square foot on cobble and bedrock in water 1 to 3 feet deep by the pipebridge. Steelhead redds on the gravel bar 100 yards upstream of the pipe bridge had only 1 to 3 inches of water at 450 cfs. These fresh redds were probably created last week while the flow was 2000 cfs. Because of spring reservoir filling, the steelhead redds at this bar probably have chronic dewatering problems.

OBSERVATIONS BY: Brad Caldwell
Appendix H1  Snorkel Surveys of Fish Distribution and Use  Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER:  Green River
DATE:  August 12, 1986

DISCHARGE OF RIVER:  197 cfs at Purification Plant gage
                      403 cfs at Auburn gage

REACH OF RIVER SNORKELED: RM 60.6 to 60.9, the Hosey Site. We snorkeled from just below the
footbridge (RM 60.9) downstream to transect 4 (FM 60.6).

VISIBILITY:  10 ft.

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steelhead adults (15-20 lbs.)</td>
<td>2 (1 was dark)</td>
</tr>
<tr>
<td>Sockeye adults (8-10 lbs.)</td>
<td>6 (dark red)</td>
</tr>
<tr>
<td>Sockeye adult (dead)</td>
<td>1</td>
</tr>
<tr>
<td>Trout (10-12 in.)</td>
<td>3</td>
</tr>
<tr>
<td>Trout juvenile (6-7 in.)</td>
<td>8</td>
</tr>
<tr>
<td>Trout juvenile (3-4 in.)</td>
<td>12</td>
</tr>
<tr>
<td>Whitefish (1 lb.)</td>
<td>18</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS:  The sockeye were spawning in a pool just below the riffles below transects 5
and 6. The redds were in 8 to 10 feet of water and the substrate was small cobble with a small amount
of large gravel and large cobble. The sockeye were apparently the same as were observed here on August 5,
1986.

REACH OF RIVER SNORKELED: RM 38.9 to 39.9 at the Car Body site. Snorkeled from upstream end
of the Car Body site (RM 39.9) to one mile downstream.

VISIBILITY:  6-8 ft.

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suckers (8 lbs.)</td>
<td>50</td>
</tr>
<tr>
<td>Whitefish (1 lb.)</td>
<td>10</td>
</tr>
<tr>
<td>Coho juveniles (2.5-4 in.)</td>
<td>80</td>
</tr>
<tr>
<td>Chinook juveniles (5-6 in.)</td>
<td>25</td>
</tr>
<tr>
<td>Trout juveniles (2.5-6)</td>
<td>100</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS:  The thousands of chinook juveniles seen last week were gone. There were
about the same number of coho juveniles and trout juveniles as seen last month. Last month 95% of the
all the salmonid juveniles observed were chinook. The car body was gone and a freshet occurred two days
ago.

OBSERVATIONS BY:  Brad Caldwell and Stephen Hirschey
Appendix H1  Snorkel Surveys of Fish Distribution and Use   Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER:  Green River                   DATE: October 10, 1986

DISCHARGE OF RIVER:  228 cfs at Purification Plant gage
                       352 cfs at Auburn gage

REACH OF RIVER SNORKELED: RM 27.2 to 27.8 at downstream Kent site. We snorkeled from 0.5 mile upstream of transect 3 Kent site (RM 27.8) downstream to transect 1 (RM 27.2).

VISIBILITY:  50 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coho adults (6-12 lbs.)</td>
<td>10</td>
</tr>
<tr>
<td>Chinook adults (15-20 lbs.)</td>
<td>4</td>
</tr>
<tr>
<td>Whitefish</td>
<td>20</td>
</tr>
<tr>
<td>Trout juveniles (5-6 in.)</td>
<td>6</td>
</tr>
<tr>
<td>Steelhead adult (7 lbs.)</td>
<td>1</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: most of the fish were observed in the pool upstream of transect 3.

REACH OF RIVER SNORKELED: RM 32.7 to 33.7. We started at Highway 18 bridge (RM 33.7) and went downstream for 1 mile.

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coho adults (1/2 were dark)</td>
<td>2000</td>
</tr>
<tr>
<td>Chinook adults</td>
<td>500</td>
</tr>
<tr>
<td>Chinook adults (dead)</td>
<td>5</td>
</tr>
<tr>
<td>Chinook juveniles (5-6 in.)</td>
<td>50</td>
</tr>
<tr>
<td>Trout juveniles (4-5 in.)</td>
<td>40</td>
</tr>
<tr>
<td>Whitefish (10-15 in.)</td>
<td>80</td>
</tr>
<tr>
<td>Suckers (large)</td>
<td>20</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: Many redds were observed in 6 to 10 feet of water with substrate of small cobble and large gravel. Many redds were also observed in 1.5 to 2 feet of water with substrate of small cobble and large gravel. Not many chinook were on the redds. The peak spawning time for chinook was over.

OBSERVATIONS BY: Brad Caldwell & Stephen Hirschey

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Appendix H1  Snorkel Surveys of Fish Distribution and Use  Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER:  Green River                  DATE:  October 14, 1986

DISCHARGE OF RIVER:  208 cfs at Purification Plant gage
                      340 cfs at Auburn gage

REACH OF RIVER SNORKELED: RM 60.3, transect 1, at the Hosey site.

VISIBILITY:  8 feet

SPAWNING CHINOOK OBSERVATIONS

<table>
<thead>
<tr>
<th>Depth</th>
<th>Velocity</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4 ft.</td>
<td>2.4 fps</td>
<td>small cobble 70%, large gravel 30%</td>
</tr>
<tr>
<td>1.7 ft.</td>
<td>1.82 fps</td>
<td>small cobble 70%, large gravel 30%</td>
</tr>
<tr>
<td>1.0 ft.</td>
<td>2.92 fps</td>
<td>small cobble 80%, large gravel 20%</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: The spawning observations were taken at 35 and 120 feet downstream of transect 1 on active redds. Twenty to 30 chinook were observed over the spawning bar. Parts of the cobble bar were exposed in the center of the channel.

REACH OF RIVER SNORKELED: RM 60.4 at the gravel bar 100 yards upstream of the pipe bridge and 100 yards downstream of transect 2 of the Hosey site.

SPAWNING CHINOOK OBSERVATIONS

<table>
<thead>
<tr>
<th>Depth</th>
<th>Velocity</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3 ft.</td>
<td>1.26 fps</td>
<td>small cobble 50%, large gravel 50%</td>
</tr>
<tr>
<td>1.5 ft.</td>
<td>1.09 fps</td>
<td>large cobble 50%, large gravel 50%</td>
</tr>
<tr>
<td>1.2 ft.</td>
<td>0.45 fps</td>
<td>large cobble 50%, large gravel 50%</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: Twenty feet of the channel against the south shore of the gravel bar where steelhead spawned last May was out of the water.

REACH OF RIVER SNORKELED: RM 60.6. This was 100 feet upstream of transect 4 at the head of the cascade. The chinook were actively spawning on two redds.

SPAWNING CHINOOK OBSERVATIONS

<table>
<thead>
<tr>
<th>Depth</th>
<th>Velocity</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9 ft.</td>
<td>1.24 fps</td>
<td>small cobble 60%, boulder 40%</td>
</tr>
<tr>
<td>1.6 ft.</td>
<td>1.75 fps</td>
<td>large gravel 40%, small cobble, 30%, boulder 30%</td>
</tr>
</tbody>
</table>

SPECIES OBSERVED          NUMBER OBSERVED
Trout juveniles (6 in.)    18
Trout adult (12 in.)       1
Whitefish                 12
Appendix H1  Snorkel Surveys of Fish Distribution and Use  Continued

ECOLOGY SNORKELING OBSERVATIONS ON GREEN RIVER, OCT. 14, 1988 Continued

REACH OF RIVER SNORKELED: RM 60.8, transect 5 at the Hosey site.

SPAWNING CHINOOK OBSERVATIONS

<table>
<thead>
<tr>
<th>Depth</th>
<th>Velocity</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 ft</td>
<td>2.27 fps</td>
<td>small cobble 60%, large gravel 40%</td>
</tr>
<tr>
<td>1.1 ft</td>
<td>2.91 fps</td>
<td>large cobble 40%, small cobble 30%</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: Chinook redds were in the center of the channel. Redds were observed in six feet of water downstream of transect five, but could not be measured.

REACH OF RIVER SNORKELED: RM 60.8, transect 6 at the Hosey site.

SPAWNING CHINOOK OBSERVATIONS

<table>
<thead>
<tr>
<th>Depth</th>
<th>Velocity</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9 ft</td>
<td>1.48 fps</td>
<td>large cobble 40%, small cobble 40%, large gravel 20%</td>
</tr>
<tr>
<td>1.4 ft</td>
<td>1.71 fps</td>
<td>small cobble 50%, large 50%</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: There were fresh redds, but we did not see fish on the redds. The redds were in the center of the channel.

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook adults</td>
<td>20</td>
</tr>
<tr>
<td>Chinook adults (dead)</td>
<td>3</td>
</tr>
<tr>
<td>Whitefish</td>
<td>6</td>
</tr>
<tr>
<td>Trout juveniles (6 in.)</td>
<td>10</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: These fish were observed in the pool upstream of transect six.
Appendix H1  Snorkel Surveys of Fish Distribution and Use  Continued

ECOLOGY SNORKELING OBSERVATIONS ON THE GREEN RIVER OCT. 14, 1988
Continued

REACH OF RIVER SNORKELED: At RM 35.5. Just upstream of transect 7 at the Nealy bridge site is a 40 yard long riffle on the right side of the river looking downstream.

SPAWNING CHINOOK OBSERVATIONS

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Velocity (fps)</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6</td>
<td>2.96</td>
<td>large gravel 50%, small cobble 40%</td>
</tr>
<tr>
<td>2.8</td>
<td>3.03</td>
<td>small cobble 50%, large gravel 50%</td>
</tr>
<tr>
<td>2.0</td>
<td>3.71</td>
<td>large cobble 50%, large gravel 50%</td>
</tr>
<tr>
<td>1.0</td>
<td>1.74</td>
<td>small cobble 70%, small gravel 30%</td>
</tr>
<tr>
<td>1.5</td>
<td>2.34</td>
<td>small cobble 50%, large gravel 50%</td>
</tr>
<tr>
<td>1.3</td>
<td>3.00</td>
<td>small cobble 50%, large gravel 50%</td>
</tr>
<tr>
<td>2.3</td>
<td>2.93</td>
<td>large gravel 60%, large cobble 40%</td>
</tr>
<tr>
<td>2.1</td>
<td>3.78</td>
<td>small cobble 60%, large gravel 40%</td>
</tr>
<tr>
<td>1.7</td>
<td>2.09</td>
<td>large gravel 70%, small cobble 30%</td>
</tr>
<tr>
<td>1.4</td>
<td>1.75</td>
<td>large cobble 50%, small gravel 30%, medium gravel 20%</td>
</tr>
</tbody>
</table>

SPECIES OBSERVED NUMBER OBSERVED
Chinook adults 20
chinook adults (dead) 18
Whitefish 12
Trout juveniles (6 in.) 4
Trout juveniles (4 in.) 10

GENERAL COMMENTS: Upstream from transect 7 there were about 30 continuous redds in the deep, fast water about 4 feet from the bank. From transect 7 to below transect 5 no redds were observed due to slow velocities. Spawning was heavy in the riffle and head of riffle just downstream of transect 5.

REACH OF RIVER SNORKELED: At RM 35.3 at transect 4 of the Nealy Bridge site.

SPECIES OBSERVED NUMBER OBSERVED
Chinook adults 9
Trout juveniles (4-5 in.) 10

SPAWNING CHINOOK OBSERVATIONS

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Velocity (fps)</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4</td>
<td>1.76</td>
<td>large gravel 80%, small cobble 20%</td>
</tr>
<tr>
<td>1.1</td>
<td>2.14</td>
<td>large gravel 70%, small cobble 30%</td>
</tr>
<tr>
<td>1.4</td>
<td>1.53</td>
<td>large gravel 50%, medium gravel 50%</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: Actively spawning salmon were on the three redds. There was evidence of mass spawning all the way across the channel with nine adult chinook in the area.
Appendix H1  Snorkel Surveys of Fish Distribution and Use  Continued

REACH OF RIVER SNORKELED: RM 35.3 to 35.0. We snorkeled the Nealy Bridge site from transect 4 (RM 35.3) down to Nealy bridge (RM 35.0).

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook adults</td>
<td>2</td>
</tr>
<tr>
<td>Chinook adults (dead)</td>
<td>9</td>
</tr>
<tr>
<td>Trout (12 in.)</td>
<td>4</td>
</tr>
<tr>
<td>Trout juveniles (6 in.)</td>
<td>10</td>
</tr>
<tr>
<td>Sucker adults</td>
<td>50</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: The chinook were spawning only in the riffles due to low flow and the resulting lack of velocity in the river. The water depth and substrate were adequate for spawning throughout the reach snorkeled but spawning areas were determined by the water velocities.

OBSERVATIONS BY: Brad Caldwell & Stephen Hirschey
Appendix H1  Snorkel Surveys of Fish Distribution and Use  Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER:  Green River  DATE:  October 18, 1986

DISCHARGE OF RIVER:  183 cfs at Purification Plant gage
                292 cfs at Auburn gage

REACH OF RIVER SNORKELED: RM 33.7 to RM 32.7. We snorkeled from the Highway 18 bridge
(RM 33.7) downstream for 1 mile.

VISIBILITY:  15 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coho adults (dark, holding)</td>
<td>25</td>
</tr>
<tr>
<td>Coho juveniles (5 in.)</td>
<td>2</td>
</tr>
<tr>
<td>Chinook adults spawning</td>
<td>15</td>
</tr>
<tr>
<td>Chinook adults (dead)</td>
<td>30</td>
</tr>
<tr>
<td>Chinook jacks spawning</td>
<td>8</td>
</tr>
<tr>
<td>Trout juveniles (4-7 in.)</td>
<td>70</td>
</tr>
<tr>
<td>Trout (7-12 in.)</td>
<td>6</td>
</tr>
<tr>
<td>Sucker adults</td>
<td>1000</td>
</tr>
<tr>
<td>Whitefish adults</td>
<td>40</td>
</tr>
<tr>
<td>Steelhead adults</td>
<td>1</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: Most of the chinook redds were observed at the head of the riffle, just
upstream of the clay bluff. The suckers were in the large glide downstream of the bluff. Chinook jacks
were on redds in water less than 1 foot deep adjacent to overhanging cover.

OBSERVATIONS BY:  Brad Caldwell and Stephen Hirschey
ECOLOGY SNORKELING OBSERVATIONS

RIVER: Green River                  DATE: October 21, 1986

DISCHARGE OF RIVER: 155 cfs at Purification Plant gage
                     286 cfs at Auburn gage

REACH OF RIVER SURVEYED: RM 35.0 to RM 34.8. We walked from Nealy Bridge (RM 35.0) downstream to 50 yards upstream of transect 1 (RM 34.8).

VISIBILITY: 15 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook adults</td>
<td>3</td>
</tr>
<tr>
<td>Chinook adults (dead)</td>
<td>34</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: No active chinook spawning was observed.

REACH OF RIVER SURVEYED: At RM 40.6. We walked transects 1 and 2 of the Flaming Geyser site.

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook adults (dead)</td>
<td>5</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: Three redds were observed in the head of the riffle just downstream of transect 1.

REACH OF RIVER SURVEYED: At RM 43.6. We walked transects 3, 4 and 5 of the Flaming Geyser site.

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook adults (dead)</td>
<td>4</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: No live chinook were observed. Redds were observed in the riffle at transect 4.

OBSERVATIONS BY: Stephen Hirschey & Doug Weston (WCC)
Appendix H1  Snorkel Surveys of Fish Distribution and Use  Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER:  Green River  Date:  October 24, 1986

DISCHARGE OF RIVER:  133 cfs at Purification Plant gage
                   234 cfs at Auburn gage

REACH OF RIVER SNORKELED:  RM 35.5 to 35.0.  We snorkeled the Nealy Bridge site from upstream of transect 7 (RM 35.5) down to Nealy bridge (RM 35.0).

VISIBILITY:  10-12 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook adults</td>
<td>3</td>
</tr>
<tr>
<td>Chinook adults (dead)</td>
<td>18</td>
</tr>
</tbody>
</table>

COMMENTS:  No chinook were actively spawning at the Nealy Bridge site.

REACH OF RIVER SNORKELED:  RM 39.5 to 39.0.  We snorkeled from transect 2 at the Car Body site (RM 39.5) downstream for 0.5 mile.

VISIBILITY:  10-12 FEET

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook adults</td>
<td>3</td>
</tr>
<tr>
<td>Chinook adults (dead)</td>
<td>4</td>
</tr>
<tr>
<td>Sucker adults</td>
<td>80</td>
</tr>
<tr>
<td>Whitefish</td>
<td>40</td>
</tr>
<tr>
<td>Trout adults (12 in.)</td>
<td>4</td>
</tr>
<tr>
<td>Trout juveniles (4 in.)</td>
<td>30</td>
</tr>
<tr>
<td>Trout juveniles (6 in.)</td>
<td>35</td>
</tr>
<tr>
<td>Searun Cutthroat trout (2-4 lbs.)</td>
<td>3</td>
</tr>
<tr>
<td>Steelhead adult (10 lbs.)</td>
<td>1</td>
</tr>
</tbody>
</table>

OBSERVATIONS BY:  Stephen Hirschey & Doug Weston (WCC)
Appendix H1  Snorkel Surveys of Fish Distribution and Use  Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER:  Green River  DATE:  November 4, 1986

DISCHARGE OF RIVER:  157 cfs at Purification Plant gage
                        285 cfs at Auburn gage

REACH OF RIVER SNORKELED: RM 33.1 to RM 32.9.  We snorkeled from an area of deep pools
(RM 33.1) downstream of the Highway 18 bridge down for 0.2 mile.

VISIBILITY:  10 feet.

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coho adults</td>
<td>55</td>
</tr>
<tr>
<td>Coho adults (dead)</td>
<td>6</td>
</tr>
<tr>
<td>Trout juveniles (4-6 in.)</td>
<td>7</td>
</tr>
<tr>
<td>Whitefish adults</td>
<td>13</td>
</tr>
<tr>
<td>Sucker adults</td>
<td>45</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS:  The six dead coho were very bright and the mortality was probably not due to
spawning. No fish were seen in the riffle. Adult coho were observed under logs and near overhanging
vegetation.

REACH OF RIVER SNORKELED: RM 35.4 to 35.0. We snorkeled the Nealy Bridge site from transect 7
(RM 35.4) down to Nealy Bridge (RM 35.0).

VISIBILITY:  10 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pink adult (in spawning colors)</td>
<td>1</td>
</tr>
<tr>
<td>Sockeye adult (in spawning colors)</td>
<td>1</td>
</tr>
<tr>
<td>Coho adults (dark)</td>
<td>60</td>
</tr>
<tr>
<td>Chum adults (dark)</td>
<td>3</td>
</tr>
<tr>
<td>Chum adults (dead)</td>
<td>2</td>
</tr>
<tr>
<td>Chinook (dead)</td>
<td>3</td>
</tr>
<tr>
<td>Whitefish</td>
<td>40</td>
</tr>
<tr>
<td>Sucker adults</td>
<td>80</td>
</tr>
<tr>
<td>Trout juvenile (6 in.)</td>
<td>1</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS:  Many fresh coho test redds were observed between transect 7 and Nealy
Bridge. Heavy algae growth over chinook redds seen two weeks ago.

OBSERVATIONS BY: Brad Caldwell & Stephen Hirschey
Appendix H1  Snorkel Surveys of Fish Distribution and Use  Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER: Green River                  DATE: December 4, 1986

DISCHARGE OF RIVER:  1590 cfs at Purification Plant gage
                      2170 cfs at Auburn gage

REACH OF RIVER SURVEYED: Nealy Bridge site

VISIBILITY: poor, water was very turbid

GENERAL COMMENTS: The water was too turbid to observe any fish.

OBSERVATIONS BY: Stephen Hirschey and Jim Farley (WDF)
Appendix H1  Snorkel Surveys of Fish Distribution and Use  Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER: Green River  DATE: December 12, 1986

DISCHARGE OF RIVER: 510 cfs at Purification Plant gage
970 cfs at Auburn gage

REACH OF RIVER SNORKELED: RM 35.4 to 35.2 and RM 34.9 to 34.4. Snorkeled the Nealy Bridge site from transect 7 (RM 35.4) to transect 4 (RM 35.2), and from transect 3 (RM 34.9) to the large pool downstream of transect one (RM 34.4).

VISIBILITY: 7 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coho adults (dead)</td>
<td>1</td>
</tr>
<tr>
<td>Coho adults</td>
<td>2</td>
</tr>
<tr>
<td>Chum adults</td>
<td>2</td>
</tr>
<tr>
<td>Chum adults (dead)</td>
<td>2</td>
</tr>
<tr>
<td>Sucker adult (dead)</td>
<td>1</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS: No juveniles were seen in any of the rootwads along the bank.

OBSERVATIONS BY: Stephen Hirschey
Appendix H1  Snorkel Surveys of Fish Distribution and Use   Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER:  Green River  DATE:  December 18, 1986

DISCHARGE OF RIVER:  431 cfs at Purification Plant gage
793 cfs at Auburn gage

REACH OF RIVER SNORKELED:  RM 61.0 to RM 60.3. We snorkeled from the Tacoma Diversion Dam (RM 61.0) to 100 feet downstream of transect one (RM 60.3).

VISIBILITY:  6 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coho adults (dark)</td>
<td>4</td>
</tr>
<tr>
<td>Sockeye adult (dead)</td>
<td>1</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS:  According to Pat at the Headworks, large numbers of red-colored fish had congregated at the diversion within the last week and were also spawning downstream under the pipe bridge at the Headworks. No juvenile salmonids were seen.

OBSERVATIONS BY: Brad Caldwell & Stephen Hirschey
Appendix H1  Snorkel Surveys of Fish Distribution and Use    Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER:  Green River  DATE:  January 6, 1987

DISCHARGE OF RIVER:  578 cfs at Purification Plant gage
1030 cfs at Auburn gage

REACH OF RIVER SNORKELED:  RM 39.9 to 38.6. We snorkeled from transect 7 at the Car Body site (RM 39.9) downstream for 1.3 miles.

VISIBILITY:  8-10 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chum adults (dead)</td>
<td>24</td>
</tr>
<tr>
<td>Chum adult</td>
<td>1</td>
</tr>
<tr>
<td>Steelhead adult</td>
<td>2</td>
</tr>
<tr>
<td>Trout juveniles (4-6 in.)</td>
<td>9</td>
</tr>
<tr>
<td>Trout (12 in.)</td>
<td>1</td>
</tr>
<tr>
<td>Sucker adults</td>
<td>60</td>
</tr>
<tr>
<td>Whitefish</td>
<td>30</td>
</tr>
</tbody>
</table>

REACH OF RIVER SNORKELED:  RM 43.8 to RM 43.6. We snorkeled at the Flaming Geyser State Park upstream of our IFIM transects at RM 43.6.

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sockeye adults (spawning colors)</td>
<td>2</td>
</tr>
<tr>
<td>Chum adults</td>
<td>2</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS:  No steelhead adults were seen at Flaming Geyser State Park. The hatchery steelhead run had been expected to be present.

OBSERVATIONS BY:  Brad Caldwell & Stephen Hirschey.
Appendix H1  Snorkel Surveys of Fish Distribution and Use    Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER:  Green River                DATE:  January 13, 1987

DISCHARGE OF RIVER:  444 at Purification Plant gage
                                      996 cfs at Auburn gage

REACH OF RIVER SNORKELED: RM 32.8 to RM 32.7. We snorkeled from below Soos Creek at RM
                                  32.8 downstream for 0.1 mile.

VISIBILITY:  4 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steelhead adult</td>
<td>1</td>
</tr>
</tbody>
</table>

REACH OF RIVER SNORKELED: RM 42.9 to RM 42.8. We snorkeled from an area downstream of
the entrance to Flaming Geyser State Park at RM 42.9 downstream for 0.1 mile.

VISIBILITY:  7 to 8 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucker adults</td>
<td>3</td>
</tr>
<tr>
<td>Whitefish</td>
<td>4</td>
</tr>
</tbody>
</table>

REACH OF RIVER SNORKELED: RM 43.6 to RM 43.4. We snorkeled starting at the restrooms in
Flaming Geyser State Park (RM 43.6) and went downstream to the large bend in the river upstream of the
bridge (RM 43.4).

VISIBILITY:  7 to 8 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steelhead adults</td>
<td>1</td>
</tr>
<tr>
<td>Sucker adults</td>
<td>5</td>
</tr>
<tr>
<td>Whitefish</td>
<td>3</td>
</tr>
</tbody>
</table>

OBSERVATIONS BY:  Brad Caldwell & Stephen Hirschey
ECOLOGY SNORKELING OBSERVATIONS

RIVER: Green River DATE: April 10, 1987

DISCHARGE OF RIVER: 941 cfs at Purification Plant gage
1410 cfs at Auburn gage

REACH OF RIVER SURVEYED: River Mile 35.4 to RM 34.9. We walked the Nealy Bridge area from 100 yards upstream of transect seven (RM 35.4) to transect 3 (RM 34.9).

VISIBILITY: Less than 1 foot

SPECIES OBSERVED NUMBER OBSERVED
Steelhead adult (dead) 1

REACH OF RIVER SNORKELED: RM 43.4 to RM 43.0. Snorkeled from the big bend in the river upstream of Flaming Geyser State Park bridge (RM 43.4) down to the bridge (RM 43.0). The current was fast, about 3.5 fps.

VISIBILITY: 7 feet

SPECIES OBSERVED NUMBER OBSERVED
Whitefish (12 in.) 10
Sucker adults 30
Steelhead adults (8-10 lbs.) 10

OBSERVATIONS BY: Stephen Hirschey
Appendix H1  Snorkel Surveys of Fish Distribution and Use  Continued

ECOLOGY SNORKELING OBSERVATIONS

RIVER:  Green River  DATE:  April 18, 1987

DISCHARGE OF RIVER:  1370 cfs at Purification Plant gage
1860 cfs at Auburn gage

REACH OF RIVER SNORKELED:  RM 35.4 to RM 34.9.  We snorkeled the Nealy Bridge area from 100 yards upstream of Transect 7 (RM 35.4) to Transect 3 (RM 34.9).

VISIBILITY:  1.5 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucker adults (3 lbs.)</td>
<td>4</td>
</tr>
</tbody>
</table>

REACH OF RIVER SNORKELED:  RM 43.7 to RM 43.0.  We snorkeled from the pool upstream of the flaming geyser (RM 43.7) at Flaming Geyser State Park down to the park’s bridge (RM 43.0).

VISIBILITY:  6 feet

<table>
<thead>
<tr>
<th>SPECIES OBSERVED</th>
<th>NUMBER OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suckers (3 lbs.)</td>
<td>3</td>
</tr>
</tbody>
</table>

OBSERVATIONS BY:  Brad Caldwell & Stephen Hirschey
### Appendix H2. Fish Periodicity Chart (DNR, 1981)

**Timing of Freshwater Phases of Anadromous Fish in the Duwamish-Green Basin**

<table>
<thead>
<tr>
<th>Species</th>
<th>Fresh Water Life Phase</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>J  F  M  A  M  J  J  A  S  O  N  D</td>
</tr>
<tr>
<td>Summer Steelhead Trout</td>
<td>Upstream Migration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spawning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incubation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juvenile Rearing**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juv. Outmigration</td>
<td></td>
</tr>
<tr>
<td>Winter Steelhead Trout</td>
<td>Upstream Migration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spawning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incubation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juvenile Rearing**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juv. Outmigration</td>
<td></td>
</tr>
<tr>
<td>Searum Cutthroat Trout</td>
<td>Upstream Migration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spawning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incubation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juvenile Rearing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juv. Outmigration</td>
<td></td>
</tr>
<tr>
<td>Fall Chinook Salmon</td>
<td>Upstream Migration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spawning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incubation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juvenile Rearing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juv. Outmigration</td>
<td></td>
</tr>
<tr>
<td>Coho Salmon</td>
<td>Upstream Migration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spawning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incubation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juvenile Rearing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juv. Outmigration</td>
<td></td>
</tr>
<tr>
<td>Chum Salmon</td>
<td>Upstream Migration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spawning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incubation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juvenile Rearing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juv. Outmigration</td>
<td></td>
</tr>
</tbody>
</table>

*Courtesy of Department of Fisheries and Game and Pacific Northwest River Basins Commission*

**Normally extends over two-year period**
OBSERVATIONS OF DEPTH USED BY
SPAWNING STEELHEAD TROUT
GREEN RIVER

DEPTH IN FEET

NUMBER OF OBSERVATIONS

0.9 1.0 1.1 1.2 1.3 1.4 1.6 1.7 1.8 1.9 2.0 2.1 2.3 2.5 2.6 2.7 2.8 2.9 3.0 3.1 3.5 3.7

DATA COLLECTED ON 4-25-86, 5-9-86, & 5-5-88
OBSERVATIONS OF VELOCITIES USED BY SPAWNING STEELHEAD TROUT GREEN RIVER

VELOCITIES MEASURED ARE MEAN COLUMN VELOCITIES
DATA COLLECTED ON 5-9-86 & 5-5-88
OBSERVATIONS OF DEPTH USED BY SPAWNING CHINOOK SALMON GREEN RIVER

DATA COLLECTED ON 9–25–86 & 10–14–86
OBSERVATIONS OF VELOCITIES USED BY
SPAWNING CHINOOK SALMON
GREEN RIVER

VELOCITIES MEASURED ARE MEAN COLUMN VELOCITIES
DATA COLLECTED ON 10-14-86
Appendix H4. Depth and Velocity Habitat-Use Curves

STEELHEAD SPAWNING – RIVER

DEPTH
0.00
0.50
1.00
5.00
10.00
99.00

PREFERENCE
0.00
1.00
1.00
1.00
1.00

ECOLOGY 7/30/87

DEPTH (FEET)
0
1
2
3
4
5
6
7
8

PREFERENCE VALUE
0
0.2
0.4
0.6
0.8
1.0

125
STEELHEAD SPAWNING - RIVER

VELOCITY  PREFERENCE
0.00      0.00
0.50      0.20
0.75      0.50
1.90      1.00
2.50      1.00
5.00      0.00
99.00     0.00

ECOLOGY 7/30/87
STEELHEAD JUVENILE – RIVER

<table>
<thead>
<tr>
<th>VELOCITY (FT./SEC.)</th>
<th>PREFERENCE VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>0.30</td>
<td>1.00</td>
</tr>
<tr>
<td>0.80</td>
<td>0.97</td>
</tr>
<tr>
<td>1.60</td>
<td>0.87</td>
</tr>
<tr>
<td>2.00</td>
<td>0.81</td>
</tr>
<tr>
<td>2.60</td>
<td>0.68</td>
</tr>
<tr>
<td>2.70</td>
<td>0.66</td>
</tr>
<tr>
<td>2.80</td>
<td>0.58</td>
</tr>
<tr>
<td>2.90</td>
<td>0.32</td>
</tr>
<tr>
<td>3.00</td>
<td>0.17</td>
</tr>
<tr>
<td>3.10</td>
<td>0.13</td>
</tr>
<tr>
<td>3.60</td>
<td>0.06</td>
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<tr>
<td>4.00</td>
<td>0.01</td>
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<tr>
<td>4.01</td>
<td>0.00</td>
</tr>
<tr>
<td>99.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

ECOLOGY 7/30/87
COHO SALMON JUVENILE - RIVER

VELOCITY | PREFERENCE
---------|---------
0.00     | 0.23    
0.15     | 0.61    
0.30     | 1.00    
0.90     | 1.00    
1.30     | 0.55    
1.90     | 0.31    
2.60     | 0.06    
3.00     | 0.00    
100.00   | 0.00    

ECOLOGY 3/05/87
Appendix H5. Substrate/Cover Code.

DEPARTMENTS OF FISHERIES & WILDLIFE
INSTREAM FLOW STUDIES SUBSTRATE AND COVER CODE APPLICATION 11/23/87

The three-digit code used describes the dominant substrate (the first number), the subdominant substrate (the second number), and the percent of only the dominant substrate (the third number). The percent of the subdominant substrate can be determined by subtraction. Dominant substrate is determined by the largest quantity of a certain substrate, not by the size of the substrate. The sum of the percent dominant and the percent subdominant will total 100 percent. The coding will not allow the dominant percent to be less than 50 percent, or greater than 90 percent. All other preference values are determined by using weighted averages. The value of the dominant substrate is multiplied by the percent of the dominant substrate, and the product is added to the product of the subdominant substrate times the percent of subdominant substrate. The sum of all the codes observed times their preference value will be a value between 0.0 and 1.0. The coding should also give a preference value of zero for the entire substrate observation when the code is class zero, one, or two, and is 50 percent or more of the observation. Where there is a situation where addition of two values could equal more than 1.0, the value will default to 1.0. Overhanging vegetation should be counted as cover if it is within 3 to 4 feet of the water surface. Cover values should be incorporated with the substrate values for both salmon and steelhead juvenile life stages and for chinook and steelhead adult holding.

### LIFE STAGE AND VALUE OF SUBSTRATE

<table>
<thead>
<tr>
<th>CODE</th>
<th>Substrate Size</th>
<th>Juvenile &amp; Adult</th>
<th>SPAWNING</th>
<th>SALMON</th>
<th>STEELHEAD &amp; TROUT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rearing</td>
<td></td>
<td></td>
<td>Spawning</td>
</tr>
<tr>
<td>0</td>
<td>Detritus</td>
<td>.1</td>
<td>0</td>
<td>.1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Silt, Clay</td>
<td>.1</td>
<td>0</td>
<td>.1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Sand</td>
<td>.1</td>
<td>0</td>
<td>.1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Small Gravel</td>
<td>0.1-0.5</td>
<td>.1</td>
<td>.3</td>
<td>0.1</td>
</tr>
<tr>
<td>4</td>
<td>Medium Gravel</td>
<td>.5-1.5</td>
<td>.3</td>
<td>1</td>
<td>.3</td>
</tr>
<tr>
<td>5</td>
<td>Large Gravel</td>
<td>1.5-3.0</td>
<td>.3</td>
<td>1</td>
<td>.3</td>
</tr>
<tr>
<td>6</td>
<td>Small Cobble</td>
<td>3.0-6.0</td>
<td>.5</td>
<td>1</td>
<td>.3</td>
</tr>
<tr>
<td>7</td>
<td>Large Cobble</td>
<td>6.0-12.0</td>
<td>.7</td>
<td>.3 *</td>
<td>.3</td>
</tr>
<tr>
<td>8</td>
<td>Boulder</td>
<td>1.0</td>
<td>0</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>Bedrock</td>
<td>3.0</td>
<td>0</td>
<td>3.0</td>
<td>0</td>
</tr>
<tr>
<td>0.1</td>
<td>Undercut bank</td>
<td>1.0</td>
<td>0</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>0.2</td>
<td>Overhanging Vegetation</td>
<td>1.0</td>
<td>1.0</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>0.3</td>
<td>Root Wad</td>
<td>1.0</td>
<td>0</td>
<td>1.0</td>
<td>0</td>
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<tr>
<td>0.4</td>
<td>Log Jam</td>
<td>1.0</td>
<td>0</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>0.5</td>
<td>Log Instream</td>
<td>.8</td>
<td>0</td>
<td>.8</td>
<td>0</td>
</tr>
<tr>
<td>0.6</td>
<td>Submerged Vegetation</td>
<td>1.0</td>
<td>0</td>
<td>.8</td>
<td>0</td>
</tr>
<tr>
<td>0.8</td>
<td>Grass/Bushes Up on Bank</td>
<td>.1</td>
<td>0</td>
<td>.1</td>
<td>0</td>
</tr>
<tr>
<td>0.9</td>
<td>Fine Organic Substrate</td>
<td>.1</td>
<td>0</td>
<td>.1</td>
<td>0</td>
</tr>
</tbody>
</table>

(* 0.6 for chinook spawning can be used, depending on river size)
Appendix I

INFLOWS FOR THE KENT, NEALY BRIDGE, AND CAR BODY SITES
Appendix I. Inflows for the Kent, Nealy Bridge, and Car Body sites  
(Ten-day, 50% exceedence flows).

<table>
<thead>
<tr>
<th>Month</th>
<th>Kent Site Inflow in cfs</th>
<th>Nealy Bridge and Car Body Sites Inflow in cfs</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-10</td>
<td>767</td>
<td>541</td>
</tr>
<tr>
<td>11-20</td>
<td>718</td>
<td>518</td>
</tr>
<tr>
<td>21-31</td>
<td>746</td>
<td>520</td>
</tr>
<tr>
<td>February</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-10</td>
<td>735</td>
<td>511</td>
</tr>
<tr>
<td>11-20</td>
<td>624</td>
<td>395</td>
</tr>
<tr>
<td>21-28</td>
<td>638</td>
<td>428</td>
</tr>
<tr>
<td>March</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-10</td>
<td>555</td>
<td>367</td>
</tr>
<tr>
<td>11-20</td>
<td>500</td>
<td>325</td>
</tr>
<tr>
<td>21-31</td>
<td>431</td>
<td>261</td>
</tr>
<tr>
<td>April</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-10</td>
<td>521</td>
<td>365</td>
</tr>
<tr>
<td>11-20</td>
<td>558</td>
<td>406</td>
</tr>
<tr>
<td>21-30</td>
<td>379</td>
<td>239</td>
</tr>
<tr>
<td>May</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-10</td>
<td>271</td>
<td>155</td>
</tr>
<tr>
<td>11-20</td>
<td>303</td>
<td>206</td>
</tr>
<tr>
<td>21-31</td>
<td>286</td>
<td>201</td>
</tr>
<tr>
<td>June</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-10</td>
<td>295</td>
<td>220</td>
</tr>
<tr>
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These statistics are ten-day averages (Log Pearson) from 1962-1986 from USGS gage data. The Kent site inflow was calculated by subtracting the flows at the Purification Plant gage from the flows at the Auburn gage. The inflows at the Nealy Bridge and Car Body sites were calculated by adding flows at the Purification Plant gage and the Big Soos Creek gage and subtracting this total from the flows at the Auburn gage.
Appendix J

LITERATURE CITED
LITERATURE CITED


Appendix K

ECOLOGY’S MISSION STATEMENT
OUR MISSION
WASHINGTON STATE DEPARTMENT OF ECOLOGY

The mission of the Department of Ecology is to protect, preserve and enhance Washington's environment and promote the wise management of our air, land and water for the benefit of current and future generations.

To accomplish this mission, Ecology will:

- Recognize its most valuable asset is its dedicated and committed employees and it will provide necessary support, training and professional development.

- Promote prevention and conservation as the most effective ways to preserve our natural resources and protect the environment.

- Enforce environmental laws and regulations in a fair and firm manner.

- Provide public education programs to promote wise use of our natural resources and encourage environmental protection.

- Offer information, technical and financial assistance to help the public, governments, businesses and industries comply with environmental laws and regulations.

- Promote the recognition that compliance with environmental laws and regulations is compatible with a sound economy.

- Promote meaningful public involvement in the development of rules, regulations and new initiatives.

- Provide leadership in addressing emerging problems and strive to bring public agencies and diverse interest groups together to address environmental issues.

- Use an integrated approach to resolve environmental issues.

- Place special emphasis on educating and working with youth to create a strong environmental ethic.

- Help state agencies set an example in environmental protection.

- Work with the executive and legislative branches to promote sound environmental policy.