AQUATIC EVALUATION

AND INSTREAM FLOW RECOMMENDATIONS

FOR SELECTED REACHES OF GERMAN GULCH CREEK

SILVER BOW COUNTY, MONTANA

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INTRODUCTION

This study was initiated to provide the State of Montana with baseline aquatic resource data on German Gulch Creek and to provide recommended minimum instream flow to protect this resource. The study was funded by the Montoro Gold Company via the Montana Department of State Lands utilizing funds collected under MEPA.

German Gulch Creek is a tributary of Silver Bow Creek, which in turn flows into the Clark Fork River. This study was initiated in response to a proposed surface mine, ore processing plant, and tailings disposal facility in the German Gulch drainage by the Montoro Gold Company of Reno, Nevada.

Information provided in this report includes quantification of fish populations, quantification of instream flows necessary for maintaining the existing fishery resource, and baseline water quality, periphyton and macroinvertebrate data.

FISH POPULATIONS

Methods

Fish populations in the study sections were sampled using a bank electrofishing unit basically consisting of a 110-v Kawasaki gas generator, a Fisher shocker box, a 500-ft cord, a stationary negative electrode, and a hand-held mobile positive electrode. A mild electric shock temporarily immobilizes the fish located in the immediate vicinity of the positive electrode, allowing them to be dip netted. The fish capturing efficiency of the unit is highly variable, since efficiency rates are influenced by stream size, the magnitude of the flow, water clarity, specific conductance, water temperature, cover types, and the species and size of the fish.

The fish population was estimated using a mark-recapture method which allows for the estimation of the total numbers and pounds (the standing crop) of fish within a stream section. For German Gulch, standing crop estimates were obtained for three 1000-ft study sections (Figure 1).

The standing crop estimates require at least two electrofishing runs through each study section. During the first (marking) run, all captured fish are anesthetized, marked with a partial caudal fin clip so they can be later identified, and released after individual lengths and weights are recorded. It is desirable to make the second (recapture) run at least two weeks after the marking run. This two-week period allows the marked fish to randomly redistribute themselves throughout the population. During the recapture run, all captured fish are again anesthetized and released after the lengths and weights of all new (unmarked) fish, and the length only of all marked fish, are recorded. The population estimate is basically obtained using the formula

$$P = \frac{MC}{R}$$

where P = estimated number of fish,

M = number of initially marked individuals,

C = number of marked and unmarked fish collected during the recapture run, and

R = number of marked fish collected during the recapture run.

This formula, although somewhat modified in its final form for statistical reasons, is the basis of the mark-recapture technique.

The numbers of fish were estimated by length groups. Those 0.5-inch length intervals having similar or equal recapture efficiencies comprise a length group. This grouping is necessary because recapture efficiencies are dependent on fish size. Generally, electrofishing is more effective for capturing larger fish due to their greater surface area and higher visibility when in the electrical field. Because recapture efficiencies are length-related, the number of fish must be estimated by length groups, then added to obtain the total estimate. Generally, at least seven recaptures are needed per length group in order to obtain a statistically valid estimate.

Pounds of fish are obtained by multiplying the average weight of the fish within each length group by the estimated number, then adding to obtain the total pounds. Estimates can also be obtained for different age groups of fish. This mark-recapture technique, which is thoroughly discussed by Vincent (1971 and 1974), has been adapted for computer analysis by the Montana Department of Fish, Wildlife and Parks (MDFWP).

Results

Durant Section

A 1000-ft section of German Gulch Creek near the confluence with Silver Bow Creek was electrofished on July 26 and August 7, 1984. Game fish captured were westslope cutthroat trout, brook trout and brown trout. No non-game fish were captured. Table 1 summarizes the electrofishing survey data for the Durant Section.

The standing crop of trout in this section was estimated using a mark-recapture method (Table 2). This section supports about 346 trout weighing 42 pounds. Westslope cutthroat trout accounted for 67% of the total trout numbers and 76% of the total biomass; brook trout accounted for 33% of the trout numbers and 24% of the biomass.

Average lengths and weights of westslope cutthroat and brook trout by age class are shown in Table 3.

Below Beefstraight Creek Section

A 1000-ft section of German Gulch Creek below the confluence of Beef-straight Creek was electrofished on July 26 and August 6, 1984. Game fish captured were westslope cutthroat trout and brook trout. No non-game fish were captured. Table 4 summarizes the electrofishing survey data for this section.

The standing crop of trout in this section was estimated using a mark-recapture method (Table 5). This section supports about 301 trout weighing 33 pounds. Westslope cutthroat trout accounted for 43% of the total trout numbers and 64% of the total trout biomass; brook trout accounted for 57% of the trout numbers and 36% of the biomass.

Average lengths and weights of westslope cutthroat and brook trout by age class are shown in Table 6.

Below Edward Creek Section

A 1000-ft section of German Gulch Creek below the confluence of Edward Creek was electrofished on July 26 and August 6, 1984. Game fish captured were westslope cutthroat trout and brook trout. No non-game fish were captured. Table 7 summarizes the electrofishing survey data for the Below Edward Creek Section.

The standing crop of trout in this section was estimated using a mark-recapture method (Table 8). This section supports about 209 trout weighing 16 pounds. Westslope cutthroat trout accounted for 80% of the total trout numbers and 88% of the biomass; brook trout accounted for 20% of the trout numbers and 12% of the biomass.

Average lengths and weights of westslope cutthroat and brook trout by age class are shown in Table 9.

Discussion

German Gulch Creek supports a unique and productive fishery. Of primary significance is the presence of a healthy population of genetically-pure westslope cutthroat trout. Tests conducted by the University of Montana Genetics Laboratory confirmed both the purity of this population and genetic distinctions from other populations of westslope cutthroat trout that have been examined (see Appendix A).

Westslope cutthroat trout are classified as a species of special concern by the State of Montana due to declining numbers, loss of habitat and interbreeding with other species. Pure westslope populations have been documented for only 25 Montana streams, representing 1.1% of the historic range (Liknes 1984). Liknes speculates that approximately 4% of the historic Montana range may still be occupied by pure westslope populations. A perusal of the population densities of pure-strain westslope cutthroat described by Liknes suggests German Gulch Creek supports one of the highest biomasses per stream of any of the pure westslope streams in Montana.

The trout population of German Gulch Creek is compared with those of 13 streams found on the adjoining Mount Haggin Wildlife Management Area in Table 10. German Gulch supports the second highest biomass of all of these streams, and the sixth highest numbers of trout. While German Gulch and Willow Creek are the only two streams in the area supporting cutthroat populations, the cutthroat population of Willow Creek has been determined to be of the Yellowstone strain (Oswald 1981).

The numbers, biomass and genetic purity of the westslope cutthroat population indicate a valuable fishery resource. Given the rarity of pure-strain westslope cutthroat trout populations and the presence of a biological barrier downstream (Silver Bow Creek) to prevent upstream migration and potential introgression of rainbow trout, every effort should be made to protect and enhance this population.

INSTREAM FLOW RECOMMENDATIONS

The instream flows needed to maintain the fish populations of German Gulch at their current level were quantified using the wetted perimeter/ inflection point method (Nelson 1984) (see Appendix B). Basically, the method provides a range of flows from which a single recommendation is selected. The flow at the high end of the range (the flow at the uppermost inflection point on the wetted perimeter-flow curve) is intended to maintain the high level of aquatic habitat potential. High level aquatic habitat potential is that flow regime which will consistently produce abundant, healthy and thriving aquatic populations. In the case of game fish species, these flows would produce abundant game fish populations capable of sustaining a good to excellent sport fishery for the size of stream involved. For rare, threatened or endangered species, flows to accomplish the high level of aquatic habitat maintenance would: 1) provide the high population levels needed to ensure the continued existence of that specie, or 2) provide the flow levels above those which would adversely affect the specie.

The flow at the low end of the range (the flow at the lowermost inflection point on the wetted perimeter-flow curve) provides for a low level of aquatic habitat potential. Flows to accomplish a low level of aquatic habitat maintenance would provide for only a low population of the species present. In the case of game fish species, a poor sport fishery could still be provided. For rare, threatened or endangered species, populations would exist at low or marginal levels. In some cases, this flow level would not be sufficient to maintain certain species.

The final recommendation is selected from this range of flows on the basis of the stream resource rating. The critical component of this rating is the fish population data. A marginal or poor fishery would likely justify a flow recommendation at or near the lower inflection point unless other considerations, such as the presence of species of special concern, warrant a higher flow. In general, only streams with exceptional resident fish populations or those providing crucial spawning and/or rearing habitats for migratory populations would be considered for a recommendation at or near the upper inflection point.

Because German Gulch supports exceptionally high numbers of genetically pure westslope cutthroat trout, a species of special concern in Montana, the flow at the uppermost inflection point on the wetted perimeter-flow curve is recommended for the period of June 16 through May 15.

For the high flow or snow runoff period of May 16 through June 15, the dominant discharge/channel morphology concept (Montana Department of Fish and Game 1979) was used to derive instream flow recommendations. The high flow recommendations are intended to flush the annual accumulation of bottom sediments and to maintain the existing channel morphology.

Recommendations were derived for two sites on German Gulch as described in the following sections.

German Gulch - Below Beefstraight Creek

Cross-sectional measurements for use in the wetted perimeter/inflection point method were made in a 96-ft section of German Gulch (SW, NW, NE, Sec. 26, T3N, R10W) located downstream from the confluence of Beefstraight Creek (Figure 1). Five riffle cross-sections were established in this section.

The wetted perimeter (WETP) computer program was calibrated to field data collected at flows of 13.3, 34.2 and 72.6 cfs.

The relationship between wetted perimeter and flow for the composite of five riffle cross-sections is shown in Figure 2. A prominent upper inflection point occurs at an approximate flow of 12 cfs. A flow of 12 cfs is therefore recommended for the low flow period of June 16 through May 15.

For the high flow or snow runoff period of May 16 through June 15, the dominant discharge/channel morphology concept was applied using USGS flow records for the gage on German Gulch (No. 12323500) located 0.5 miles upstream from the mouth. These high flow recommendations are shown in Table 11.

German Gulch - Below Edward Creek

Cross-sectional measurements for use in the wetted perimeter/inflection point method were made in an approximate 30-ft section of German Gulch (SW, NW, SE, Sec. 34, T3N, R10W) located downstream from the confluence of Edward Creek (Figure 1). Five riffle cross-sections were established in this section. The WETP computer program was calibrated to field data collected at flows of 2.7, 9.4 and 25.3 cfs.

The relationship between wetted perimeter and flow for the composite of five riffle cross-sections is shown in Figure 3. A prominent upper inflection point occurs at an approximate flow of 2.5 cfs. A flow of 2.5 cfs is therefore recommended for the low flow period of June 16 through May 15.

Flow recommendations for the high flow period cannot be derived due to the absence of long-term USGS gage records for this site.

Discussion of Flow Recommendations

A policy of the MDFWP when deriving flow recommendations for unregulated mountain streams supporting fish is to prohibit flow depletions in winter. The justification for protecting winter flows is primarily based on the fact that winter is the period most detrimental to trout survival in mountain streams exposed to icing and other severe weather conditions. For these streams, the harsh winter environment ultimately limits the numbers and pounds of trout that can be maintained indefinitely by the aquatic habitat. Winter flow depletions would only serve to aggravate an already stressful situation, leading to even greater winter losses and the possible devastation of fish populations.

The fact that the flows in Montana's mountain streams are lowest in the winter further justifies the policy of protecting winter flows. The assumption that more water provides space for more fish has led to the well-accepted conclusion that the period of lowest stream flows is most limiting to fish. The coupling of the low flow period with harsh winter weather conditions, as occurs in Montana, greatly increases the severity of the stream environment in winter.

The recommended instream flows for German Gulch will preclude all water depletions in winter (November through March) and some other periods as well. This is demonstrated in Table 12, which compares the flow recommendations for the Below Beefstraight Creek study site to the 10th, 50th and 90th percentile monthly flows at the USGS gage located 0.5 miles upstream from the mouth. The 10th, 50th and 90th percentile flows provide a measure of stream flows during a very wet, typical and drought year, respectively.

During a very wet year (10th percentile flows), the recommendations equal or exceed the available flows for the months of October through March. Therefore, water would be unavailable for consumptive uses during these six months. During a typical or normal water year (50th percentile flows), the recommendations equal or exceed the available flows for the months of August through March, making water unavailable for consumptive uses during these eight months. During a drought year (90th percentile flows), the recommendations exceed the available flows for all months, thus preventing depletions year-round.

Given the extremely high aquatic resource value of German Gulch and the Department's policy of recommending flows that will maintain the fisheries resource at its present level, lesser recommendations cannot be justified for German Gulch.

WATER QUALITY

Water Quality Methods

Water quality of German Gulch Creek was monitored on July 18, August 6, and September 4, 1984. Locations sampled were downstream from the confluence with Edward Creek, downstream from the confluence with Beefstraight Creek, and near the mouth.

Water temperature and electrical conductivity were measured in the field. Surface grab samples were also taken and were later analyzed for calcium, magnesium, bicarbonate, sulfate, nitrate and nitrite (as N), hardness (as $CaCO_3$), zinc, iron, and copper. Finally, a depth integrated sample was taken and total suspended solids concentration was later determined.

Metals samples were acidified in the field with concentrated nitric acid; nutrient samples were preserved with sulfuric acid. Standard procedures were used for all analytical measurements (APHA 1975). The Laboratory Division of the Montana Department of Health and Environmental Sciences, an EPA-certified laboratory, performed the laboratory analyses.

Water Quality Results

The quality of water in German Gulch Creek is presently excellent (Table 13). Calcium is the predominant cation and bicarbonate is the predominant anion. The upper reaches in the vicinity of Edward Creek are relatively low in hardness and alkalinity. Below Beefstraight Creek, both the alkalinity and hardness more than doubled in concentration. Because of the above, pH increased from an average of 7.80 below Edward Creek to 8.30 near the mouth.

All analyzed metals were present at low concentrations. Zinc and copper concentrations were near or below detection limits on all three sampling dates; iron concentrations were also low. Concentrations of all three metals were well below established criteria for protection of aquatic life (EPA 1976). Similarly, concentrations of nitrate and nitrite (as nitrogen) were near or below detection.

Water quality concerns raised in association with the proposed mine include acid mine drainage, metals pollution, and increased nutrient additions. The relatively low buffering capacity and hardness of the upper reaches of German Gulch Creek render it vulnerable to acid mine drainage and metals pollution if they were to occur. Usage of nitrogenous blasting compounds at the mine could also significantly increase nutrient loading in the drainage.

Chlorophyll Methods

Natural stream substrates (small rocks having dimensions on the order of 3 to 9 cm length, 2 to 5.5 cm width, and 1 to 4 cm height) with attached periphyton were collected on July 18, 1984 from German Gulch Creek near Butte. Samples were collected from the same three locations chosen for water monitoring. Rocks were randomly removed from the stream bottom and were placed in pint canning jars; typically, five rocks were placed in each jar. The jars were then capped, labeled, and wrapped in aluminum foil to prevent light from entering. Jars were transferred in ice to the laboratory where the samples were frozen to prevent breakdown of chlorophyll.

Jars were later removed from the freezer and a known volume of 90% v/v acetone was added to each. The jars were then recapped and stored for 21 to 22.5 hours under refrigerated conditions (occasional agitation was provided) to provide time for the chlorophyll and other pigments to leach into the acetone. Previous work has shown that 90% of the periphytic pigments are leached into solution after 20 to 24 hours (Weber et al 1980). Next, an aliquot of the acetone was transferred to a curette and absorbance was measured using a Bausch and Lomb Spectronic 70 Spectrophotometer. Finally, surface area of the rocks was estimated by the method of Kaiser et al (1977), and periphyton standing crop was estimated via the chlorophyll levels according to the chromatic equations that are presented in Weber et al (1980).

Chlorophyll Results

In general, there was good agreement between replicates from all three locations (Table 14). The stream reach below Beefstraight Creek appears to be less productive than either of the other two sampling locations. Greatest production of periphytic biomass occurred near the mouth.

Periphyton productivity of German Gulch Creek is relatively high compared to other Montana streams (Ingman et al 1979, Bahls et al 1981), and was in a range similar to that reported for the Yellowstone River near Billings (Klarich 1976). Estimated average standing crop of chlorophyll for Montana waters (assuming an asymptote at 35 days) is 1.7 ug Chl a/cm^2. Periphyton standing crops in German Gulch below Edward Creek (3.19 ug CHl a/cm^2) and near the mouth (4.16 ug Chl a/cm^2) were well above this average. Nitrogen compounds measured during the water monitoring were present at very low concentrations. Perhaps German Gulch Creek is nitrogen limited.

PERIPHYTON

Periphyton Methods

Periphyton samples were collected from each of the three German Gulch inventory sites by scraping natural stream bottom materials (primarily gravel and larger rock substrates) with a sharp utensil. The scrapings were then immediately transferred on site to small, labelled vials, and they were preserved with Lugol's solution for transport and storage until laboratory analyses could be undertaken of the gulch's periphyton communities.

The laboratory evaluations of the natural substrate scrapings from the German Gulch stations were separately initiated by first removing the obviously non-diatomaceous plant matter from the vials for a microscopic taxonomic examination and generic identification. As an added step, temporary wet mounts of a small portion of the less well-defined part of the same collections were prepared to further check for the presence of any soft-bodied algal filaments and cells. This accessory manipulation led to the initiation of supplemental generic identifications, and qualitative abundance estimates were also made for each of the soft-bodied algal forms that were encountered in the three project samples. Subsequently, permanent mounts were prepared from the scrapings from each of the sites for use in conducting the diatom species and variety taxonomic assessments and for use in completing the diatom percent relative abundance (PRA) tabulations.

To prepare the permanent slides for each of the project's periphyton collections, aliquots of the collected periphytic materials from the three sites were separately oxidized and treated in accord with the procedures that are presented in Standard Methods (American Public Health Association et al 1975). This was done to clean the diatom frustules for the purpose of facilitating the essential taxonomic work, and the cleansing technique resulted in the production of three randomly strewn mounts that are directly amenable to a microscopic evaluation. These slides were then surveyed microscopically in a preliminary fashion in order to develop taxa listings of the stations' diatom assemblages. This particular analytical step required the application of a taxonomic keying effort by referencing the appropriate literature sources (e.g., Patrick and Reimer 1966), and the diatoms were identified to the generic, specific, and varietal systematic levels as this proved to be feasible in any particular case.

Following such preliminary applications, the diatoms on each of the slides were partially and randomly counted by taxa in a formal manner until a total of about 415 frustules had been tabulated for each of the preparations. The modified short-count approach that was used has been described by Weber (1973), and PRA values were ultimately calculated for each of the diatom taxa that had been formally counted from any one of the permanent slides. However, a "trace" designation had to be assigned to those diatoms of a mount that were spotted in the various preliminary scans but then not actually tabulated during the formal counts.

The raw data of the inventory's periphyton community analyses therefore consist of the diatom and non-diatom taxa listings plus the diatom's PRA values and the qualitative abundance estimates of the soft-bodied forms. These raw data can be obtained from the collecting agency. But as a final analytical step, the project's diatom count data were later reduced and refined for the interpretive and descriptive needs of this report by calculating Shannon-Wiener diversity and index values for each of the station's periphyton collections. The mathematical manipulations that are involved in producing such indices are extensively described in Weber (1973).

Periphyton Results

Four soft-bodied algal genera (the blue-green Nostoc and Oscillatoria, and the green algae Closterium and Ulothrix) and a minimum of 82 species and varieties of diatoms were identified through the three German Gulch samples. A list of periphyton species and calculations of percent relative abundance for the German Gulch study sites are included in Appendix C. A breakdown of the taxa numbers by site and the diversity and equitability characteristics of the stations are presented in Table 15. The number of different taxa that were recognized in the scrapings from a site provides a general indication of the stations' floral richness, while the diversity and equitability expressions function to illustrate the overall structure of a periphyton community.

Of the non-diatomaceous algae, Oscillatoria and Closterium were found to be relatively rare through all three of the project sites, while Nostoc was seen to be fairly abundant at the upper and middle locations on the gulch but non-abundant in its lower reach. In opposition, Ulothrix was observed to be quite common at the gulch's downstream station but rare at its upstream locales. However, the low or high abundances of these particular soft-bodied forms do not necessarily point to the existence of any distinct environmental problems; rather, Nostoc, as one example, is oftentimes prevalent in waters that can be described as having a largely pristine nature (Ingman et al 1979).

Of the many diatom taxa, a significant proportion (82%) proved to be relatively uncommon components of the gulch's periphytic associations with mean PRA's across the stations at less than 2.0%. But the low abundances of this particular group of diatoms are again not necessarily suggestive of environmental perturbations since a large coterie of miscellaneous species is almost always typical of a healthy ecological system. At the same time, the occurrence of a small selection of abundant forms is also descriptive of most periphyton communities. In keeping with this theme, fifteen of the German Gulch diatom taxa with mean PRA values in excess of 2.0% can be classified as being conspicuous and common periphytic representatives of the project waterway by demonstrating high abundances at one or more of the sites.

The more common of the German Gulch diatoms can be listed as follows in the order of their relative abundance levels and their mean PRA values: Fragilaria vaucheriae (11.1%), Gomphonema olivaceum (9.1%), Cocconeis placentula (9.1%), Achnanthes lanceolata (9.0%), Nitzschia dissipata (6.9%), Navicula cryptocephala variety veneta (5.4%), Hannaea arcus (3.8%), Fragilaria pinnata (3.1%), Rhoicosphenia curvata (3.1%), Achnanthes minutissima (2.8%), Synedra ulna (2.5%), Nitzscia kutzingiana (2.5%), Cymbella affinis (2.3%), Diatoma hiemale variety mesodon (2.1%), and Navicula tripunctata (2.1%).

Ten examples of the 67 less common German Gulch diatoms with some recorded in trace (t) amounts can be listed as follows: Amphipleura pellucida (0.07%), Cymbella sinuata (1.3%), Didymosphenia geminata (t), Eunotia perpusilla (0.17%), Meridian circulare (0.7%), Navicula lanceolata (t), Nitzschia palea (1.5%), Pinnularia borealis (0.1%), Stauroneis smithii (t), and Surirella ovata (1.0%). Furthermore, extremely large numbers of diatom species and varieties (and genera) were not observed in the German Gulch samples (e.g., Biddulphia laevis, Epithemia sorex, and Gyrosigma acuminatum). However, such broad-ranging absences can be judged as commonplace through all of the earth's biological assemblages, and the occurrence of missing taxa thereby is certainly not unique to the German Gulch periphyton communities.

The fifteen common German Gulch diatoms accounted for about 72% of the study's total frustule counts, and the remaining tabulations were thinly spread among the 67 remaining, less common forms. Such a dominance by a disproportionately small assortment of species is in agreement with the community structures that can be recognized in most of the natural biological systems. In the case of extensively polluted streams, this dominance would be more thickly spread across a much smaller set of periphytic organisms with a much reduced level of floral richness, i.e., with a much narrower selection of the rarer diatom species, and such pollutive restrictions do not appear to be evident in the German Gulch collections.

The environmental status of German Gulch was additionally judged by reviewing the Shannon-Wiener diversity numbers of the three periphyton samples. To set the stage for making such evaluations, the refined data of this kind that are now on hand for numerous Montana streams as available in Ingman et al (1979), Bahls et al (1979), and Bahls et al (1981) were first assessed for comparative purposes. As revealed by these reports, a statewide average of 42.7 diatom taxa was secured for the summer season with an average Shannon-Wiener diversity value for this same period of 3.99. These mean values can then be used as a reference point for judging the biological aspects and the structures of the German Gulch periphyton scrapings.

In conjunction with such statewide means, Montana's streams also produced a typically high taxa count of 63.6 species with a maximum of 67, and 12% of the collections produced taxa numbers in excess of 60 species. The streams further produced a typically high diversity of 4.87 with a maximum of 5.00, and 12% of the samples provided diversities in excess of 4.77 units. Contrariwise, these same Montana waters produced typically low taxa numbers and diversity levels of 25.1 and 2.85 respectively with minimums of 22 and

2.55, and 12% of the statewide collections demonstrated taxa numbers and diversities below 30 and 3.20 units during the warm weather season.

In terms of interpretation as outlined by Ingman et al (1979) and Weber (1973), stream periphyton samples with diatom species numbers and Shannon-Wiener diversities around or in excess of the statewide means (i.e., greater than about 40 taxa to a maximum near 67 with a diversity greater than 4.00 to a maximum of about 5.00 units) would tend to be indicative of an excellent biological health with the absence of any marked pollutive stress or other perturbations. In general, periphyton collections with somewhat lower taxa numbers between 25 and 40 and with somewhat lower diversities between 3.00 and 4.00 units are also indicative of fairly good environmental conditions. However, values in these latter ranges could be suggestive of the occurrence of comparatively mild instream problems, and the likelihood and severity of such a potential stress would be expected to be enhanced to some small degree as the taxa numbers and diversities fall to the 25 and 3.00 level respectively.

But as a more consistent and accurate reference guideline, periphytic taxa numbers and diversities that lie below the 25 and 3.00 levels respectively have been found to be more definitely suggestive of a pollutive problem. Furthermore, a progressively greater severity of instream stress might be anticipated with the lower diversity values in those instances where diversities are found to reside in the 3.00 to zero range. Periphytic diversities below 2.00, in turn, are particularly demonstrative of an extreme perturbation with the zero value representative of the diagnostic limit.

Periphytic evidence of somewhat marked environmental difficulties has been uncovered for a small number of Montana's streams as revealed by the minimum statewide taxa number and diversity readings that were listed previously. However, the below 2.00 diversity extreme was not uncovered while conducting the statewide biological inventories, and this fact points to the overall good environmental health that is evident in most of the State's waters. As will be described below, German Gulch would appear to fall into this same "good-health" category.

With regard to the German Gulch periphyton collections, diatom taxa numbers and diversities as summarized in Table 15 were found to be typically above or near the state averages, and they were observed to be well above the diagnostically critical 25 and 2.00 or 3.00 levels. These juxtapositions thereby are indicative of a generally good biological health along the gulch with absence of any significant environmental degradations. In relation to the lower German Gulch site near its mouth, taxa numbers and diversities were calculated to be somewhat lower than those upstream, but they remain adequately high so as to be also suggestive of a fairly good biological condition. For the most part, therefore, German Gulch can be readily distinguished from those few Montana streams that demonstrated relatively low diversity values and that demonstrated the potential for facing adverse environmental stress.

Nevertheless, the fact that the taxa numbers and diversities of the lower gulch site fell into the 25 to 40 and 3.00 to 4.00 ranges points to the possible occurrence of some very mild environmental problems in the bottom section of the waterway. Thus, another statistical evaluation was performed leading to the calculation of equitability indices in order to shed additional light on the environmental status of the lower gulch station.

Along with diversity, equitability is another community index that can be used as a check to further assess the ecological shape of a periphyton collection. This equitability index (e) basically compares the number of taxa that were actually retrieved from a sampling site with a theoretical taxa number that should have been obtained in response to the sample's diversity on the basis of a mathematical model (Weber 1973). Values for e that are near one show a close correspondence of the field data to the theoretical model with a highly equitable distribution of abundances among the collected taxa. Values of e near zero show the opposite trend and a distinctively inequitable distribution of abundances among the collected organisms. In the main, healthy and unpolluted ecosystems tend to demonstrate a highly equitable abundance distribution with index values above 0.50, while degraded and disturbed ecosystems tend to show a poor equitability with index values below 0.50 and approaching zero.

Most commonly, equitability numbers between 0.60 and 0.80 are obtained from nondegraded streams, and higher e values near 1.00 are rarely found in the real world. As a result, periphytic samples exhibiting e readings between 0.60 and 0.80 are definitely indicative of good environmental conditions and a lack of severe pollution. In a few rare occasions, e values above 0.80 can be obtained; such high indices are also suggestive of non-polluting situations, although they typically refer to a natural physical stress as might be subjected in a torrential stream.

At the other end of the scale, low e numbers between 0.00 and 0.30 are fairly accurately diagnostic of some types of instream disturbance that causes an inequitable distribution of abundance among the taxa, and even fairly slight degradations can depress a community's equitability rating to such a low level (Weber 1973). In response, periphyton collections that produce poor equitabilities and index values in this lower 0.00 and 0.30 range are suggestive of environmental perturbations in the associated stream reach. Equitabilities in the 0.30 to 0.60 range, which affords an intermediate condition, are representative of borderline or marginal situations as follows: values of e above 0.50 but less than 0.60 would tend to delineate the somewhat low probability of a very small impact, while e values below 0.50 but above 0.30 would tend to delineate the greater likelihood of some adverse but largely mild environmental effect.

With reference to the German Gulch equitability calculations, both the species and the varietal equitabilities in Table 15 were observed to lie in the 0.60 to 0.80 range for all three of the German Gulch stations, and these observations point to a good environmental health with the absence of any significant pollutive stress. Equitabilities were seen to decline to a small extent to the lower gulch site in parallel with this station's reduced Shannon-Wiener diversities, and this downstream drop in diversity was interpreted to illustrate the development of a very mild perturbation in the lower reach of the gulch. But the fact that the bottom station's periphyton equitability was greater than 0.60 acts to confirm the mildness of the potential effect, if such an effect actually exists.

Based on these diversity and equitability index assessments, German Gulch appears to be in an excellent to good environmental and biological condition at the present time. Therefore, the prediction of the absence of any marked pollutive inputs into the waters of the gulch would seem to be a valid judgment that can now be put forth for the project's waterway.

AQUATIC MACROINVERTEBRATES

Study Area

Aquatic macroinvertebrate sample sites were located at three stations (Upper, Middle and Lower), which correspond to the same stations at which fish population data were collected. The Upper, Middle and Lower stations correspond to the Below Edward Creek, Below Beefstraight Creek and Durant Sections, respectively, described in the Fisheries section.

Methods

Aquatic macroinvertebrates were collected with a modified Surber sampler which had a one square foot sample surface area. Three square foot samples were collected from each of the three sample sites on May 21, 1984 and August 6, 1984. The sampler was placed in riffle habitats which had cobble substrates (3" to 6") and depths of approximately 6 inches. Invertebrates were collected by scrubbing the larger cobble with a brush and disturbing the finer substrate with a three-pronged garden claw. Samples were concentrated in a series 30 sieve, transferred to labelled containers and preserved in 10% formalin. The samples were returned to the laboratory where macroinvertebrates were separated from the gravel and detritus by order and transferred to labelled vials containing 70% ethanol.

Macroinvertebrates were identified to the lowest practicable taxon, usually genus or species, and enumerated. Identifications were made by using keys written by Allen and Edmunds (1962 and 1963), Bauman et al (1977), Brinkhurst and Jamieson (1971), Brown (1972), Edmunds et al (1976), Hamilton and Saether (1970), Jensen (1966), Johannsen (1934 and 1935) and Wiggins (1977). Chironomid larvae and microdrile oligochaetes were mounted on glass microscope slides in Hydramount. Microdrile oligochaetes were cleared in Amman's lactophenol prior to mounting.

Results

Species Richness and Community Composition

A total of 70 taxa were identified from the German Gulch samples. Samples collected at the Upper, Middle and Lower Sites yielded 41, 51 and 52 taxa, respectively. Twenty-eight taxa were common to all three sites while each of the three stations yielded taxa unique to the site (7 at the Upper, 6 at the Middle and 10 at the Lower). Summer samples exhibited an increase in species richness over spring samples at all three sample sites (Table 16).

Mean numbers of taxa collected per sample are presented by sample site and by sample site and season in Table 17. Mean numbers of taxa per square foot sample are related to species distribution and species diversity in the sample habitat. The highest mean numbers of taxa per sample occurred at the Middle Site while the lowest means occurred at the Upper Site. Mean numbers of taxa per sample showed an increase in the summer samples over the spring samples at all three stations. Spring numbers of taxa per sample at the Lower Site were nearly identical to those observed at the Upper Site, while numbers observed at the Lower Site approximated the mean for the Middle Site.

A checklist of the taxa collected from German Gulch Creek and their distributions among the three sample sites is presented in Table 18. The fauna of German Gulch Creek was dominated by rheophilous forms typical of small montane tributaries. The rheophile community is extremely constant and enjoys a worldwide uniformity. The rheophile habitat is marked by steep gradient, swift current velocity, boulder-rubble-cobble substrates, cold thermal regime and a periphyton-detritus production base. Examples of rheophilous organisms collected in German Gulch Creek included: Cinygmula, Epeorus spp., D. doddsi, D. spinifera, C. hystrix, R. robusta, Amphinemura, Zapada, P. expansa, Parapsyche, Rhyacophila, Glossosoma, Apatania, Heterlimnius Diamesa, Stempellinella, C. nostocicola, etc. The fauna observed at the Upper and Lower Sites was generally limited to rheophile forms; however, the fauna of the Lower Site included facultative forms collected only at that station. Such facultative forms are common inhabitants of larger rivers and lowland streams of the region and are tolerant of a wider range of substrate type, current velocity, dissolved oxygen and water temperature than the rheophile community. Facultative forms collected only at the Lower Site included: Pseudocloeon sp., P. badia, Hydropsyche sp., Narpus sp., Brillia sp., Cardiocladius sp., Cricotopus (Cricotopus) sp., Eiseniella sp. and Haplotaxis sp.

Macroinvertebrate Abundance

A total of 3,847 aquatic macroinvertebrates were collected in the German Gulch samples of which 30% were collected from the Upper Site, 52% from the Middle Site and 18% from the Lower Site. Summer samples from the Upper and Lower Sites exhibited marked increases in abundance over the spring samples (Table 17); however, spring and summer abundance was equal at the Middle Site.

Mean numbers of macroinvertebrates per square foot are presented by sample site and by sample site and season in Table 17. Macroinvertebrate abundance was lowest at the Lower Site ($115/ft^2$), intermediate at the Upper Site ($191/ft^2$) and highest at the Middle Site ($335/ft^2$). The Middle Site represented a relatively productive habitat characterized by a dense growth of filamentous algae on the cobble substrate, while substrates at the Upper and Lower Sites were colonized by diatoms.

Summer numbers of macroinvertebrates per square foot averaged 213% higher at the Lower Site and 220% higher at the Upper Site than spring numbers at either station, while spring and summer abundance was equal at the Middle Site. This, in conjunction with the suggested increased productivity of the Middle Site, was probably related to the presence of a large beaver dam located immediately upstream from the Middle Site. The dam may have afforded protection from harsh winter ice conditions, thus maintaining high spring numbers of macroinvertebrates, while providing some nutrient enrichment to stimulate production.

Macroinvertebrate numbers per sample by individual taxon are given in Tables 19, 20 and 21 for the Upper, Middle and Lower Sites. Macroinvertebrate numbers were dominated by Diptera and Ephemeroptera at all three stations. While numbers of Ephemeroptera were relatively evenly distributed among the species, numbers of Diptera were markedly dominated by the chironomid, *Cricotopus* c.f. *nostocicola*. This dominance occurred only at the Upper and Middle Sites. *Cricotopus* c.f. *nostocicola* is a midge larva which lives symbiotically in colonies of the blue-green alga *Nostoc* and is characteristic of rheophile habitats.

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Table 1. Summary of electrofishing survey data collected for the 1000-ft Durant Section of German Gulch Creek (T3N, R10W, S12,13) on July 26 and August 7, 1984.

Species	No. Captured	Length Range (inches)
Westslope cutthroat	201	2.5 - 11.3
Brook trout	79	2.3 - 8.6
Brown trout	1	8.3

Table 2. Estimated standing crop of trout in the 1000-ft Durant Section of German Gulch Creek (T3N, R10W, S12,13) on July 26, 1984 (80% confidence intervals in parentheses).

Species	Length Group (inches)	Per 1000 Feet Number	Per 1000 Feet Pounds
Westslope cutthroat	4.0 - 5.9	84	4
	6.0 -11.3	149	28
		233 (± 34)	32 (± 4)
Brook trout	4.0 - 5.9	67	3
	6.0 - 8.6	46	7
		113 (± 29)	10 (± 4)
Total Trout		346 (± 45)	42 (± 4)

Table 3. Average length and weight of cutthroat and brook trout by age class in the Durant Section of German Gulch Creek (T3N, R10W, S12,13).

Species	Age Class	Average Length (inches)	Average Weight (pounds)
Westslope cutthroat	I	5.0	0.05
	II	7.0	0.13
	III	8.2	0.21
	IV+	9.2	0.30
Brook trout	I	4.6	0.04
	II	6.3	0.09
	III+	7.8	0.19

Table 4. Summary of electrofishing survey data collected for the 1000-ft Below Beefstraight Creek Section of German Gulch Creek (T3N, R10W, S26) on July 26 and August 6, 1984.

Species	No. Captured	Length Range (inches)
Westslope cutthroat	112	2.3 - 10.5
Brook trout	125	1.9 - 9.6

Table 5. Estimated standing crop of trout in the 1000-ft Below Beefstraight Creek Section of German Gulch Creek (T3N, R10W, S26) on July 26, 1984 (80% confidence intervals in parentheses).

Species	Length Group (inches)	Per 1000 Feet Number	Per 1000 Feet Pounds
Westslope cutthroat	4.0 - 5.9	30	1
	6.0 -10.5	101	20
		131 (± 25)	21 (± 4)
Brook trout	4.0 - 5.9	109	4
	6.0 - 9.6	61	8
		170 (± 42)	12 (± 2)
Total Trout		301 (± 42)	33 (± 4)

Table 6. Average lengths and weights of Westslope cutthroat and brook trout by age class in the Below Beefstraight Creek Section of German Gulch Creek (T3N, R10W, S26).

Species	Age Class	Average Length (inches)	Average Weight (pounds)
Westslope cutthroat	I	4.8	0.04
	II	6.9	0.13
	III	8.3	0.22
	IV+	9.7	0.35
Brook trout	I	6.4	0.10
	II	8.3	0.21
	III	9.4	0.32

Table 7. Summary of electrofishing survey data collected for the 1000-ft below Edward Creek Section of German Gulch Creek (T3N, R10W, S34) on July 26 and August 6, 1984.

Species	No. Captured	Length Range (inches)
Westslope cutthroat	147	2.8 - 10.6
Brook trout	43	2.0 - 8.1

Table 8. Estimated standing crop of trout in the 1000-ft Below Edward Creek Section of German Gulch Creek (T3N, R10W, S34) on July 26, 1984 (80% confidence intervals in parentheses).

Species	Length Group (inches)	Per 1000 Feet Number	Per 1000 Feet Pounds
Westslope cutthroat	4.0 - 5.9	123	6
	6.0 -10.6	45	8
		168 (± 23)	14 (± 1)
Brook trout	3.2 - 5.9	30	1
	6.0 - 8.1	11	1
		41 (± 10)	2 (± 0)
Total Trout		209 (± 25)	16 (± 1)

Table 9. Average lengths and weights of westslope cutthroat and brook trout by age class in the Below Edward Creek Section of German Gulch Creek (T3N, R10W, S34).

Species	Age Class	Average Length (inches)	Average Weight (pounds)
Westslope cutthroat	I	5.1	0.05
	II	7.1	0.14
	III	8.6	0.22
	IV+	9.3	0.30
Brook trout	I	4.0	0.03
	II	6.2	0.10
	III+	7.1	0.15

Table 10. Estimated standing crops of trout in 1000-ft study sections of streams in the German Gulch vicinity (P denotes presence in numbers too low to make reliable estimates)(Data from Oswald 1981).

Location	Brook Trout No.	Brook Trout Lbs.	Rainbows No.	Rainbows Lbs.	Cutthroat No.	Cutthroat Lbs.	Total Trout No.	Total Trout Lbs.
Seymour	519	41	--	--	--	--	519	41
Sullivan	602	29	--	--	--	--	602	29
Twelve-mile	314	27	--	--	--	--	314	27
Slaughterhouse	182	19	P	--	--	--	182	19
Ten-mile	353	31	P	--	--	--	353	31
Seven-mile	183	13	P	--	--	--	183	13
Deep	166	18	18	3	--	--	184	21
Six-mile	392	13	20	1	P	--	412	14
Oregon	265	24	P	--	--	--	265	24
American	160	12	8	1	--	--	168	13
California	130	16	30	3	--	--	160	19
French[1]	P	--	P	--	--	--	--	--
Willow	677	37	--	--	63	8	740	45
German Gulch (Durant)	113	10	--	--	233	32	346	42

[1] Montana Department of Fish, Wildlife and Parks (1981).

Table 11. High flow recommendations based on the dominant discharge/channel morphology concept (USGS flow gage record data).

Time Period	Flow Recommendations (cfs)[1]
May 16 - 31	53
June 1 - 15	58

[1] Plus the dominant discharge of approximately 139 cfs, which should be maintained for one 24-hour period during May 16 - June 15.

Table 12. Instream flow recommendations (cfs) for German Gulch at the Below Beefstraight Creek study site compared to the 10th, 50th and 90th percentile monthly flows (cfs).

		Percentile Flow (cfs)[3]		
Time Period	Recommendations (cfs)[1]	10th[4] (Wet Year)	50th[5] (Typical Year)	90th[6] (Dry Year)
January	12	8.0	6.0	5.0
February	12	9.0	6.5	4.3
March	12	11.7	7.5	5.0
April	12	25.7	15.5	9.3
May 1 - 15	12	109.4	64.0	41.3
May 16 - 31	53[2]			
June 1 - 15	58[2]	150.1	70.5	43.3
June 16 - 30	12			
July	12	48.8	26.5	10.6
August	12	17.4	12.0	6.3
September	12	13.4	9.0	8.0
October	12	12.0	9.0	7.0
November	12	10.0	8.0	5.3
December	12	10.0	7.0	5.0

[1] Derived using the wetted perimeter/inflection point method and the dominant discharge/channel morphology concept.

[2] Plus the dominant discharge of approximately 139 cfs, which should be maintained for one 24-hour period during May 16 - June 15.

[3] Derived by the USGS using recorded and reconstituted flows at the gage site on German Gulch located 0.5 miles upstream from the mouth (No. 12323500), 1951 - 1982.

[4] The 10th percentile is the flow that is exceeded in 1 of 10 years; in other terms, in 1 year out of 10 there is more water than the 10th percentile flowing in the stream.

[5] The 50th percentile is the flow that is exceeded in 5 of 10 years; in other terms, in 5 years out of 10 there is more water than the 50th percentile flowing in the stream.

[6] The 90th percentile is the flow that is exceeded in 9 of 10 years; in other terms, in 9 years out of 10 there is more water than the 90th percentile flowing in the stream.

Table 13. Means, ranges, and standard deviations of chemical and physical parameters for German Gulch Creek, Montana (Samples collected on July 18, August 6, and September 4, 1984).

Parameter[1]	Below Edward Creek			Below Beefstraight Creek			Near Mouth		
	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
Calcium	16	(14-18)	2	33	(32-34)	1	32	(31-33)	1
Magnesium	1.8	(1.5-2.1)	0.3	6.3	(5.6-6.7)	0.5	6.1	(5.6-6.5)	0.4
Bicarbonate	50	(47-53)	3	123	(113-134)	11	123	(107-139)	16
Sulfate	11.2	(10.0-12.6)	1.1	6.9	(5.6-9.0)	1.5	8.6	(6.2-11.0)	2.4
Nitrate + Nitrite (as N)		(<0.01)			(0.01)			(<0.01-0.01)	
Temperature (°C)	13.0	(11.6-15.5)	1.7	11.5	(9.7-13.3)	1.5	13.4	(10.7-13.5)	2.2
Conductivity (umhos/cm^2)	111	(78-139)	25	207	(180-221)	19	210	(172-230)	27
pH (standard units)	7.80	(7.40-8.25)	0.34	8.05	(7.95-8.2)	0.10	8.30	(8.15-8.40)	0.10
Hardness (as $CaCO_3$)	45	(40-49)	5	104	(101-107)	3	103	(101-106)	3
Alkalinity (as $CaCO_3$)	44	(39-51)	5	107	(97-120)	12	106	(87-116)	13
TSS		(<1.2-10.0)			(<2.9-<7.9)			(<2.6-<9.5)	
Zinc		(<0.005-0.006)			(<0.005-<0.020)			(<0.005-<0.010)	
Iron		(0.2)		0.08	(0.06-0.09)	0.02	0.06	(0.04-0.08)	0.02
Copper		(<0.01)			(<0.01)			(<0.01)	

[1] All concentrations expressed in mg/l unless specified otherwise.

Table 14. Concentrations of chlorophyll a, b, and c (ug/cm^2) for three locations in German Gulch Creek, July 18, 1984.

Location	Chlorophyll ug/cm^2 a	b	c
Below Edward Creek			
Replicate 1	3.06	0.216	0.550
Replicate 2	3.31	0.175	0.687
Mean	3.19	0.196	0.619
Below Beefstraight Creek			
Replicate 1	0.98	0.007	0.103
Replicate 2	1.45	0.012	0.129
Mean	1.21	0.010	0.116
Near Mouth			
Replicate 1	3.54	0.329	0.419
Replicate 2	4.77	0.271	0.636
Mean	4.16	0.300	0.528

Table 15. Floral richness and Shannon-Wiener diatom diversity characteristics of natural substrate periphyton scrapings from three locations on German Gulch Creek, July 18, 1984.

Biological Parameters	Upper Site (below Edwards Creek)	Middle Site (below Beefstraight Creek)	Lower Site (near mouth)	All Sites
Non-Diatom Genera Observed	4	3	3	4
Diatom Genera Observed	19	25	18	29
Diatom Genera Counted	19	20	14	24
Diatom Species Observed	40	55	36	70
Diatom Species Counted	37	41	28	56
Diatom Varieties Observed	44	63	40	82
Diatom Varieties Counted	41	49	31	66
Trace Diatom Genera	0	5	4	5
Trace Diatom Species	3	14	8	14
Trace Diatom Varieties	3	14	9	16
Species Diversity	4.216	4.440	3.463	--
Varietal Diversity	4.382	4.644	3.740	--
Species Equitability	0.738	0.782	0.644	--
Varietal Equitability	0.750	0.756	0.625	--

Table 16. Analysis of species richness (numbers of seperable taxa) observed at the Upper, Middle and Lower sample sites on German Gulch Creek in May and August, 1984.

	Upper		Middle		Lower	
Total No. Taxa Per Site	41		51		52	
Total No. Taxa Per Season	SP	SU	SP	SU	SP	SU
By Sample Site	27	32	37	41	27	49
Mean No. Taxa Per Sample By Sample Site	20.5		29.3		24.8	
Mean No. Taxa Per Sample	SP	SU	SP	SU	SP	SU
By Sample Site and Season	17.0	24.0	25.3	33.3	17.7	32.0

Table 17. Analysis of aquatic macroinvertebrate abundance in square foot samples collected at the Upper, Middle and Lower sample sites on German Gulch Creek in May and August, 1984.

	Upper		Middle		Lower	
Total Numbers Per Site	1145		2010		692	
Total Numbers Per Season	SP	SU	SP	SU	SP	SU
By Sample Site	273	872	1005	1005	167	525
Mean Numbers Per Square Ft By Sample Site	191		335		115	
Mean Numbers Per Square Ft	SP	SU	SP	SU	SP	SU
By Sample Site and Season	91	291	335	335	56	175

Table 18. Systematic checklist and distribution among sample sites (Upper, Middle and Lower) of aquatic macroinvertebrates collected from German Gulch Creek in May and August, 1984.

TAXA	SPRING			SUMMER		
	Upp	Mid	Low	Upp	Mid	Low
EPHEMEROPTERA						
Siphlonuridae						
Ameletus sp.	-	X	-	-	-	X
Baetidae						
Baetis bicaudatus	X	X	X	X	X	X
Baetis spp.	-	X	X	-	X	X
Pseudocloeon sp.	-	-	-	-	-	X
Heptageniidae						
Cinygmula spp.	X	X	X	X	X	X
Epeorus deceptivus	-	-	-	X	X	X
Epeorus grandis	-	-	-	X	X	-
Epeorus longimanus	X	X	X	X	X	-
Rhithrogena robusta	X	X	X	X	X	X
Rhithrogena sp.	-	X	X	-	-	X
Leptophlebiidae						
Paraleptophlebia sp.	-	X	-	-	X	X
Ephemerellidae						
Caudatella hystrix	-	X	X	-	X	X
Drunella coloradensis	X	X	X	X	X	X
Drunella doddsi	X	X	-	X	X	X
Drunella spinifera	-	X	-	X	X	X
Ephemerella infrequens	-	X	X	-	X	X
Seratella tibialis	-	-	-	X	X	X
PLECOPTERA						
Nemouridae						
Amphinemura sp.	-	-	-	-	X	X
Nemoura sp.	-	X	-	-	-	-
Zapada sp.	X	-	-	X	X	-
Taeniopterygidae						
Taenionema sp.	X	X	X	-	-	-
Capniidae						
Capnia group*	-	-	-	X	X	X
Eucapnopsis brevicauda	X	-	-	-	-	-
Peltoperlidae						
Yoraperla brevis	X	-	-	-	-	-
Pteronarcydae						
Pteronarcella badia	-	-	-	-	-	X
Perlodidae						
Cultus sp.	-	X	-	-	X	-
Kogotus sp.	-	X	-	-	-	-
Megarcys sp.	X	-	-	X	X	X
Pictetiella expansa	-	X	-	-	-	-
Perlidae						
Doroneuria theodora	-	X	X	-	-	X
Chloroperlidae						
Chloroperlinae**	X	-	X	X	X	X

Table 18. Continued.

TAXA	SPRING Upp	SPRING Mid	SPRING Low	SUMMER Upp	SUMMER Mid	SUMMER Low
TRICHOPTERA						
Philopotamidae						
Dolophilodes sp.	-	-	-	-	X	X
Hydropsychidae						
Arctopsyche sp.	-	X	X	-	X	X
Hydropsyche sp.	-	-	-	-	-	X
Parapsyche sp.	X	X	-	X	X	-
Rhyacophilidae						
Rhyacophila spp.	X	X	-	X	X	X
Glossosomatidae						
Glossosoma sp.	X	X	X	X	X	X
Hydroptilidae						
Agraylea sp.	X	-	-	-	-	-
Ochrotrichia sp.	-	-	-	-	X	-
Brachycentridae						
Brachycentrus sp.	X	X	-	-	X	X
Micrasema sp.	X	X	X	X	X	X
Limnephilidae						
Apatania sp.	-	-	X	X	X	X
Ecclisomyia sp.	X	-	-	-	-	-
COLEOPTERA						
Elmidae						
Heterlimnius corpulentus	-	X	X	X	X	X
Narpus sp.	-	-	-	-	-	X
Haliplidae						
Brychius sp.	-	X	-	-	-	-
DIPTERA						
Tipulidae						
Antocha sp.	-	X	X	X	-	X
Hexatoma sp.	-	X	X	X	X	X
Limnophila sp.	-	-	-	X	-	-
Chironomidae						
Diamesa sp.	-	-	X	X	-	-
Pseudokiefferiella sp.	-	-	-	X	X	X
Micropsectra sp.	X	X	X	-	X	X
Stempellinella sp.	X	-	-	X	-	-
Brillia sp.	-	-	-	-	-	X
Cardiocladius sp.	-	-	-	-	-	X
Cricotopus (C.) sp.	-	-	-	-	-	X
Cricotopus c.f. *nostocicola*	X	X	X	X	X	X
Cricotopus (C.) / *Orthocladius* (O.) spp.***	X	X	-	X	X	X
Eukiefferiella spp.	X	X	-	X	X	X
Orthocladius (Eudactylocladius) spp.	-	-	-	X	X	-
Orthocladius (Euorthocladius) spp.	-	X	-	-	-	X
Parametriocnemus sp.	X	-	-	-	-	-
Paraphaenocladius sp.	X	-	-	-	-	-
Simuliidae						
Prosimulium sp.	-	-	X	-	-	-
Simulium sp.	-	-	-	-	X	X

Table 18.Continued

TAXA	SPRING Upp	SPRING Mid	SPRING Low	SUMMER Upp	SUMMER Mid	SUMMER Low
NEMATODA	-	X	X	-	X	X
TURBELLARIA	X	X	X	X	X	X
OLIGOCHAETA						
Lumbricidae						
Eiseniella sp.	-	-	X	-	-	X
Haplotaxidae						
Haplotaxis sp.	-	-	-	-	-	X
Naididae						
c.f. *Homochaeta naidina*	X	X	X	X	X	X
Total Number of Taxa Collected	27	37	27	32	41	49

* Capnia group = *Capnia*, *Mesocapnia* and *Utacapnia* unseperable in larval stage.

** Subfamily Chloroperlinae = *Alloperla*, *Suwallia*, *Sweltsa* and *Triznaka* unseperable in larval stage.

*** Most species of *Cricotopus* (Cricotopus) and *Orthocladius* (Orthocladius) are unseperable in larval stage.

Table 19. Numbers of macroinvertebrates collected per square foot Surber sample from the Upper Site on German Gulch Creek in May and August, 1984.

TAXA	Spring Sample A	B	C	TOTAL	Summer Sample A	B	C	TOTAL
EPHEMEROPTERA								
Baetis bicaudatus	1	3	2	6	4	20	29	53
Cinygmula spp.	6	8	11	25	11	1	11	23
Epeorus deceptivus	-	-	-	-	13	6	26	45
E. grandis	-	-	-	-	-	-	15	15
E. longimanus	-	-	1	1	6	1	5	12
Rhithrogena robusta	2	1	2	5	6	2	18	26
Drunella coloradensis	-	10	2	12	2	3	1	6
D. doddsi	-	1	-	1	4	3	2	9
D. spinifera	-	-	-	-	-	2	-	2
Seratella tibialis	-	-	-	-	4	3	7	14
Total Ephemeroptera	9	23	18	50	50	41	114	205
PLECOPTERA								
Zapada sp.	1	-	-	1	5	6	19	30
Taenionema sp.	1	3	2	6	-	-	-	-
Capnia group	-	-	-	-	1	1	-	2
Eucapnopsis brevicauda	2	2	1	5	-	-	-	-
Yoraperla brevis	1	-	1	2	-	-	-	-
Megarcys sp.	-	1	-	1	1	5	2	8
Chloroperlinae	1	1	-	2	1	-	1	2
Total Plecoptera	6	7	4	17	8	12	22	42
TRICHOPTERA								
Parapsyche sp.	-	2	-	2	-	3	1	4
Rhyacophila spp.	1	5	1	7	6	6	5	17
Glossosoma sp.	8	7	1	16	2	1	8	11
Agraylea sp.	1	-	-	1	-	-	-	-
Brachycentrus sp.	-	1	-	1	-	-	-	-
Micrasema sp.	-	1	-	1	1	-	1	2
Apatania sp.	-	-	-	-	-	1	-	1
Ecclisomyia sp.	1	-	-	1	-	-	-	-
Total Trichoptera	11	16	2	29	9	11	15	35
COLEOPTERA								
Heterlimnius corpulentus	-	-	-	-	3	4	3	10
Total Coleoptera	-	-	-	-	3	4	3	10
DIPTERA								
Antocha sp.	-	-	-	-	-	1	-	1
Hexatoma sp.	-	-	1	1	1	-	1	2
Limnophila sp.	-	-	-	-	1	-	-	1
Diamesa sp.	-	-	-	-	1	1	-	2
Pseudokiefferiella sp.	-	-	-	-	1	-	-	1
Micropsectra sp.	1	-	-	1	-	-	-	-
Stempellinella sp.	1	-	-	1	-	1	-	1
Cricotpus c.f. nostocicola	13	56	64	133	118	351	43	512
Cricotopus / Orthocladius spp.	-	1	-	1	10	-	2	12
Eukiefferiella spp.	1	2	1	4	4	3	1	8

Table 19. Continued.

TAXA	Spring Sample A	B	C	TOTAL	Summer Sample A	B	C	TOTAL
DIPTERA (Continued)								
Orthocladius (Eudact.) sp.	-	-	-	-	8	4	2	14
Parametriocnemus sp.	-	1	-	1	-	-	-	-
Paraphaenocladius sp.	1	-	-	1	-	-	-	-
Total Diptera	17	60	66	143	144	361	49	554
TURBELLARIA	1	-	-	1	2	-	-	2
Total Turbellaria	1	-	-	1	2	-	-	2
OLIGOCHAETA								
c.f. *Homochaeta naidina*	5	22	6	33	13	7	4	24
Total Oligochaeta	5	22	6	33	13	7	4	24
TOTAL TAXA	18	19	14		25	24	23	
TOTAL NUMBERS MACROINVERTS.	49	128	96	273	229	436	207	872

Table 20. Numbers of macroinvertebrates collected per square foot Surber sample from the Middle Site on German Gulch Creek in May and August, 1984.

TAXA	Spring Sample A	B	C	TOTAL	Summer Sample A	B	C	TOTAL
EPHEMEROPTERA								
Ameletus sp.	2	-	-	2	-	-	-	-
Baetis bicaudatus	20	12	13	45	23	4	14	41
Baetis spp.	7	7	5	19	9	3	9	21
Cinygmula spp.	10	19	12	41	8	4	8	20
Epeorus deceptivus	-	-	-	-	6	10	12	28
E. grandis	-	-	-	-	1	-	2	3
E. longimanus	6	31	9	46	-	-	1	1
Rhithrogena robusta	2	-	-	2	3	1	1	5
Rhithrogena sp.	1	3	4	8	-	-	-	-
Paraleptophlebia sp.	1	1	-	2	3	-	1	4
Caudatella hystrix	4	1	1	6	33	7	11	51
Drunella coloradensis	37	33	43	113	3	2	2	7
D. doddsi	2	1	3	6	12	24	36	72
D. spinifera	-	-	2	2	25	7	7	39
Ephemerella infrequens	51	21	25	97	2	-	-	2
Seratella tibialis	-	-	-	-	22	5	9	36
Total Ephemeroptera	143	129	117	389	150	67	113	330
PLECOPTERA								
Amphinemura sp.	-	-	-	-	2	-	4	6
Nemoura sp.	-	2	-	2	-	-	-	-
Zapada sp.	-	-	-	-	2	-	1	3
Taenionema sp.	4	2	2	8	-	-	-	-
Capnia group	-	-	-	-	-	-	3	3
Cultus sp.	2	-	1	3	-	-	1	1
Kogotus sp.	-	1	2	3	-	-	-	-
Megarcys sp.	-	-	-	-	1	-	-	1
Pictetiella expansa	-	1	-	1	-	-	-	-
Doroneuria theodora	-	1	-	1	-	-	-	-
Chloroperlinae	-	-	-	-	13	1	1	15
Total Plecoptera	6	7	5	18	18	1	10	29
TRICHOPTERA								
Dolophilodes sp.	-	-	-	-	1	1	1	3
Arctopsyche sp.	7	-	4	11	13	4	16	33
Parapsyche sp.	5	-	3	8	4	5	5	14
Rhyacophila spp.	9	2	9	20	7	6	12	25
Glossosoma sp.	1	4	1	6	1	1	-	2
Ochrotrichia sp.	-	-	-	-	-	-	1	1
Brachycentrus sp.	3	7	-	10	-	6	2	8
Micrasema sp.	4	-	1	5	22	3	15	40
Apatania sp.	-	-	-	-	1	1	1	3
Total Trichoptera	29	13	18	60	49	27	53	129
COLEOPTERA								
Heterlimnius corpulentus	5	5	14	24	54	16	11	81
Brychius sp.	-	-	1	1	-	-	-	-
Total Coleoptera	5	5	15	25	54	16	11	81

Table 20. Continued.

TAXA	Spring Sample A	B	C	TOTAL	Summer Sample A	B	C	TOTAL
DIPTERA								
Antocha sp.	-	1	3	4	-	-	-	-
Hexatoma sp.	-	-	1	1	-	1	-	1
Pseudokiefferiella sp.	-	-	-	-	4	8	3	15
Micropsectra sp.	2	-	-	2	11	-	6	17
Cricotopus c.f. *nostocicola*	144	247	96	487	77	110	66	253
Cricotopus / *Orthocladius* spp.	8	3	1	12	9	2	3	14
Eukiefferiella spp.	1	-	-	1	56	24	24	104
Orthocladius (Eudact.) sp.	-	-	-	-	1	2	2	5
Orthocladius (Euorth.) spp.	-	-	1	1	-	-	-	-
Simulium sp.	-	-	-	-	-	6	2	8
Total Diptera	155	251	102	508	158	153	106	417
NEMATODA	-	1	-	1	2	-	2	4
Total Nematoda	-	1	-	1	2	-	2	4
TUBELLARIA	2	-	-	2	5	1	3	9
Total Turbellaria	2	-	-	2	5	1	3	9
OLIGOCHAETA								
c.f. *Homochaeta naidina*	1	1	-	2	3	1	2	6
Total Oligochaeta	1	1	-	2	3	1	2	6
TOTAL TAXA	27	24	25		34	29	37	
TOTAL NUMBERS MACROINVERTS.	341	407	257	1005	439	266	300	1005

Table 21. Numbers of macroinvertebrates collected per square foot Surber sample from the Lower Site on German Gulch Creek in May and August, 1984.

TAXA	Spring Sample				Summer Sample			
	A	B	C	TOTAL	A	B	C	TOTAL
EPHEMEROPTERA								
Ameletus sp.	-	-	-	-	2	-	-	2
Baetis bicaudatus	2	4	3	9	-	-	2	2
Baetis spp.	1	4	4	9	6	4	1	11
Pseudocloeon sp.	-	-	-	-	-	2	-	2
Cinygmula spp.	31	16	19	66	-	4	2	6
Epeorus deceptivus	-	-	-	-	10	2	6	18
E. longimanus	1	4	7	12	1	-	-	1
Rhithrogena robusta	1	1	2	4	-	3	7	10
Rhithrogena sp.	-	-	2	2	4	6	6	16
Paraleptophlebia sp.	-	-	-	-	-	-	1	1
Caudatella hystrix	-	1	-	1	5	2	2	9
Drunella coloradensis	3	3	1	7	2	11	2	15
D. doddsi	-	-	-	-	9	6	7	22
D. spinifera	-	-	-	-	1	-	1	2
Ephemerella infrequens	3	3	1	7	1	-	-	1
Seratella tibialis	-	-	-	-	1	-	-	1
Total Ephemeroptera	42	36	39	117	42	40	37	119
PLECOPTERA								
Amphinemura sp.	-	-	-	-	9	7	14	30
Capnia group	-	-	-	-	-	-	1	1
Pteronarcella badia	-	-	-	-	-	1	-	1
Megarcys sp.	-	-	-	-	2	6	3	11
Taenionema sp.	-	-	1	1	-	-	-	-
Doroneuria theodora	2	1	1	4	1	1	-	2
Chloroperlinae	-	4	-	4	1	2	6	9
Total Plecoptera	2	5	2	9	13	17	24	54
TRICHOPTERA								
Dolophilodes sp.	-	-	-	-	14	1	-	15
Arctopsyche sp.	-	1	-	1	15	11	11	37
Hydropsyche sp.	-	-	-	-	-	-	1	1
Rhyacophila spp.	-	-	-	-	9	3	2	14
Glossosoma sp.	2	1	3	6	2	-	-	2
Brachycentrus sp.	-	-	-	-	1	2	-	3
Micrasema sp.	-	1	-	1	-	1	1	2
Apatania sp.	-	1	-	1	-	1	-	1
Total Trichoptera	2	4	3	9	41	19	15	75
COLEOPTERA								
Heterlimnius corpulentus	2	-	2	4	12	89	13	114
Narpus sp.	-	-	-	-	-	2	-	2
Total Coleoptera	2	-	2	4	12	91	13	116
DIPTERA								
Antocha sp.	2	-	-	2	-	3	-	3
Hexatoma sp.	1	1	-	2	-	1	-	1

Table 21. Continued.

TAXA	Spring Sample A	Spring Sample B	Spring Sample C	Spring Sample TOTAL	Summer Sample A	Summer Sample B	Summer Sample C	Summer Sample TOTAL
DIPTERA (Continued)								
Diamesa sp.	3	2	1	6	-	-	-	-
Pseudokiefferiella sp.	-	-	-	-	-	2	-	2
Micropsectra sp.	-	1	-	1	-	2	2	4
Brillia sp.	-	-	-	-	-	1	-	1
Cardiocladius sp.	-	-	-	-	-	6	-	6
Cricotopus (CRIC.) sp.	-	-	-	-	2	1	1	4
Cricotopus c.f. *nostocicola*	-	-	1	1	1	12	3	16
Cricotopus / *Orthocladius* spp.	-	-	-	-	-	13	2	15
Eukiefferiella spp.	-	-	-	-	7	11	8	26
Orthocladius (Euorth.) spp.	-	-	-	-	-	8	1	9
Simulium sp.	-	1	-	1	15	6	7	28
Total Diptera	6	5	2	13	25	66	24	115
NEMATODA	1	-	-	1	1	1	-	2
Total Nematoda	1	-	-	1	1	1	-	2
TUBELLARIA	-	3	-	3	1	6	3	10
Total Turbellaria	-	3	-	3	1	6	3	10
OLIGOCHAETA								
Eiseniella sp.	2	3	3	8	-	-	1	1
Haplotaxis sp.	-	-	-	-	-	2	-	2
c.f. *Homochaeta naidina*	1	1	1	3	6	22	3	31
Total Oligochaeta	3	4	4	11	6	24	4	34
TOTAL TAXA	16	21	16		28	38	30	
TOTAL NUMBERS MACROINVERTS.	58	57	52	167	141	264	120	525

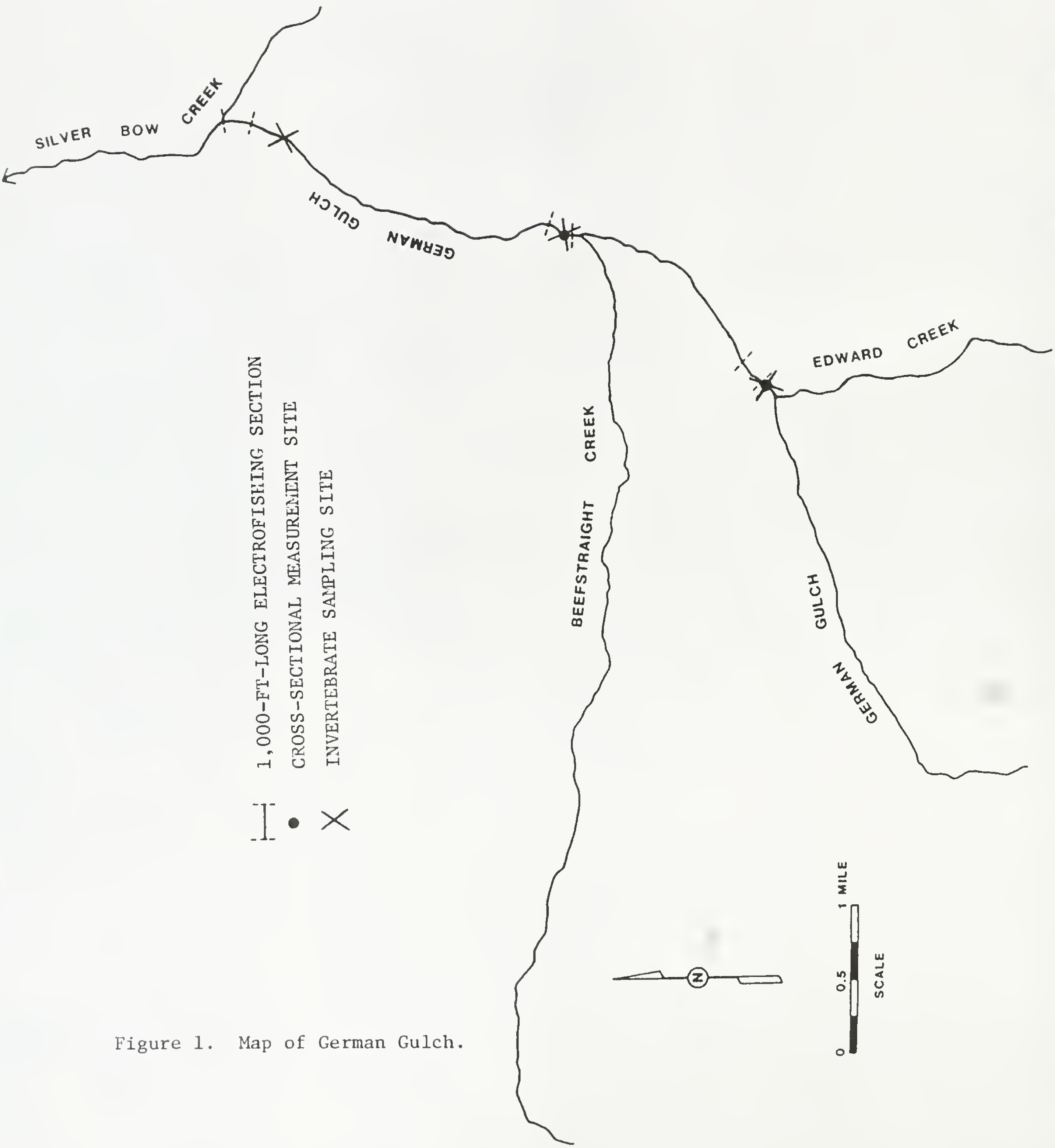

Figure 1. Map of German Gulch.

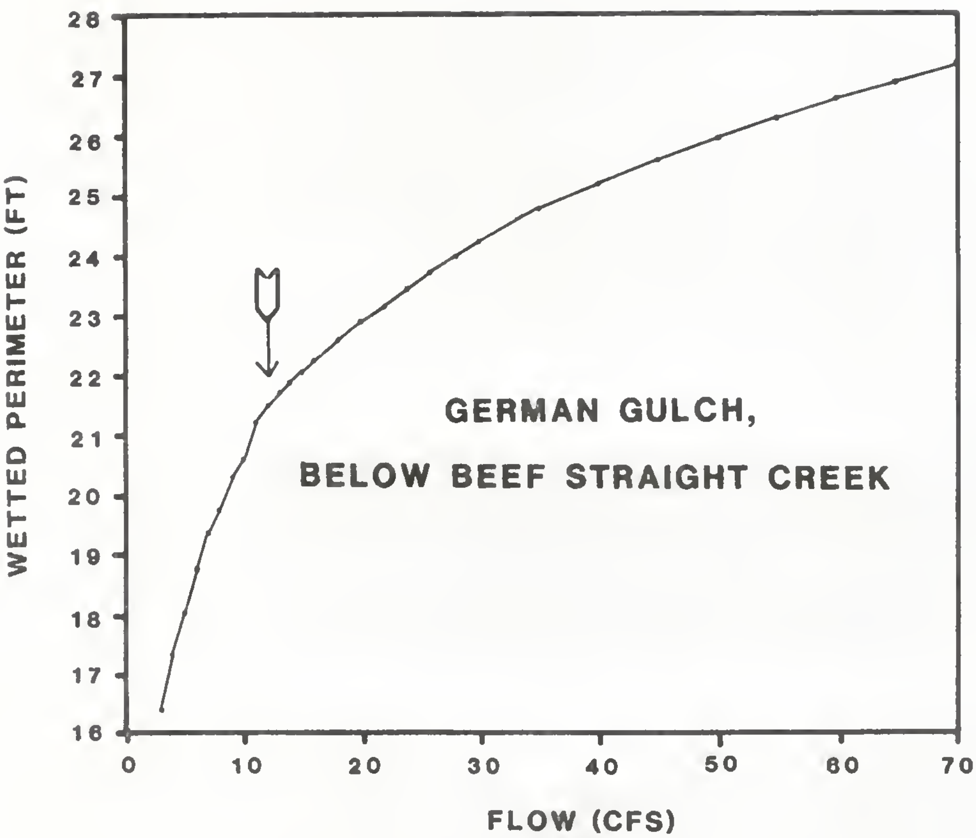

Figure 2. The relationship between wetted perimeter and flow for a composite of five riffle cross-sections in German Gulch below the confluence of Beefstraight Creek.

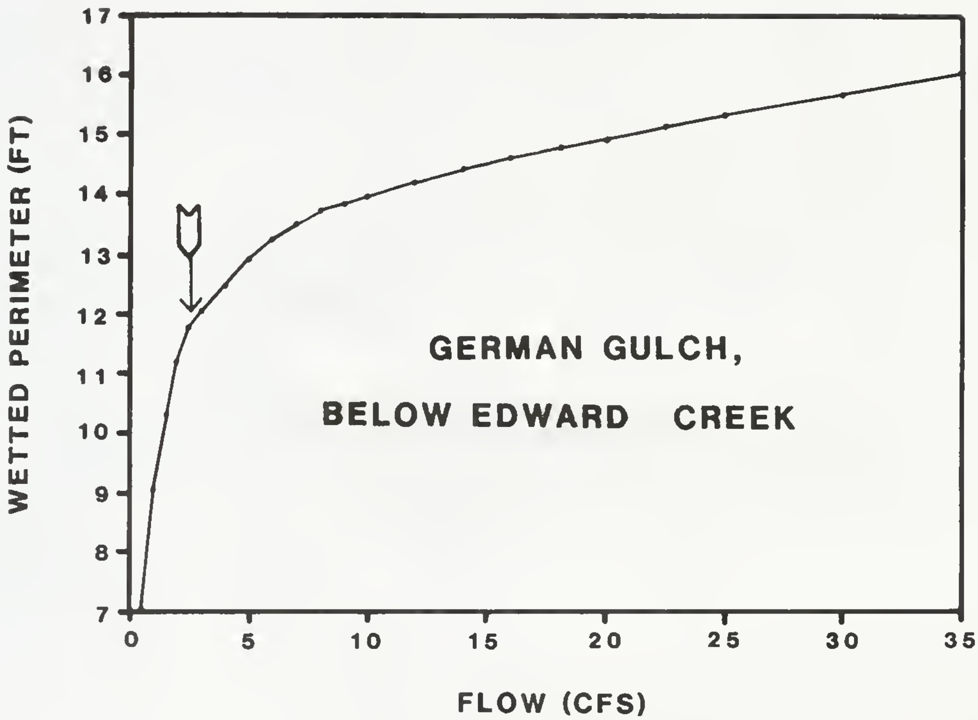

Figure 3. The relationship between wetted perimeter and flow for a composite of five riffle cross-sections in German Gulch below the confluence of Edward Creek.

APPENDIX A

University of Montana

Department of Zoology • Missoula, Montana 59812 • (406) 243-5122

August 27, 1984

Mr. Bruce Rehwinkel
Box 251
Whitehall, MT 59759

Dear Bruce:

We have completed the electrophoretic analysis of the Salmo sample you collected from German Gulch Creek (N=39, S 26, T 3N, R 10W) on 27 July 1984. We examined the protein products of 45 loci in all the fish (Table 1). Thirteen of these loci can be used to differentiate westslope cutthroat (S. clarki lewisi), Yellowstone cutthroat (S. c. bouvieri), and rainbow trout (S. gairdneri) (Table 2). There is no evidence of rainbow or Yellowstone cutthroat trout genetic material in the sample at any of these loci. With this sample size, we would detect even as little as one percent rainbow or Yellowstone genes in the population over 99 percent of the time. Thus, this is almost certainly a genetically 'pure' population of westslope cutthroat trout.

There is evidence of genetic variation at seven of the loci examined (Table 3). We have detected the Idh3(71) allele only at low frequencies (i.e. less than 0.10) in a few other populations of westslope cutthroat trout. This allele, however, is present in the German Gulch Creek westslope cutthroat trout at a very high frequency (0.974). This indicates that this population is genetically distinct from the other populations that we have examined, and thus, represents an extremely valuable resource.

We have not detected many pure populations of westslope cutthroat trout among the numerous samples that we have analyzed from western Montana. Most populations suspected to be pure westslope cutthroat trout also contain rainbow or Yellowstone cutthroat trout genetic material. The available data indicate that the westslope cutthroat is in danger of extinction. In order to ensure the continued existence of this native species, it is important to preserve all pure populations that are identified.

Sincerely,

Robb F. Leary

Robb F. Leary
Genetics Laboratory

Fred W. Allendorf

Fred W. Allendorf
Professor

RFL/pkf
Enclosures

TABLE 1

Loci and enzymes examined (E=eye, L=liver, M=muscle)

Enzyme	Loci	Tissue
Adenylate kinase (AK)	Ak1,2	M
Alcohol dehydrogenase (ADH)	Adh	L
Aspartate aminotransferase (AAT)	Aat1,2	L
	Aat(3,4)	M
Creatine kinase (CK)	Ck1,2	M
	Ck3,CkC1,2	E
Glucose phosphate isomerase (GPI)	Gpi1,2,3	M
Glyceraldehyde-3-phosphate dehydrogenase (GAP)	Gap3,4	E
Glycerol-3-phosphate dehydrogenase (G3P)	G3p1,2	L
Glycyl-leucine Peptidase (GL)	Gl1,2	E
Isocitrate dehydrogenase (IDH)	Idh1,2	M
	Idh3,4	L
Lactate dehydrogenase (LDH)	Ldh1,2	M
	Ldh3,4,5	E
Leucyl-glycyl-glycine peptidase (LGG)	Lgg	E
Malate dehydrogenase (MDH)	Mdh(1,2)	L
	Mdh(3,4)	M
Malic enzyme (ME)	Me1,2,3	M
	Me4	L
Phosphoglucomutase (PGM)	Pgm1,2	M
6-Phosphogluconate dehydrogenase (6PG)	6Pg	M
Sorbitol dehydrogenase (SDH)	Sdh	L
Superoxide dismutase (SOD)	Sod	L
Xanthine dehydrogenase (XDH)	Xdh	L

Note: The protein products of the pairs of loci in ( ) are electrophoretically indistinguishable. Thus, they are considered to be single tetrasomic loci in all analyses.

TABLE 2

Loci that can be used to differentiate rainbow, westslope cutthroat, and Yellowstone cutthroat trout. Alleles are designated as the proportional migration distance in the gel relative to the distance traveled by the common allele in rainbow trout which is given a mobility of 100.

	Alleles		
Loci	Rainbow	Westslope	Yellowstone
Aat1	100	200,250	165
Ck2	100	84	84
CkC1	100,38	100,38	38
Gl1	100,115,90	100	101
Gpi3	100	92	100
Idh1	100	100	-75
Idh3,4	100,114,71,40	100,86,71,40,Null	100,71
Lgg	100,135	100	135
Me1	100,55	88	100
Me3	100,75	100,75	90
Me4	100	100	110
Pgm1	100,Null	100,Null	Null
Sdh	100,200,40	40,100	100

TABLE 3

Allele frequencies at the variable loci in the German Gulch Creek population of westslope cutthroat trout.

Locus	Alleles	Frequencies
CkC1	100	0.885
	38	0.115
Gap4	100	0.974
	Null	0.026
Idh3	71	0.974
	Null	0.026
Idh4	100	0.321
	40	0.679
Ldh4	100	0.974
	112	0.026
Mdh1,2	100	0.942
	125	0.013
	40	0.045
Proportion Polymorphic Loci		0.143
Average Heterozygosity		0.024

APPENDIX B

GUIDELINES FOR USING THE WETTED PERIMETER (WETP) COMPUTER PROGRAM OF THE MONTANA DEPARTMENT OF FISH, WILDLIFE AND PARKS

By
Frederick A. Nelson
Montana Department of Fish, Wildlife and Parks
8695 Huffine Lane
Bozeman, Montana 59715

Revised
July, 1984

TABLE OF CONTENTS

INTRODUCTION

The wetted perimeter and discharge relationships for selected channel cross-sections are a useful tool for deriving instream flow recommendations for the rivers and streams of Montana. Wetted perimeter is the distance along the bottom and sides of a channel cross-section in contact with water (Figure 1). As the discharge in a stream channel decreases, the wetted perimeter also decreases, but the rate of loss of wetted perimeter is not constant throughout the entire range of discharges. Starting at zero discharge, wetted perimeter increases rapidly for small increases in discharge up to the point where the stream channel nears its maximum width. Beyond this break or inflection point, the increase of wetted perimeter is less rapid as discharge increases. An example of a wetted perimeter-discharge relationship showing a well-defined inflection point is given in Figure 2. The instream flow recommendation is selected at or near this inflection point.

The MDFWP developed in 1980 a relatively simple wetted perimeter predictive (WETP) computer model for use in its instream flow program. This model eliminates the relatively complex data collecting and calibrating procedures associated with the hydraulic simulation computer models in current use while providing more accurate and reliable wetted perimeter predictions.

The WETP computer program was written by Dr. Dalton Burkhalter, aquatic consultant, 1429 S. 5th Ave., Bozeman, Montana 59715. The program is written in FORTRAN IV and is located at the computer center, Montana State University, Bozeman. Direct all correspondence concerning the program to Fred Nelson, Montana Department of Fish, Wildlife and Parks, 8695 Huffine Lane, Bozeman, Montana 59715.

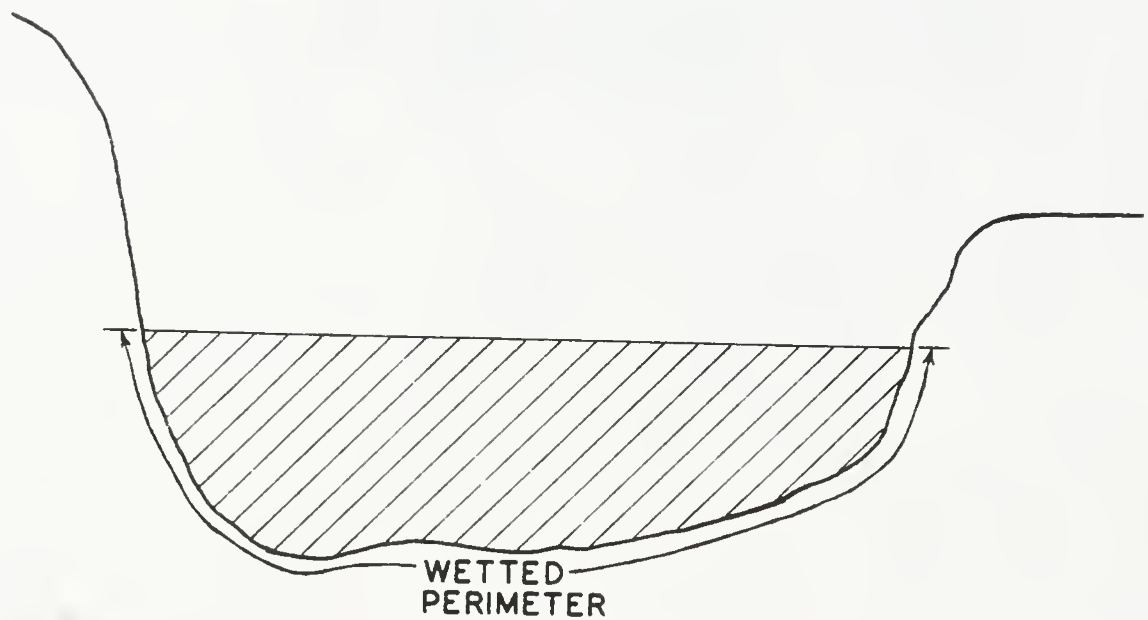

Figure 1. The wetted perimeter in a channel cross-section.

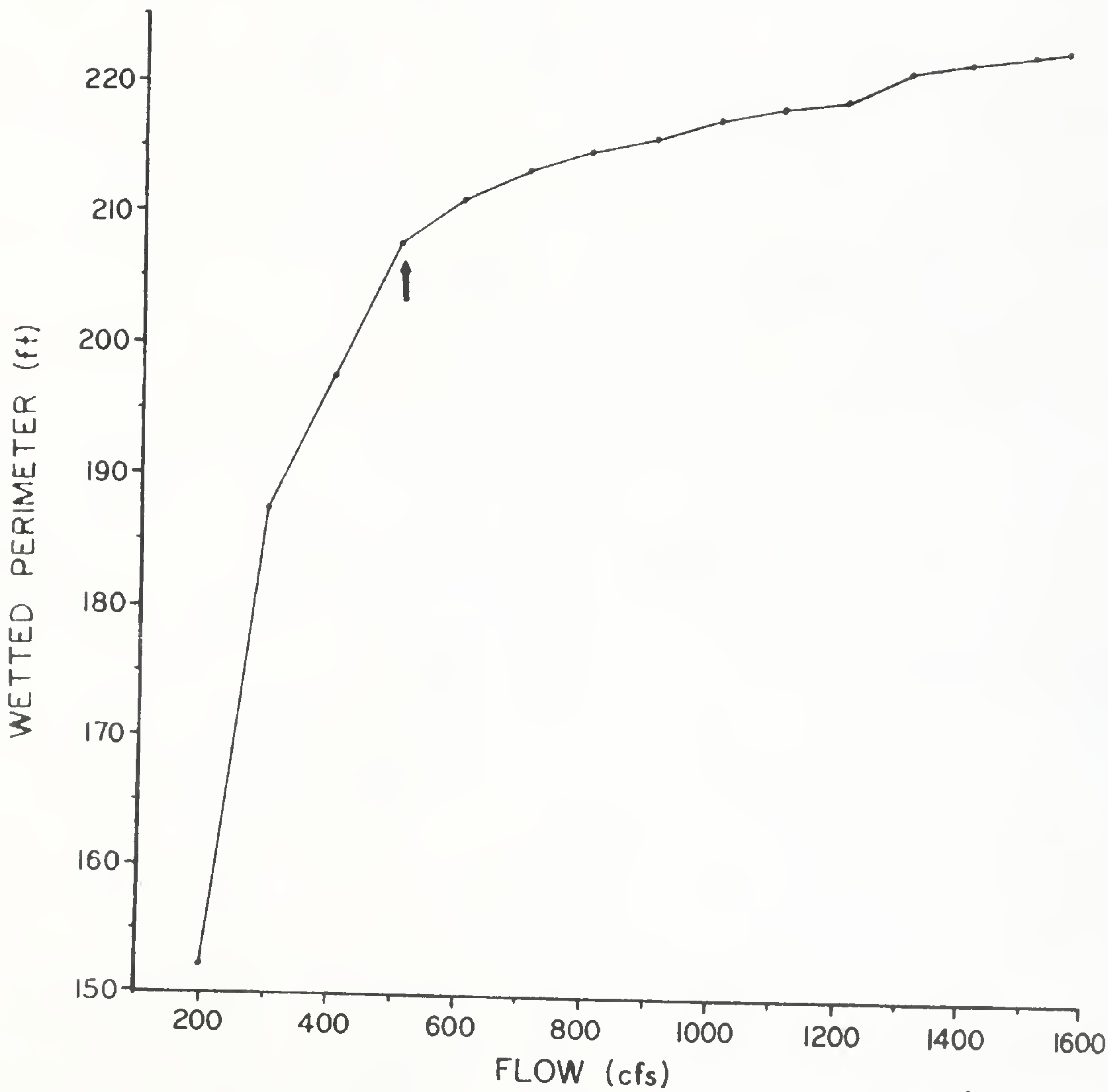

Figure 2. An example of a relationship between wetted perimeter and flow for a riffle cross-section.

DERIVING RECOMMENDATIONS USING WETTED PERIMETER

When formulating flow recommendations for a waterway, the annual flow cycle is divided into two separate periods. They consist of a relatively brief runoff or high flow period, when a large percentage of the annual water yield is passed through the system, and a nonrunoff or low flow period, which is characterized by relatively stable base flows maintained primarily by groundwater outflow. For headwater rivers and streams, the high flow period generally includes the months of May, June and July while the remaining months encompass the low flow period.

Separate instream flow methods are applied to each period. Further, it is necessary to classify a waterway as a stream or river and to use a somewhat different approach when deriving low flow recommendations for each. A waterway is considered a stream if the mean annual flow is less than approximately 200 cfs.

Method for the Low Flow Period - Streams

The wetted perimeter/inflection point method is presently the primary method being used by the MDFWP for deriving low flow recommendations for streams. This method is primarily based on the assumption that the food supply is a major factor influencing a stream's carrying capacity (the numbers and pounds of fish that can be maintained indefinitely by the aquatic habitat). The principal food of many of the juvenile and adult game fish inhabiting the streams of Montana is aquatic invertebrates, which are primarily produced in stream riffle areas. The method assumes that the game fish carrying capacity is proportional to food production, which in turn is proportional to the wetted perimeter in riffle areas. This method is a slightly modified version of the Washington Method (Collings, 1972 and 1974), which is based on the premise that the rearing of juvenile salmon is proportional to food production and in turn is proportional to the wetted perimeter in riffle areas. The Idaho Method (White and Cochnauer, 1975 and White, 1976) is also based on a similar premise.

The plot of wetted perimeter versus flow for stream riffle cross-sections generally shows two inflection points, the uppermost being the more prominant. In the example (Figure 3), these inflection points occur at approximate flows of 8 and 12 cfs. Beyond the upper inflection point, large changes in flow cause only very small changes in wetted perimeter. The area available for food production is considered near optimal beyond this point. At flows below the upper inflection point, the stream begins to pull away from the riffle bottom until, at the lower inflection point, the rate of loss of wetted perimeter begins to rapidly accelerate. Once flows are reduced below the

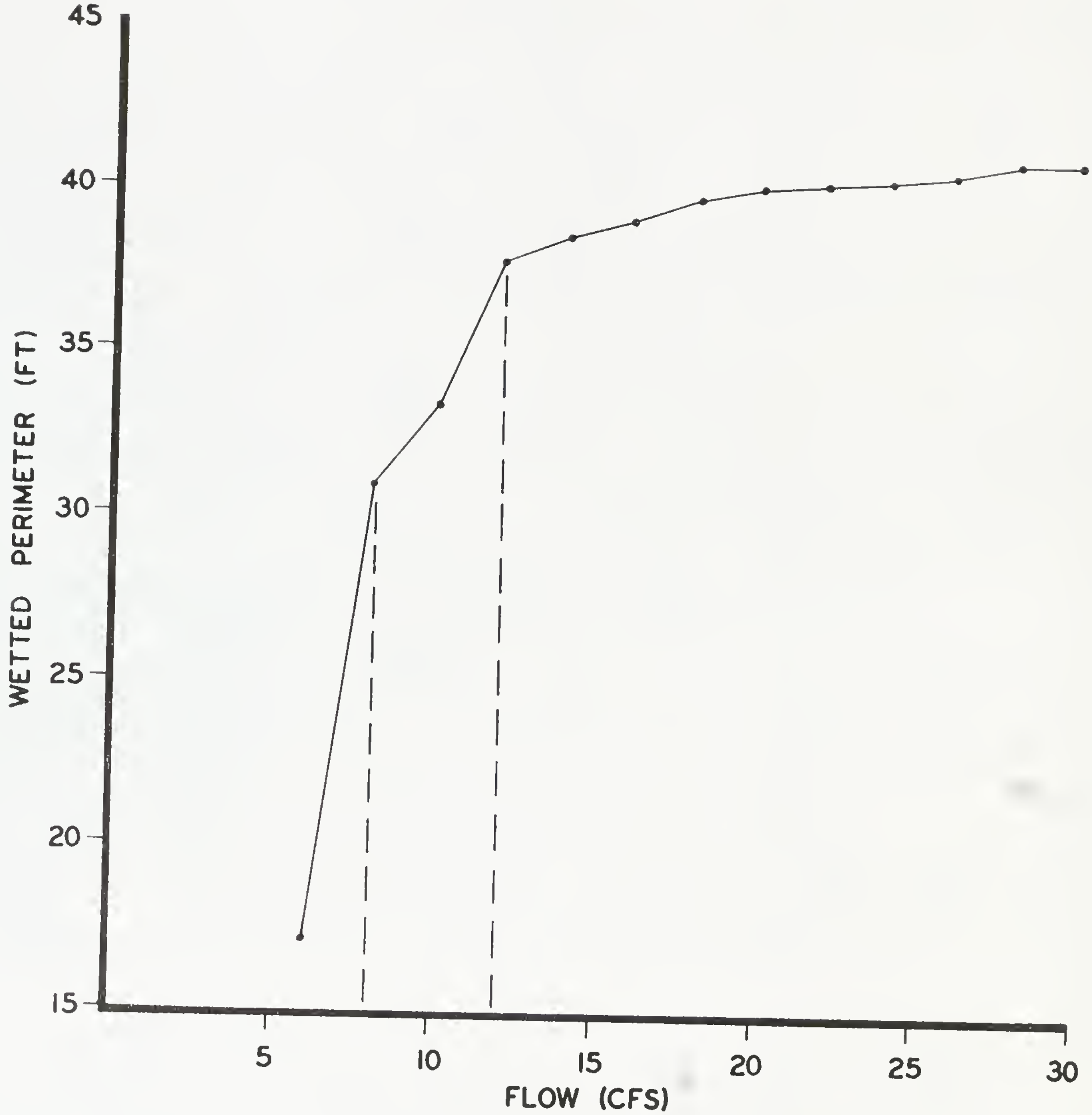

Figure 3. An example of a relationship between wetted perimeter and flow for a stream riffle cross-section.

lower inflection point, the riffle bottom is being exposed at an accelerated rate and the area available for food production greatly diminishes.

The wetted perimeter-flow relationship may also provide an index of other limiting factors that influence a stream's carrying capacity. One such factor is cover. Cover, or shelter, has long been recognized as one of the basic and essential components of fish habitat. Cover serves as a means for avoiding predators and provides areas of moderate current speed used as resting and holding areas by fish. It is fairly well documented that cover improvements will normally increase the carrying capacity of streams, especially for larger size fish. Cover can be significantly influenced by streamflow.

In the headwater streams of Montana, overhanging and submerged bank vegetation are important components of cover. The wetted perimeter-flow relationship for a stream channel may bear some similarity to the relationship between bank cover and flow. At the upper inflection point, the water begins to pull away from the banks, bank cover diminishes and the stream's carrying capacity declines. Flows exceeding the upper inflection point are considered to provide near optimal bank cover. At flows below the lower inflection point, the water is sufficiently removed from the bank cover to severely reduce its value as fish shelter.

It has been demonstrated that riffles are also critical areas for spawning sites of brown trout and shallow inshore areas are required for the rearing of brown and rainbow trout fry (Sando, 1981). It is therefore assumed that, in addition to maximizing bank cover and food production, the flows exceeding the upper inflection point would also provide the most favorable spawning and rearing conditions.

Riffles are the area of a stream most affected by flow reductions (Bovee, 1974 and Nelson, 1977). Consequently, the flows that maintain suitable riffle conditions will also maintain suitable conditions in pools and runs, areas normally inhabited by adult fish. Because riffles are the habitat most affected by flow reductions and are essential for the well-being of both resident and migratory fish populations, they should receive the highest priority for instream protection.

The wetted perimeter/inflection point method provides a range of flows (between the lower and upper inflection points) from which a single instream flow recommendation can be selected. Flows below the lower inflection point are judged undesirable based on their probable impacts on food production, bank cover and spawning and rearing habitat, while flows exceeding the upper inflection point are considered to provide a near optimal habitat for fish. The lower and upper inflection points are believed to bracket those flows needed to maintain the low and high levels of aquatic habitat potential. These flow levels are defined as follows:

1. High Level of Aquatic Habitat Potential - That flow regime which will consistently produce abundant, healthy and thriving aquatic populations. In the case of game fish species, these flows would produce abundant game fish populations capable of sustaining a good to excellent sport fishery for the size of stream involved. For rare, threatened or endangered species, flows to accomplish the high level of aquatic habitat maintenance would: 1) provide the high population levels needed to ensure the continued existence of that species, or 2) provide the flow levels above those which would adversely affect the species.

2. Low Level of Aquatic Habitat Potential - Flows to accomplish a low level of aquatic habitat maintenance would provide for only a low population of the species present. In the case of game fish species, a poor sport fishery could still be provided. For rare, threatened or endangered species, their populations would exist at low or marginal levels. In some cases, this flow level would not be sufficient to maintain certain species.

The final flow recommendation is selected from this range of flows by the fishery biologist who collected, summarized and analyzed all relevant field data for the streams of interest. The biologist's rating of the stream resource forms the basis of the flow selection process. Factors considered in the evaluation include the level of recreational use, the existing level of environmental degradation, water availability and the magnitude and composition of existing fish populations. The fish population information, which is essential for all streams, is a major consideration. A marginal or poor fishery would likely justify a flow recommendation at or near the lower inflection point unless other considerations, such as the presence of species of special concern (arctic grayling and cutthroat trout, for example), warrant a higher flow. In general, only streams with exceptional resident fish populations or those providing crucial spawning and/or rearing habitats for migratory populations would be considered for a recommendation at or near the upper inflection point. The process of deriving the flow recommendation for the low flow period thus combines a field method (wetted perimeter/inflection point method) with a thorough evaluation by a field biologist of the existing stream resource.

It is recommended that at least three and preferably five riffle cross-sections are used in the analysis. The final flow recommendation is derived by averaging the recommendations for each cross-section, or the computed wetted perimeters for all riffle cross-sections at each flow of interest averaged and the recommendation selected from the wetted perimeter-flow relationship for the composite of all cross-sections. The latter method is preferred.

A study evaluating the wetted perimeter/inflection point method for small trout streams was completed at the Cooperative Fisheries Research Unit, Montana State University, as a thesis project (Randolph and White, 1984). An innovative approach in which stream sections were isolated with weirs and wild rainbow trout added during the high flow period, saturating the habitat, was used. Changes in trout carrying capacity, as determined by the movement of trout out of the sections, were measured as the flow decreased. The derived relationships between flow and trout carrying capacity were then compared to the relationships between flow and various habitat parameters, including the riffle wetted perimeter. The authors reported that in the pool-riffle habitats of their study stream the wetted perimeter/inflection point method worked well, while in run-riffle habitats the method underestimated the flow that was needed to maintain rainbow trout at a reasonable level. In no case did the method overestimate the summer instream flow needs.

Method for the Low Flow Period - Rivers

The Montana Department of Fish, Wildlife and Parks completed a study in 1980 that validated the wetted perimeter method as applied to the trout rivers of southwest Montana (Nelson, 1980a, 1980b and 1980c). In this study, the actual trout standing crop and flow relationship were derived from long-term data collected for five reaches of the Madison, Gallatin, Big Hole and Beaverhead Rivers, all nationally acclaimed wild trout fisheries. These relationships provided a range of flow recommendations for each reach. Flows less that the lower limit were judged undesirable since they led to substantial reductions of the standing crops of adult trout or the standing crops of a particular group of adults, such as trophy-size trout. Flows greater than the upper limit supported the highest adult standing crops during the study period. Flows between the lower and upper limits are broadly defined as those flows supporting intermediate standing crops or those standing crops that normally occur within each reach. The final recommendation was selected from this range of flows.

The range of flows derived from the trout-flow relationships for the five river reaches were compared to those derived from the wetted perimeter method as applied to riffle areas. The study results showed that the inflection point flows had a somewhat different impact on the trout standing crops of rivers than previously assumed for streams. For rivers, the flow at the upper inflection point is a fairly reliable estimate of the lower limit of the range of flows derived from the trout-flow relationships or, in other terms, flows less than the upper inflection point are undesirable as recommendations since they appear to lead to substantial reductions of the standing crops of adult trout.

The flow at the upper inflection point is not necessarily the preferred recommendation for all trout rivers. The "Blue Ribbon" rivers may require a higher flow in order to maintain the sport fishery resource at the existing level. In general, flows less than the upper inflection point are undesirable as flow recommendations regardless of the rating of the river resource.

DESCRIPTION OF THE WETP PROGRAM

The WETP program uses 2 to 10 sets of stage (water surface elevation) measurements taken at different known discharges (flows) to establish a rating curve. This curve has the equation, $Q = p(S - zf)^n$ where:

> Q = discharge
> S = stage height
> zf = stage height at zero flow
> p = a constant
> n = a constant exponent.

The relationship of measured points, if perfect, would plot as a straight line on log - log paper with n equal to the slope of the line and p equal to the discharge when (S - zf) = 1. The actual line is determined by least squares regression using the measured points. Once the stage-discharge rating curve for each cross-section is determined, the stage at a flow of interest can be predicted. This rating curve, when coupled with the cross-sectional profile, is all that is needed to predict the wetted perimeter at most flows of interest.

The stage height at zero flow (zf) may be taken as the lowest elevation on the cross-sectional profile for riffles but is more difficult to determine for non-riffles, particularly pools, in which case the procedures of Rantz (1982) should be consulted. The applicable portions of that paper are included in Appendix A.

The zf value for a non-riffle cross-section can also be measured in the field. It is the highest elevation of the thalweg (as referenced to the bench mark elevation) at the downstream control, which is typically the head of a riffle. The control is a channel feature which causes water to backup in an upstream direction.

The value of zf is controlled by use of an option record (OPTS) in the input data. If the option is set to one, zf is either set to a value supplied by the user or, in the absence of a supplied value, zf is automatically set to the lowest elevation in the cross-sectional profile. If the user does not want zf to equal the lowest elevation in the cross-sectional profile, the values for zf are entered on the XSEC records. The option record must be the first entry in the data file and is illustrated in Appendices B and C.

The option of setting zf to zero by setting the option record to zero is also available. Prior to this program revision, all results were obtained with zf automatically set to zero. Option zero is included solely for the purpose of comparing results. Because the program now incorporates zf into the calculations, the accuracy of the hydraulic predictions for those flows of interest that are less than the lowest measured calibration flow should improve over calculations previously made with zf = 0.

The program should be run using three sets of stage-discharge data collected at a high, intermediate and low flow. Additional data sets are desirable, but not necessary. The three measurements are made when runoff is receding (high flow), near the end of runoff (intermediate flow) and during late summer-early fall (low flow). The high flow should be considerably less than the bankfull flow, while the low flow should approximate the lowest flow that normally occurs during the summer-fall field season. Sufficient spread between the highest and lowest calibration flows is needed in order for the program to compute a linear, sloping rating curve.

The WETP program will run using only two sets of stage-discharge data. This practice is not recommended since substantial "two-point" error can result.

In addition to wetted perimeter (WETP), the program also predicts other hydraulic characteristics that can be used in deriving flow recommendations for selected time periods and life functions. These are the mean depth (DBAR) in ft, mean velocity (VBAR) in ft/sec, top width (WDTH) in ft, cross-sectional area (AREA) in ft^2, stage (STGE) in ft, and maximum depth (DMAX) in ft.

A useful program option, termed the width-at-given-depth (WAGD) option, will calculate for up to 10 given depths the width (in ft) and percentage of the top width having depths greater than or equal to the given values. The width and percentage of the longest, continuous segment having the required depths is also listed for each flow of interest. This option is illustrated in Appendices B and C.

FIELD DATA REQUIREMENTS

The required inputs to the WETP program for each cross-section are:

1. Three sets of stage-discharge data measured at a high, intermediate and low flow. The stage height at zero flow (zf) is mandatory only when the program is applied to non-riffle areas.

2. The cross-sectional profile which consists of channel elevations (vertical distances) and the horizontal distance of each elevation measurement from the headstake (zero point). Up to 150 sets of measurements per cross-section are accepted by the program.

The following are needed to document field work:

1. Slides or photographs of the study area and cross-sections at the time field data are collected.

2. Field notebooks containing all surveying data, notes and calculations, recorded in a neat, consistent manner.

FIELD METHODS

Equipment

1. Level (a self-leveling or automatic level such as a Wild NAKI is preferred).

2. 25-ft, telescoping, fiberglas level rod.

3. 50-500 ft canyon line or other suitable measuring tape. Tape should be calibrated to 0.1 ft.

4. Rebar cut in 30-inch pieces (stakes). Two stakes are needed per cross-section.

5. Two clamps (modified vise grips with flat jaws).

6. Engineers field notebook.

7. Pencils.

8. Current meter and rod, stopwatch and beeper box. Gurley or Price AA current meters are preferred. A Marsh-McBirney instantaneous readout current meter can be used in place of a Gurley or Price AA meter, provided the instantaneous meter is correctly calibrated.

9. Small sledge hammer.

10. Camera.

11. Fluorescent spray paint and flagging.

12. Forms for recording stream discharges and cross-sectional profiles.

13. A rod fitted with a porcelain, enameled, iron gage (Part No. 15405, Leupold and Stevens, Inc., P.O. Box 688, Beaverton, Oregon 97075) for measuring water depths. A current meter rod can be substituted.

Selecting Study Areas and Placing Cross-sections

Follow these guidelines when selecting study areas and placing cross-sections.

1. It is best to locate study areas and stake cross-sections during low water <u>prior</u> to the onset of runoff. It will be difficult to select these sites during the high water period when data collection begins.

2. Place the cross-sections in riffle areas if the wetted perimeter/inflection point method will be used to derive recommendations.

Cross-sections can be placed in a single riffle or a number of different riffles. Cross-sections should describe the typical riffle habitats within the stream reach being studied. Other critical habitat types can also be used, depending on your chosen method.

3. Describe the riffles using 3 to 10 cross-sections. It is recommended that at least 3 and preferably 5 riffle cross-sections are used. The program accepts 1 to 10 cross-sections per study area.

4. The WETP model assumes that the water surface elevations at the water's edge on the left bank (WEL) and right bank (WER) of a cross-section are always equal at a given flow. This is a valid assumption since the water surface elevations at WEL and WER generally remain within 0.1 ft of each other as the flow changes, provided the water surface elevations at WEL and WER were matched when the cross-section was established. Avoid placing cross-sections in areas where this assumption is likely to be violated, such as sharp bends in rivers and multiple channels containing islands. If cross-sections through these areas are unavoidable, you should proceed with caution.

5. Place the headstake marking each cross-section well up on the bank. Drive the headstake almost flush with the ground and mark well. In addition to marking the cross-section, the headstake is also your zero reference point for measuring horizontal distances across the cross-section. Headstakes for all the cross-sections within a study area should be located on the same bank.

   Another stake is driven directly across from the headstake on the opposite bank. Place this stake so that the water surface elevations at the WEL and WER of the established cross-section are equal or similar (within 0.05 ft). This will require the use of a level and level rod. This stake is used to mark the cross-section on the bank opposite the headstake and also to attach the measuring tape when the channel profile is measured, so should not be driven to ground level. Cross-sections, when established, should be roughly perpendicular to the banks.

6. Number the cross-sections consecutively from downstream to upstream (the downstream-most cross-section is #1).

7. Measure the distances between cross-sections. This is an optional measurement that might be useful in locating cross-sections during return trips.

8. Remember, the WETP model is invalidated if channel changes occur in the study area during the data collecting process. For this reason, the collection of all field data should be completed during the period beginning when runoff is receding and ending with the onset of runoff the

following year. The stream channel is expected to be stable during this period.

Establishing Bench Marks

Establish a bench mark at or near your study area. The bench mark is a point that will not be disturbed or moved. A nail driven into the base of a tree, a fixed spot on a bridge abutment and a survey stake driven into the ground are examples of bench marks. Designating one of the cross-sectional headstakes within a study area as the bench mark is an acceptable practice. Bench marks should be well marked and described in your field notebook so they can be easily located during return trips. All channel and water surface elevations are established relative to the bench mark, which is assigned an elevation of 100.00 or 10.00 ft. Use 10.00 ft whenever possible.

For streams having "heavy" vegetative cover, the use of a single bench mark may not be practical. In this case, the individual headstakes can be used as bench marks. For example, the headstake for cross-section #1 could serve as the bench mark for cross-sections #1 and 2, while the headstake for cross-section #3 could serve as the bench mark for cross-sections #3, 4 and 5. Each headstake could also serve as the bench mark for that individual cross-section. While this is not the best surveying technique, certain stream reaches may require its use. Be sure to carefully record in your notebook which headstakes are used as bench marks to avoid confusion and errors on return trips.

Remember, channel and water surface elevations for all cross-sections within a study area do not have to be tied to a single bench mark for the WETP program to run properly. However, the use of a single bench mark enhances your field technique.

Surveying Techniques

The reader is referred to Spence (1975) and Bovee and Milhous (1978) for a discussion of the surveying techniques used to measure cross-sectional profiles and water surface elevations. Both papers should be read by those unfamiliar with the mechanics of surveying. All investigators must receive field training before attempting any measurements.

It is important to be consistent and to use good technique when collecting and recording data. Record all data in your notebook and complete all calculations while in the field, so that any surveying errors can be detected and corrected. Remember, your field notebooks may be examined in court or hearing proceedings. Good quality equipment such as an automatic level is also an asset.

Measuring Water Surface Elevations (Stages)

Water surface elevations should be measured for each cross-section at three different flows. If cross-sections are established prior to runoff, then you must return to the study area at least three more times, when runoff is receding (high flow), near the end of runoff (intermediate flow) and during late summer or early fall (low flow).

It should be noted that it is unnecessary to collect surface elevation measurements for all of the cross-sections within a study area at the same flows. For example, if another cross-section is added to the study area at a later date, the calibration flows for this new cross-section do not have to match those for the remaining cross-sections. It is also unnecessary to have the same number of calibration flows for all of the cross-sections within a study area.

Water surface elevations are measured at the water's edge directly opposite the stake marking the cross-section on each bank. The stretching of a tape across the cross-section is unnecesary, since the horizontal distances from the headstake to the WEL and WER are not needed. Measure water surface elevations to the nearest 0.01 ft. The mechanics of this measurement are discussed in Bovee and Milhous (1978). Once water surface elevations are calculated, repeat the measurements and check for surveying errors. If a single bench mark is used, then water surface elevations should increase with the upstream progression of cross-sections.

As previously discussed, the WETP model assumes that the water surface elevations at WEL and WER are always equal at a selected flow of interest. In a stream channel, the surface elevations at the WEL and WER of a cross-section should remain fairly equal as the flow varies, provided the elevations at WEL and WER were matched when the cross-section was established. Consequently, it is necessary to measure the water surface elevations at both WEL and WER during all return trips to verify this assumption. These two measurements should always be within approximately 0.1 ft of one another. For the larger waterways, a greater difference is allowable. Average these two measurements to obtain the water surface elevation that is entered on the coding sheets.

Measuring Stream Discharges

The flow through the study area must be measured each time water surface elevations are determined. On the larger waterways, it is best to locate study areas near USGS gage stations to eliminate a discharge measurement.

Use standard USGS methods when measuring discharges. Publications of Bovee and Milhous (1978), Buchanan and Somers (1969), and Smoot and Novak (1968) describe these methods and provide information on the maintenance of current meters. Read these publications before attempting any discharge measurements. Field training is also mandatory.

Measuring Cross-sectional Profiles

The channel profile has to be determined for each cross-section. Unlike the measurement of water surface elevations, this has to be done only once. It is best to measure profiles at the lowest calibration flow when wading is easiest. For the unwadable, larger waterways that require the use of a boat, profiles are best measured at an intermediate calibration flow.

For wadable streams, a measuring tape is stretched across the cross-section with the zero point set on top of the headstake. Setting the headstake at zero, while not mandatory, is a good practice that provides consistency in your field technique. Never attach the tape directly to the headstake. The tape is attached with a vise grip to a stake that is driven behind the headstake. A vise grip can be attached directly to the stake on the opposite bank to stretch and hold the tape in place.

Elevations are now measured betweeen the headstake and water's edge using the level rod. Elevations are measured at major breaks in the contour. The horizonatal distance of each elevation measurement from the headstake (zero point) is also recorded. Elevations are also measured between the water's edge at the opposite bank and the opposite stake and the horizontal distance from the headstake recorded for each measurement. Elevations of the exposed portions of instream rocks and boulders are also measured in this manner. Measure elevations to the nearest 0.01 ft and horizontal distances to the nearest 0.1 ft.

Be sure to collect profile measurements for points well above the water's edge. It is a good practice, although not mandatory, to begin at the headstake (0.0 distance) and end at the stake on the opposite bank. Remember, the highest elevations on both banks of the cross-sectional profile must be substantially higher than the stage at the highest calibration flow, if predictions are to be made for flows of interest that exceed the highest calibration flow.

For the segment of the cross-section containing water, a different approach involving the measurement of water depth is used. Water depth is measured using a current meter rod or a rod fitted with a porcelain, enameled, iron gage. Do not use your level rod. Measure depths at all major breaks in the bottom contour. Generally, 10-30 depth measurements are needed for streams and creeks. Measure depths to the nearest 0.05 ft (current meter rod) or 0.01 ft (rod fitted with gage). For each depth measurement, record the horizontal distance from the headstake (zero point). The bottom elevation at each distance from the headstake is determined by subtracting the water depth from the water surface elevation (average for WEL and WER). For example, if the average water surface elevation is 9.26 ft and at 10.2 ft from the headstake the water depth is 0.90 ft, then the bottom elevation at this distance is 8.36 ft (9.26 ft minus 0.90 ft). The elevations for all points covered by water are calculated in this manner.

For the unwadable, larger waterways, cross-sectional profiles are measured using a boat, depth recorder and range finder. Graham and Penkal (1978) describe this technique.

The WETP program will handle vertical banks. When recording these data, the horizontal distance from the headstake to both the top and bottom of the vertical will be the same, but the elevations will be different.

The program will not handle undercut banks. These data have to be adjusted before being entered on the coding sheets. The best method is to treat undercuts as vertical banks. To accomplish this, the horizontal distance from the headstake to the bottom of the undercut is substituted for the horizontal distance to the top of the undercut, creating a vertical bank.

The program will handle islands, bars and multiple channels, provided the water surface elevations at all the water's edges of the cross-section remain relatively equal as the total stream flow changes. Since this is unlikely, these areas should be avoided when establishing cross-sections.

OFFICE METHODS

WETP Data Format

An example describing the WETP format is given in Appendix B. Much of the format is self-explanatory. Carefully examine this example and the explanatory notations before attempting to code your data on the coding sheets.

The five cross-sections in the example were located in riffles. The stage height at zero flow (zf) was therefore set to the lowest elevation in the cross-sectional profile for each.

All elevations in the example were established relative to a single bench mark, which was assigned an elevation of 100.00 ft for illustration only. A bench mark elevation of 10.00 ft would be more appropriate and should be used whenever possible.

Enter the WETP data on the coding sheets in the following manner:

1. Flows of interest (up to 100 flows are accepted by the program)

   Integers in cfs or with decimal points (not to exceed six characters, including decimal point, if used)

2. Cross-sectional profile data (up to 150 sets of measurements are accepted)

   Distances from headstake - nearest 0.1 ft
   Channel elevations - nearest 0.01 ft

3. Stage-discharge data (2 to 10 sets of measurements are accepted)

   Stages (water surface elevations) - nearest 0.01 ft
   Discharges (flows) - nearest 0.1 cfs

4. Stage height at zero flow (zf) data (1 for each cross-section if desired)

   zf - nearest 0.01 ft

If the cross-sectional profile, stage-discharge and zf data are entered in the above manner, decimal points <u>are not</u> needed. However, decimal points can be used if desired.

Selecting Flows of Interest

You will be extrapolating data for flows of interest that are less than the lowest measured calibration flow for a particular cross-section. The extrapolation of data beyond the highest calibration flow is a less desirable option since our main interest is to derive minimum flow recommendations. Remember, the stage-discharge rating curve generally flattens out at extremely high (above bankfull) and extremely low flows. At these flows, the predicted stages from the measured rating curve are inaccurate and will lead to inaccurate hydraulic predictions.

Use the following guidelines when selecting flows of interest (Bovee and Milhous, 1978):

1. <u>Two point stage-discharge rating curve</u>

   Hydraulic predictions should not be made for flows which are less than 0.77 times the minimum measured flow, nor for flows higher than 1.3 times the maximum measured flow.

2. <u>Three point (or greater) stage-discharge rating curve</u>

   Hydraulic predictions should not be made for flows which are less than 0.4 times the minimum measured flow, nor for flows higher than 2.5 times the maximum measured flow.

<u>WETP Data Output</u>

The output for the input example in Appendix B is given in Appendix C. Carefully examine this output.

When reviewing your outputs, consider the following:

1. Errors

   Carefully check the profile and stage-discharge data on the printouts for errors. The keypunch operators occasionally make errors, even though they carefully proof the data files. The vast majority of errors, however, are the result of format and recording errors on the coding sheets. If corrections are needed, mark all changes on the coding sheets in <u>red</u> ink or pencil and return to Fred Nelson so the file can be corrected and your data rerun.

2. Error messages

   The vast majority of error messages that occasionally appear on the printouts are a result of undetected format errors on the coding sheets. These are easily corrected and the file rerun before the printout is sent to the cooperator.

   An error message will appear when predictions are requested for flows of interest having stages higher than the highest elevations in the cross-sectional profile. Additional profile measurements collected higher up on the banks will correct this problem, if deemed necessary.

3. r^2 values

If the r^2 value for a stage-discharge rating curve is less than approximately 0.90, the cross-section should be eliminated from the analysis. Low r^2 values may be due to errors, so recheck the stage and discharge measurements before eliminating these cross-sections. For those cross-sections having only two sets of stage-discharge measurements (remember, this practice is not recommended), r^2 values are automatically 1.000 and consequently of no use in assessing the reliability of the hydraulic predictions.

OTHER USES FOR THE WETP OUTPUT

The wetted perimeter/inflection point method, as previously described, is the primary method the MDFWP is presently using to derive instream flow recommendations for the waterways of Montana. The WETP program and output can also be used in other ways for deriving recommendations. Some of these uses are discussed in the following examples.

Passage of Migratory Trout

Many streams, particularly those in northwest Montana, provide important spawning and rearing habitats for migratory salmonids. Sufficient stream flows are needed not only to maintain the spawning and rearing habitats, but also to pass adults through shallow riffle areas and other natural barriers while moving to their upstream spawning areas.

Trout passage criteria relating to stream depth have been developed in Oregon and Colorado (Table 1). These criteria, when used in conjunction with the WETP output for critical riffle areas, can be used to derive minimum passage flows. For example, passage criteria developed by the Colorado Division of Wildlife for streams 20 ft and wider indicate that the minimum average depth needed to pass trout through riffles is 0.5-0.6 ft. The output for the Tobacco River (Table 2) shows that the average depth for all five riffle cross-sections exceeds 0.5 ft, the approximate minimum average depth required for passage, at a flow of approximately 120 cfs. A flow of at least 120 cfs is therefore recommended during the spawning period to facilitate the passage of adult trout to upstream spawning areas.

Table 1. Trout passage criteria (from Wesche and Rechard, 1980).

Species	Source	Minimum Depth (ft)	Average Depth (ft)	Where Developed
Large Trout >20 inches	Thompson 1972	0.6	---	Oregon
Other Trout <20 inches	Thompson 1972	0.4	---	Oregon
Trout (on streams 20 ft or greater)	Colo. Div. of Wild. 1976	---	0.5-0.6 across riffles	Colorado
Trout (on streams 10-20 ft wide)	Colo. Div. of Wild. 1976	---	0.2-0.4 across riffles	Colorado

Table 2. Average depths for five riffle cross-sections in the Tobacco River, Montana, at selected flows of interest. Average depths were derived using the WETP computer program.

	Average Depth (ft)				
Flow (cfs)	Riffle cs #1	Riffle cs #2	Riffle cs #3	Riffle cs #4	Riffle cs #5
100	.44	.65	.79	.68	.47
110	.49	.69	.85	.72	.52
120	.54	.73	.91	.75	.57

The minimum depth criteria developed in Oregon could also be used in conjunction with the WAGD option of the WETP program to derive passage recommendations. For this evaluation, criteria are developed requiring at least a certain percentage of the top width of a cross-section to have water depths greater than or equal to the minimum needed for fish passage. In Oregon, at least 25% of the top width and a continuous portion equaling at least 10% of the top width are used (Thompson, 1972). The flow that satisfies these criteria for all cross-sections is recommended.

Goose Nesting Requirement

The maintenance of adequate flows around islands selected by Canada geese for nesting is necessary to insure that the nests are protected from mammalian predators. Under low flow conditions, these predators have easy access to the islands and can significantly reduce goose production. The security of the islands is a primary factor in their selection as nest sites by geese. This security is provided by adequate side channel flows, which are a function of depth, width, and velocity. Since wetted perimeter is a function of both width and depth, its relationship to discharge is believed to be the best indicator of the minimum flows that are needed to maintain secure nesting islands.

The wetted perimeter/inflection point method is applied to the shallowest area of the side channel bordering each nesting island. A wetted perimeter-side channel discharge curve is generated for each cross-section and the inflection point determined. A curve correlating the side channel flow to the total river flow is also derived during the field season. From these curves, the total river discharge that would provide the inflection point flow in each side channel is determined. The final recommendation is derived by averaging the recommendations for each island or choosing the river flow that would maintain at least the inflection point flow around all the islands being sampled in the study area. The latter method is preferred.

Depth and width criteria could also be developed and used in conjunction with the WACD option of the WETP program to formulate flow recommendations for nesting.

Maintenance of Spawning and Rearing Habitats in Side Channels

Side channels provide important and sometimes critical spawning and rearing habitats for many cold and warm water fish species. The maintenance of these habitats is dependent on adequate side channel flows.

The wetted perimeter/inflection point method, when applied to the riffle areas of critical side channels, will provide a measure of the side channel flow that is needed to maintain the spawning and rearing habitats at acceptable levels. When this side channel recommendation is used in conjunction with a curve correlating the side channel flow to the total river flow, the total river flow that would maintain adequate side channel flow can be determined.

This method is applied to a series of side channels and the final recommendation derived by averaging the recommendations for each or choosing the river flow that would maintain at least the inflection point flow in all the sampled side channels. The latter method is again preferred.

Recreational Floating Requirement

Minimum depth and width criteria have been developed for various types of boating craft by the Cooperative Instream Flow Service Group of the U.S. Fish and Wildlife Service (Hyra, 1978). These are listed in Table 3.

Table 3. Required stream width and depth for various recreation craft.

Recreation Craft	Required Depth (ft)	Required Width (ft)
Canoe-kayak	0.5	4
Drift boat, row boat-raft	1.0	6
Tube	1.0	4
Power boat	3.0	6
Sail boat	3.0	25

These criteria are minimal and would not provide a satisfactory experience if the entire river was at this level. However, if the required depths and widths are maintained in riffles and other shallow areas, then these minimum conditions will only be encountered a short time during the float and the remainder of the trip will be over water of greater depths.

Cross-sections are placed in the shallowest area along the waterway. The WACD option of the WETP program is used to determine the flow that will satisfy the minimum criteria for the craft of interest. For example, if deriving a recommendation for power boats, the flow providing depths ° 3.0 ft for at least a 6.0 ft, continuous length of top width is recommended. When a series of cross-sections are used, the results for each cross-section are analyzed separately and the flow satisfying the criteria for all cross-sections is recommended.

This analysis can be expanded using additional criteria. For example, in addition to the above criteria for power boats, it can also be required that a certain percentage of the top width, such as 25%, has depths ≥ 3.0 ft. Remember, you will have to justify all criteria used in your analysis.

FINAL CONSIDERATIONS

Be sure to compare your instream flow recommendations to the water availability. For gaged streams, many summary flow statistics, such as the mean and median monthly flow of record, are available for comparison. For ungaged streams, instantaneous flow measurements collected by various state and federal agencies and simulated data are useful. The primary purpose is to determine if the recommendation is reasonable based on water availability. It is also desirable, for future planning, to define the period in which water in excess of the recommendation is available for consumptive uses and to quantify this excess.

It is common for the low flow recommendations for many of the headwater rivers and streams to equal or exceed the normal water availability for the months of November through March. This is the winter period when the natural flows are lowest for the year. These naturally occurring low flows, when coupled with the adverse effects of surface and anchor ice formation and the resulting scouring of the channel at ice-out, can impact the fishery. Consequently, water depletions during the winter have the potential to be extremely harmful to the already stressed fish populations. For headwater rivers and streams, it is generally accepted that little or no water should be removed during the critical winter period if fish populations are to be maintained at existing levels.

The recommendations derived from the wetted perimeter/inflection point method only apply to the low flow or nonrunoff months. For the high flow or runoff period, flow recommendations should be based on those flows judged necessary for flushing bottom sediments and maintaining the existing channel morphology. This method, termed the dominant discharge/channel morphology concept (Montana Department of Fish and Game, 1979), requires at least ten years of continuous USGS gage records for deriving high flow recommendations, so cannot be applied to most streams.

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APPENDIX A

Calculation of stage height at zero flow (zf) from Rantz (1982)

period. On the other hand, if, as is usually the case, discharge measurements are lacking to define the upper end of the rating, the defined lower part of the rating curve must be extrapolated to the highest stage experienced. Such extrapolations are always subject to error, but the error may be reduced if the analyst has a knowledge of the principles that govern the shape of rating curves. Much of the material in this chapter is directed toward a discussion of those principles, so that when the hydrographer is faced with the problem of extending the high-water end of a rating curve he can decide whether the extrapolation should be a straight line, or whether it should be concave upward or concave downward.

The problem of extrapolation can be circumvented, of course, if the unmeasured peak discharge is determined by use of the indirect methods discussed in chapter 9. In the absence of such peak-discharge determinations, some of the uncertainty in extrapolating the rating may be reduced by the use of one or more of several methods of estimating the discharge corresponding to high values of stage. Four such methods are discussed in the section titled "High-flow Extrapolation."

In the discussions that follow it was generally impractical to use both English and metric units, except where basic equations are given. Consequently English units are used throughout, unless otherwise noted.

STAGE-DISCHARGE CONTROLS

The subject of stage-discharge controls was discussed in detail in chapter 3, but a brief summary at this point is appropriate.

The relation of stage to discharge is usually controlled by a section or reach of channel downstream from the gage that is known as the station control. A section control may be natural or manmade; it may be a ledge of rock across the channel, a boulder-covered riffle, an overflow dam, or any other physical feature capable of maintaining a fairly stable relation between stage and discharge. Section controls are often effective only at low discharges and are completely submerged by channel control at medium and high discharges. Channel control consists of all the physical features of the channel that determine the stage of the river at a given point for a given rate of flow. These features include the size, slope, roughness, alinement, constrictions and expansions, and shape of the channel. The reach of channel that acts as the control may lengthen as the discharge increases, introducing new features that affect the stage-discharge relation.

Knowledge of the channel features that control the stage-discharge relation is important. The development of stage-discharge curves where more than one control is effective, and where the number of

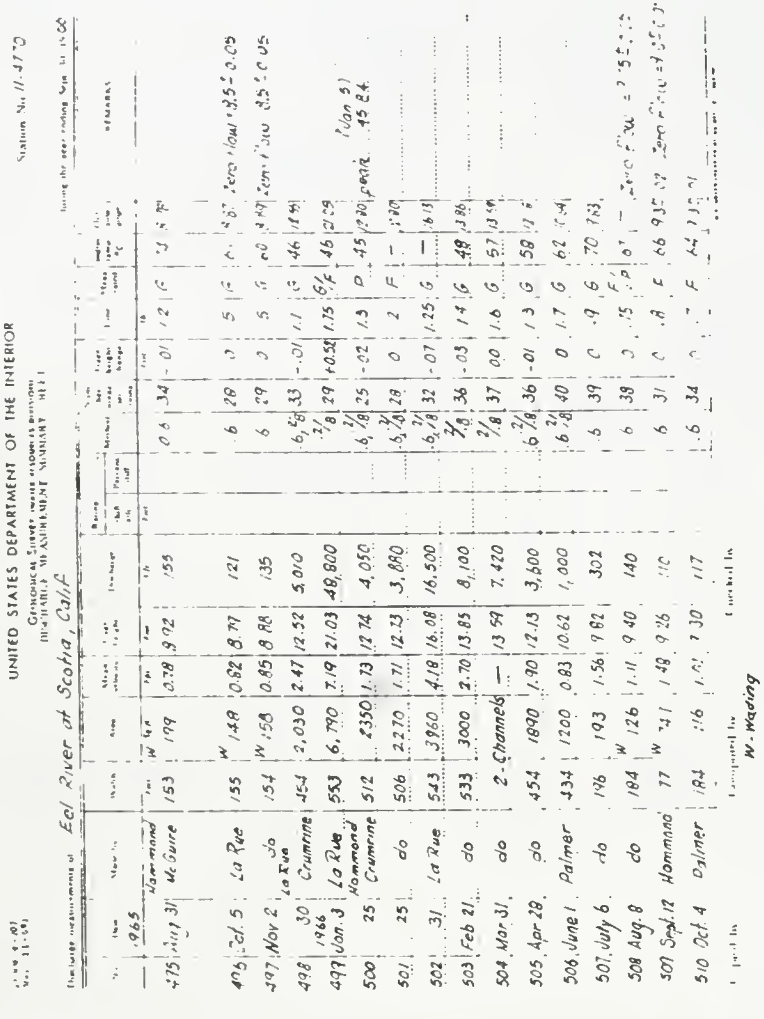
measurements is limited, usually requires judgment in interpolating between measurements and in extrapolating beyond the highest measurements. That is particularly true where the controls are not permanent and the various discharge measurements are representative of changes in the positioning of segments of the stage-discharge curve.

GRAPHICAL PLOTTING OF RATING CURVES

Stage-discharge relations are usually developed from a graphical analysis of the discharge measurements plotted on either rectangular-coordinate or logarithmic plotting paper. In a preliminary step the discharge measurements available for analysis are tabulated and summarized on a form such as that shown in figure 139. Discharge is then plotted as the abscissa, corresponding gage height is plotted as the ordinate, and a curve or line is fitted by eye to the plotted points. The plotted points carry the identifying measurement numbers given in figure 139; the discharge measurements are numbered consecutively in chronological order so that time trends can be identified.

At recording-gage stations that use stilling wells, systematic and significantly large differences between inside (recorded) gage heights and outside gage heights often occur during periods of high stage, usually as a result of intake drawdown (see section in chapter 4 titled, "Stilling Wells"). For stations where such differences occur, both inside and outside gage heights for high-water discharge measurements are recorded on the form shown in figure 139, and in plotting the measurements for rating analysis, the outside gage readings are used first. The stage-discharge relation is drawn through the outside gage readings of the high-water discharge measurements and is extended to the stage of the outside high-water marks that are observed for each flood event. The stage-discharge relation is next transposed to correspond with the inside gage heights obtained from the stage-recorder at the times of discharge measurement and at flood peaks. It is this transposed stage-discharge relation that is used with recorded stages to compute the discharge.

The rationale behind the above procedure is as follows. The outside gage readings are used for developing the rating because the hydraulic principles on which the rating is based require the use of the true stage of the stream. The transposition of the rating to inside (recorded) stages is then made because the recorded stages will be used with the rating to determine discharge. The recorded stages are used for discharge determination because if differences exist between inside and outside gage readings, those differences will be known only for those times when the two gages are read concurrently. If the



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
DISCHARGE MEASUREMENT SUMMARY

Discharge measurements of Eel River at Scotia, Calif.

No.	Date	Made by	Width	Area	Mean velocity	Gage height	Discharge	Method	No. secs.	Gage change	Time
475	1965 July 31	Hammond McGuire	153	199	0.78	9.92	155	0.6	34	-.01	1.2
496	Oct. 5	La Rue	155	148	0.82	8.77	121	.6	28	0	.5
497	Nov 2	La Rue do	154	158	0.85	8.88	135	.6	29	0	.5
498	30	Crumrine	454	2,030	2.47	12.52	5,010	.6, .2/.8	33	-.01	1.1
499	1966 Jan. 3	La Rue	553	6,790	7.19	21.03	48,800	.2/.8	29	+0.52	1.75
500	25	Hammond Crumrine	512	2350	1.73	12.74	4,050	.6, .2/.8	25	-.02	1.3
501	25	do	506	2,270	1.71	12.23	3,880	.6, .2/.8	28	0	2
502	31	La Rue	543	3960	4.18	16.08	16,500	.6, .2/.8	32	-.07	1.25
503	Feb 21	do	533	3000	2.70	13.85	8,100	.2/.8	36	-.03	1.4
504	Mar. 31	do	2-Channels	—	—	13.59	7,420	.2/.8	37	.00	1.6
505	Apr 28	do	454	1890	1.90	12.13	3,600	.6, .2/.8	36	-.01	1.3
506	June 1	Palmer	434	1200	0.83	10.62	1,000	.6, .2/.8	40	0	1.7
507	July 6	do	196	193	1.56	9.82	302	.6	39	0	.9
508	Aug. 8	do	184	126	1.11	9.40	140	.6	38	0	.15
509	Sept. 12	Hammond	77	121	1.48	9.26	110	.6	31	0	.8
510	Oct 4	Palmer	184	116	1.01	7.30	117	.6	34	[illegible]	[illegible]

Remarks: Zero flow 3.5 ± 0.05 (Oct. 5; Nov. 2); Jan. 5 peak 45.84; Zero flow (Aug. 8; Sept. 12).

Computed by W. Wading

FIGURE 139.—Example of form used for tabulating and summarizing current-meter discharge measurements.

outside gage heights were used with the rating to determine discharge, variable corrections, either known or assumed, would have to be applied to recorded gage heights to convert them to outside stages. We have digressed here to discuss differences between inside and outside gage heights, because in the discussions that follow no distinction between the two gages will be made.

The use of logarithmic plotting paper is usually preferred for graphical analysis of the rating because in the usual situation of compound controls, changes in the slope of the logarithmically plotted rating identify the range in stage for which the individual controls are effective. Furthermore, the portion of the rating curve that is applicable to any particular control may be linearized for rational extrapolation or interpolation. A discussion of the characteristics of logarithmic plotting follows.

The measured distance between any two ordinates or abscissas on logarithmic graph paper, whose values are printed or indicated on the sheet by the manufacturer of the paper, represents the difference between the logarithms of those values. Consequently, the measured distance is related to the ratio of the two values. Therefore, the distance between pairs of numbers such as 1 and 2, 2 and 4, 3 and 6, 5 and 10, are all equal because the ratios of the various pairs are identical. Thus the logarithmic scale of either the ordinates or the abscissas is maintained if all printed numbers on the scale are multiplied or divided by a constant. This property of the paper has practical value. For example, assume that the logarithmic plotting paper available has two cycles (fig. 140), and that ordinates ranging from 0.3 to 15.0 are to be plotted. If the printed scale of ordinates is used and the bottom line is called 0.1, the top line of the paper becomes 10.0, and values between 10.0 and 15.0 cannot be accommodated. However, the logarithmic scale will not be distorted if all values are multiplied by a constant. For this particular problem, 2 is the constant used in figure 140, and now the desired range of 0.3 to 15.0 can be accommodated. Examination of figure 140 shows that the change in scale has not changed the distance between any given pair of ordinates; the position of the ordinate scale has merely been transposed.

We turn now to a theoretical discussion of rating curves plotted on logarithmic graph paper. A rating curve, or a segment of a rating curve, that plots as a straight line of logarithmic paper has the equation,

$$Q = p(G - e)^{N}, \qquad (53)$$

where

Q is discharge;

$(G - e)$ is head or depth of water on the control—this value is indicated by the ordinate scale printed by the manufacturer or

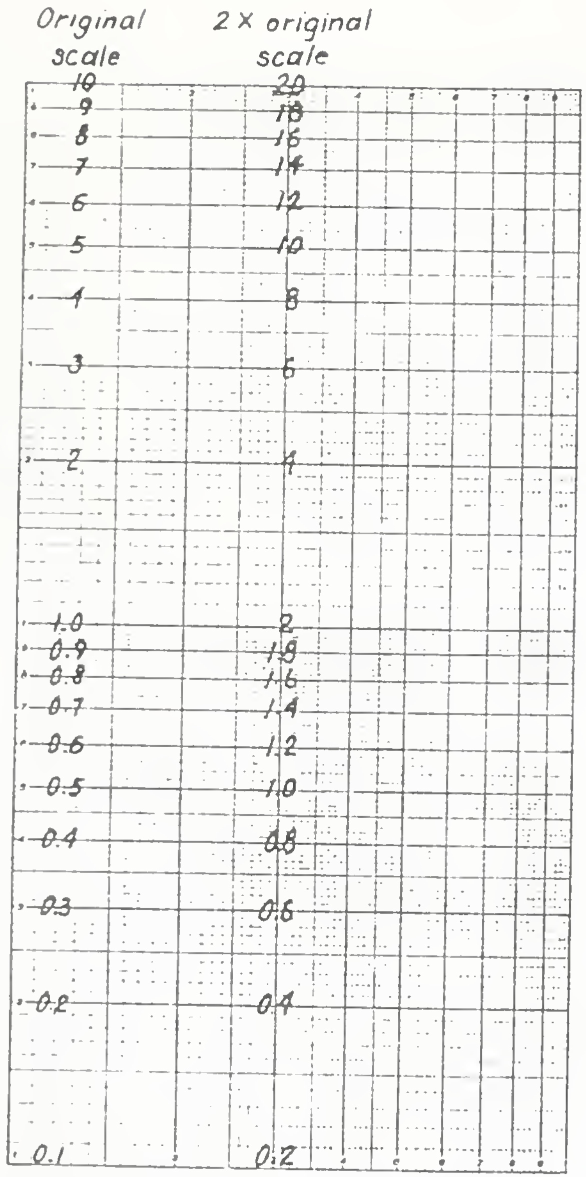


FIGURE 140.—Example showing how the logarithmic scale of graph paper may be transposed

by the ordinate scale that has been transposed, as explained in the preceding paragraph.

G is gage height of the water surface

e is gage height of zero flow for a section control of regular shape, or the gage height of effective zero flow for a channel control or a section control of irregular shape;

p is a constant that is numerically equal to the discharge when the head ($G - e$) equals 1.0 ft or 1.0 m, depending on whether English or metric units are used, and

N is slope of the rating curve. (Slope in equation 53 is the ratio of the horizontal distance to the vertical distance. This unconventional way of measuring slope is necessary because the dependent variable Q is always plotted as the abscissa.)

We assume now that a segment of an established logarithmic rating is linear, and we examine the effect on the rating of changes to the control. If the width of the control increases, p increases and the new rating will be parallel to and to the right of the original rating. If the width of the control decreases, the opposite effect occurs; p decreases and the new rating will be parallel to and to the left of the original rating. If the control scours, e decreases and the depth ($G - e$) for a given gage height increases; the new rating moves to the right and will no longer be a straight line but will be a curve that is concave downward. If the control becomes built up by deposition, e increases and the depth ($G - e$) for a given gage height decreases; the new rating moves to the left and is no longer linear but is a curve that is concave upward.

When discharge measurements are originally plotted on logarithmic paper, no consideration is given to values of e. The gage height of each measurement is plotted using the ordinate scale provided by the manufacturer or, if necessary, an ordinate scale that has been transposed as illustrated in figure 140. We refer now to figure 141. The inside scale ($e = 0$) is the scale printed by the paper manufacturer. Assume that the discharge measurements have been plotted to that scale and that they define the curvilinear relation between gage height (G) and discharge (Q) that is shown in the topmost curve. For the purpose of extrapolating the relation, a value of e is sought, which when applied to G, will result in a linear relation between ($G - e$) and Q. If we are dealing with a section control of regular shape, the value of e will be known; it will be the gage height of the lowest point of the control (point of zero flow). If we are dealing with a channel control or section control of irregular shape, the value of e is the gage height of *effective* zero flow. The gage height of effective zero flow is not the gage height of some identifiable feature on the irregular section control or in the channel but is actually a mathematical constant that is considered as a gage height to preserve the concept of a logarithmically linear head-discharge relation. Effective zero flow is usually determined by a method of successive approximations.

In successive trials, the ordinate scale in figure 141 is varied for e values of 1, 2 and 3 ft, each of which results in a different curve, but each new curve still represents the same rating as the top curve. For example, a discharge of 30 ft³/s corresponds to a gage height (G) of 5.5 ft on all four curves. The true value of e is 2 ft, and thus the rating plots as a straight line if the ordinate scale numbers are increased by that value. In other words, while even on the new scale a discharge of 30 ft³/s corresponds to a gage height (G) of 5.5 ft, the head or depth on the control for a discharge of 30 ft³/s is ($G-e$), or 3.5 ft; the linear rating marked $e = 2$ crosses the ordinate for 30 ft³/s at 5.5 ft on the new scale and at 3.5 ft on the manufacturer's, or inside, scale. If values of e smaller than the true value of 2 ft are used, the rating curve will be concave upward, if values of e greater than 2 ft are used, the curve will be concave downward. The value of e to be used for a rating curve, or for a segment of a rating curve, can thus be determined by adding or subtracting trial values of e to the numbered scales on the logarithmic plotting paper until a value is found that results in a straight-line plot of the rating. It is important to note that if the logarithmic ordinate scale must be transposed by multiplication or division to accommodate the range of stage to be plotted, that transposition must be made before the ordinate scale is manipulated for values of e.

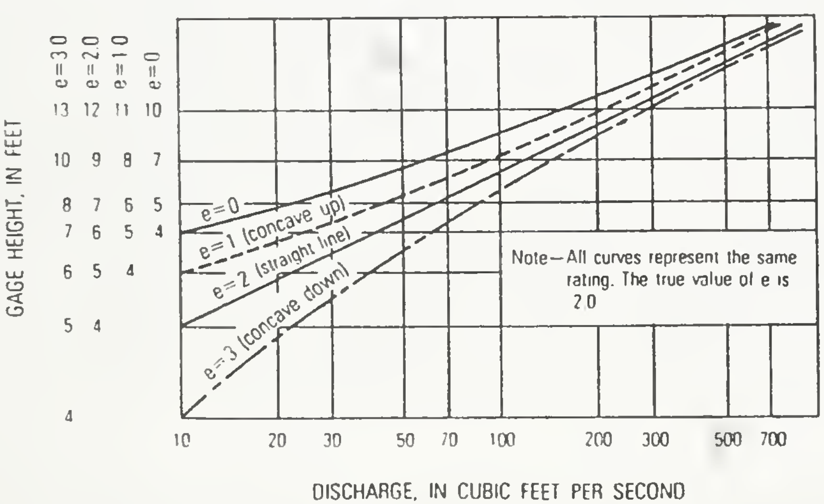


FIGURE 141.—Rating-curve shapes resulting from the use of differing values of effective zero flow.

A more direct solution for e, as described by Johnson (1952) is illustrated in figure 142. A plot of G versus Q has resulted in the solid-line curve which is to be linearized by subtracting a value of e from each value of G. The part of the rating between points 1 and 2 is chosen, and values of G_1, G_2, Q_1 and Q_2 are picked from the coordinate scales. A value of Q_3 is next computed, such that

$$Q_3^2 = Q_1 Q_2$$

From the solid-line curve, the value of G_3 that corresponds to Q_3 is picked. In accordance with the properties of a straight line on logarithmic plotting paper,

$$(G_3 - e)^2 = (G_1 - e)(G_2 - e). \qquad (54)$$

Expansion of terms in equation 54 leads to equation 55 which provides a direct solution for e.

$$e = \frac{G_1 G_2 - G_3^2}{G_1 + G_2 - 2G_3} \qquad (55)$$

A logarithmic rating curve is seldom a straight line or a gentle curve for the entire range in stage. Even where a single cross section of the channel is the control for all stages, a sharp break in the

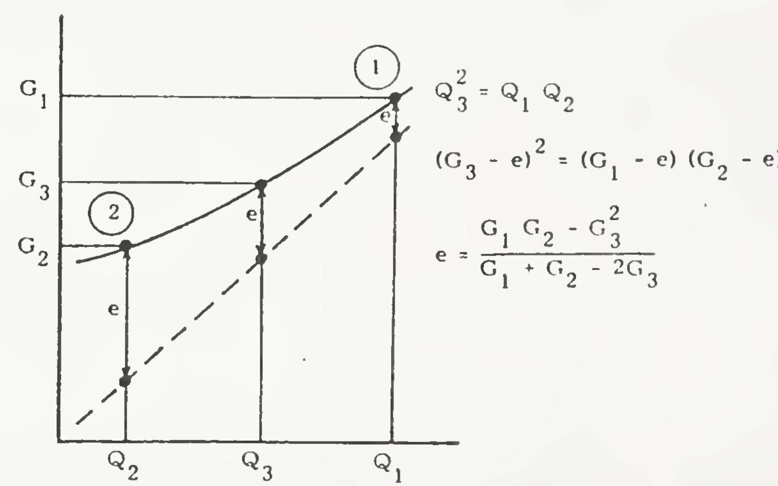


FIGURE 142.—Schematic representation of the linearization of a curve on logarithmic graph paper.

contour of the cross section, such as an overflow plain, will cause a break in the slope of the rating curve. Commonly, however, a break in slope is due to the low-water control being drowned out by a downstream section control becoming effective or by channel control becoming effective.

The use of rectangular-coordinate paper for rating analysis has certain advantages, particularly in the study of the pattern of shifts in the lower part of the rating. A change in the low-flow rating at many sites results from a change in the elevation of effective zero flow (e), which means a constant shift in gage height. A shift of that kind is more easily visualized on rectangular-coordinate paper because on that paper the shift curve is parallel to the original rating curve, the two curves being separated by a vertical distance equal to the change in the value of e. On logarithmic paper the two curves will be separated by a variable distance which decreases as stage increases. A further advantage of rectangular-coordinate paper is the fact that the point of zero flow can be plotted directly on rectangular-coordinate paper, thereby facilitating extrapolation of the low-water end of the rating curve. That cannot be done on logarithmic paper because zero values cannot be shown on that type of paper.

As a general rule logarithmic plotting should be used initially in developing the general shape of the rating. The final curve may be displayed on either type of graph paper and used as a base curve for the analysis of shifts. A combination of the two types of graph paper is frequently used with the lower part of the rating plotted on an inset of rectangular-coordinate paper or on a separate sheet of rectangular-coordinate paper.

A–5

SECTION CONTROLS

ARTIFICIAL CONTROLS

At this point we digress from the subject of logarithmic rating curves to discuss the ratings for artificial section controls. A knowledge of the rating characteristics of controls of standard shape is necessary for an understanding of the rating characteristics of natural controls, almost all of which have irregular shapes. On pages that follow we first discuss thin-plate weirs, then broad-crested weirs, and finally flumes.

Thin-plate weirs are generally used in small clear-flowing streams, particularly where high accuracy is desired and adequate maintenance can be provided, as in small research watersheds. Flumes are preferred for use in small streams and canals that carry sediment and debris, and in other situations where the head loss (backwater) associated with a thin-plate weir is unacceptable. Most types of flume may also be used under conditions of submergence, as opposed to free-flow conditions, thereby permitting them to operate with even smaller head loss but with some loss of accuracy of the stage-discharge relation. The broad-crested weirs are commonly used in the larger streams.

TRANSFERABILITY OF LABORATORY RATINGS

Standard shapes or dimensions are commonly used in building artificial controls, and many of these standard structures have been rated in laboratory model studies (World Meteorological Organization, 1971). The transfer of a laboratory discharge rating to a structure in the field requires the existence, and maintenance, of similitude between laboratory model and prototype, not only with regard to the structure, but also with regard to the approach channel. For example, scour and (or) fill in the approach channel will change the head-discharge relation, as will algal growth on the control structure. Both the structure and the approach channel must be kept free from accumulations of debris, sediment, and vegetal growth. Flow conditions downstream from the structure are significant only to the extent that they control the tailwater elevation, which may influence the operation of structures designed for free-flow conditions.

Because of the likelihood of the existence or development of conditions that differ from those specified in a laboratory model study, the policy of the Geological Survey is to calibrate the prototype control in the field by discharge measurements for the entire range of stage that is experienced. (See section in chapter 3 titled, "Artificial Controls.") In-place calibration is sometimes dispensed with where the artificial control is a standard thin-plate weir having negligible velocity of approach.

THIN-PLATE WEIRS

The surface of the weir over which the water flows is the crest of the weir. A thin-plate weir has its crest beveled to a chisel edge and is always installed with the beveled face on the downstream side. The crest of a thin-plate weir is highly susceptible to damage from floating debris, and therefore such weirs are used as control structures almost solely in canals whose flow is free of floating debris. Thin-plate weirs are not satisfactory for use in canals carrying sediment-laden water because they trap sediment and thereby cause the gage pool to fill with sediment, sometimes to a level above the weir crest. The banks of the canal must also be high enough to accommodate the increase in stage (backwater) caused by the installation of the weir, the weir plate being an impedance to flow in the canal. The commonly used shapes for thin-plate weirs are rectangular, trapezoidal, and triangular or V-notch.

APPENDIX B

Example of WETP input format

IBM — Title and location of study area

FORTRAN Coding Form

GX28-7327-6 U/M 050** Printed in U.S.A.

Bear Creek-Big Hole Drainage - SW, SE, Sec. 34, T2N, R12W

Fred Nelson — 6-27-84

Page 1 of 4

ØPTS	1										
QARD	1.5										
QARD	2										
QARD	2.5										
QARD	3										
QARD	3.5										
QARD	4										
QARD	5										
QARD	6										
QARD	7										
QARD	8										
QARD	9										
QARD	10										
QARD	15										
QARD	20										
QARD	25										
QARD	30										
QARD	40										
QARD	50										
QARD	60										
XSEC	1										
	1	0	9657	9	9642	15	9600	16	9424	21	9411	30	9389
	1	41	9386	51	9383	60	9363	61	9297	63	9283	64	9273
	1	68	9253	73	9243	78	9233	83	9233	88	9223	93	9233

Flows of interest.
Up to 100 flows allowed.
Enter as integers or with decimal points.

Profile Data

Distance from headstake

Channel elevation

Reads as 1.5 ft

Reads as 96.00 ft

Do not enter profile data past space 70.

Cross-section identification

Stage Height At Zero Flow (zf) Option

I. Riffles

Set OPTS to one.

zf will equal lowest elevation on cross-sectional profile.

II. Non-Riffles

Set OPTS to one and enter zf on the XSEC records.

III. Want zf to equal zero.

Set OPTS to zero.

Use only for comparing results.

*A standard card form, IBM electro 888157, is available for punching statements from this form

**Number of forms per pad may vary slightly

IBM

FORTRAN Coding Form

GX28-7327-6 U/M 050**
Printed in U.S.A.

PROGRAM Bear Creek

PAGE 2 OF 4

	1	98	9238	103	9243	108	9243	113	9243	118	9248	123	9263
	1	128	9268	133	9273	135	9283	140	9314	150	9330	159	9350
	1	162	9407	170	9485	182	9502	194	9536				
CAL1	1		9359		334	← Calibration data for CS#1 - high flow							
CAL2	1		9321		113	← "				" - intermediate flow			
CAL3	1		9283		38	← "				" - low flow			
XSEC	2												
	2	0	9726	4	9719	10	9676	19	9632	20	9463	25	9404
	2	35	9383	43	9396	44	9357	52	9356	54	9342	63	9342
	2	75	9332	77	9323	80	9318	85	9313	90	9313	91	9293
	2	96	9293	101	9293	107	9288	113	9298	117	9293	120	9273
	2	125	9273	130	9273	135	9273	137	9293	138	9323	139	9393
	2	140	9435	147	9464	155	9483	158	9515	168	9531	179	9536
	2	190	9552										
CAL1	2		9390		334	Water surface elevations							
CAL2	2		9357		113	Each is the average for the WEL and WER							
CAL3	2		9323		38	Without decimal points, reads as 93.90, 93.57 and 93.23 ft							
XSEC	3												
	3	0	9799	10	9782	20	9755	29	9724	36	9706	46	9674
	3	51	9662	52	9602	63	9600	74	9607	81	9618	90	9630
	3	99	9636	109	9636	118	9619	127	9601	130	9590	133	9585
	3	138	9575	141	9565	147	9555	150	9550	155	9540	160	9535
	3	165	9530	170	9515	175	9525	180	9520	185	9515	190	9540
	3	195	9545	198	9550	199	9590	200	9697	201	9717	210	9709

*A standard card form, IBM electro 888157, is available for punching statements from this form.

**Number of forms per pad may vary slightly

IBM FORTRAN Coding Form

GX28-7327-6 U/M 050
Printed in U.S.A.

Program: Bear Creek

Page 3 of 4

	3	195	9545	198	9550	199	9590	200	9697	201	9717	210	9709
	3	220	9707	224	9741	231	9746	240	9748	250	9751		
CAL1	3		9663		334	Calibration flows							
CAL2	3		9626		113								
CAL3	3		9590		38	Without decimal points, reads as 33.4, 11.3 and 3.8 cfs							
XSEC	4												
	4	0	9863	10	9848	14	9824	24	9813	34	9809	43	9800
	4	50	9785	60	9766	70	9761	80	9746	90	9734	96	9700
	4	101	9687	108	9673	109	9661	110	9661	116	9661	121	9656
	4	130	9656	140	9656	145	9656	147	9651	153	9646	158	9646
	4	160	9636	165	9626	170	9626	175	9616	185	9626	195	9626
	4	200	9631	205	9636	210	9636	215	9636	220	9641	223	9646
	4	228	9646	234	9651	238	9656	242	9661	244	9666	250	9667
	4	255	9687	261	9717	265	9742	272	9748	278	9763	287	9754
	4	295	9740	310	9743	342	9745	346	9793	353	9829	361	9829
CAL1	4		9714		334								
CAL2	4		9685		113								
CAL3	4		9661		38								
XSEC	5			For non-riffle cross-sections enter zf here									
	5	0	9830	10	9806	14	9793	16	9769	18	9675	19	9640
	5	22	9625	30	9615	40	9615	50	9625	58	9615	60	9625
	5	65	9620	70	9630	80	9635	90	9635	98	9645	102	9655
	5	105	9675	106	9688	110	9706	119	9690	122	9680	129	9687
	5	135	9705	141	9736	149	9747	152	9775	161	9782	170	9788

IBM

FORTRAN Coding Form

GX28-7327-6 U/M 050**
Printed in U.S.A

Bear Creek

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FORTRAN STATEMENT

```
    5   180 9777   190 9765   200 9754   215 9748   231 9746   242 9753
    5   244 9809   248 9831   254 9842   265 9842
CAL1 5      9725        334
CAL2 5      9697        113
CAL3 5      9675         38
D .4 1.0
PØØL 1 2 3 4 5
PØØL 3 4 5
```

Optional Entry

In this example, results are also averaged for CS# 3, 4 and 5. Use as many POOL entries as needed.

Mandatory Entry

Prints results for each cross-section as well as the averages for all cross-sections.

Width-At-Given-Depth (WAGD) Option

Up to 10 depths allowed. Separate depths of interest with single space. In this example, asking for length of top width having depths $\geq$ .4 ft and 1.0 ft.

*Number of forms per pad may vary slightly

APPENDIX C

Example of WETP data output

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W
PROGRAM WETP

*** MONTANA DEPT. OF FISH, WILDLIFE AND PARKS ***

Program WETP Rev. 1-84 (16 June 1984)

Program WETP calculates the following parameters for a stream cross-section. Up to 10 stream cross-sections may be pooled together to obtain an average of pooled cross-sections. Cross-sections may be defined by up to 150 points.

WETP - wetted perimeter
DBAR - average depth
VBAR - average velocity throughout cross-sectional area
WDTH - top width of cross-section
AREA - cross-sectional area
STGE - water surface elevation
DMAX - maximum depth
WTOT - width at a depth > or = to a given value
WMAX - max. cont. width at a depth > or = to a given value
PTOT - ratio of WTOT/WDTH expressed as a percent
PMAX - ratio of WMAX/WDTH expressed as a percent

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

CROSS-SECTION DATA

1		2		3		4		5						
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X
.0	96.57	.0	97.26	.0	97.99	.0	98.63	.0	98.30					
.9	96.42	.4	97.19	1.0	97.82	1.0	98.48	1.0	98.06					
1.5	96.00	1.0	96.76	2.0	97.55	1.4	98.24	1.4	97.93					
1.6	94.24	1.9	96.32	2.9	97.24	2.4	98.13	1.6	97.69					
2.1	94.11	2.0	94.63	3.6	97.06	3.4	98.09	1.8	96.75					
3.0	93.89	2.5	94.04	4.6	96.74	4.3	98.00	1.9	96.40					
4.1	93.86	3.5	93.83	5.1	96.62	5.0	97.85	2.2	96.25					
5.1	93.83	4.3	93.96	5.2	96.02	6.0	97.66	3.0	96.15					
6.0	93.63	4.4	93.57	6.3	96.00	7.0	97.61	4.0	96.15					
6.1	92.97	5.2	93.56	7.4	96.07	8.0	97.46	5.0	96.25					
6.3	92.83	5.4	93.42	8.1	96.18	9.0	97.34	5.8	96.15					
6.4	92.73	6.3	93.42	9.0	96.30	9.6	97.00	6.0	96.25					
6.8	92.53	7.5	93.32	9.9	96.36	10.1	96.87	6.5	96.20					
7.3	92.43	7.7	93.23	10.9	96.36	10.8	96.73	7.0	96.30					
7.8	92.33	8.0	93.18	11.8	96.19	10.9	96.66	8.0	96.35					
8.3	92.33	8.5	93.13	12.7	96.01	11.0	96.61	9.0	96.35					
8.8	92.23	9.0	93.13	13.0	95.90	11.6	96.61	9.8	96.45					
9.3	92.33	9.1	92.93	13.3	95.85	12.1	96.56	10.2	96.55					
9.8	92.38	9.6	92.93	13.8	95.75	13.0	96.56	10.5	96.75					
10.3	92.43	10.1	92.93	14.1	95.65	14.0	96.56	10.6	96.88					
10.8	92.43	10.7	92.88	14.7	95.55	14.5	96.56	11.0	97.06					
11.3	92.43	11.3	92.98	15.0	95.50	14.7	96.51	11.9	96.90					
11.8	92.48	11.7	92.93	15.5	95.40	15.3	96.46	12.2	96.80					
12.3	92.63	12.0	92.73	16.0	95.35	15.8	96.46	12.9	96.87					
12.8	92.68	12.5	92.73	16.5	95.30	16.0	96.36	13.5	97.05					
13.3	92.73	13.0	92.73	17.0	95.15	16.5	96.26	14.1	97.36					
13.5	92.83	13.5	92.73	17.5	95.25	17.0	96.26	14.9	97.47					
14.0	93.14	13.7	92.93	18.0	95.20	17.5	96.16	15.2	97.75					
15.0	93.30	13.8	93.23	18.5	95.15	18.5	96.26	16.1	97.82					
15.9	93.50	13.9	93.93	19.0	95.40	19.5	96.26	17.0	97.88					
16.2	94.07	14.0	94.35	19.5	95.45	20.0	96.31	18.0	97.77					
17.0	94.85	14.7	94.64	19.8	95.50	20.5	96.36	19.0	97.65					
18.2	95.02	15.5	94.83	19.9	95.90	21.0	96.36	20.0	97.54					
19.4	95.36	15.8	95.15	20.0	96.97	21.5	96.36	21.5	97.48					
.0	.00	16.8	95.31	20.1	97.17	22.0	96.41	23.1	97.46					
.0	.00	17.9	95.36	21.0	97.09	22.3	96.46	24.2	97.53					
.0	.00	19.0	95.52	22.0	97.07	22.8	96.46	24.4	98.09					
.0	.00	.0	.00	22.4	97.41	23.4	96.51	24.8	98.31					
.0	.00	.0	.00	23.1	97.46	23.8	96.56	25.4	98.42					
.0	.00	.0	.00	24.0	97.48	24.2	96.61	26.5	98.42					
.0	.00	.0	.00	25.0	97.51	24.4	96.66	.0	.00					
.0	.00	.0	.00	.0	.00	25.0	96.67	.0	.00					
.0	.00	.0	.00	.0	.00	25.5	96.87	.0	.00					
.0	.00	.0	.00	.0	.00	26.1	97.17	.0	.00					
.0	.00	.0	.00	.0	.00	26.5	97.42	.0	.00					

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

.0	.00	.0	.00	.0	.00	27.2	97.48	.0	.00
.0	.00	.0	.00	.0	.00	27.8	97.63	.0	.00
.0	.00	.0	.00	.0	.00	28.7	97.54	.0	.00
.0	.00	.0	.00	.0	.00	29.5	97.40	.0	.00
.0	.00	.0	.00	.0	.00	31.0	97.43	.0	.00
.0	.00	.0	.00	.0	.00	34.2	97.45	.0	.00
.0	.00	.0	.00	.0	.00	34.6	97.93	.0	.00
.0	.00	.0	.00	.0	.00	35.3	98.29	.0	.00
.0	.00	.0	.00	.0	.00	36.1	98.29	.0	.00

CALIBRATION DATA

1		2		3		4		5					
Q	S	Q	S	Q	S	Q	S	Q	S	Q	S	Q	S
33.4	93.59	33.4	93.90	33.4	96.63	33.4	97.14	33.4	97.25				
11.3	93.21	11.3	93.57	11.3	96.26	11.3	96.85	11.3	96.97				
3.8	92.33	3.8	93.23	3.8	95.90	3.8	96.61	3.8	96.75				

REGRESSION CURVE CONSTANTS

CONSTANTS AND R-SQUARED VALUES ARE GIVEN FOR THE
REGRESSION LOG (S - ZF) = A + B * LOG Q

1		2		3		4		5						
A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
-.429	.377	-.514	.391	-.299	.313	-.549	.358	-.382	.279					

R2	R2	R2	R2	R2	R2	R2	F
.987	.984	.992	.997	1.000			
ZF	ZF	ZF	ZF	ZF	ZF	ZF	Z
92.23	92.73	95.15	96.16	96.15			

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W
COMPUTED VALUES

FLOW= 1.5 CFS

XSEC		1	2	3	4	5						AVG
WETP		6.21	5.10	6.28	8.20	8.75	.00	.00	.00	.00	.00	6.91
DBAR		.24	.23	.36	.16	.34	.00	.00	.00	.00	.00	.26
VBAR		1.01	1.37	.71	1.19	.52	.00	.00	.00	.00	.00	.96
WDTH		6.11	4.73	5.97	8.14	8.46	.00	.00	.00	.00	.00	6.68
AREA		1.49	1.09	2.12	1.26	2.87	.00	.00	.00	.00	.00	1.77
STGE		92.66	93.09	95.72	96.49	96.61	.00	.00	.00	.00	.00	94.91
DMAX		.43	.36	.57	.33	.46	.00	.00	.00	.00	.00	.43
WTOT	.40	.34	.00	2.55	.00	3.01	.00	.00	.00	.00	.00	1.18
WMAX		.34	.00	2.55	.00	2.16	.00	.00	.00	.00	.00	1.01
PTOT		5.60	.00	42.66	.00	35.64	.00	.00	.00	.00	.00	16.78
PMAX		5.60	.00	42.66	.00	25.51	.00	.00	.00	.00	.00	14.75
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 2.0 CFS

XSEC		1	2	3	4	5						AVG
WETP		6.82	5.70	6.55	8.91	8.86	.00	.00	.00	.00	.00	7.37
DBAR		.27	.25	.40	.18	.38	.00	.00	.00	.00	.00	.29
VBAR		1.11	1.54	.82	1.28	.63	.00	.00	.00	.00	.00	1.07
WDTH		6.71	5.28	6.19	8.84	8.53	.00	.00	.00	.00	.00	7.11
AREA		1.81	1.30	2.45	1.57	3.20	.00	.00	.00	.00	.00	2.06
STGE		92.71	93.13	95.77	96.52	96.65	.00	.00	.00	.00	.00	94.96
DMAX		.48	.40	.62	.36	.50	.00	.00	.00	.00	.00	.47
WTOT	.40	.84	1.50	3.19	.00	4.57	.00	.00	.00	.00	.00	2.02
WMAX		.84	1.50	3.19	.00	4.57	.00	.00	.00	.00	.00	2.02
PTOT		12.51	28.47	51.53	.00	53.61	.00	.00	.00	.00	.00	29.23
PMAX		12.51	28.47	51.53	.00	53.61	.00	.00	.00	.00	.00	29.23
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 2.5 CFS

XSEC		1	2	3	4	5						AVG
WETP		7.12	6.11	6.83	9.28	8.95	.00	.00	.00	.00	.00	7.66
DBAR		.30	.26	.43	.20	.40	.00	.00	.00	.00	.00	.32
VBAR		1.19	1.67	.91	1.36	.72	.00	.00	.00	.00	.00	1.17
WDTH		6.98	5.66	6.43	9.21	8.58	.00	.00	.00	.00	.00	7.37

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

AREA		2.10	1.50	2.73	1.84	3.47	.00	.00	.00	.00	.00	2.33
STGE		92.76	93.17	95.82	96.55	96.69	.00	.00	.00	.00	.00	95.00
DMAX		.53	.44	.67	.39	.54	.00	.00	.00	.00	.00	.51
WTOT	.40	1.90	1.59	3.79	.00	4.80	.00	.00	.00	.00	.00	2.42
WMAX		1.90	1.59	3.79	.00	4.80	.00	.00	.00	.00	.00	2.42
PTOT		27.16	28.19	58.96	.00	55.89	.00	.00	.00	.00	.00	34.04
PMAX		27.16	28.19	58.96	.00	55.89	.00	.00	.00	.00	.00	34.04
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
FLOW=	3.0 CFS											
XSEC		1	2	3	4	5						AVG
WETP		7.25	6.39	7.08	12.11	9.03	.00	.00	.00	.00	.00	8.37
DBAR		.33	.29	.45	.18	.43	.00	.00	.00	.00	.00	.34
VBAR		1.27	1.78	1.00	1.41	.81	.00	.00	.00	.00	.00	1.25
WDTH		7.09	5.91	6.64	12.04	8.63	.00	.00	.00	.00	.00	8.06
AREA		2.36	1.69	2.99	2.13	3.71	.00	.00	.00	.00	.00	2.58
STGE		92.79	93.20	95.86	96.58	96.71	.00	.00	.00	.00	.00	95.03
DMAX		.56	.47	.71	.42	.56	.00	.00	.00	.00	.00	.54
WTOT	.40	2.46	1.68	4.34	.28	5.19	.00	.00	.00	.00	.00	2.79
WMAX		2.46	1.68	4.34	.28	5.19	.00	.00	.00	.00	.00	2.79
PTOT		34.64	28.34	65.41	2.32	60.14	.00	.00	.00	.00	.00	38.17
PMAX		34.64	28.34	65.41	2.32	60.14	.00	.00	.00	.00	.00	38.17
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
FLOW=	3.5 CFS											
XSEC		1	2	3	4	5						AVG
WETP		7.38	6.60	7.33	12.54	9.10	.00	.00	.00	.00	.00	8.59
DBAR		.36	.31	.47	.19	.45	.00	.00	.00	.00	.00	.36
VBAR		1.35	1.88	1.09	1.45	.89	.00	.00	.00	.00	.00	1.33
WDTH		7.19	6.10	6.86	12.46	8.68	.00	.00	.00	.00	.00	8.26
AREA		2.60	1.86	3.23	2.42	3.93	.00	.00	.00	.00	.00	2.81
STGE		92.83	93.23	95.89	96.60	96.74	.00	.00	.00	.00	.00	95.06
DMAX		.60	.50	.74	.44	.59	.00	.00	.00	.00	.00	.57
WTOT	.40	2.96	1.75	4.73	.64	5.74	.00	.00	.00	.00	.00	3.16
WMAX		2.96	1.75	4.73	.64	5.74	.00	.00	.00	.00	.00	3.16
PTOT		41.18	28.68	68.94	5.10	66.10	.00	.00	.00	.00	.00	42.00
PMAX		41.18	28.68	68.94	5.10	66.10	.00	.00	.00	.00	.00	42.00

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
FLOW=	4.0 CFS											
												AVG
XSEC		1	2	3	4	5						
WETP		7.49	6.69	7.47	13.37	9.16	.00	.00	.00	.00	.00	8.84
DBAR		.39	.33	.49	.20	.47	.00	.00	.00	.00	.00	.38
VBAR		1.42	1.98	1.16	1.48	.97	.00	.00	.00	.00	.00	1.40
WDTH		7.29	6.16	6.97	13.28	8.71	.00	.00	.00	.00	.00	8.48
AREA		2.82	2.02	3.44	2.70	4.12	.00	.00	.00	.00	.00	3.02
STGE		92.86	93.26	95.93	96.62	96.76	.00	.00	.00	.00	.00	95.08
DMAX		.63	.53	.78	.46	.61	.00	.00	.00	.00	.00	.60
WTOT	.40	4.42	1.82	4.96	.96	7.10	.00	.00	.00	.00	.00	3.85
WMAX		4.42	1.82	4.96	.96	7.10	.00	.00	.00	.00	.00	3.85
PTOT		60.72	29.46	71.12	7.23	81.55	.00	.00	.00	.00	.00	50.02
PMAX		60.72	29.46	71.12	7.23	81.55	.00	.00	.00	.00	.00	50.02
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
FLOW=	5.0 CFS											
												AVG
XSEC		1	2	3	4	5						
WETP		7.69	6.86	7.69	13.76	9.25	.00	.00	.00	.00	.00	9.05
DBAR		.43	.37	.54	.24	.51	.00	.00	.00	.00	.00	.42
VBAR		1.55	2.15	1.30	1.55	1.12	.00	.00	.00	.00	.00	1.53
WDTH		7.45	6.28	7.13	13.66	8.75	.00	.00	.00	.00	.00	8.65
AREA		3.23	2.32	3.84	3.22	4.46	.00	.00	.00	.00	.00	3.42
STGE		92.91	93.30	95.98	96.66	96.80	.00	.00	.00	.00	.00	95.13
DMAX		.68	.57	.83	.50	.65	.00	.00	.00	.00	.00	.65
WTOT	.40	5.03	2.37	5.31	3.04	7.50	.00	.00	.00	.00	.00	4.65
WMAX		5.03	1.94	5.31	3.04	7.50	.00	.00	.00	.00	.00	4.56
PTOT		67.45	37.74	74.45	22.25	85.68	.00	.00	.00	.00	.00	57.51
PMAX		67.45	30.84	74.45	22.25	85.68	.00	.00	.00	.00	.00	56.13
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
FLOW=	6.0 CFS											
												AVG

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

XSEC		1	2	3	4	5					
WETP		7.87	7.26	9.51	14.33	9.77	.00	.00	.00	.00	.00	9.75
DBAR		.47	.39	.47	.26	.52	.00	.00	.00	.00	.00	.42
VBAR		1.67	2.31	1.42	1.62	1.26	.00	.00	.00	.00	.00	1.66
WDTH		7.60	6.63	8.89	14.22	9.22	.00	.00	.00	.00	.00	9.31
AREA		3.60	2.60	4.22	3.70	4.77	.00	.00	.00	.00	.00	3.78
STGE		92.96	93.35	96.03	96.70	96.83	.00	.00	.00	.00	.00	95.17
DMAX		.73	.62	.88	.54	.68	.00	.00	.00	.00	.00	.69
WTOT	.40	5.34	4.14	5.61	3.55	7.78	.00	.00	.00	.00	.00	5.28
WMAX		5.34	2.14	5.61	3.55	7.78	.00	.00	.00	.00	.00	4.88
PTOT		70.21	62.47	63.16	24.96	84.38	.00	.00	.00	.00	.00	61.04
PMAX		70.21	32.22	63.16	24.96	84.38	.00	.00	.00	.00	.00	54.99
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 7.0 CFS

XSEC		1	2	3	4	5					AVG
WETP		8.00	7.76	10.47	14.47	10.23	.00	.00	.00	.00	.00	10.19
DBAR		.51	.40	.47	.29	.52	.00	.00	.00	.00	.00	.44
VBAR		1.78	2.45	1.51	1.69	1.39	.00	.00	.00	.00	.00	1.76
WDTH		7.69	7.10	9.76	14.34	9.64	.00	.00	.00	.00	.00	9.71
AREA		3.93	2.86	4.63	4.13	5.05	.00	.00	.00	.00	.00	4.12
STGE		93.01	93.38	96.07	96.73	96.86	.00	.00	.00	.00	.00	95.21
DMAX		.78	.65	.92	.57	.71	.00	.00	.00	.00	.00	.73
WTOT	.40	5.57	4.65	5.81	4.01	7.97	.00	.00	.00	.00	.00	5.60
WMAX		5.57	4.65	5.81	4.01	7.97	.00	.00	.00	.00	.00	5.60
PTOT		72.44	65.43	59.54	27.93	82.73	.00	.00	.00	.00	.00	61.62
PMAX		72.44	65.43	59.54	27.93	82.73	.00	.00	.00	.00	.00	61.62
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 8.0 CFS

XSEC		1	2	3	4	5					AVG
WETP		8.12	8.22	11.00	14.67	10.53	.00	.00	.00	.00	.00	10.51
DBAR		.55	.41	.49	.31	.54	.00	.00	.00	.00	.00	.46
VBAR		1.89	2.57	1.59	1.76	1.50	.00	.00	.00	.00	.00	1.86
WDTH		7.76	7.53	10.22	14.54	9.89	.00	.00	.00	.00	.00	9.99
AREA		4.24	3.12	5.02	4.54	5.32	.00	.00	.00	.00	.00	4.45
STGE		93.05	93.42	96.11	96.75	96.89	.00	.00	.00	.00	.00	95.24
DMAX		.82	.69	.96	.59	.74	.00	.00	.00	.00	.00	.76

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

WTOT	.40	5.89	4.67	5.94	4.42	8.09	.00	.00	.00	.00	.00	5.80
WMAX		5.89	4.67	5.94	4.42	8.09	.00	.00	.00	.00	.00	5.80
PTOT		75.88	62.11	58.12	30.42	81.75	.00	.00	.00	.00	.00	61.66
PMAX		75.88	62.11	58.12	30.42	81.75	.00	.00	.00	.00	.00	61.66
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
FLOW=	9.0 CFS											
XSEC		1	2	3	4	5						AVG
WETP		8.22	9.21	11.49	14.87	10.82	.00	.00	.00	.00	.00	10.92
DBAR		.58	.40	.51	.33	.55	.00	.00	.00	.00	.00	.47
VBAR		1.99	2.65	1.67	1.83	1.62	.00	.00	.00	.00	.00	1.95
WDTH		7.82	8.48	10.64	14.73	10.15	.00	.00	.00	.00	.00	10.36
AREA		4.53	3.39	5.40	4.91	5.56	.00	.00	.00	.00	.00	4.76
STGE		93.08	93.45	96.15	96.78	96.92	.00	.00	.00	.00	.00	95.28
DMAX		.85	.72	1.00	.62	.77	.00	.00	.00	.00	.00	.79
WTOT	.40	6.33	4.70	6.06	5.74	8.19	.00	.00	.00	.00	.00	6.21
WMAX		6.33	4.70	6.06	5.74	8.19	.00	.00	.00	.00	.00	6.21
PTOT		80.92	55.46	56.93	39.01	80.73	.00	.00	.00	.00	.00	62.61
PMAX		80.92	55.46	56.93	39.01	80.73	.00	.00	.00	.00	.00	62.61
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
FLOW=	10.0 CFS											
XSEC		1	2	3	4	5						AVG
WETP		8.32	9.29	11.95	15.06	11.11	.00	.00	.00	.00	.00	11.15
DBAR		.61	.43	.52	.35	.56	.00	.00	.00	.00	.00	.49
VBAR		2.08	2.74	1.74	1.90	1.72	.00	.00	.00	.00	.00	2.04
WDTH		7.89	8.53	11.03	14.91	10.41	.00	.00	.00	.00	.00	10.55
AREA		4.80	3.65	5.76	5.26	5.80	.00	.00	.00	.00	.00	5.05
STGE		93.12	93.48	96.18	96.80	96.94	.00	.00	.00	.00	.00	95.30
DMAX		.89	.75	1.03	.64	.79	.00	.00	.00	.00	.00	.82
WTOT	.40	6.75	4.73	6.23	6.03	8.29	.00	.00	.00	.00	.00	6.41
WMAX		6.75	4.73	6.23	6.03	8.29	.00	.00	.00	.00	.00	6.41
PTOT		85.54	55.45	56.49	40.46	79.65	.00	.00	.00	.00	.00	63.52
PMAX		85.54	55.45	56.49	40.46	79.65	.00	.00	.00	.00	.00	63.52
WTOT	1.00	.00	.00	.66	.00	.00	.00	.00	.00	.00	.00	.13
WMAX		.00	.00	.39	.00	.00	.00	.00	.00	.00	.00	.08

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

PTOT		.00	.00	5.99	.00	.00	.00	.00	.00	.00	.00	1.20
PMAX		.00	.00	3.53	.00	.00	.00	.00	.00	.00	.00	.71
FLOW=	15.0 CFS											
XSEC		1	2	3	4	5						AVG
WETP		9.30	10.40	14.20	15.79	12.30	.00	.00	.00	.00	.00	12.40
DBAR		.69	.51	.57	.44	.59	.00	.00	.00	.00	.00	.56
VBAR		2.50	3.12	2.02	2.21	2.20	.00	.00	.00	.00	.00	2.41
WDTH		8.72	9.47	13.02	15.60	11.48	.00	.00	.00	.00	.00	11.66
AREA		6.01	4.80	7.43	6.80	6.83	.00	.00	.00	.00	.00	6.37
STGE		93.26	93.61	96.32	96.90	97.03	.00	.00	.00	.00	.00	95.43
DMAX		1.03	.88	1.17	.74	.88	.00	.00	.00	.00	.00	.94
WTOT	.40	7.30	5.99	6.96	8.58	8.49	.00	.00	.00	.00	.00	7.46
WMAX		7.30	5.99	6.96	8.58	8.49	.00	.00	.00	.00	.00	7.46
PTOT		83.77	63.26	53.47	54.98	73.92	.00	.00	.00	.00	.00	65.88
PMAX		83.77	63.26	53.47	54.98	73.92	.00	.00	.00	.00	.00	65.88
WTOT	1.00	.33	.00	2.57	.00	.00	.00	.00	.00	.00	.00	.58
WMAX		.33	.00	2.57	.00	.00	.00	.00	.00	.00	.00	.58
PTOT		3.84	.00	19.70	.00	.00	.00	.00	.00	.00	.00	4.71
PMAX		3.84	.00	19.70	.00	.00	.00	.00	.00	.00	.00	4.71
FLOW=	20.0 CFS											
XSEC		1	2	3	4	5						AVG
WETP		10.02	10.62	16.20	16.29	12.78	.00	.00	.00	.00	.00	13.18
DBAR		.76	.61	.61	.50	.65	.00	.00	.00	.00	.00	.63
VBAR		2.83	3.45	2.22	2.47	2.60	.00	.00	.00	.00	.00	2.71
WDTH		9.33	9.51	14.82	16.08	11.88	.00	.00	.00	.00	.00	12.32
AREA		7.08	5.80	9.01	8.08	7.70	.00	.00	.00	.00	.00	7.53
STGE		93.38	93.72	96.43	96.99	97.11	.00	.00	.00	.00	.00	95.52
DMAX		1.15	.99	1.28	.83	.96	.00	.00	.00	.00	.00	1.04
WTOT	.40	7.65	6.31	8.94	12.16	8.62	.00	.00	.00	.00	.00	8.74
WMAX		7.65	6.31	7.32	12.16	8.62	.00	.00	.00	.00	.00	8.41
PTOT		81.96	66.33	60.31	75.66	72.55	.00	.00	.00	.00	.00	71.36
PMAX		81.96	66.33	49.43	75.66	72.55	.00	.00	.00	.00	.00	69.19
WTOT	1.00	2.28	.00	3.99	.00	.00	.00	.00	.00	.00	.00	1.25
WMAX		2.28	.00	3.99	.00	.00	.00	.00	.00	.00	.00	1.25
PTOT		24.39	.00	26.90	.00	.00	.00	.00	.00	.00	.00	10.26
PMAX		24.39	.00	26.90	.00	.00	.00	.00	.00	.00	.00	10.26
FLOW=	25.0 CFS											
XSEC		1	2	3	4	5						AVG
WETP		10.59	10.80	16.39	16.61	12.98	.00	.00	.00	.00	.00	13.47
DBAR		.82	.70	.70	.56	.70	.00	.00	.00	.00	.00	.70

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

VBAR		3.11	3.76	2.41	2.72	2.96	.00	.00	.00	.00	.00	2.99
WDTH		9.80	9.54	14.84	16.37	12.02	.00	.00	.00	.00	.00	12.51
AREA		8.04	6.66	10.39	9.20	8.43	.00	.00	.00	.00	.00	8.54
STGE		93.48	93.81	96.53	97.05	97.17	.00	.00	.00	.00	.00	95.61
DMAX		1.25	1.08	1.38	.89	1.02	.00	.00	.00	.00	.00	1.12
WTOT	.40	7.82	7.37	10.37	13.47	8.72	.00	.00	.00	.00	.00	9.55
WMAX		7.82	7.37	7.80	13.47	8.72	.00	.00	.00	.00	.00	9.04
PTOT		79.85	77.28	69.83	82.29	72.54	.00	.00	.00	.00	.00	76.36
PMAX		79.85	77.28	52.53	82.29	72.54	.00	.00	.00	.00	.00	72.90
WTOT	1.00	4.77	1.69	4.96	.00	1.49	.00	.00	.00	.00	.00	2.58
WMAX		4.77	1.69	4.96	.00	1.32	.00	.00	.00	.00	.00	2.55
PTOT		48.70	17.75	33.40	.00	12.40	.00	.00	.00	.00	.00	22.45
PMAX		48.70	17.75	33.40	.00	10.94	.00	.00	.00	.00	.00	22.16

FLOW= 30.0 CFS

XSEC		1	2	3	4	5						AVG
WETP		10.84	11.60	16.55	16.87	13.15	.00	.00	.00	.00	.00	13.80
DBAR		.90	.73	.78	.61	.75	.00	.00	.00	.00	.00	.75
VBAR		3.36	4.03	2.59	2.94	3.31	.00	.00	.00	.00	.00	3.25
WDTH		9.93	10.20	14.86	16.59	12.13	.00	.00	.00	.00	.00	12.74
AREA		8.92	7.44	11.58	10.19	9.07	.00	.00	.00	.00	.00	9.44
STGE		93.57	93.89	96.61	97.11	97.22	.00	.00	.00	.00	.00	95.68
DMAX		1.34	1.16	1.46	.95	1.07	.00	.00	.00	.00	.00	1.20
WTOT	.40	8.13	8.53	11.34	14.29	9.04	.00	.00	.00	.00	.00	10.27
WMAX		8.13	8.53	8.21	14.29	8.77	.00	.00	.00	.00	.00	9.59
PTOT		81.87	83.66	76.28	86.13	74.50	.00	.00	.00	.00	.00	80.49
PMAX		81.87	83.66	55.25	86.13	72.29	.00	.00	.00	.00	.00	75.84
WTOT	1.00	5.39	2.02	5.46	.00	3.28	.00	.00	.00	.00	.00	3.23
WMAX		5.39	1.89	5.46	.00	2.27	.00	.00	.00	.00	.00	3.00
PTOT		54.27	19.82	36.74	.00	27.08	.00	.00	.00	.00	.00	27.58
PMAX		54.27	18.56	36.74	.00	18.72	.00	.00	.00	.00	.00	25.66

FLOW= 40.0 CFS

XSEC		1	2	3	4	5						AVG
WETP		11.51	12.94	17.23	17.29	13.44	.00	.00	.00	.00	.00	14.48
DBAR		1.00	.79	.89	.70	.83	.00	.00	.00	.00	.00	.84
VBAR		3.82	4.48	2.93	3.35	3.93	.00	.00	.00	.00	.00	3.70
WDTH		10.45	11.35	15.39	16.96	12.32	.00	.00	.00	.00	.00	13.29
AREA		10.47	8.94	13.65	11.93	10.17	.00	.00	.00	.00	.00	11.03
STGE		93.73	94.02	96.74	97.22	97.31	.00	.00	.00	.00	.00	95.80
DMAX		1.50	1.29	1.59	1.06	1.16	.00	.00	.00	.00	.00	1.32
WTOT	.40	9.07	9.47	13.45	15.01	10.09	.00	.00	.00	.00	.00	11.42
WMAX		9.07	9.47	8.95	15.01	8.90	.00	.00	.00	.00	.00	10.28

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

PTOT		86.79	83.43	87.40	88.51	81.89	.00	.00	.00	.00	.00	85.60
PMAX		86.79	33.43	58.17	88.51	72.23	.00	.00	.00	.00	.00	77.83
WTOT	1.00	6.84	4.68	6.04	.88	5.12	.00	.00	.00	.00	.00	4.71
WMAX		6.84	4.68	6.04	.88	5.12	.00	.00	.00	.00	.00	4.71
PTOT		65.49	41.22	39.25	5.17	41.55	.00	.00	.00	.00	.00	38.54
PMAX		65.49	41.22	39.25	5.17	41.55	.00	.00	.00	.00	.00	38.54

FLOW= 50.0 CFS

XSEC		1	2	3	4	5						AVG
WETP		13.02	13.27	17.72	17.64	13.80	.00	.00	.00	.00	.00	15.09
DBAR		1.00	.89	.98	.78	.88	.00	.00	.00	.00	.00	.91
VBAR		4.20	4.86	3.24	3.72	4.51	.00	.00	.00	.00	.00	4.11
WDTH		11.86	11.54	15.76	17.26	12.61	.00	.00	.00	.00	.00	13.81
AREA		11.90	10.29	15.45	13.44	11.09	.00	.00	.00	.00	.00	12.43
STGE		93.86	94.14	96.86	97.31	97.38	.00	.00	.00	.00	.00	95.91
DMAX		1.63	1.41	1.71	1.15	1.23	.00	.00	.00	.00	.00	1.43
WTOT	.40	9.68	9.52	14.83	15.61	10.94	.00	.00	.00	.00	.00	12.11
WMAX		9.68	9.52	14.83	15.61	9.08	.00	.00	.00	.00	.00	11.74
PTOT		81.58	82.49	94.08	90.46	86.73	.00	.00	.00	.00	.00	87.07
PMAX		81.58	82.49	94.08	90.46	72.01	.00	.00	.00	.00	.00	84.12
WTOT	1.00	7.28	5.40	6.64	3.70	7.34	.00	.00	.00	.00	.00	6.07
WMAX		7.28	5.40	6.64	3.70	7.34	.00	.00	.00	.00	.00	6.07
PTOT		61.37	46.82	42.12	21.42	58.23	.00	.00	.00	.00	.00	45.99
PMAX		61.37	46.82	42.12	21.42	58.23	.00	.00	.00	.00	.00	45.99

FLOW= 60.0 CFS

XSEC		1	2	3	4	5						AVG
WETP		14.72	13.51	18.15	18.22	14.34	.00	.00	.00	.00	.00	15.79
DBAR		.99	.99	1.06	.83	.91	.00	.00	.00	.00	.00	.96
VBAR		4.48	5.22	3.52	4.06	5.03	.00	.00	.00	.00	.00	4.46
WDTH		13.48	11.65	16.08	17.81	13.10	.00	.00	.00	.00	.00	14.42
AREA		13.41	11.50	17.04	14.79	11.92	.00	.00	.00	.00	.00	13.73
STGE		93.97	94.25	96.96	97.38	97.45	.00	.00	.00	.00	.00	96.00
DMAX		1.74	1.52	1.81	1.22	1.30	.00	.00	.00	.00	.00	1.52
WTOT	.40	9.93	9.75	14.85	16.07	11.67	.00	.00	.00	.00	.00	12.45
WMAX		9.93	9.56	14.85	16.07	9.24	.00	.00	.00	.00	.00	11.93
PTOT		73.64	83.69	92.35	90.22	89.14	.00	.00	.00	.00	.00	85.81
PMAX		73.64	82.04	92.35	90.22	70.55	.00	.00	.00	.00	.00	81.76
WTOT	1.00	7.63	6.14	7.06	5.79	7.90	.00	.00	.00	.00	.00	6.91
WMAX		7.63	6.14	7.06	5.79	7.90	.00	.00	.00	.00	.00	6.91
PTOT		56.58	52.71	43.93	32.49	60.37	.00	.00	.00	.00	.00	49.22
PMAX		56.58	52.71	43.93	32.49	60.37	.00	.00	.00	.00	.00	49.22

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

COMPUTED VALUES

FLOW= 1.5 CFS

XSEC	1	2	3	4	5						AVG
WETP	.00	.00	6.28	8.20	8.75	.00	.00	.00	.00	.00	7.74
DBAR	.00	.00	.36	.16	.34	.00	.00	.00	.00	.00	.28
VBAR	.00	.00	.71	1.19	.52	.00	.00	.00	.00	.00	.81
WDTH	.00	.00	5.97	8.14	8.46	.00	.00	.00	.00	.00	7.52
AREA	.00	.00	2.12	1.26	2.87	.00	.00	.00	.00	.00	2.08
STGE	.00	.00	95.72	96.49	96.61	.00	.00	.00	.00	.00	96.27
DMAX	.00	.00	.57	.33	.46	.00	.00	.00	.00	.00	.45

WTOT	.40	.00	.00	2.55	.00	3.01	.00	.00	.00	.00	.00	1.85
WMAX		.00	.00	2.55	.00	2.16	.00	.00	.00	.00	.00	1.57
PTOT		.00	.00	42.66	.00	35.64	.00	.00	.00	.00	.00	26.10
PMAX		.00	.00	42.66	.00	25.51	.00	.00	.00	.00	.00	22.72
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 2.0 CFS

XSEC	1	2	3	4	5						AVG
WETP	.00	.00	6.55	8.91	8.86	.00	.00	.00	.00	.00	8.11
DBAR	.00	.00	.40	.18	.38	.00	.00	.00	.00	.00	.32
VBAR	.00	.00	.82	1.28	.63	.00	.00	.00	.00	.00	.91
WDTH	.00	.00	6.19	8.84	8.53	.00	.00	.00	.00	.00	7.85
AREA	.00	.00	2.45	1.57	3.20	.00	.00	.00	.00	.00	2.40
STGE	.00	.00	95.77	96.52	96.65	.00	.00	.00	.00	.00	96.32
DMAX	.00	.00	.62	.36	.50	.00	.00	.00	.00	.00	.50

WTOT	.40	.00	.00	3.19	.00	4.57	.00	.00	.00	.00	.00	2.59
WMAX		.00	.00	3.19	.00	4.57	.00	.00	.00	.00	.00	2.59
PTOT		.00	.00	51.53	.00	53.61	.00	.00	.00	.00	.00	35.05
PMAX		.00	.00	51.53	.00	53.61	.00	.00	.00	.00	.00	35.05
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 2.5 CFS

XSEC	1	2	3	4	5						AVG
WETP	.00	.00	6.83	9.28	8.95	.00	.00	.00	.00	.00	8.35
DBAR	.00	.00	.43	.20	.40	.00	.00	.00	.00	.00	.34
VBAR	.00	.00	.91	1.36	.72	.00	.00	.00	.00	.00	1.00
WDTH	.00	.00	6.43	9.21	8.58	.00	.00	.00	.00	.00	8.07

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

AREA		.00	.00	2.73	1.84	3.47	.00	.00	.00	.00	.00	2.68
STGE		.00	.00	95.82	96.55	96.69	.00	.00	.00	.00	.00	96.35
DMAX		.00	.00	.67	.39	.54	.00	.00	.00	.00	.00	.53
WTOT	.40	.00	.00	3.79	.00	4.80	.00	.00	.00	.00	.00	2.86
WMAX		.00	.00	3.79	.00	4.80	.00	.00	.00	.00	.00	2.86
PTOT		.00	.00	58.96	.00	55.89	.00	.00	.00	.00	.00	38.28
PMAX		.00	.00	58.96	.00	55.89	.00	.00	.00	.00	.00	38.28
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 3.0 CFS

XSEC		1	2	3	4	5						AVG
WETP		.00	.00	7.08	12.11	9.03	.00	.00	.00	.00	.00	9.41
DBAR		.00	.00	.45	.18	.43	.00	.00	.00	.00	.00	.35
VBAR		.00	.00	1.00	1.41	.81	.00	.00	.00	.00	.00	1.07
WDTH		.00	.00	6.64	12.04	8.63	.00	.00	.00	.00	.00	9.10
AREA		.00	.00	2.99	2.13	3.71	.00	.00	.00	.00	.00	2.94
STGE		.00	.00	95.86	96.58	96.71	.00	.00	.00	.00	.00	96.38
DMAX		.00	.00	.71	.42	.56	.00	.00	.00	.00	.00	.56
WTOT	.40	.00	.00	4.34	.28	5.19	.00	.00	.00	.00	.00	3.27
WMAX		.00	.00	4.34	.28	5.19	.00	.00	.00	.00	.00	3.27
PTOT		.00	.00	65.41	2.32	60.14	.00	.00	.00	.00	.00	42.62
PMAX		.00	.00	65.41	2.32	60.14	.00	.00	.00	.00	.00	42.62
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 3.5 CFS

XSEC		1	2	3	4	5						AVG
WETP		.00	.00	7.33	12.54	9.10	.00	.00	.00	.00	.00	9.66
DBAR		.00	.00	.47	.19	.45	.00	.00	.00	.00	.00	.37
VBAR		.00	.00	1.09	1.45	.89	.00	.00	.00	.00	.00	1.14
WDTH		.00	.00	6.86	12.46	8.68	.00	.00	.00	.00	.00	9.33
AREA		.00	.00	3.23	2.42	3.93	.00	.00	.00	.00	.00	3.19
STGE		.00	.00	95.89	96.60	96.74	.00	.00	.00	.00	.00	96.41
DMAX		.00	.00	.74	.44	.59	.00	.00	.00	.00	.00	.59
WTOT	.40	.00	.00	4.73	.64	5.74	.00	.00	.00	.00	.00	3.70
WMAX		.00	.00	4.73	.64	5.74	.00	.00	.00	.00	.00	3.70
PTOT		.00	.00	68.94	5.10	66.10	.00	.00	.00	.00	.00	46.71
PMAX		.00	.00	68.94	5.10	66.10	.00	.00	.00	.00	.00	46.71

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 4.0 CFS

												AVG
XSEC		1	2	3	4	5						
WETP		.00	.00	7.47	13.37	9.16	.00	.00	.00	.00	.00	10.00
DBAR		.00	.00	.49	.20	.47	.00	.00	.00	.00	.00	.39
VBAR		.00	.00	1.16	1.48	.97	.00	.00	.00	.00	.00	1.20
WDTH		.00	.00	6.97	13.28	8.71	.00	.00	.00	.00	.00	9.66
AREA		.00	.00	3.44	2.70	4.12	.00	.00	.00	.00	.00	3.42
STGE		.00	.00	95.93	96.62	96.76	.00	.00	.00	.00	.00	96.44
DMAX		.00	.00	.78	.46	.61	.00	.00	.00	.00	.00	.62
WTOT	.40	.00	.00	4.96	.96	7.10	.00	.00	.00	.00	.00	4.34
WMAX		.00	.00	4.96	.96	7.10	.00	.00	.00	.00	.00	4.34
PTOT		.00	.00	71.12	7.23	81.55	.00	.00	.00	.00	.00	53.30
PMAX		.00	.00	71.12	7.23	81.55	.00	.00	.00	.00	.00	53.30
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 5.0 CFS

												AVG
XSEC		1	2	3	4	5						
WETP		.00	.00	7.69	13.76	9.25	.00	.00	.00	.00	.00	10.23
DBAR		.00	.00	.54	.24	.51	.00	.00	.00	.00	.00	.43
VBAR		.00	.00	1.30	1.55	1.12	.00	.00	.00	.00	.00	1.32
WDTH		.00	.00	7.13	13.66	8.75	.00	.00	.00	.00	.00	9.85
AREA		.00	.00	3.84	3.22	4.46	.00	.00	.00	.00	.00	3.84
STGE		.00	.00	95.98	96.66	96.80	.00	.00	.00	.00	.00	96.48
DMAX		.00	.00	.83	.50	.65	.00	.00	.00	.00	.00	.66
WTOT	.40	.00	.00	5.31	3.04	7.50	.00	.00	.00	.00	.00	5.28
WMAX		.00	.00	5.31	3.04	7.50	.00	.00	.00	.00	.00	5.28
PTOT		.00	.00	74.45	22.25	85.68	.00	.00	.00	.00	.00	60.79
PMAX		.00	.00	74.45	22.25	85.68	.00	.00	.00	.00	.00	60.79
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 6.0 CFS

AVG

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

XSEC		1	2	3	4	5						
WETP		.00	.00	9.51	14.33	9.77	.00	.00	.00	.00	.00	11.20
DBAR		.00	.00	.47	.26	.52	.00	.00	.00	.00	.00	.42
VBAR		.00	.00	1.42	1.62	1.26	.00	.00	.00	.00	.00	1.43
WDTH		.00	.00	8.89	14.22	9.22	.00	.00	.00	.00	.00	10.77
AREA		.00	.00	4.22	3.70	4.77	.00	.00	.00	.00	.00	4.23
STGE		.00	.00	96.03	96.70	96.83	.00	.00	.00	.00	.00	96.52
DMAX		.00	.00	.88	.54	.68	.00	.00	.00	.00	.00	.70
WTOT	.40	.00	.00	5.61	3.55	7.78	.00	.00	.00	.00	.00	5.65
WMAX		.00	.00	5.61	3.55	7.78	.00	.00	.00	.00	.00	5.65
PTOT		.00	.00	63.16	24.96	84.38	.00	.00	.00	.00	.00	57.50
PMAX		.00	.00	63.16	24.96	84.38	.00	.00	.00	.00	.00	57.50
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 7.0 CFS

XSEC		1	2	3	4	5						AVG
WETP		.00	.00	10.47	14.47	10.23	.00	.00	.00	.00	.00	11.72
DBAR		.00	.00	.47	.29	.52	.00	.00	.00	.00	.00	.43
VBAR		.00	.00	1.51	1.69	1.39	.00	.00	.00	.00	.00	1.53
WDTH		.00	.00	9.76	14.34	9.64	.00	.00	.00	.00	.00	11.25
AREA		.00	.00	4.63	4.13	5.05	.00	.00	.00	.00	.00	4.60
STGE		.00	.00	96.07	96.73	96.86	.00	.00	.00	.00	.00	96.55
DMAX		.00	.00	.92	.57	.71	.00	.00	.00	.00	.00	.73
WTOT	.40	.00	.00	5.81	4.01	7.97	.00	.00	.00	.00	.00	5.93
WMAX		.00	.00	5.81	4.01	7.97	.00	.00	.00	.00	.00	5.93
PTOT		.00	.00	59.54	27.93	82.73	.00	.00	.00	.00	.00	56.73
PMAX		.00	.00	59.54	27.93	82.73	.00	.00	.00	.00	.00	56.73
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 8.0 CFS

XSEC		1	2	3	4	5						AVG
WETP		.00	.00	11.00	14.67	10.53	.00	.00	.00	.00	.00	12.07
DBAR		.00	.00	.49	.31	.54	.00	.00	.00	.00	.00	.45
VBAR		.00	.00	1.59	1.76	1.50	.00	.00	.00	.00	.00	1.62
WDTH		.00	.00	10.22	14.54	9.89	.00	.00	.00	.00	.00	11.55
AREA		.00	.00	5.02	4.54	5.32	.00	.00	.00	.00	.00	4.96
STGE		.00	.00	96.11	96.75	96.89	.00	.00	.00	.00	.00	96.59
DMAX		.00	.00	.96	.59	.74	.00	.00	.00	.00	.00	.77

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

WTOT	.40	.00	.00	5.94	4.42	8.09	.00	.00	.00	.00	.00	6.15
WMAX		.00	.00	5.94	4.42	8.09	.00	.00	.00	.00	.00	6.15
PTOT		.00	.00	58.12	30.42	81.75	.00	.00	.00	.00	.00	56.77
PMAX		.00	.00	58.12	30.42	81.75	.00	.00	.00	.00	.00	56.77
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 9.0 CFS

XSEC		1	2	3	4	5						AVG
WETP		.00	.00	11.49	14.87	10.82	.00	.00	.00	.00	.00	12.39
DBAR		.00	.00	.51	.33	.55	.00	.00	.00	.00	.00	.46
VBAR		.00	.00	1.67	1.83	1.62	.00	.00	.00	.00	.00	1.71
WDTH		.00	.00	10.64	14.73	10.15	.00	.00	.00	.00	.00	11.84
AREA		.00	.00	5.40	4.91	5.56	.00	.00	.00	.00	.00	5.29
STGE		.00	.00	96.15	96.78	96.92	.00	.00	.00	.00	.00	96.61
DMAX		.00	.00	1.00	.62	.77	.00	.00	.00	.00	.00	.79
WTOT	.40	.00	.00	6.06	5.74	8.19	.00	.00	.00	.00	.00	6.67
WMAX		.00	.00	6.06	5.74	8.19	.00	.00	.00	.00	.00	6.67
PTOT		.00	.00	56.93	39.01	80.73	.00	.00	.00	.00	.00	58.89
PMAX		.00	.00	56.93	39.01	80.73	.00	.00	.00	.00	.00	58.89
WTOT	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PTOT		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PMAX		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

FLOW= 10.0 CFS

XSEC		1	2	3	4	5						AVG
WETP		.00	.00	11.95	15.06	11.11	.00	.00	.00	.00	.00	12.70
DBAR		.00	.00	.52	.35	.56	.00	.00	.00	.00	.00	.48
VBAR		.00	.00	1.74	1.90	1.72	.00	.00	.00	.00	.00	1.79
WDTH		.00	.00	11.03	14.91	10.41	.00	.00	.00	.00	.00	12.12
AREA		.00	.00	5.76	5.26	5.80	.00	.00	.00	.00	.00	5.61
STGE		.00	.00	96.18	96.80	96.94	.00	.00	.00	.00	.00	96.64
DMAX		.00	.00	1.03	.64	.79	.00	.00	.00	.00	.00	.82
WTOT	.40	.00	.00	6.23	6.03	8.29	.00	.00	.00	.00	.00	6.85
WMAX		.00	.00	6.23	6.03	8.29	.00	.00	.00	.00	.00	6.85
PTOT		.00	.00	56.49	40.46	79.65	.00	.00	.00	.00	.00	58.87
PMAX		.00	.00	56.49	40.46	79.65	.00	.00	.00	.00	.00	58.87
WTOT	1.00	.00	.00	.66	.00	.00	.00	.00	.00	.00	.00	.22
WMAX		.00	.00	.39	.00	.00	.00	.00	.00	.00	.00	.13

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

PTOT		.00	.00	5.99	.00	.00	.00	.00	.00	.00	.00	2.00
PMAX		.00	.00	3.53	.00	.00	.00	.00	.00	.00	.00	1.18
FLOW=	15.0 CFS											
XSEC		1	2	3	4	5						AVG
WETP		.00	.00	14.20	15.79	12.30	.00	.00	.00	.00	.00	14.10
DBAR		.00	.00	.57	.44	.59	.00	.00	.00	.00	.00	.53
VBAR		.00	.00	2.02	2.21	2.20	.00	.00	.00	.00	.00	2.14
WDTH		.00	.00	13.02	15.60	11.48	.00	.00	.00	.00	.00	13.37
AREA		.00	.00	7.43	6.80	6.83	.00	.00	.00	.00	.00	7.02
STGE		.00	.00	96.32	96.90	97.03	.00	.00	.00	.00	.00	96.75
DMAX		.00	.00	1.17	.74	.88	.00	.00	.00	.00	.00	.93
WTOT	.40	.00	.00	6.96	8.58	8.49	.00	.00	.00	.00	.00	8.01
WMAX		.00	.00	6.96	8.58	8.49	.00	.00	.00	.00	.00	8.01
PTOT		.00	.00	53.47	54.98	73.92	.00	.00	.00	.00	.00	60.79
PMAX		.00	.00	53.47	54.98	73.92	.00	.00	.00	.00	.00	60.79
WTOT	1.00	.00	.00	2.57	.00	.00	.00	.00	.00	.00	.00	.86
WMAX		.00	.00	2.57	.00	.00	.00	.00	.00	.00	.00	.86
PTOT		.00	.00	19.70	.00	.00	.00	.00	.00	.00	.00	6.57
PMAX		.00	.00	19.70	.00	.00	.00	.00	.00	.00	.00	6.57
FLOW=	20.0 CFS											
XSEC		1	2	3	4	5						AVG
WETP		.00	.00	16.20	16.29	12.78	.00	.00	.00	.00	.00	15.09
DBAR		.00	.00	.61	.50	.65	.00	.00	.00	.00	.00	.59
VBAR		.00	.00	2.22	2.47	2.60	.00	.00	.00	.00	.00	2.43
WDTH		.00	.00	14.82	16.08	11.88	.00	.00	.00	.00	.00	14.26
AREA		.00	.00	9.01	8.08	7.70	.00	.00	.00	.00	.00	8.26
STGE		.00	.00	96.43	96.99	97.11	.00	.00	.00	.00	.00	96.84
DMAX		.00	.00	1.28	.83	.96	.00	.00	.00	.00	.00	1.02
WTOT	.40	.00	.00	8.94	12.16	8.62	.00	.00	.00	.00	.00	9.91
WMAX		.00	.00	7.32	12.16	8.62	.00	.00	.00	.00	.00	9.37
PTOT		.00	.00	60.31	75.66	72.55	.00	.00	.00	.00	.00	69.51
PMAX		.00	.00	49.43	75.66	72.55	.00	.00	.00	.00	.00	65.88
WTOT	1.00	.00	.00	3.99	.00	.00	.00	.00	.00	.00	.00	1.33
WMAX		.00	.00	3.99	.00	.00	.00	.00	.00	.00	.00	1.33
PTOT		.00	.00	26.90	.00	.00	.00	.00	.00	.00	.00	8.97
PMAX		.00	.00	26.90	.00	.00	.00	.00	.00	.00	.00	8.97
FLOW=	25.0 CFS											
XSEC		1	2	3	4	5						AVG
WETP		.00	.00	16.39	16.61	12.98	.00	.00	.00	.00	.00	15.33
DBAR		.00	.00	.70	.56	.70	.00	.00	.00	.00	.00	.65

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

VBAR		.00	.00	2.41	2.72	2.96	.00	.00	.00	.00	.00	2.70
WDTH		.00	.00	14.84	16.37	12.02	.00	.00	.00	.00	.00	14.41
AREA		.00	.00	10.39	9.20	8.43	.00	.00	.00	.00	.00	9.34
STGE		.00	.00	96.53	97.05	97.17	.00	.00	.00	.00	.00	96.92
DMAX		.00	.00	1.38	.89	1.02	.00	.00	.00	.00	.00	1.10
WTOT	.40	.00	.00	10.37	13.47	8.72	.00	.00	.00	.00	.00	10.85
WMAX		.00	.00	7.80	13.47	8.72	.00	.00	.00	.00	.00	9.99
PTOT		.00	.00	69.83	82.29	72.54	.00	.00	.00	.00	.00	74.89
PMAX		.00	.00	52.53	82.29	72.54	.00	.00	.00	.00	.00	69.12
WTOT	1.00	.00	.00	4.96	.00	1.49	.00	.00	.00	.00	.00	2.15
WMAX		.00	.00	4.96	.00	1.32	.00	.00	.00	.00	.00	2.09
PTOT		.00	.00	33.40	.00	12.40	.00	.00	.00	.00	.00	15.27
PMAX		.00	.00	33.40	.00	10.94	.00	.00	.00	.00	.00	14.78

FLOW= 30.0 CFS

XSEC		1	2	3	4	5						AVG
WETP		.00	.00	16.55	16.87	13.15	.00	.00	.00	.00	.00	15.52
DBAR		.00	.00	.78	.61	.75	.00	.00	.00	.00	.00	.71
VBAR		.00	.00	2.59	2.94	3.31	.00	.00	.00	.00	.00	2.95
WDTH		.00	.00	14.86	16.59	12.13	.00	.00	.00	.00	.00	14.53
AREA		.00	.00	11.58	10.19	9.07	.00	.00	.00	.00	.00	10.28
STGE		.00	.00	96.61	97.11	97.22	.00	.00	.00	.00	.00	96.98
DMAX		.00	.00	1.46	.95	1.07	.00	.00	.00	.00	.00	1.16
WTOT	.40	.00	.00	11.34	14.29	9.04	.00	.00	.00	.00	.00	11.55
WMAX		.00	.00	8.21	14.29	3.77	.00	.00	.00	.00	.00	10.42
PTOT		.00	.00	76.28	86.13	74.50	.00	.00	.00	.00	.00	78.97
PMAX		.00	.00	55.25	86.13	72.29	.00	.00	.00	.00	.00	71.22
WTOT	1.00	.00	.00	5.46	.00	3.28	.00	.00	.00	.00	.00	2.92
WMAX		.00	.00	5.46	.00	2.27	.00	.00	.00	.00	.00	2.58
PTOT		.00	.00	36.74	.00	27.08	.00	.00	.00	.00	.00	21.27
PMAX		.00	.00	36.74	.00	18.72	.00	.00	.00	.00	.00	18.49

FLOW= 40.0 CFS

XSEC		1	2	3	4	5						AVG
WETP		.00	.00	17.23	17.29	13.44	.00	.00	.00	.00	.00	15.98
DBAR		.00	.00	.89	.70	.83	.00	.00	.00	.00	.00	.81
VBAR		.00	.00	2.93	3.35	3.93	.00	.00	.00	.00	.00	3.41
WDTH		.00	.00	15.39	16.96	12.32	.00	.00	.00	.00	.00	14.89
AREA		.00	.00	13.65	11.93	10.17	.00	.00	.00	.00	.00	11.92
STGE		.00	.00	96.74	97.22	97.31	.00	.00	.00	.00	.00	97.09
DMAX		.00	.00	1.59	1.06	1.16	.00	.00	.00	.00	.00	1.27
WTOT	.40	.00	.00	13.45	15.01	10.09	.00	.00	.00	.00	.00	12.85
WMAX		.00	.00	8.95	15.01	8.90	.00	.00	.00	.00	.00	10.96

Bear Creek - Big Hole Drainage - SW, SE, SEC 34, T2N, R12W

PTOT		.00	.00	87.40	88.51	81.89	.00	.00	.00	.00	.00	85.93
PMAX		.00	.00	58.17	88.51	72.23	.00	.00	.00	.00	.00	72.97
WTOT	1.00	.00	.00	6.04	.88	5.12	.00	.00	.00	.00	.00	4.01
WMAX		.00	.00	6.04	.88	5.12	.00	.00	.00	.00	.00	4.01
PTOT		.00	.00	39.25	5.17	41.55	.00	.00	.00	.00	.00	28.66
PMAX		.00	.00	39.25	5.17	41.55	.00	.00	.00	.00	.00	28.66

FLOW= 50.0 CFS

												AVG
XSEC		1	2	3	4	5						
WETP		.00	.00	17.72	17.64	13.80	.00	.00	.00	.00	.00	16.39
DBAR		.00	.00	.98	.78	.88	.00	.00	.00	.00	.00	.88
VBAR		.00	.00	3.24	3.72	4.51	.00	.00	.00	.00	.00	3.82
WDTH		.00	.00	15.76	17.26	12.61	.00	.00	.00	.00	.00	15.21
AREA		.00	.00	15.45	13.44	11.09	.00	.00	.00	.00	.00	13.33
STGE		.00	.00	96.86	97.31	97.38	.00	.00	.00	.00	.00	97.18
DMAX		.00	.00	1.71	1.15	1.23	.00	.00	.00	.00	.00	1.36
WTOT	.40	.00	.00	14.83	15.61	10.94	.00	.00	.00	.00	.00	13.79
WMAX		.00	.00	14.83	15.61	9.08	.00	.00	.00	.00	.00	13.17
PTOT		.00	.00	94.08	90.46	86.73	.00	.00	.00	.00	.00	90.42
PMAX		.00	.00	94.08	90.46	72.01	.00	.00	.00	.00	.00	85.52
WTOT	1.00	.00	.00	6.64	3.70	7.34	.00	.00	.00	.00	.00	5.89
WMAX		.00	.00	6.64	3.70	7.34	.00	.00	.00	.00	.00	5.89
PTOT		.00	.00	42.12	21.42	58.23	.00	.00	.00	.00	.00	40.59
PMAX		.00	.00	42.12	21.42	58.23	.00	.00	.00	.00	.00	40.59

FLOW= 60.0 CFS

												AVG
XSEC		1	2	3	4	5						
WETP		.00	.00	18.15	18.22	14.34	.00	.00	.00	.00	.00	16.90
DBAR		.00	.00	1.06	.83	.91	.00	.00	.00	.00	.00	.93
VBAR		.00	.00	3.52	4.06	5.03	.00	.00	.00	.00	.00	4.20
WDTH		.00	.00	16.08	17.81	13.10	.00	.00	.00	.00	.00	15.66
AREA		.00	.00	17.04	14.79	11.92	.00	.00	.00	.00	.00	14.58
STGE		.00	.00	96.96	97.38	97.45	.00	.00	.00	.00	.00	97.26
DMAX		.00	.00	1.81	1.22	1.30	.00	.00	.00	.00	.00	1.44
WTOT	.40	.00	.00	14.85	16.07	11.67	.00	.00	.00	.00	.00	14.20
WMAX		.00	.00	14.85	16.07	9.24	.00	.00	.00	.00	.00	13.39
PTOT		.00	.00	92.35	90.22	89.14	.00	.00	.00	.00	.00	90.57
PMAX		.00	.00	92.35	90.22	70.55	.00	.00	.00	.00	.00	84.37
WTOT	1.00	.00	.00	7.06	5.79	7.90	.00	.00	.00	.00	.00	6.92
WMAX		.00	.00	7.06	5.79	7.90	.00	.00	.00	.00	.00	6.92
PTOT		.00	.00	43.93	32.49	60.37	.00	.00	.00	.00	.00	45.60
PMAX		.00	.00	43.93	32.49	60.37	.00	.00	.00	.00	.00	45.60

APPENDIX C

APPENDIX C

Green and Bluegreen Algae

German Gulch Creek

Station 1 (Below Beefstraight Creek)

Nostoc	abundant
Oscillatoria	rare
Closterium	rare

Station 2 (Below Edward Creek)

Nostoc	abundant
Oscillatoria	rare
Closterium	rare
Ulothrix	rare

Station 3 (Mouth)

Nostoc	sparse
Closterium	rare
Ulothrix	abundant

DIATOM COUNT DATA

German Gulch Below Beefstraight Creek

Taxon	Count	Relative Abundance
Achnanthes		
lanceolata Breb. ex Kutz.	56	13.5%
lanceolata var exigua Grun.	8	1.9%
minutissima Kutz.	11	2.7%
Amphipleura		
pellucida (Kutz.) Kutz.	1	.2%
Amphora		
ovalis var pediculus (Kutz.) V.H. ex DeT.		T
perpusilla (Grun.) Grun.	1	.2%
Caloneis		
bacillum (Grun.) Cl.	2	.5%
Cocconeis		
placentula Ehr.	44	10.6%
placentula var euglypta (Ehr.) Cl.	1	.2%
Cymbella		
affinis Kutz.	11	2.7%
cistula var. gibbosa Brun.		T
minuta Hilse	1	.2%
sinuata Greg.	10	2.4%
Cyclotella		
meneghiniana Kutz.	1	.2%
Diatoma		
hiemale (Roth.) Heib.	4	1.0%
hiemale var. mesodon (Ehr.) Grun.	9	2.2%
Didymosphenia		
geminata (Lyngb.) M.Schmidt.		T
Diploneis		
smithii var. pumila (Grun.) Hust.		T
Fragilaria		
construens var venter (Ehr.) Grun.	12	2.9%
leptostauron (Ehr.) Hust.	12	2.9%
pinnata Ehr.	11	2.7%
vaucheria (Kutz.) Peters.	41	9.9%
Frustulia		
vulgaris (Thwaites) DeT.		T

German Gulch Below Beefstraight Creek (Continued)

Taxon	Count	Relative Abundance
Gomphonema		
angustatum (Kutz.) Rabh.	4	1.0%
angustatum var intermedia Grun.	3	.7%
angustatum var productum Grun.	5	1.2%
dichotomum Kutz.	1	.2%
Gomphoneis		
herculeana (Ehr.) Cl.		T
Hannea		
arcus (Ehr.) Patr.	8	1.9%
Hantzschia		
amphioxys (Ehr.) Grun.	1	.2%
Melosira		
varians	2	.5%
granulata	2	.5%
Meridian		
circulare (Grev.) Ag.	2	.5%
circulare var constrictum (Ralfs) V.H.	2	.5%
Navicula		
bacillum Ehr.	1	.2%
capitata Ehr.	2	.5%
clementis Grun.		T
cryptocephala var veneta (Kutz.) Rabh.	32	7.7%
elginensis (Greg.) Ralfs		T
lanceolata (Ag.) Kutz.		T
pupula Kutz.		T
tripunctata (O.F. Mull.) Bory	19	4.6%
viridula (Kutz.) Kutz. emend. V.H.	1	.2%
viridula var avenacea (Breb. ex Grun.) V.H.	2	.5%
sp.	1	.2%
Neidium		
kozlowii var parvum Mereschk.		T
Nitzschia		
amphibia	3	.7%
dissipata (Kutz.) Grun.	7	1.7%
fonticola (Grun.) Grun.		T
frustulum	5	1.2%
kutzingiana	4	1.0%
linearis (Ag. ex W.Sm.) W.Sm.	4	1.0%
palea	8	1.9%
sp.	7	1.7%

German Gulch Below Beefstraight Creek (Continued)

Taxon	Count	Relative Abundance
Pinnularia		
biceps Greg.	2	.5%
borealis Ehr.		T
burkii Patr.	1	.2%
maior (Kutz.) Rabh.		T
Rhoicosphenia		
curvata (Kutz.) Grun. ex Rabh.	24	5.8%
Surirella		
angustata	1	.2%
ovata Kutz.	5	1.0%
Synedra		
ulna (Nitz.) Ehr.	17	4.1%
ulna var contracta Ostr.	1	.2%
TOTAL	413	

DIATOM COUNT DATA

German Gulch Below Edward Creek

Taxon	Count	Relative Abundance
Achnanthes		
lanceolata Breb. ex Kutz.	48	11.2%
lanceolata var dubia Grun.	8	1.9%
minutissima Kutz.	22	5.1%
Amphora		
ovalis var pediculus (Kutz.) V.H. ex DeT.	1	.2%
Caloneis		
bacillum (Grun.) Cl.	1	.2%
Cocconeis		
placentula Ehr.	62	14.4%
placentula var euglypta (Ehr.) Cl.	2	.5%
Cymbella		
minuta Hilse	11	2.6%
muelleri Hust.		T
sinuata Greg.	4	.9%
Diatoma		
anceps (Ehr.) Kirchn.	2	.5%
hiemale (Roth.) Heib.	1	.2%
hiemale var. mesodon (Ehr.) Grun.	17	4.0%
Diatomella		
balfouriana Grev.	4	.9%
Fragilaria		
leptostauron (Ehr.) Hust.	4	.9%
pinnata Ehr.	19	4.4%
pinnata var capitellata (Grun.) Patr.	5	1.2%
vaucheria (Kutz.) Peters.	58	13.6%
Frustulia		
vulgaris (Thwaites) DeT.	1	.2%
Gomphonema		
angustatum (Kutz.) Rabh.	2	.5%
dichotomum Kutz.	14	3.2%
parvulum Kutz.	2	.5%
sp.	2	.5%
Gomphoneis		
herculeana (Ehr.) Cl.	8	1.9%

German Gulch Below Edward Creek (Continued)

Taxon	Count	Relative Abundance
Hannea		
arcus (Ehr.) Patr.	4	.9%
Meridian		
circulare (Grev.) Ag.	7	1.6%
Navicula		
arvensis Hust.	7	1.6%
cryptocephala var veneta (Kutz.) Rabh.	14	3.2%
pupula Kutz.	3	.7%
viridula (Kutz.) Kutz. emend. V.H.	1	.2%
sp.	1	.2%
Nitzschia		
dissipata (Kutz.) Grun.	23	5.4%
fonticola (Grun.) Grun.	2	.5%
kutzingiana Hilse	17	4.0%
linearis (Ag. ex W.Sm.) W.Sm.	3	.7%
palea (Kutz.) W.Smith	10	2.3%
romana	3	.7%
sp.	8	1.9%
Pinnularia		
biceps Greg.		T
borealis Ehr.	1	.2%
stomophora (Grun.) Cl		T
Rhoicosphenia		
curvata (Kutz.) Grun. ex Rabh.	13	3.0%
Synedra		
ulna (Nitz.) Ehr.	1	.2%
TOTAL	428	

DIATOM COUNT DATA

Mouth of German Gulch

Taxon	Count	Relative Abundance
Achnanthes		
lanceolata Breb. ex Kutz.	9	2.2%
minutissima Kutz.	2	.5%
Cocconeis		
placentula Ehr.	9	2.2%
placentula var euglypta (Ehr.) Cl.	1	.2%
Cymbella		
affinis Kutz.	17	4.1%
cistula (Ehr.) Kirchn.		T
minuta Hilse		T
prostrata (Berk.) Cl		T
sinuata Greg.	2	.5%
Diatoma		
hiemale (Roth.) Heib.	1	.2%
hiemale var. mesodon (Ehr.) Grun.	1	.2%
Fragilaria		
leptostauron (Ehr.) Hust.	3	.7%
pinnata Ehr.	9	2.2%
vaucheria (Kutz.) Peters.	41	9.8%
Frustulia		
vulgaris (Thwaites) DeT.		T
Gomphonema		
angustatum (Kutz.) Rabh.	2	.5%
olivaceum	114	27.3%
parvulum Kutz.	11	2.6%
Gomphoneis		
herculeana (Ehr.) Cl.	3	.7%
Hannea		
arcus (Ehr.) Patr.	36	8.6%
Hantzschia		
amphioxys (Ehr.) Grun.	1	.2%

Mouth of German Gulch (Continued)

Taxon	Count	Relative Abundance
Navicula		
arvensis Hust.	3	.7%
capitata Ehr.	1	.2%
cryptocephala var veneta (Kutz.) Rabh.	22	5.3%
salinarum Grun.	2	.5%
tripunctata (O.F. Mull.) Bory	7	1.7%
Nitzschia		
dissipata (Kutz.) Grun.	57	13.7%
fonticola (Grun.) Grun.	4	1.0%
kutzingiana Hilse	11	2.6%
linearis (Ag. ex W.Sm.) W.Sm.	2	.5%
palea (Kutz.) W. Smith	1	.2%
Pinnularia		
borealis Ehr.		T
sp.		T
Rhoicosphenia		
curvata (Kutz.) Grun. ex Rabh.	2	.5%
Rhopalodia		
gibba var ventricosa (Kutz.) H and M. Peraq		T
Stauroneis		
smithii Pant.		T
Surirella		
ovata Kutz.	8	1.9%
ovata var Pinnata W. Sm.		T
Synedra		
ulna (Nitz.) Ehr.	14	3.3%
ulna var contracta Ostr.	21	5.0%
TOTAL	417	