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MONTANA DEPARTMENT OF FISH, WILDLIFE AND PARKS

Handbook for the Assessment of Small Hydroelectric Developments

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PERMITS AND LICENSES

The small hydro developer must obtain a number of federal and state permits and licenses before construction can begin at a project site. These include:

I. Federal Permits and Licenses

A. Federal Energy Regulatory Commission (FERC) License or License Exemption

The Federal Energy Regulatory Commission (FERC) is the primary licensing and regulatory agency for all non-federal hydroelectric development.

A potential small hydro developer must obtain a FERC license or exemption from licensing if the power will be sold to a utility that is connected to an interstate grid system and/or on a navigable stream. All projects which sell power to a local or regional utilities or REA are considered to be connected to an interstate grid system.

Basically, FERC issues eight types of licenses or permits: Preliminary Permits, Minor Licenses, Major Licenses, Case-by-Case Exemptions, Categorical Exemptions, Small Conduit Exemptions, Transmission Lines, and Relicensing. These eight licenses or permits are defined below:

DEFINITIONS

Preliminary Permits: Issued to applicants for the purpose of studying the feasibility of the site.

Minor Licenses - (Short Form License): Issued for small-scale hydropower projects of 5 MW or less.

Major Licenses: Issued for large-scale hydropower projects greater than 5 MW.

Case-by-Case Exemptions: Projects of 5 MW or less can be exempted from licensing if they utilize an existing non-federal dam or natural water feature which would not require a dam. A natural water feature is defined as a dam not more than 10 feet high.

Categorical Exemptions: On January 19, 1982, FERC passed Rule 202 which would allow certain projects of 5 MW or less that are proposed at existing dam sites to be excluded from licensing requirements. Order 202 has been challenged and, as of June 1983, FERC suspended all activities under order 202 until such time as the challenge is resolved.

Small Conduit Exemptions: Projects of 15 MW or less, utilizing a conduit on non-federal land and not an integral part of a dam may be exempted from licensing.

Transmission Lines: FERC has jurisdiction over those transmission facilities that are part of a licensed hydroelectric project.

Relicensing: All project licenses are issued for 50 years or less. To continue operation after that period, a facility must be relicensed.

Those licenses that apply to small hydro (less than 5 MW) include the preliminary permit, the case-by-case exemption, the categorical exemption and the minor or short form licenses. They are briefly discussed below.

Preliminary Permits

Preliminary permits are issued to applicants for the purpose of studying the feasibility of a project and to conduct investigations and surveys necessary for preparation of a license application. The permit is optional to the applicant. It gives the permittee priority rights in applying for a construction license. The issued permit is in effect for three years or less and does not authorize construction of the project. The normal term for a preliminary permit for small hydro is 18 months. The FERC only occasionally issues a preliminary permit for a 24 month duration for small hydro.

A developer has the option to first apply for a preliminary permit, or apply directly for a license or exemption from licensing. The preliminary permit has the advantage of giving a developer priority rights for the project site while studying the feasibility of the project and preparing a license or exemption application.

The FERC publishes notices in the Federal Register requesting comments on all preliminary permits. The agency comment period for preliminary permits can vary from 30 to 60 days. The Montana Department of Fish, Wildlife and Parks (MDFWP) responds to most preliminary permits utilizing one of the following options:

1. Send form letter stating general concern and requesting additional stream flow data (Appendix A).

2. Send specific comments if preliminary project assessment warrants it. This is usually done for those projects where we have sufficient existing data and can address specific issues.

3. Intervene in FERC licensing process.

Once all interested parties submit comments, FERC analyzes the comments and decides to either issue or deny the preliminary permit. FERC can, but rarely does, hold a public hearing on a preliminary permit. They also can grant Intervention Status to any party who has a vested interest in the project. FERC rarely denies a preliminary permit unless there are competing applications for the same site.

When FERC issues a preliminary permit, they incorporate stipulations concerning surveys, inventories, and feasibility studies that must be conducted as part of the permit. FERC attaches their Form P-1 entitled "Terms and Conditions of Preliminary Permits" to the permits and adds additional stipulations as they deem necessary. Some stipulations included are that the permittee must (1) determine feasibility of the project, (2) establish stream gaging stations as deemed appropriate by the Geological Survey, (3) designate a liaison officer as a contact, (4) consult with the U.S. Fish and Wildlife Service (FWS), the State Game and Fish agency, and National Marine Fisheries Service (NMFS), (5) if federal lands are involved, consult with the agency administering the land (BLM or FS), and (6) begin investigations and establish contact with appropriate agencies within 60 days of issuance of the permit.

The permittee must conduct studies as stipulated by FERC. If the permittee fails to demonstrate adequate progress on required studies, FERC can withdraw the permit.

In the time frame allotted for a preliminary permit (3 years or less), the permittee must determine the feasibility of the project. If it is viable, a license or exemption application can be prepared and submitted to FERC.

At some point during the preliminary permit, the permittee must appoint a liaison officer and establish contact with the fish and wildlife agencies for purposes of consultation. During consultation, the MDFWP indicates environmental problems and concerns with the proposed project and indicates data requirements for project assessment purposes and any studies that may be necessary.

<u>Case-by-Case Exemptions</u>

In 1980, the Federal Energy and Regulatory Commission (FERC), responding to the Energy

Security Act of 1980, issued Order 106 which established regulations to exempt certain projects on a case specific basis from all or part of Part 1 of the Federal Power Act, including licensing.

For a project to be exemptable under Order 106, it must have a total installed capacity less than 5 MW and would utilize an existing non-federal dam or would utilize a natural water feature without the need for a dam or man-made impoundment. A natural water feature is defined as a dam 10 ft. or less in height.

An applicant for a case-by-case exemption must consult with the appropriate state game and fish department and FWS to solicit Terms and Conditions (T&C) that are necessary to protect fish and wildlife resources. Any T&Cs we prescribe are binding on the applicant if the exemption is granted by FERC. Copies of letters from the State Game and Fish Department and FWS, or a summary of the consultation process must be included, in the Exhibit E (Environmental Report) portion of the application to FERC.

During the exemption process, the DFWP has two opportunities for influencing the proposed project. The applicant must consult with the DFWP prior to his submitting an application for exemption to the FERC (Phase I).

During Phase I we have 30 days to respond directly to the applicant. FERC's regulations state "at least 30 days"; however, FERC has recently interpreted the 30 days to be sufficient time for consultation. If the applicant becomes unreasonable however, we have several options. After FERC processes and "Notices" the exemption application, we have 60 days to respond to FERC with comments, terms and additions or intervention (Phase II).

FERC rules and regulations provide for extensions of time when "compelling evidence" is presented. In the opinion of FERC, however, situations such as manpower constraints and site access problems (e.g., project areas covered by snow) are not sufficient reasons to extend comment periods or delay the exemption process. What constitutes compelling evidence is not clear. Therefore, time extensions for exemption applications should not be relied upon.

Categorical Exemption

The categorical exemption (FERC Order 202) allows a simplified exemption process provided certain conditions are met. Categorical exemptions are limited to the addition of generating capacity (5MW or less) to existing dams.

Categorical exemptions severely restrict input by fish and wildlife agencies. There are, however, fairly restrictive standard conditions which are attached to the exemption and should provide a measure of protection. For example, the existing flow regime cannot be altered in any way. Likewise, reservoir operating levels must remain as they would have been without the project. The powerhouse outlet cannot be located any further than 300 ft. downstream from the dam.

The use of categorical exemptions is rare in Montana. In addition, FERC Order 202 is currently under judicial appeal and, as of June 1983, FERC has suspended action on 202 appeals until the court case is resolved.

Small Conduit Exemption

Section 213 of PURPA provided the commission with the authority to grant an exemption from the licensing requirements for small conduit hydroelectric facilities with a total installed generating capacity of 15 MW or less. Facilities qualifying for this exemption must be located on non-federal lands, and must utilize for generation only the hydroelectric potential of a man-made conduit that was constructed for another purpose. These conduits are primarily used for distribution of water for agricultural, municipal or industrial consumption and not primarily for generation of electricity. Examples of this are the Philipsburg and Whitefish water power projects located on the water supply systems for these two towns.

Short Form License

The FERC has expanded the applicability of the "Short Form" application to include all projects of 5 MW or less. The FERC short form license regulations provide a simplified procedure and reduce the amount of information required for projects with a proposed total capacity of 5 MW or less.

There is a significant difference in procedure, from our viewpoint, between a case-by-case exemption and a short form license. In the case-by-case exemption process, any terms, conditions and stipulations we deem necessary to protect fish and wildlife are automatically acccepted by FERC and incorporated in the exemption. In a short form license, however, our comments and terms, conditions and stipulatons are not considered by FERC to be binding. Instead, they are considered by FERC along with the applicant's position. The FERC makes the decision on appropriate conditions, stipulations and mitigation for short form license projects. If the decision is not satisfactory, the DFWP would then have to resort to appeal procedures.

B. Special Use Permit

Mandatory for all projects wholly or partially constructed on federal land. Administered by the USFS, BLM or other federal agency.

C. Section 404 Permit

Mandatory for all projects at the diversion and powerhouse discharge sites. Required for the discharge of dredged or fill material (includes the placement of concrete and rock) into waters of the United States. Administered by the Omaha District of the Army Corps of Engineers for streams east of the Divide and the Seattle District for streams west of the Divide. One of three permits (individual, general or nationwide) is required, depending on the scope of the project and size of the involved stream. Contact with the Corps should be made prior to construction to determine permit requirements.

In addition, the applicant must also obtain a "401" certification, which is noticed and issued in conjunction with the "404" permit. To obtain this certification, the Water Quality Bureau, Montana Department of Health and Environmental Sciences (MDHES), must review the project design and express the State's opinion that the project operation will not result in a violation of the applicable water quality standards, which primarily include water turbidity and gas saturation.

II. State of Montana Permits and Licenses

A. Water Use Permit

Mandatory for most projects. Allows the applicant to appropriate water, putting it to beneficial use. Administered by the Water Resource Division, Montana Department of Natural Resources and Conservation (MDNRC).

B. Natural Streambed and Land Preservation Act of 1975 ("310") Permit

Mandatory for all projects being constructed by private persons or organizations on public and private lands. Allows construction to occur within the high water marks of a perennial flowing stream. Needed for the diversion and powerhouse discharge sites and all stream crossings. Administered by the local Conservation District.

A "124" permit has similar requirements as the "310" permit, but applies only to state, county and municipal subdivisions of state government and federal agencies working on public lands. Administered by the MDFWP.

C. Montana Pollutant Discharge Elimination System (MPDES) Permit
A MPDES discharge permit is required for project construction unless a developer anticipates no discharge into the stream during construction dewatering. Administered by the Water Quality Bureau, MDHES.

D. Section 3a Authorization
An increase in water turbidity caused by project construction will be exempt from the applicable state water quality standard for turbidity unless the Water Quality Bureau, MDHES, is advised by the MDFWP, following a "310" or "124" inspection, that the project may result in a significant increase in turbidity. In this case, the project will be exempt from the applicable turbidity standard only if it is carried out in accordance with conditions prescribed by the MDHES in a Section 3a authorization. An application must be submitted to the MDHES and an authorization issued before construction can begin.

E. Floodplain and Flooding Management Act Permit
A permit is required for those projects being constructed in officially designated floodplains. Administered by the local governing body, usually the County Commissioners or a designated committee such as the Zoning Board. The Floodplain Management Section, MDNRC, provides technical assistance. Floodplain maps are available for

inspection at the local clerk and recorder's office.

There's no established order for obtaining the necessary federal and state permits and licenses. It is best, although not mandatory, to start the process by first obtaining a preliminary permit from FERC. The sole purpose of a preliminary permit is to secure priority to file for a FERC license or license exemption while the developer obtains data and performs studies to determine the economic, engineering and environmental feasibility of the project. The preliminary permit allows up to a statutory maximum of three years (permits for most small hydro projects are issued for only 18 months) for the permittee to perform the required studies to support a license or exemption application. If the results of these studies and the consultations with the fish and wildlife management agencies prove the project to be feasible, the permittee then can proceed to obtain the required permits and licenses. This option allows the developer adequate time to fully investigate all preliminary phases of project development while protecting his priority to develop the site. It also allows unfeasible projects to be eliminated early in the process, saving the developer time, money and unnecessary paper work.

PARTICIPATION OF THE MONTANA DEPARTMENT OF FISH, WILDLIFE AND PARKS (MDFWP)

The MDFWP, as the agency responsible for the management of the State's fish and wildlife resources, participates in all the federal and state permitting and licensing processes for small hydro developments. In general, the MDFWP is entrusted with extensive review authority, consults with and makes recommendations to the permitting and licensing agencies and, in the case of FERC license exemptions, directly conditions an exemption with stipulations protecting fish, wildlife and recreational values. Contact with the MDFWP early in the planning stages of a project is strongly recommended to avoid possible problems and delays. It is in the interest of the developer to be aware of potential conflicts with fish, wildlife and recreational interests and of the means for minimizing these conflicts early in the planning process.

The input of the MDFWP in the various permitting processes is discussed as follows:

I. Federal Permits and Licenses

A. FERC License or License Exemption

See discussion under PERMITS AND LICENSES

B. Special Use Permit

The MDFWP actively consults with the relevant federal agencies. The Department may recommend that the project be opposed or provide recommendations for mitigating environmental impacts.

C. Section 404 Permit and 401 Certification

The MDFWP reviews and comments on applications for permits, and reports permit violations to the Corps.

II. State of Montana Permits and Licenses

A. Water Use Permit

The Water Rights Bureau, when processing a water permit application for a hydro project, solicits comments from all relevant agencies, including the MDFWP, concerning the potential environmental impacts of the proposed project. Based on these comments, it is determined whether or not the application for a water permit requires the preparation of an Environmental Impact Statement (EIS) as prescribed by the Montana Environmental Policy Act. The applicant is required to pay for the EIS when the application involves the use of 10,000 or more acre-feet of water per year or 15 or more cubic feet per second and the cost exceeds $2,500. This fee is paid to the MDNRC and any amount not expended is refunded to the applicant. A water use permit will not be issued until the EIS, if required, is completed. In most cases, an EIS should take about 6-8 months to complete.

An EIS is more likely to be required for those projects in which the developer begins the permitting and licensing process by first applying for a state water use permit. This is based on the fact that, once a water permit application is correct and complete, the MDNRC has 90 days to notify the applicant if an EIS and fee are required. In many cases insufficient time is available to adequately address the need for an EIS, particularly in those areas where little or no biological data are available to base a determination. The MDNRC is more likely to require an EIS in these situations. If the applicant, however, begins the process by first receiving a FERC preliminary permit, up to 18 months are available to assess the environmental feasibility of the project. This period is sufficient for the applicant to consult with the relevant fish, wildlife and land management agencies, for the MDFWP to conduct field evaluations and, if the project is environmentally acceptable, to formulate measures to minimize fish, wildlife and recreational impacts. When a state water use permit is later applied for, the environmental impacts will already be assessed and mitigation measures developed, negating the need for an EIS.

Specific information is required by the Water Rights Bureau before a water permit application for hydro development is considered correct and complete (see Appendix B for a listing of the required information). Once the application is correct and complete and the EIS completed, if needed, the notice of application for a water permit is published. The MDFWP has the opportunity to submit comments or file an objection if the interests of the Department are adversely affected by the proposed appropriation.

Objections to water permit applications are routinely filed for hydro projects involving streams in which the MDFWP claims instream water rights or holds instream flow reservations. Hydro development on these streams would in most cases interfere with the senior instream rights and reservations of the Department.

The MDFWP holds instream flow reservations on most of the major tributaries to the middle and upper portions of the Yellowstone River. The amounts of the reserved flows for each stream are fixed and vary by month. Streams with claimed instream water rights (Murphy's rights and others) include:

Ashley Creek (Tributary to Flathead River)
Beaverhead River
Big Spring Creek
Bitterroot River
Blackfoot River
Elkhorn Creek (Beartooth W.M.A.)
Flathead River
Gallatin River
Madison River
Middle Fork of Flathead River
Missouri River
North Fork of Flathead River
Rock Creek (Tributary to Clark Fork River)
Smith River
South Fork of Flathead River
Tobacco River
West Gallatin River
Yellowstone River
Young Creek (Tributary to Lake Koocanusa)

Before a permit is issued specific criteria must be satisfied. These are listed in Appendix B.

Some developers are attempting to circumvent the water permitting process by developing their projects using an old water right filing for hydroelectric generation in lieu of a water use permit. While this option is available at some sites, problems can arise. A serious consideration is the question of abandonment. Many of the old hydro projects covered by these water right filings were in fact never built or, if constructed, were abandoned 50 or more years ago. Consequently, these claimed rights may prove invalid during the statewide water adjudication that is presently underway.

Another consideration is that the points of diversion and/or places of use for the new developments are generally different from the sites as previously developed and described in the old water right filings. The developer is required to apply to the MDNRC for authorization to make these site changes. The application is noticed and an objection can be submitted if the interests of the MDFWP are adversely affected.

Regardless of the means used to perfect a state water claim (via a water use permit or old water right filing as reclaimed under Senate Bill 76, Montana's Water Adjudication Act), an instream flow stipulation, if deemed necessary, will appear in the developer's FERC license or license exemption. The developer is required to maintain the stipulated flow within the project boundaries to meet federal licensing requirements.

B. "310" Permit

The team that inspects the construction sites for proposed small hydro developments includes a representative of the MDFWP. The Department can recommend to the Conservation District Board of Supervisors that the permit be denied, modified or conditions attached to minimize any adverse impacts on the fish, wildlife and recreational resources.

In the case of a "124" permit, an application must be submitted to the MDFWP before construction can begin. The Department can approve, modify or deny an application.

The applicant should be aware that the issuance of a "310" or "124" permit does not constitute consultation with the MDFWP as required under Subpart K - Exemption of Small Hydroelectric Power Projects of Five Megawatts or Less or any other FERC licensing procedure.

C. MPDES Discharge Permit

The MDFWP reviews and comments on applications for permits, and reports permit violations to the MDHES.

D. Section 3a Authorization

Following a "310" or "124" inspection, the MDFWP advises the MDHES of whether or not a 3a authorization is necessary for a project.

E. Floodplain and Floodway Management Act Permit

The MDFWP reports violations to the administering governmental groups.

CONDUCTING AN ENVIRONMENTAL INVENTORY

The fish, wildlife, land, water and recreational resources within the project area must be inventoried before the MDFWP can act on a particular hydro proposal. A small hydro development can impact a sizable tract of land since a typical project consists of a diversion structure and powerhouse connected by a penstock ranging from 1,000 feet to several miles in length, a permanent access road to the diversion site and a transmission line to interface with existing utility lines. An extensive inventory may be necessary since a myriad of habitat types, animal species and recreational activities can be impacted.

When Department personnel conduct an environmental inventory, important questions to be considered and determinations to be made are discussed as follows:

A. Fisheries Inventory

1. Determine the size, species composition and relative abundance of the resident fish populations within the project area. A electrofishing population estimate using a mark-recapture or two-catch method is desirable (see Appendix C for a description of the mark-recapture and two-catch methods).

2. Does the stream provide spawning and rearing habitats or an avenue of migration for nonresident gamefish populations? If so, how important is the stream for these migratory populations? Where do these activities occur in relation to the proposed project area? It should be noted that in some

species, such as bull trout, juvenile fish are reared in high gradient areas upstream from spawning areas.

3. What are the periods of use by migratory gamefish populations?

4. What is the potential for sediment, gas supersatuation, etc., to impact downstream fish habitat?

   Obviously, the MDFWP will require greater protection for those streams that support high numbers of gamefish for the size and type of stream involved, are inhabitated by species of "special concern" (cutthroat trout and arctic grayling, for example), or provide important spawning and rearing habitats for migratory gamefish populations.

B. Wildlife Inventory

1. Where possible, determine the relative abundance of the important wildlife species. Concentrate on big game animals, endangered species, raptors, waterfowl and furbearers.

2. Are there migration corridors within the project area?

3. Do portions of the project area provide critical shelter and forage for wildlife? During what periods are these habitats used?

4. Does the project area include big game winter range and big game calving and nursery areas?

C. Recreation Inventory

1. What are the types and magnitude of the recreational activities within the project area?

2. Would development alter recreational uses?

D. Land and Water Inventory

1. What are the present and future management objectives for the lands within the project area? Does hydro development conflict with these objectives?

2. Are there roads and other developments within the project area? Are other developments being proposed?

3. What is the general condition of the watershed? Are portions of the watershed degraded?

4. Are there plans to reclaim any degraded portions of the watershed?

5. Are there existing water quality problems relating to mining, logging, stream dewatering, etc.?

6. Could hydro development alleviate any existing environmental problems?

7. Does the project involve public or private lands?

8. Is any portion of the project area already a part of a mitigation plan?

9. Is the area suitable for development based on area geology and soil types?

10. Will the project affect stream stability?

11. Are there water depletions (irrigation, municipal, etc.) within the project boundaries?

ASSESSING ENVIRONMENTAL IMPACTS AND FORMULATING MITIGATION MEASURES

Before discussing mitigation measures, it should be understood that there are small hydro projects being proposed in areas in which the environmental impacts are too devastating to justify the minor amount of power produced. The MDFWP is opposing these developments. Some examples are a number of streams in northwest Montana that have been developed as spawning and rearing tributaries for gamefish residing in Lake Koocanusa (Libby Dam) to partially mitigate the fishery habitat losses resulting from reservoir construction, and projects being proposed for roadless, undeveloped areas that are being managed for wildlife or primitive recreation.

There are also situations in which small hydro developments produce no environmental impacts. An example is the Philipsburg water power project in which the existing water supply reservoir and pipeline were retrofitted for hydro production. The impacts of other projects may be too insignificant to require mitigation. A project on a very small stream that is devoid of fish and located on private land may qualify. Examples are the Cascade and Barney Creek projects in Park County.

When assessing environmental impacts and formulating mitigation measures, issues that should be addressed are discussed as follows:

1. Instream Flow Protection

   Virtually all small hydro projects have the capability to divert the entire stream flow during much of the year, thereby jeopardizing the fish populations in the section of stream betweeen the diversion site and the powerhouse outlet. The length of the dewatered section can vary greatly, ranging from a few hundred feet up to many miles. Most projects propose to dewater, on the average, about 2-3 miles of stream.

To protect the fishery resource, the MDFWP requires that a continuous, minimum instream flow is maintained within the project boundaries during the non-winter months. During the winter, the policy of the MDFWP for most projects on unregulated mountain streams that support fish is to prohibit winter flow depletions altogether. The rationale for this policy is thoroughly discussed in Appendix D.

To ensure that the minimum flow is provided, the MDFWP normally requires the diversion structure to be designed to automatically bypass the required instream flow before any water is diverted into the penstock. All flow must bypass the diversion structure when the natural stream flow is less than the required minimum.

If a portion of the flow within the project boundaries is being diverted for irrigation, stock, domestic or other consumptive uses, the developer is required to bypass, in addition to the stipulated instream flow, sufficient water to meet the needs of the other senior users. Consequently, a diversion structure that automatically bypasses only the stipulated instream flow will not maintain the required minimum throughout the project area since depletions will periodically occur. In this case, the MDFWP will generally not require an automatic bypass structure since the amount that must be bypassed to meet the needs of all users could vary daily. The developer, however, will be required to install approved flow measuring devices to ensure that the required instream flow is being maintained throughout the project area, to keep flow records and to submit these records when requested by the MDFWP. Records of the rate and volume of water diverted and bypassed, including dates, could also be required.

In addition to meeting the needs of fish, sufficient instream flows are also needed to maintain the riparian habitat. Stream dewatering could kill the riparian vegetation, severely impacting bank stability and the wildlife species that utilize the riparian zone for shelter and forage.

The MDFWP quantifies the required instream flow for the non-winter months using the wetted perimeter/inflection point method, which requires the collection of stream cross-sectional measurements at a minimum of two different flows taken after the spring runoff period. In most cases, the required instream flow cannot be finalized until after the summer field season is completed. The wetted perimeter/inflection point method is described in Guidelines for Using the Wetted Perimeter (WETP) Computer Program of the Montana Department of Fish, Wildlife and Parks (Appendix E).

Other instream flow methods are sometimes used in conjunction with the wetted perimeter/inflection point method if a constant minimum is inadequate for meeting the needs of the aquatic ecosystem. For example, those streams that provide important spawning habitat for migratory fish populations may require a higher flow during the spawning period to facilitate the passage of migrants to their upstream spawning areas. In this case, a method different from the wetted perimeter/inflection point method would be required for deriving a passage recommendation.

For most projects, the MDFWP will generally require that a constant minimum flow is maintained within the project boundaries during the non-winter months. It should be understood, however, that the stipulated minimums for some streams could vary seasonally, depending on the needs of the fish. There are also cases in which the MDFWP will not require instream flow protection. This category could include small streams barren of fish and intermittent streams. Those exempt streams will be determined on an individual basis.

Some developers are proposing to bypass a fixed percentage, such as 25 percent, of the available flow for instream uses in lieu of a constant minimum. This concept is generally unacceptable since it can result in the severe dewatering of the stream during some time periods. Secondly, it is extremely difficult, if not impossible, to operate a diversion in a manner that will continuously bypass a fixed percentage of the flow. The available flow can change daily and, as a result, so will the amount that must be bypassed.

Streamflow can be highly variable at different points within proposed diversion reaches in mountain streams due to geological structures that influence groundwater flow. Flow measurements should be made at instream flow transects and also at proposed diversion points so that requested flows can be adjusted to amounts that must be released at the diversion point.

In summary, the MDFWP requires the small hydro developer to demonstrate to our satisfaction that the project can in fact be designed, constructed and operated in a manner that will guarantee that the required instream flows will be maintained within the project boundaries at all times. It is important to thoroughly address this issue during the "310" inspection.

2. Fishways

For those streams providing important spawning and rearing habitats or an avenue of migration for migratory gamefish populations, state-of-the-art fishways that will effectively pass upstream and downstream migrating adults and juveniles are required on all diversion dams that block or impede fish movements. The fishway should be designed to pass at least the minimum flow being stipulated for fish passage. This issue should be addressed during the "310" inspection as well as during the FERC licensing procedures.

3. Screens and Racks

The penstock shall, in most cases, be suitably screened or racked to prevent the entry of juvenile and adult fish into the intake, and the powerhouse outlet designed so that the outlet flows do not attract fish from the natural stream channel. This may be accomplished using various energy dissipaters and fish barriers. These issues should be addressed during the "310" inspection as well as during the FERC licensing procedures.

Where physically practical, the desirable screen location is at the diversion entrance and parallel to the stream flow and adjacent bank line. Screen mesh or perforations and approach velocities recommended by the National Marine Fisheries Service for juvenile salmonids are listed below.

1. <u>Screen Mesh or Perforations</u>

   A. Screen openings may be round, square, rectangular, continuous slot, or any combination thereof, provided structural integrity and cleaning operations are not impaired.

   B. Fingerlings (min. lenth: 60 mm).

      Screen openings shall not exceed 0.25 inch (6.4 mm) in the narrow direction.

   C. Fry (max. length: 59 mm).

      Screen openings shall not exceed 0.125 inch (3.2 mm) in the narrow direction.

   D. Screen material shall provide a minimum of 40 percent open area.

2. <u>Approach Velocity</u> (Velocity component perpendicular to and approximately three inches in front of the screen face)

   A. Salmonid fry (max. length: 59 mm). The approach velocity shall not exceed 0.5 fps.

   B. Salmonid fingerling (60 mm and longer).

The approach velocity shall not exceed 1.0 fps.

The National Marine Fisheries Service will review fish passage and screening facilities to determine their effectiveness. Requests for such review should be made through the hydropower coordinator in the Fisheries Division in Helena.

4. Construction Periods

During certain time periods, it may be necessary to limit construction activities in the project area to protect fish and wildlife interests. For example, if the project area contains key, big game winter range, vehicular access should be blocked for the period the animals use this habitat. During winter, animals face the combined stresses of snow, cold weather, limited food supply and pregnancy. Under these conditions, even minor disturbances are likely to have serious effects on survival and reproductive performance. All winter range should be closed to motorized use between December 1 and May 15. Exceptions may be established through consultation with area wildlife managers.

Calving grounds and nursery areas having concentrated big game use should be closed to motor vehicles during periods of peak use. In the case of elk, calving usually occurs in late May through mid-June and high mountain meadows are used as nursery areas in late June and July.

Construction activities within the stream and on the stream banks may not be desirable during gamefish spawning and egg incubation periods. The sediments resulting from this activity can cover spawning areas and kill eggs, leading to poor reproductive success.

5. Penstock Construction

The penstock, the pipe that conveys water from the diversion site to the powerhouse, may be of sufficient diameter to impede or block the movements of wildlife and recreationists if laid above ground. This problem is of particular concern when the penstock traverses big game winter range, calving and nursery areas, or high use recreation areas. In some cases, the MDFWP will require that the penstock be buried to minimize these impacts.

The proposed penstock route should be carefully examined. A straight, direct alignment of the penstock between the diversion site and powerhouse is generally required to maximize power generating efficiency and to minimize construction costs. In some cases, the MDFWP will require that the penstock be aligned in the access road or use existing roadways to minimize adverse impacts. Penstock right-of-ways should be as narrow as possible to reduce land disturbance and subsequent sediment delivery to the stream.

6. Diversion Structures

The proposed location, design and plan of operation of a diversion are key issues that must be closely evaluated, particularily during the "310" inspection.

The location is critical. It is mandatory that the site is stable and not subject to slumping or channel changes. Diversions at marginal sites will require continual maintenance to keep them operational, increasing the damage to the aquatic environment.

Diversions that accumulate sediments and gravels are unacceptable since periodic dredging will be required to keep the diversion operational. This is of particular importance for those streams that carry heavy bed loads during the spring runoff. Seasonal dredging is in violation of the Montana Water Quality Act and the Natural Streambed and Land Preservation Act.

Virtually all structures must be designed to automatically bypass a guaranteed minimum flow, to allow the bedload to pass during the high flow period, and, in some cases, to provide effective fish passage. The developer must demonstrate to the satisfaction of the MDFWP that the diversion can be designed, constructed and operated in a manner that will guarantee that these requirements will be satisfied (See Appendix F for a discussion of the design concepts that can be used to determine if a proposed diversion structure can bypass a minimum flow and bedload).

For those projects being constructed at existing dams and diversions, it is important to determine how the project will alter existing water quality (oxygen and nitrogen levels, water temperature, and water turbidity are important) and the pattern and magnitude of the existing flow releases. Mitigation measures can also be required at these sites.

7. Reservoirs

The vast majority of the diversion structures at proposed small hydro sites form pools having a capacity of less than two acre-feet. Some developers, however, are proposing diversion dams that create storage reservoirs. These reservoirs are generally of little or no value for fish, wildlife and recreation due to the severe drawdowns that are necessary for year-round power production and other factors. In most cases, the creation of a reservoir does not in any manner compensate for the fish and wildlife habitat that is lost as a result of inundation and stream dewatering. The MDFWP generally opposes those small hydro projects requiring storage reservoirs, particularly those on public lands.

8. Access Roads

An access road is needed at a small hydro development not only to transport heavy equiment and materials to the construction site, but also to perform periodic maintenance and repairs once the project is operational. A permanent road is a necessity since vehicular access will be needed for the life of the project.

Access roads can be a key environmental issue at small hydro sites, particularily for those projects being proposed in roadless areas, primitive recreation areas, or areas containing critical wildlife habitat. Roads are incompatible with many management objectives. Obviously, the MDFWP will react more favorably to those projects that utilize existing roads for both project access and penstock alignment.

9. Transmission Lines

A transmission line is an integral, although often ignored, component of a small hydro project. A project can require many miles of new line in order to interface with existing utility lines. The habitat losses resulting from line construction can be extensive.

The proposed route of the transmission line is an important consideration. Lines crossing critical wildlife habitats, such as big game winter ranges and calving areas, should be carefully evaluated. Alternative routes may be required to minimize the environmental impacts. Underground lines are another option that can be investigated.

Above ground transmission lines must be constructed using a raptor-proof design to prevent the electrocution of hawks, eagles, falcons and other birds of prey. Electrocution hazards can be practically eliminated by incorporating the construction techniques outlined in the Raptor Research Report No. 4, 1981 - Suggested Practices for Raptor Protection on Powerlines - The State of the Art in 1981. A copy may be obtained by writing: Raptor Research Foundation, Department of Veterinary Biology, University of Minnesota, St. Paul, Minnesota 55101. The potential for powerline collisions can be reduced by placing lines underground or in such a manner as to avoid areas used by raptors for nesting, roosting and hunting.

10. Erosion Control

A plan to effectively control soil erosion on areas disturbed during construction must be developed.

Disturbed areas include penstock and powerline routes, access roads, and powerhouse and diversion construction sites. The plan should include the revegetation of disturbed areas with native grasses, forbes and shrubs.

A plan to effectively control water turbidity and instream sedimentation at the diversion and powerhouse construction sites must also be developed before project construction can begin.

11. Multiple Impacts

A typical small hydro development consists of many different componets, which, as a whole, can impact a sizable land mass and a variety of wildlife species and recreational activites. When assessing the environmental impacts, it is extremely important to thoroughly evaluate all facets of a project before deriving any conclusions concerning the magnitude of the impacts. The impact of a single component may not be significant, yet the project as a whole may be devastating.

12. Cumulative Impacts

Cumulative fisheries impacts can be most severe when dealing with migratory species and species of special concern. These impacts can be on-site (dewatering, sedimentation, temperature alterations, turbine mortality) as well as off-site (sedimentation, potential gas supersaturation and temperature alterations in downstream areas). Impacts of hydro development may also interact with impacts of other land use activities (logging, grazing, irrigation, etc.) to produce unacceptable cumulative effects.

The FERC can be petitioned to conduct a consolidated review of all proposed projects when the potential for cumulative impacts on fish and wildlife resources in a drainage basin is recognized. FERC is currently funding a cumulative impact assessment for small hydro projects in the Salmon River Basin in Idaho. The Bonneville Power Administration is funding a similar study in the Swan River drainage in Montana.

Cumulative assessments require a data base which contains the amounts and locations of important habitat for fish and wildlife species of interest. This information may already exist or may require additional inventory work. The second stage of the analysis involves the determination of existing resources within the area(s) influenced by proposed hydro projects. This site-specific information can then be applied to the drainage-wide data base to determine potential losses. If proposed projects are located on USFS lands it may be possible to predict the effects of sediment production on downstream salmonid spawning and rearing areas using a method developed by the USFS.

13. Compensation for Unavoidable Losses

Effective fish passage, mandatory instream flows, access restrictions and other measures are intended to avoid losses to the existing fish, wildlife and recreational resources. Regardless of the mitigation measures employed, unavoidable losses, either temporary or permanent, may occur to the fish, wildlife and recreational resources during or after project construction.

To fully replace the unavoidable losses, the MDFWP could require compensation in the form of fish habitat improvements, land acquisitions and easements, stream bank fencing, construction of spawning channels, contributions to major reclamation projects or other acceptable measures. In-kind compensation or enhancement measures in nearly all cases will have to be conducted off site to be effective.

14. Gas Supersaturation

CONDITIONS AND STIPULATIONS

During the FERC licensing or exepmtion process, it is possible to submit to the FERC terms, conditions and stipulations which, if attached to the license, would minimize or eliminate certain environmental impacts. Listed below are standard conditions which are useful in addressing several of the common impacts associated with small hydro.

Not all of the standard conditions would be used on any one project. Each small hydro project should be assessed on an individual basis and those terms and conditions selected which are most applicable to that specific project. In addition, some projects may require the development of additional conditions specific to that individual project.

1. Instream Flow

   a) Diversionary hydro project

      A continous instream surface water flow of at least X cfs will be maintained in the natural channel of Y Creek from the diversion structure to the point where all flows diverted are returned as surface water to the natural stream channel. When natural flows are less the X cfs, all flow will bypass the diversion structure. These stipulated flows are to be protected under a state water right acquired in accordance with provisions of Montana water law.

b) Dam

A continuous instream water flow of at least X cfs (or percentile flow) shall be released from the dam, regardless of whether it will be used for hydroelectric generation. This flow shall be maintained to point Z on Y Creek, and shall be protected in accordance with provisions of Montana water law.

Diversion Structure

1.

a. The diversion structure will be designed to automatically bypass the required instream flow before any water is diverted into the penstock.

or

b. A water gaging station will be established immediately below the point of diversion (or immediately upstream from the powerhouse out fall) to ensure that the required instream flow is maintained in X Creek. The gage station is required to provide an accuracy level acceptable to the US Geological Survey. Accurate flow records of the rate and volume of water diverted and bypassed, including dates, will be maintained and sent to the MDFWP at the beginning of each month.

or

c. a + b

2. The intake structure and diversion dam must be designed to allow a natural downstream movement of bedload materials.

3. An automatic shut-off valve must be installed in the diversion structure which will discontinue water withdrawals in the event of pipeline or penstock rupture.

4. Provisions must be made to eliminate air entrainment in the intake and pipeline. Dissolved gases in the waters discharged back to the natural stream channel must not exceed water quality standards (i.e., 110% of saturation).

5. The intake structure will be suitably screened or racked to prevent the entry of juvenile and adult fish into the intake.

6. The diversion structure must contain effective fish passage facilities to allow for both upstream and downstream movement of fish.

Tailrace

1. The powerhouse tailrace will be suitably screened or racked to prevent the entry of juvenile and adult fish. Additionally, the tailrace outflow into the adjacent stream should be accomplished so that erosion of the existing channel or embankment does not occur. Energy dissipators should be installed as necessary. Tailraces should be designed to avoid false attractant flows to fish migrating upstream.

Penstock

1. Penstock alignment will be determined in conjunction with the USFS on Forest Service lands.

2. The penstock will be aligned to avoid critical wildlife habitat.

3. The penstock will be aligned to avoid unstable soil areas.

4. Penstock alignment will utilize the existing roadway. Width of the penstock right-of-way shall not exceed ____ feet.

5. The penstock will be buried.

6. Stream crossings:
   a. The penstock crossing at X Creek will be suspended or bridged over the creek.

   b. The penstock crossing at X Creek will be buried beneath the streambed.

Transmission Lines

1. Above ground transmission lines will be constructed using a raptor proof design.

2. The transmission line will be buried.

3. The transmission line alignment will be determined in conjunction with the USFS/DFWP.

Construction

1. Construction/vehicular access will not occur between December 1 and June 15 to avoid disturbing deer, elk and moose that winter and calve within the area. The closed period may be shortened after consultation with the MDFWP if the distribution of the big game species within the

project area is altered by mild weather and below average snowpack.

2. Instream and streambank construction work will be timed to avoid impacts on salmonid spawning, egg incubation and fry emergence. Critical time periods will be determined in consultation with the MDFWP.

3. A plan to effectively control instream sedimentation and water turbidity below the diversion site shall be developed before construction begins.

4. A plan will be developed to control soil erosion on areas disturbed during construction. The plan will include the revegetation of disturbed areas with native grasses, forbes and shrubs.

5. Montana's Natural Streambed and Land Preservation Act of 1975 will be complied with at all diversions, stream crossings and at the powerhouse discharge site.

702/J/os6.20

APPENDIX

APPENDIX A

1420 East Sixth Avenue
Helena, MT 59620

Mr. Kenneth F. Plumb, Secretary
Federal Energy Regulatory Commission
825 North Capitol Street, N.E.
Washington, D.C. 20426

COMMENTS - Project No.

Dear Mr. Plumb:

We would like to comment on the application for preliminary permit for the

If a preliminary permit is issued, the applicant should determine what impacts would incur to the fish, wildlife and recreational resources from construction and operation of the project. Every effort should be made by the applicant to minimize or compensate for any unavoidable impacts. It should also be noted that along with consideration for the impacts on fish, wildlife and recreational resources, the applicant should address the impacts of the proposed project on archaeological/historical/cultural resources.

Items of major concern are any changes in the timing and/or quantity of instream flows which may result from the project. In this regard, a determination should be made of monthly high, low and mean stream flows and compared to monthly diversionary requirements for the project. The project should provide adequate instream flows for fisheries and wildlife habitat and maintenance of riparian zones. Additional concerns are the impacts associated with road location and construction.

Once the preliminary permit is obtained, the applicant should contact the Montana Department of Fish, Wildlife and Parks (Fisheries and Parks divisions), the U.S. Fish and Wildlife Service (Billings Area Office) and the State Historic Preservation Office for existing data and to help identify needed studies to determine impacts and ways of mitigating adverse impacts to fish, wildlife and recreational resources and archaeological/historical/cultural resources.

Sincerely,

/cm
703/B

APPENDIX B

TO: POTENTIAL HYDRO-POWER DEVELOPERS

Before an application can be considered correct and complete, the following information is required:

Engineering Plan--structures and equipment associated with facility:

1) Diversion and intake facilities
2) Penstock or conduit (plan and profile):
   a) diameter and thickness
   b) buried or above ground
   c) pressure ratings
   d) materials

3) Generating unit and powerhouse (size, type, kw, etc.)
4) Facility used to return water to creek (design of tailrace facility)
5) Estimations of:
   a) average head of plant
   b) hydraulic capacity in cfs.
   c) average flow of conduit and stream hydrograph a P.O.D.
   d) itemized cost of project for assessing E.I.S. fee
6) Transmission line
7) Engineer and qualifications

Reservoir--Is a reservoir proposed? Construction material (earth,concrete, etc.) Supply preliminary engineering design. If an existing dam, provide explanation of operation before and after installation (release schedule - existing vs. proposed).

a) capacity (L x W x H and volume)
b) spillways and by-pass structures (type and capacity)
c) operating criteria - monthly, peaking, run of river.

Before a permit will be issued the criteria for issurance of permit most be satisfied.

85-2-311. (Temporary) Criteria for issuance of permit. (1) Except as provided in subsections (2) and (3), the department shall issue a permit if the applicant proves by substantial credible evidence that the following criteria are met:

a) there are unappropriated waters in the source of supply:

i) at times when the water can be put to the use proposed by the applicant;

ii) throughout the period during which the applicant seeks to appropriate, the amount requested is available;

b) the water rights of a prior appropriator will not be adversely affected;

c) the proposed means of diversion, construction, and operation of the appropriation works are adequate;

d) the proposed use of water is a beneficial use;

e) the proposed use will not interfere unreasonably with other planned uses or developments for which a permit has been issued or for which water has been reserved.

(2) (a) The department may not issue a permit for an appropriation of 10,000 or more acre-feet of water a year or 15 or more cubic feet per second of water unless it affirmatively finds:

(i) the criteria in subsection (1) are met;

(ii) the applicant has proven by clear and convincing evidence that the rights of a prior appropriator will not be adversely affected;

(iii) the proposed appropriation is a reasonable use. Such a finding shall be based on a consideration of the following:

(A) the existing demands on the state water supply, as well as projected demands such as reservations of water for future beneficial purposes, including municipal water supplies, irrigation systems, and minimum streamflows for the protection of existing water rights and aquatic life;

(B) the benefits to the applicant and the state;

(C) the economic feasibility of the projects;

(D) the effects on the quantity, quality, and potability of water for existing beneficial uses in the source of supply;

(E) the effects on private property rights by any creation of or contribution to saline seep; and

(F) the probable significant adverse environmental impacts of the proposed use of water as determined by the department pursuant to Title 75, chapter 1, or Title 75, chapter 20.

For any further questions please contact this office:

BOZEMAN WATER RIGHTS FIELD OFFICE
1201 EAST MAIN
BOZEMAN, MONTANA 59715

PH- 406-586-3136

APPENDIX C

FISH POPULATION ESTIMATION TECHNIQUES IN MONTANA

Richard Vincent

Fisheries Biologist, Montana Department of Fish, Wildlife and Parks

INTRODUCTION

In Montana, considerable emphasis has been placed on measuring wild trout populations in the larger trout rivers. In order to obtain useable population data, there was a need to set up uniform fish population sampling and estimation procedures. The Peterson-type mark-and-recapture technique is the most commonly used population estimation technique in Montana. This method involves sampling and marking fish in a given section of stream through electrofishing, and then after a given period of time, resampling the fish population in the study section to make the fish population estimate.

Electrofishing Techniques

Stream electrofishing can be done either using a boat to transport the electrofishing gear down through the study section or by electrofishing while wading up or down through the stream section. Usually the "bank" or "wade" system is used where either the stream is small (less than 100 cfs) or the section is short (less than 1000 feet). In Montana, the most common system used is boat or "float" electrofishing. Most study sections in Montana range in length from one to five miles. Boat electrofishing can be done using either a "drift" (non motorized) or motorized boat. The "drift" electrofishing boat is powered by either a person walking behind the boat or oars and includes a mobile positive electrode and a fixed negative electrode. Motor powered boats usually use the fixed multiple positive electrode system known as a "boom shocker."

These electrofishing systems can be powered by either continuous direct or pulsating direct current. Pulsating direct current usually provides a larger field of effective galvanotaxis than continuous d.c., but has a tendency to increase the incidence of galvanonarcosis making capture difficult when the drift technique is used. Continuous d.c. has a smaller field of galvanotaxis, but fish show a stronger "attraction" to the positive electrode since the incidence of galvanonarcosis is low, making it more ideal in drift boat systems.

With the boat electrofishing system where sections are long (1-5 miles), sampled fish must periodically be weighed, measured, marked and released throughout the study area. This insures maximum chance to mix with the unmarked fish and minimizes the effect of emigration from the study section. Marking of the fish can be done through tagging or fin clipping.

Water temperature, turbidity and conductivity affect the catchability of fish in most streams. Salmonids are more easily captured when water temperatures range between 40-55°F. Below 40°F galvanonarcosis increases and galvanotaxis decreases. Usually streams with high conductivities show increased capture (efficiency) rates, except where conductivities are unusually high.

Fish Population Estimation Formulas

Almost all fish population estimates in Montana utilize some form of the Peterson-type mark-and-recapture method. This entails marking a certain number of fish, allowing time for marked fish to mix with the unmarked fish and then resampling the fish population to determine the correct marked to unmarked ratio. In Montana, Chapman's modification of the basic Peterson formula (Pop. Est. = MC/R) is used to insure more reliable estimates where fish populations are small and/or marked recapture numbers are low. Chapman's modification (Chapman, 1951) is as follows:

$$\text{Pop. Est. (N)} = \frac{(M + 1)\ (C + 1)}{R + 1} \quad - \text{ where,}$$

M = number of fish marked, C = number of fish in the recapture sample and R = number of marked fish in the recapture sample. The formula for the variance is:

$$\text{Variance} = \frac{(\text{Pop. Est.})^2\ (C - R)}{(C + 1)\ (R + 2)}$$

The confidence interval is computed as follows: Standard Deviation = ± 2 Var. for 95% levels and ± 1.282 Var. for 80% levels.

The basic assumption of mark-and-recapture population estimates is that marked fish are randomly distributed by size within the whole population.

Population Estimation Procedures

In order to insure quality population estimates, certain factors should be considered to maximize the quality of final estimate.

1. Correct length of study section.
2. Size of fish population in the study section.
3. Sampling efficiency and size.
4. Time interval between mark-and-recapture periods.
5. Proper selection of size groups.
6. Effect of movement.

Study sections should be of adequate length to insure a large enough fish population where even with low sampling efficiencies adequate sample sizes can be obtained to insure a quality population estimate. Larger sections tend to minimize the effect of fish movement in and/or out of each end of the study section. As a general rule, study sections should be more than 1000 feet. Where the size of the stream exceeds 100 cfs or sampling efficiencies are less than 20%, the section should be at least one mile in length. Access points, fish population densities, sampling efficiencies and marked recapture numbers are the major considerations in setting up the exact section length.

It is generally easier to estimate fish populations where the population size is high (1000 or greater). Where population numbers are high, correct sample sizes can be obtained, even if daily sampling efficiencies are low, by using the multiple mark-recapture system. This technique uses the sum of two or more marking trips as total marked and the sum of two or more recapture trips as the recapture sample. The marking sequence should be done in as short a time interval as possible. Whereas, recapture runs need not be on consecutive days, since fish mortality after the marking sequence should not alter the mark-unmarked ratio. The assumption is that marked and unmarked fish die at an equal rate. In using the multiple recapture system, some of the fish taken in the first recapture run may appear in following recapture runs. These fish can be dealt with in two ways: (1) sampling without replacement - fish examined in previous recapture runs (marked or unmarked) can only be used in their initial appearance; and (2) sampling with replacement - fish processed in previous recapture runs (marked or unmarked) can be used in subsequent recapture runs. Using the same fish more than once adds no bias to the population estimate, as the marked-unmarked ratio is not being altered. The advantage is the recapture sample is larger adding more accuracy to the final estimate.

Probably the most difficult parameter to determine in previously unstudied areas is the correct number of fish to mark. Generally, the minimum number to mark is 20% where the population is less than 1000, 15% where numbers range from 1000-5000 and 10% where numbers exceed 5000. Since in many cases the exact population size is unknown, adjustments in the total sample size must be made by increasing the number of recapture trips. A good index to determine when total sample sizes are adequate is through the number of marked recaptures. Robson and Reiger (1964) showed that a minimum of four (4) recaptures per estimation group were necessary to remove any mathematical bias. In Montana, the minimum recapture number is generally seven (7).

In order to insure proper mixing of the marked fish with the unmarked fish in the section, a certain period of time must elapse between the marking and recapture sequences. Adequate mixing of marked fish can often be determined in the first recapture run. If marked recaptured fish are taken in unusually large amounts (high mark-unmarked ratio) in some areas and unusually low amounts in other areas, improper mixing may have occurred. This "clumping" of marked fish means more time must be allowed before recapture samples can be taken. Where inadequate time has been allowed between mark-and-recapture samples, marked fish are often found near release sites and generally is more pronounced with small fish. Small brown trout (less than 10 inches) are prone to remain where released, especially if there is good bank cover. Usually, an inadequate time interval between mark-and-recapture samples leads to an underestimation of the population. In Montana, the proper time interval is accepted at 7-14 days. The only constraint on the time interval would be growth, as marked fins could be difficult to identify and size groups of marked fish would change.

Since a population estimate for any species of fish can rarely be made from a single size group, as catchability changes with size, total number estimates are made by summing two or more size group estimates. Proper selection of size (length) groups is essential to compute accurate estimates of age groups, mortality rates and total biomass. The catchability (efficiency) rate for various length groups can be determined by computing the ratio of marked to unmarked fish in the recapture sample. Since efficiency rates vary with stream type, water temperature, flow rate, type of sampling gear, season of the year and fish size, it is useful to construct an efficiency curve for each estimate. To obtain this curve, fish from the recapture sample should be tabulated and then a general efficiency curve for this species and time period can be made (Figure 1). Figure 2 shows some examples of efficiency curves found in various types of streams. Using the tabulated mark-recapture data plus the efficiency curve, proper length groups can be selected as shown in Table 1. The criteria used to select the proper length groups are: (1) all fish within each group are of equal catchability, and (2) there must be at least four recaptures per group. Once size group estimates are made, estimates for age groups, other size groups, mortality rates and biomass can be made (Vincent, 1971). The importance of proper size group arrangement cannot be over-emphasized. For example, using data shown in Table 1 and making only one size group (M = 779 x C = 633 ÷ R = 55), the number estimate was only 2% lower but age groups and biomass varied significantly. Using a single size group, the 6.9 inch and smaller fish were underestimated by 36% and the 13.5 inch and larger fish were overestimated by 26%. This would destroy accurate estimates of biomass, age groups and mortality rates.

Table 1. Wild rainbow trout population estimates for various size groups from 4.8 inches through 17.4 inches.

Size Group (in.)	Marked M	Recapture C	Marked Recap. R	Efficiency Rate	Population Estimate
4.8- 6.9	158	137	7	5.1%	2741
7.0- 7.9	106	91	6	6.6%	1405
8.0- 9.4	82	60	10	16.7%	459
9.5-11.4	137	108	12	11.1%	1156
11.5-13.4	174	137	14	10.3%	1609
13.5-17.4	122	100	11	11.0%	1034
Total	779	633	60	9.5%	8404

Occasionally fish population estimates are destroyed, when estimates are made during periods of significant movement such as spawning. Movement generally inflates the population estimate as: (1) marked fish move out of section between mark-and-recapture sampling, while unmarked fish move into section; (2) unmarked fish move into study section between mark-and-recapture sampling; and (3) fish concentrate in study section prior to mark or recapture sampling. Two spring estimates from the Gallatin River, Montana, one prior to spawning and one during spawning illustrate this situation (Table 2).

Figure 1. Efficiency curve for rainbow trout for the Madison River.

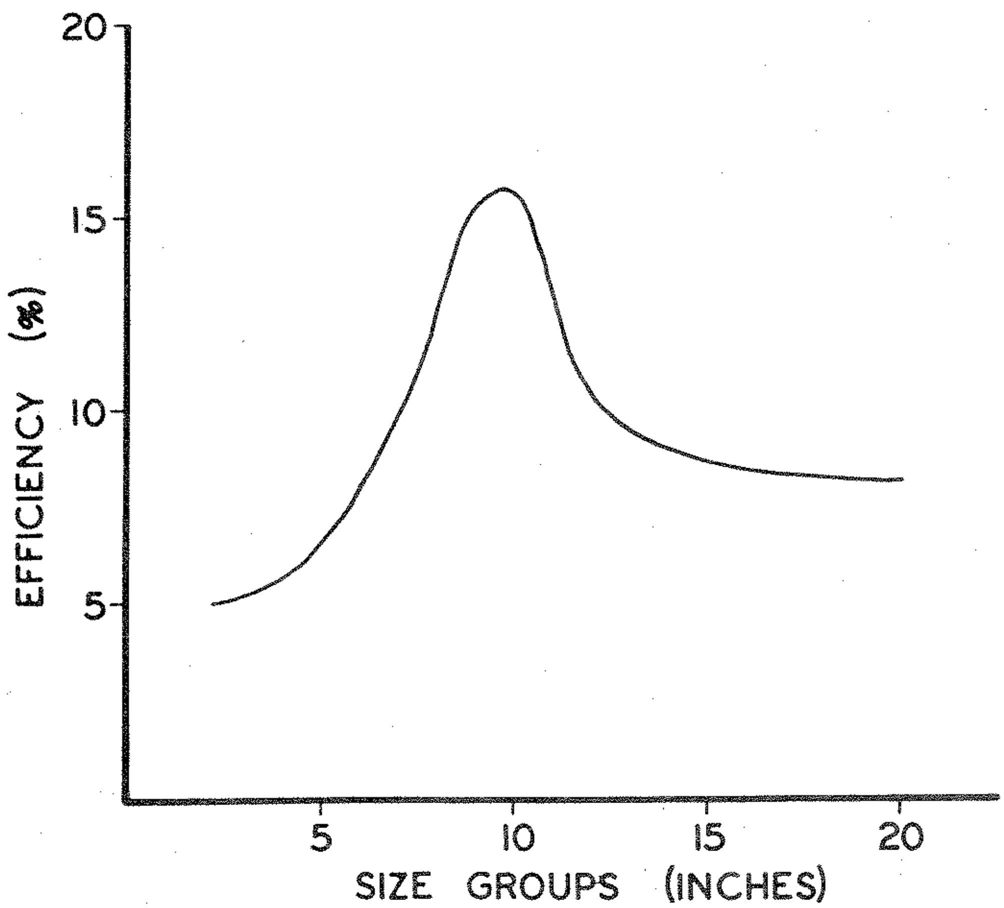

Figure 2. Comparison of efficiency curves found in four river habitat types.

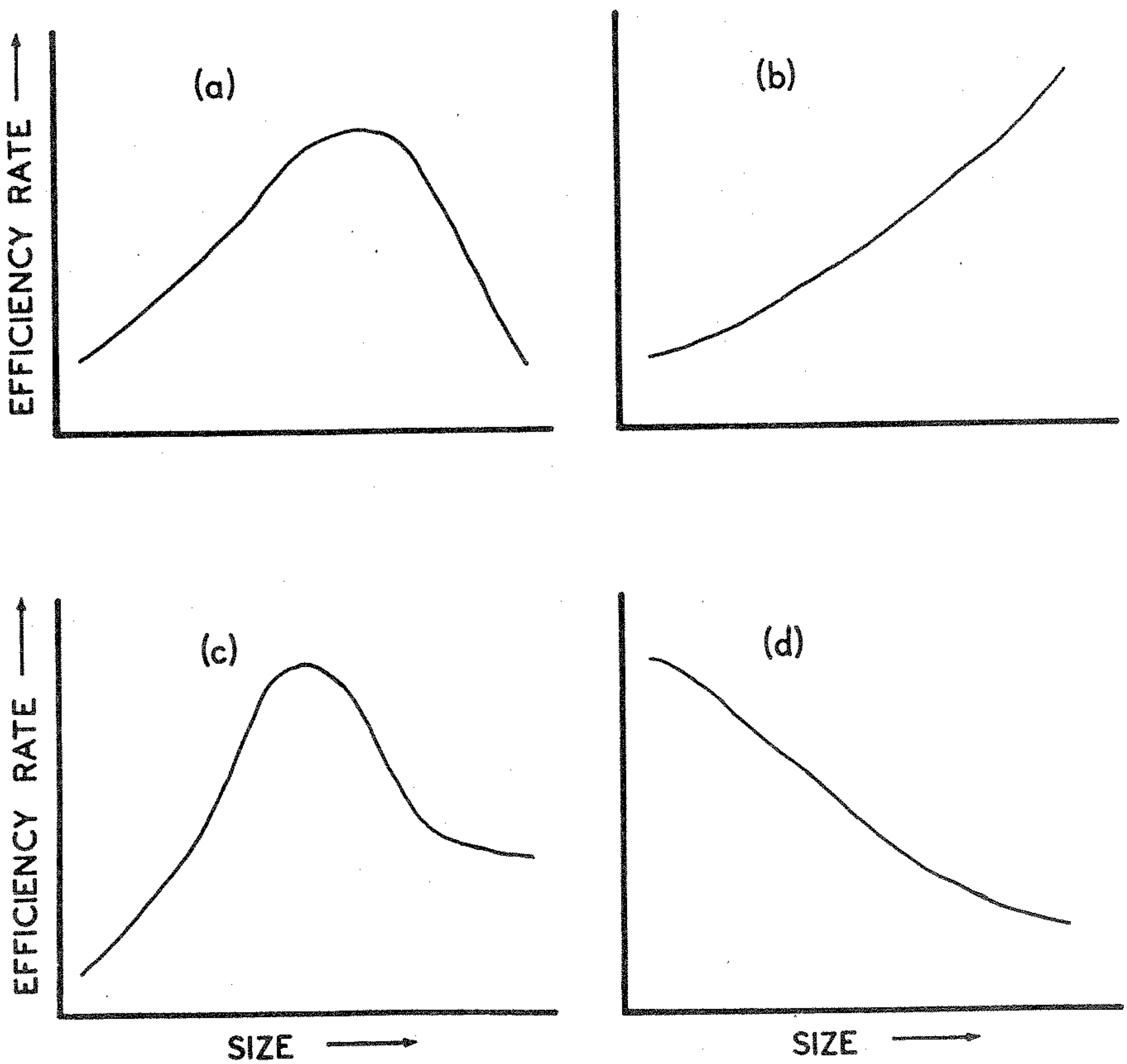

Table 2. Comparison of efficiency rates for rainbow trout prior to and during spawning movement, March-April, 1981.

Size Group (in.)	Pre-spawning Movement Pop. Est.	Eff.	Est. During Spawning Pop. Est.	Eff.	Difference
5.0- 8.4	4410	3.8%	4512	6.0%	+ 2.3%
8.5-10.4	2171	7.8%	2142	14.0%	- 1.3%
10.5-11.9	1240	8.3%	1283	15.1%	+ 3.4%
12.0-19.9	1003	9.1%	1412	12.2%	+29.0%

The three size group estimates for non-spawning trout (less than 11.9 inches) only varied 1.3-3.4% between the two time periods, which those of spawning size showed a 29% increase with the second estimate. The comparison of efficiency rates for each size group for the two periods show the pre-spawning efficiency rates increased with size, however, the spawning period estimate showed a decrease in efficiency rate for the largest size group (12.0 inches and larger). This probably was due to an influx of unmarked spawners which diluted the marked-unmarked ratio causing an overestimation of large trout numbers and biomass.

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A COST-EFFECTIVE ELECTROFISHING TECHNIQUE TO DETERMINE FISH POPULATION SIZE IN SMALL HEADWATER STREAMS IN MONTANA

By: Stephen A. Leathe
Montana Department of Fish, Wildlife and Parks

September, 1983

BACKGROUND

A large number of small hydro projects have been proposed for tributaries to the Swan River as well as for other watersheds in Montana. Due to the large number of potential small hydro developments and limitations of manpower and travel funds within the Montana Department of Fish, Wildlife and Parks, it has become necessary to develop reliable time and cost-effective methods for estimating fish population numbers in tributary streams.

Many of the small hydro projects proposed in western Montana are located in areas not directly accessible by road. Hence, it became desirable to perfect an accurate fish population estimation technique that could be employed in such areas by a small crew (two people) and require only one trip to the proposed project area. The two-pass method described herein meets all of the above criteria.

TECHNIQUE

A 300 to 600 foot section of stream was blocked at the lower end using a section of four to six foot tall unweighted, heavy duty 1/4 inch mesh seine netting. The netting was anchored in the streambed using rocks; strung between trees using parachute cord, and was occasionally propped up in the middle with sticks. The upper end of the section was blocked by a natural feature (small waterfall or other barrier), or with another net.

Two thorough downstream electrofishing pass were done, starting at the top of the section. Electrofishing passes were sometimes made in an upstream direction in low gradient silty streams when disturbance of the streamed caused excessive turbidity. The crew stopped and worked the fish collected during the first electrofishing pass and held these fish in a net or holding pen until the second pass was completed. It was recommended that a minimum of 90 minutes elapsed between the initiation of the first and second electrofishing passes to allow the remaining fish in the section to readjust. All fish were held until the completion of the estimate in the event that the fish would have to be marked and redistributed through the section to allow a mark-recapture estimate.

Equipment used in electrofishing tributaries to the Swan River was lightweight and portable so that it could be transported by a crew of two fieldworkers. Coffelt BP 1-C backpack electrofishing units powered by 300-watt gasoline generators were used with good success. Lightweight, breakdown holding pens were made using small diameter PVC pipe. Block nets consisted of unweighted seine netting material with no floats. Tubular spring scales (available from Forestry Suppliers Inc.) were used to weigh fish and lightweight fish measuring boards were constructed. Spare fuel was carried in a small backpacker's fuel bottle. A backpack was used by one of the crew members to carry the necessary equipment while the other person carried the backpack shocker and the two lightweight hand-held electrofishing electrodes.

CALCULATION OF POPULATION ESTIMATE

The fish population estimate was calculated in the field using the following formula from Seber (1973):

$$\hat{N} = \frac{(n_1)^2}{n_1 - n_2}$$

Where n_1 = number of fish captured during first electrofishing pass, and

n_2 = number of fish captured during second electrofishing pass.

The probability of capture ($\hat{p}$) was calculated using the formula:

$$\hat{p} = \frac{n_1 - n_2}{n_1}$$

Population estimates were calculated for fish 75mm and larger since electrofishing was not sufficiently effective in capturing fish smaller than 75mm. Population estimates were considered to be satisfactory when, for the fish species of interest, one of the following two criteria were met:

1. $\hat{p} \geq 0.60$, or
2. $\hat{p} \geq 0.50$ and $N \geq 50$.

In other words, when the probability of capture ($\hat{p}$) was sufficiently large (i.e. 0.6 or greater), the resulting population estimate was considered to be valid regardless of population size ($\hat{N}$). When fish populations were relatively large (50 or more fish), the resulting population estimates were considered to be suitable for survey and inventory purposes whenever the probability of capture ($\hat{p}$) was 0.50 or larger. If the fish population will be monitored repetitively on a long term basis, it is suggested that the probability of capture ($\hat{p}$) be 0.60 or larger regardless of population size.

Using the criteria presented above, fish population estimates calculated for tributaries to the Swan River usually were bracketed by 95% confidence intervals that were within ±25% of the estimate. The population estimate may also be calculated for specific size or age classes of a particular fish species if one of these criteria are met for each group. When neither of the above criteria are met (i.e. when $\hat{N} < 50$ and $\hat{p}$ is not .60 or larger) it is suggested that captured fish be marked and redistributed through the section for a mark-recapture estimate.

The following example from Seber (1973) illustrates these calculations:

Example: Two successive electric fishings in a section of a small stream yielded 79 and 28 trout ($\geq$ 75mm long) respectively.

$$\hat{N} = \frac{(n_1)^2}{n_1 - n_2} = \frac{(79)^2}{(79 - 28)} = 122$$

$$\hat{p} = \frac{n_1 - n_2}{n_1} = \frac{79 - 28}{79} = 0.65$$

The calculated probability of capture in this example was large ($\hat{p}$ = 0.65), hence criterion #1 above was met and the population estimate would be considered valid. The standard deviation and confidence interval would be calculated in the office as follows:

$$\text{Standard deviation} = \frac{n_1 n_2 \sqrt{n_1 + n_2}}{(n_1 - n_2)^2} = \frac{79(28)\sqrt{79 + 28}}{(51)^2} = 8.8$$

$$\text{95\% confidence interval} = \hat{N} \pm 1.96 \text{ (Std. deviation)}$$

$$= 122 \pm 1.96 \ (8.8)$$

$$= 122 \pm 17$$

$$105 < \hat{N} < 139$$

RELIABILITY

The two-pass method worked very well for estimating fish populations (mostly 3 to 8 inch fish) in small (less than 20 cfs) tributaries to the Swan River. Two-pass estimates were adequate (according to criteria 1 and 2 above) for 27 of the 29 stream sections in the Swan drainage that were electrofished during 1982. Agreement between two-pass and mark-recapture population estimates was good for cutthroat and bull trout populations when the two methods were compared in sections of four tributaries to the Swan River. Shepard and Graham (1983) summarized numerous comparisons made between two-pass and mark-recapture estimates on tributaries in the upper Flathead river system. They concluded that two-pass estimates were valid for streams having discharges of not more than 20 cfs when the probability of capture ($\hat{p}$) was 0.60 or larger. Satisfactory two-pass estimates have on several occasions been obtained on streams larger then 20 cfs in the Swan drainage.

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APPENDIX D

INTRODUCTION

The literature contains little information concerning the instream flow methods that can be applied to mountain streams to determine the amount of flow that is needed during the winter months to sustain the existing wild trout populations. Due to the lack of published methods, the Montana Department of Fish, Wildlife and Parks (MDFWP) has developed its own policy regarding winter flow depletions. This policy is based on biological considerations reported in the literature and the physical characteristics of Montana's trout streams in winter.

The purpose of this paper is to briefly review the literature pertaining to trout streams in winter and present arguments in support of the present instream flow policy of the MDFWP.

LITERATURE REVIEW

Trout Mortalities in Winter

It is well accepted that substantial losses of wild trout can occur in winter, particularily in mountain streams that are subject to icing and other harsh weather conditions. Needham et al (1945) reported that the overwinter losses of all brown trout ranged from 26 to 85 percent and averaged

60 percent over four years in Convict Creek, a small stream in the Sierra Nevada Mountains of California. Winter losses of the larger trout (four inches and longer) were higher, ranging from 48 to 91 percent and averaging 80 percent over four years.

In Montana, there is little quantitative data documenting the winter trout mortality that occurs in mountain streams. Mortality data, however, are available for study sections of the upper Gallatin and upper Madison rivers (Table 1). The physical environment of these rivers, like mountain streams, is also affected by icing and other harsh winter conditions. Even though the trout in these rivers are subject to angler related mortalities in summer, the winter mortality rates usually exceed those during the warmer months, a fact attributable to the severity of the winter environment.

Evidence of elevated mortalities in winter indicates that the winter environment ultimately limits the numbers and pounds of trout that can be maintained indefinitely by the aquatic habitat of high elevation streams. Severe winter conditions appear to affect all age-groups of trout, although Stalnaker and Milhous (1983) consider the overwinter losses of young-of-the-year trout to be most limiting to the population.

Table 1. Summer (mid April - mid September) and winter (mid September - mid April) mortality rates (%) for age II and older trout in study sections of the Madison and Gallatin rivers (unpublished data from R. Vincent, Fisheries Biologist, MDFWP, Bozeman).

Rainbow Trout - Durnam Study Section - Gallatin River

	Mortality (%)		
Year	Summer	Winter	Annual
1980-81	17	53	61

Brown Trout - Varney Study Section - Madison River

	Mortality (%)		
Year	Summer	Winter	Annual
1977-78	-	47	-
1978-79	33	9	39
1979-80	24	50	62
1980-81	21	42	54
1981-82	9	-	-

Rainbow Trout - Snoball Study Section - Madison River

	Mortality (%)		
Year	Summer	Winter	Annual
1980-81	28	34	52

Causes of Winter Mortality

Various studies have addressed the causes of winter mortality in mountain streams. Maciolek and Needham (1952) observed that heavy subsurface ice created dams, which blocked the flow into side channels and caused a substantial mortality of trout in Convict Creek, California. Ice, slush, collapsing snow banks, and fluctuating flows resulting from the periodic breakup of ice dams were considered by Reimers (1957) to greatly influence winter trout losses. Needham and Jones (1959) concluded that the primary causes of winter mortality in higher elevation streams exposed to severe weather conditions were:

1. The sudden collapse of snow and ice into the water, causing death by either direct crushing or suffocation against the stream substrate, or both.

2. The dewatering of sections of streams through the creation of ice jams and snow and anchor ice dams, resulting in the suffocation of fish.

3. The sudden dewatering of flooded side channels or other areas by the breakup and dispersal of ice and snow dams, resulting in the suffocation of fish.

Anchor ice in particular can be very destructive to trout and other aquatic life (Butler, 1979). During nights when clear skies provide maximum radiant heat loss from the land and water and air temperatures are low enough to supercool the stream, small ice crystals, called frazil ice, form in the water. The frazil ice drifts downstream and attaches to the first object in its path, accumulates and forms a mat of anchor ice over the bottom. Frazil ice alone can be harmful to fish by plugging their mouths and gills, resulting in suffocation. Tack (1938) reported such a fish kill in trout ponds.

As the anchor ice accumulates, ice dams are built up in various sections of the stream. As the ice mass builds, the stream becomes elevated and is forced out of its bed, becoming impounded in areas frequently flooded in the spring. Areas habitually used by fish can be obliterated by the ice, causing fish to lose their orientation and swim aimlessly through the ice caverns. As heat from the sun is absorbed during the day, the anchor ice and ice dams melt and the stream quickly returns to its former bed, stranding fish and other aquatic organisms in the overflow areas. This sequence can be repeated night after night if conditions are right.

Heavy snow cover on the ground, streambanks and tops of instream boulders insulates against radiant heat loss and prevents the supercooling of the stream. Anchor ice is therefore more likely to form during periods of sparse snow cover, such as early winter and in drought years.

The work of the above authors indicates that sudden catastrophes such as suffocation under collapsed snowbanks or the dewatering of stream sections by ice dams are primarily responsible for the high mortalities of stream dwelling trout in winter.

Trout Food Supply in Winter

Winter is often thought of as a period when food is abundant in trout streams. This belief is based on the fact that most of the semi-aquatic insects that serve as the primary food of stream trout overwinter on the stream bottom in their immature stages before emerging as winged adults during the warmer months. Logan (1961) found the bottom food organisms to be abundant during the winter in Bridger Creek, a small stream arising in the Bridger Mountains of Montana. Convict Creek, California, supported higher standing crops of aquatic food organisms during the winter than in summer (Maciolek and Needham, 1952).

The winter food supply can be depleted by ice action. Reimers (1957) continued the bottom sampling program initiated by Maciolek and Needham for Convict Creek and bottom organisms which were readily consumed by trout, even when the water temperature was between 32 and 33 F (Needham and Jones, 1959). Maciolek and Needham (1952) made a similar observation, reporting that trout in Convict Creek, California, fed regularly in the freezing water throughout the winter. Reimers (1957) stated that reduced winter feeding among healthy stream dwelling trout should be attributed to the scarcity or unavailablity of food rather than a lack of interest in food. He also found that digestion proceeded slowly but steadily at temperatures closely approaching the freezing point.

Although trout will actively feed in winter and digest and utilize this food, feeding does not appear to be an absolute necessity for winter survival. Starvation experiments conducted by Reimers (1957) indicated that healthy trout are adapted to and are capable of surviving many months of fasting, especially in cold water. While an abundant winter food supply is obviously an asset to the well-being of stream trout, the ability of healthy trout to survive long periods of starvation relegates winter food conditions to a secondary role in determining winter survival. However, food scarcity can be a significant mortality factor in severe winters when the physical environment is barely tolerable to trout (Reimers, 1957).

Winter Trout Movements

The studies of Stefanich (1951), Logan (1961), Lewis (1967) and Leathe and McMullin (1984) support the conclusion that the vast majority of resident trout inhabiting Montana's mountain streams are found year-round within a relatively limited home territory. This applies to mountain streams in other areas of North America as well (Miller, 1957 and Rinne, 1982).

In contrast to these findings, Chapman and Bjornn (1968) reported that salmonids in some Idaho streams move downstream in the fall, a response attributed to declining water temperatures, with non-anadromous species often returning upstream in the spring. Mallett (1963) reported a downstream movement of westslope cutthroat trout in the fall and an upstream movement in the spring in the Middle Fork of the Salmon River. Similar movements of westslope cutthroat trout have not been observed in Montana (Montana Department of Fish and Game, 1979 and Graham et al, 1980).

Wickers et al (1982) used implanted transmitters to investigate the movements of brown trout under surface ice cover in the Laramie River, Wyoming. Near freezing water temperatures were found to significantly decrease movements. When ice cover and low water temperatures first occurred, brown trout showed an increase in movement, attributed to re-orientation, followed by a decrease in movement as the winter progressed. In contrast, Logan (1961) reported that the movements of rainbow trout in Bridger Creek, Montana, appeared to be slightly greater in December, January and February when the temperatures were low and surface ice was present. Much of the movement reported by Logan was highly localized as indicated by the fact that, during the 10-month study, over half of all tagged trout found in the 900 foot long study section were recovered within 150 feet of their initial place of capture.

Habitat Selection in Winter

Needham and Jones (1959) observed that rainbow and brook trout in Sagehen Creek, California, were in close proximity to shelter during winter daylight hours. Shelter consisted of overhanging bushes, projecting snow banks, and a deep sheltered pool protected by exposed roots. Trout were more numerous in shallow water during the night than during the day.

Cooper (1953), working on brook trout streams in Michigan, reported that in spring, summer and fall trout were found in pools, riffles or near cover within the main stream. These habitats were completely deserted during winter, when the trout were found only in low velocity areas under banks, in piles of stones and rocks or amid heavy accumulations of brush and debris.

Wickers et al (1982) tenatively defined the winter microhabitat preferences for adult brown trout in medium sized streams that were totally ice covered. Preferred resting microhabitats (assumed to be the most heavily used microhabitats by trout) were areas having a thick covering of sheet ice, water depths of 0.50 - 0.99 feet, mean velocities <0.50 fps, and a substrate consisting of rubble and gravel. Brown trout preferred shallower depths when total ice cover was present in contrast to the pre-ice resting preference for deep pools. This finding is in agreement with Logan (1961), who observed that rainbow trout in Bridger Creek, Montana, were mainly found in pools during spring, summer and fall, while in winter many trout moved into shallower water having surface ice cover.

Lewis (1967) reported that brown and rainbow trout in Little Prickly Pear Creek, Montana, tended to move into pools in winter while in summer trout inhabited pools and riffles about equally. Chapman and Bjornn (1968) concluded that there are advantages for stream dwelling salmonids to occupy deeper, quiet waters associated with cover in winter. The greater use of the deeper habitats in winter, as reported by these authors, is in contrast to the findings of Logan (1961) and Wickers et al (1982).

Hartman (1963) stated that juvenile rainbow trout, brown trout and coho salmon have seasonal behavioral similarities.

Juveniles of these species in winter show a stronger association with the bottom than in summer. It was postulated that such winter behavior affords protection against predation and displacement. Movement away from cover or the emergence from the bottom in summer allows the juveniles to effectively feed during the season when drifting food is more abundant and the higher metabolic rate allows more food to be used.

Some salmonids enter the substrate in winter. Chapman and Bjornn (1968) reported that young steelhead and chinook salmon, anadromous species not found in Montana, often overwinter in the stream substrate under large stones, rocks and debris. Hanson (1977) documented this behavior for resident cutthroat, which entered the substrate when winter water temperatures decreased to 4.4C or less. This behavior was considered an adaption to avoid predators, physical damage by ice and unnecessary energy expenditures (Chapman and Bjornn, 1968).

Habitat selection by salmonids can be different in winter than during warmer periods, a conclusion substantiated by the work of the above authors. There is, however, no general concensus concerning the makeup of the preferred winter habitats. Many factors, including the species and life stages of fish and the presence or absence of surface ice and other forms of cover, appear to influence winter habitat usage. Subsurface ice can also play an important role by obliterating typical fish habitats and flooding and dewatering others. This forces fish to utilize whatever habitat remains regardless of its suitability.

Winter Activity of Trout

Maciolek and Needham (1952) and Needham and Jones (1959) observed actively feeding trout in California mountain streams throughout the winter when water temperatures were at or near freezing. In the latter study, trout also defended territories during the winter.

These findings dispute the commonly held opinion that wintering trout in mountain streams are indifferent to food and exist in a torpid or inactive state. Other observations, such as young salmonids entering the substrate in winter and juveniles showing a stronger association with the bottom in winter than during warmer months, demonstrate that in some situations fish are less active in winter.

Winter Water Availability in Montana

Unlike regions of the U.S. having greater rainfall, monthly stream flows in the mountain streams of Montana are almost totally dependent on the annual snowpack. As a result, streams exhibit two distinct flow periods; a relatively brief snow runoff period when a large percentage of the annual water yield passes through the stream, and a lengthy nonrunoff or low flow period, characterized by relatively stable base flows maintained primarily by ground water outflow.

Regional differences are evident when the monthly water availability for Montana's mountain streams is compared to that for streams in other parts of the U.S., such as the East coast (Figure 1). The monthly values in this figure are an average for five unregulated streams in each of the two regions.

For Montana's streams, approximately 76 percent of the mean annual water yield is passed during the snow runoff months of May, June and July, leaving only 24 percent to be passed during the remaining nine months. In contrast, approximately 56 percent of the annual water yield for East coast streams passes during the three high flow months of March, April, and May, leaving 44 percent for the remaining nine months.

In Montana, the period of lowest flows occurs during the winter from November through March. During each of these five months, from 1.4 to 2.1 percent of the annual water yield is passed, on the average. In the East, the period of lowest flows occurs during summer and early fall from July

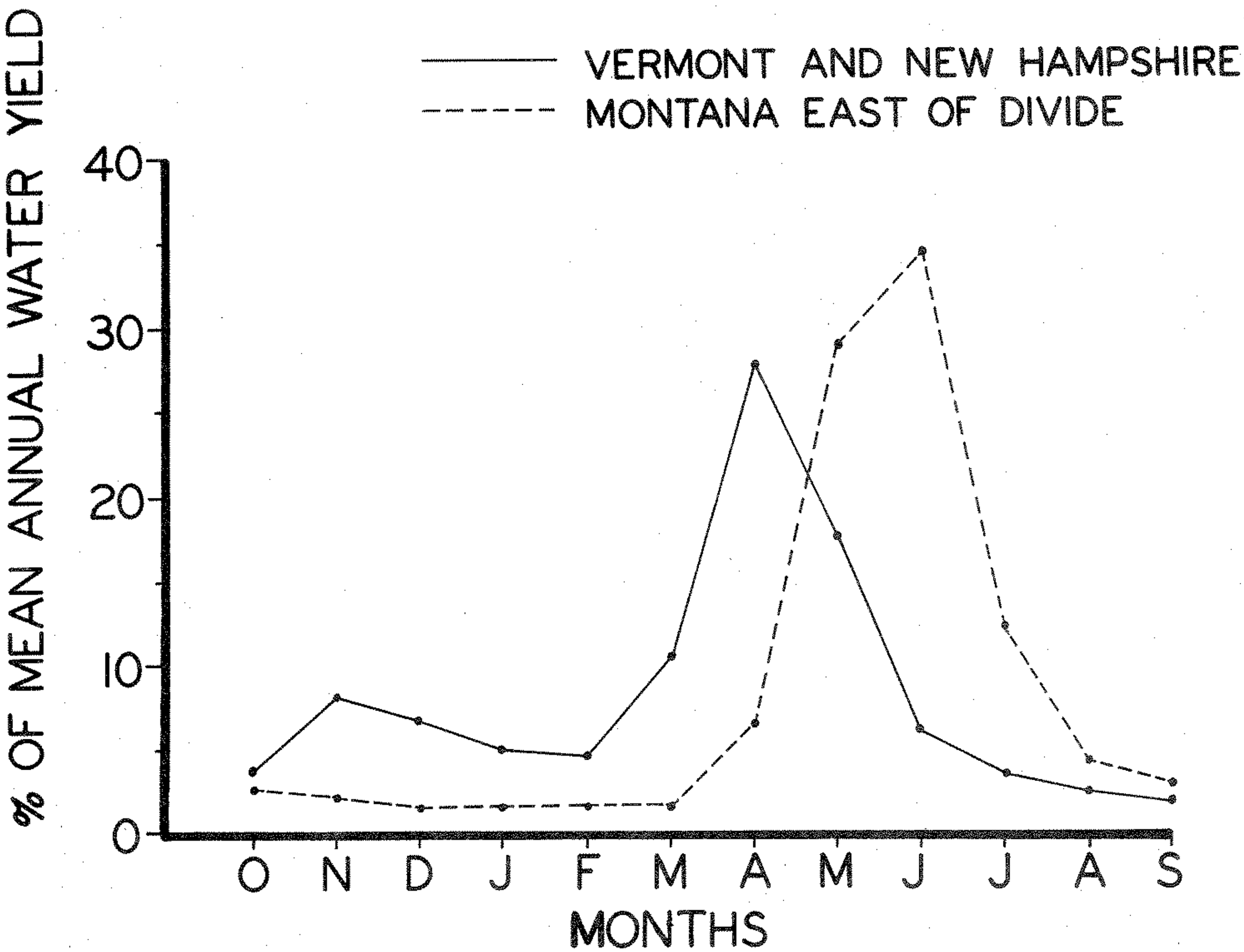

Figure 1. Comparison of monthly water availability for East coast streams (Vermont and New Hampshire) and mountain trout streams in Montana (east of Continental Divide).

through October. During each of these four months, from 1.9 to 3.4 percent of the annual water yield is passed.

Three basic differences are evident;

1. Monthly water availability in Montana's streams is less evenly distributed than occurs in the East, a region where annual precipitation is greater and where rainfall contributes significantly to year-round flows.

2. The availability of water is greatest in Montana in May, June and July. In contrast, the high flow period in the East begins in late winter.

3. The period of lowest flows in Montana occurs in winter, while Eastern streams have their lowest flows in summer.

SUMMARY OF LITERATURE REVIEW

1. Trout mortality rates in high elevation streams that are subjected to harsh winter weather conditions are typically higher in winter than during the warmer months. This supports the well accepted view that the winter environment ultimately limits the trout carrying capacity of mountain streams.

2. Sudden catastrophes associated with the severity of winter weather such as suffocation under collapsed snowbanks or the alternate dewatering and flooding of stream sections by ice dams are primarily responsible for the elevated trout mortalities in winter.

3. Anchor ice can be very destructive to trout and other aquatic life.

4. Trout in mountain streams were observed to feed regularly in winter whenever drifting food organisms were available.

5. The semi-aquatic insects that provide food for trout can be depleted by ice action during a typical winter.

6. The ability of healthy trout to survive long periods of starvation, especially in cold water, relegates winter food conditions to a secondary role in determining winter survival.

7. The commonly held opinion that trout in mountain streams winter in a torpid or inactive state is disputed in the literature.

8. It is unlikely that the resident trout populations of the vast majority of mountain streams in Montana undergo significant movements or migrations in winter.

9. Habitat usage by trout in winter can be different from that in warmer periods. However, there is no general concensus concerning the makeup of the preferred winter habitats.

10. Subsurface ice plays an important role in determining winter habitat usage by periodically obliterating some local habitats and alternately flooding and dewatering others, forcing fish to utilize whatever habitat remains regardless of its suitability.

11. In Montana's mountain streams, the period of lowest flow occurs in winter from November through March. During each of these five months, from 1.4 to 2.1

percent of the mean annual water yield is passed, on the average.

WINTER INSTREAM FLOW POLICY AND RATIONALE

The winter instream flow approach of the MDFWP has been to recommend a level of instream flow protection that severely restricted or eliminated winter withdrawals in most years. This approach has been recently revised to prohibit winter water depletions altogether. 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 that are subjected 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 the fish populations.

The fact that the flows in Montana's mountain streams are lowest in the winter further justifies the policy of prohibiting winter depletions. The assumption that more water provides space for more fish has let 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, a situation occurring in Montana, increases the severity of the stream environment in winter.

Winter flow depletions will expose a greater area of the stream bed to radiant heat loss, thereby increasing the likelihood the stream will supercool and form anchor ice. Because flows are already at their lowest natural levels in winter, even small depletions can greatly increase the amount of exposed stream bed. The volume of water in a stream channel alone may provide some insulation against heat loss, slowing down the supercooling process and in turn the formation of anchor ice. When anchor ice does form, obliterating some stream habitats and alternately flooding and dewatering others, the maintenance of the normal stream flow likely benefits fish by providing greater survival space. Mortalities caused by catastropic weather events will be even greater if the escape space is reduced, an event likely to result when winter flows are depleted. Total stream freeze-up is also possible given sufficient winter depletions. Such an event occurred in Rattlesnake Creek, Montana, following winter flow reductions (D. Workman, per. comm.).

In winter the primary concern in regard to food production is to maintain enough wetted habitat to overwinter the immature stages of the semi-aquatic insects that serve as the primary food of stream trout. Sufficient food must be available to allow the trout to recover from the rigors of winter and begin to grow when the water warms and fish metabolism increases. Trout survival will be affected if the spring rise in water temperature is not accompanied by an increase in food.

A less important function of the food producing area in winter is to supply food for wintering trout. While the scarcity or unavailability of food is only considered a secondary cause of winter mortality, it can be important during those winters in which the physical condition of the environment is so degraded by ice as to be barely tolerable to trout.

The naturally occurring low flows of winter reduce the amount of riffle habitat (the food producing area of streams) to its lowest level of the year. Due to the wide, shallow configuration of riffles, flow reductions affect this habitat type much more severely than the deeper pools and runs. Winter flow levels alone, particularly during below normal water years, can affect the food supply through its influence on the amount of riffle habitat that is available to overwinter the bottom organisms. Ice action can further deplete the food organisms by subjecting riffle sections to sudden scouring and partial drying and freezing during the anchor ice cycles. The combination of harsh weather conditions and the naturally occurring low flows can severely reduce the food supply in some years, potentially affecting trout survival during the winter and in subsequent months as well. Winter flow depletions have the potential to reduce the food supply even further.

The eggs of several species of salmonids (brook trout, brown trout, bull trout, kokanee salmon and mountain whitefish) are deposited in the gravels of mountain streams during the fall. Incubation of these eggs proceeds slowly during the winter months due to low water temperatures, and the fry typically emerge from the gravels during early spring. During the winter incubation period these eggs are susceptible to mechanical destruction resulting from ice scour as well as mortality caused by freezing and dessication. Winter flow depletions have the potential to aggravate the above causes of egg mortality.

When considering the severity of the winter environment and its impact on trout and other aquatic life, a prudent approach for deriving instream flow recommendations for Montana'a unregulated mountain streams is to prohibit winter (approximately November through March) flow depletions altogether. Until studies of the winter flow needs of trout can prove otherwise, a policy of no winter depletions is advisable if the goal is to maintain the trout populations at their existing levels. Given this goal and the available biological information, no other approach can be justified at this time.

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APPENDIX E

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

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Revised
January, 1983

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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.

FORMULATING 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.

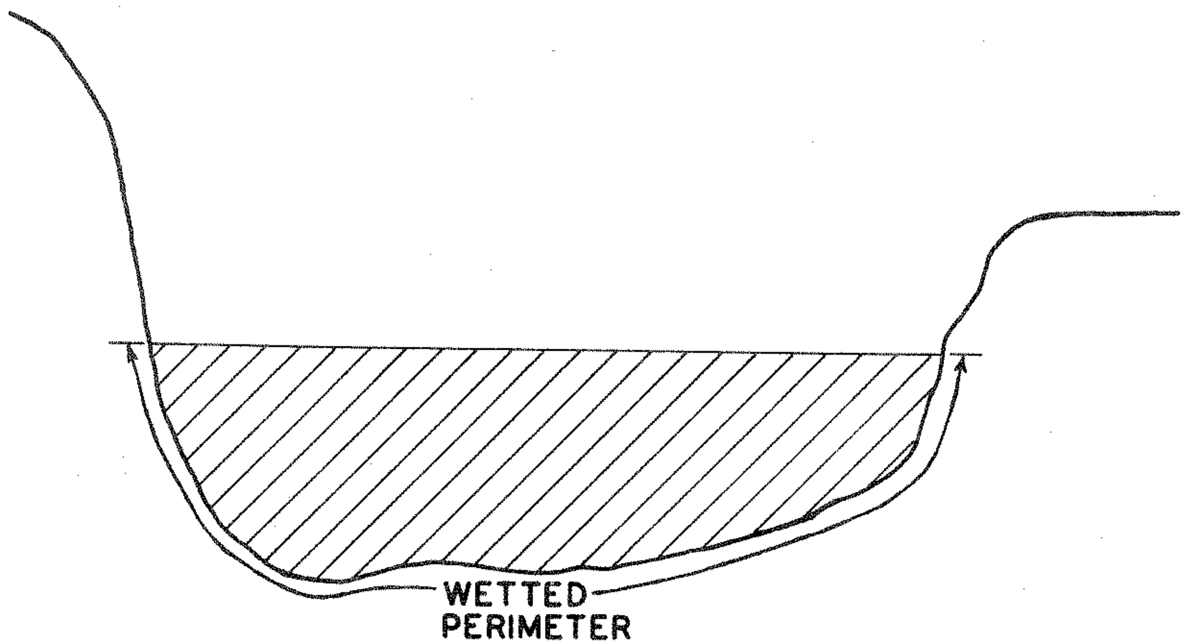

Figure 1. The wetted perimeter in a channel cross-section.

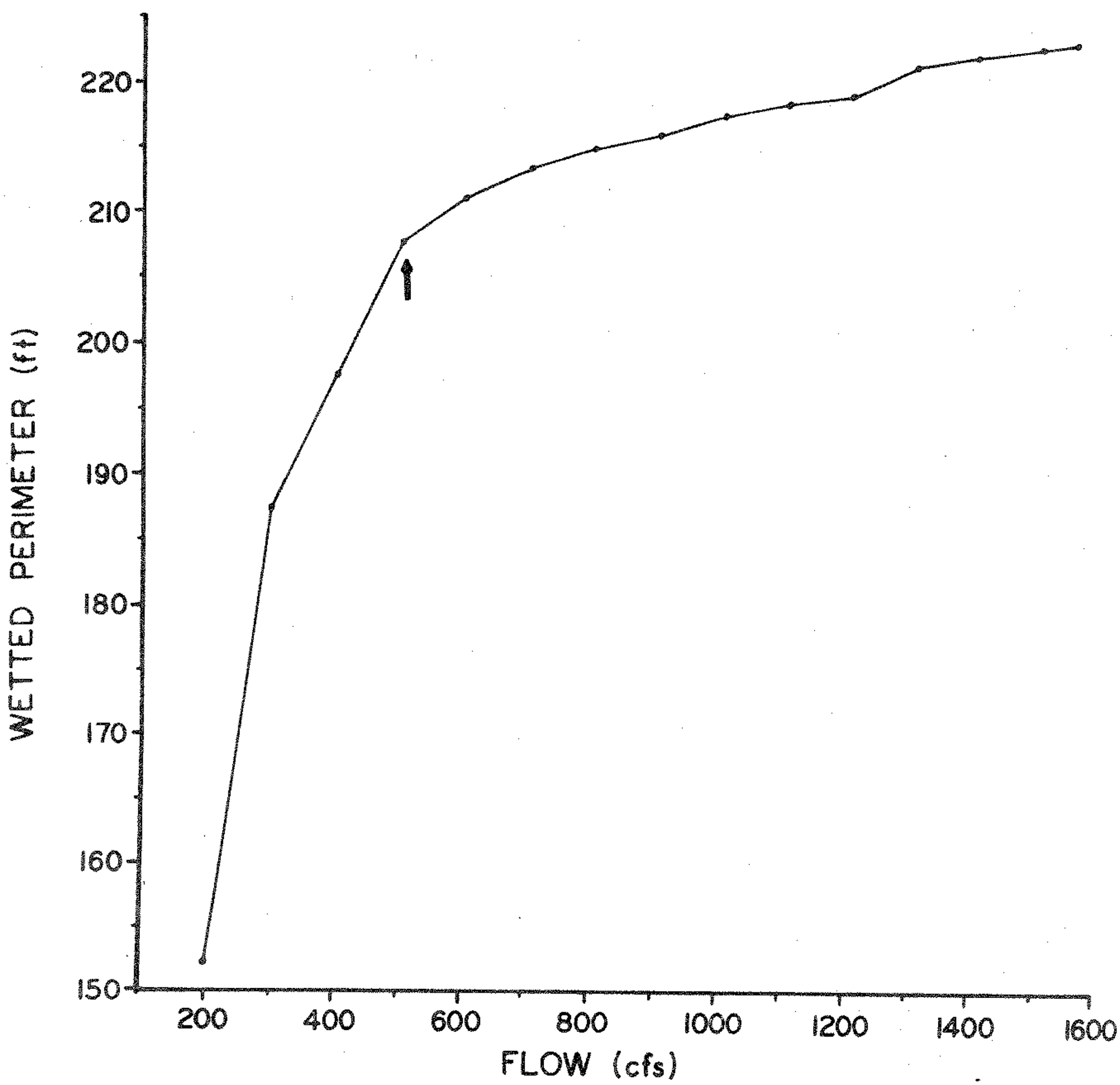

Figure 2. An example of a relationship between wetted perimeter and flow for a riffle cross-section.

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 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.

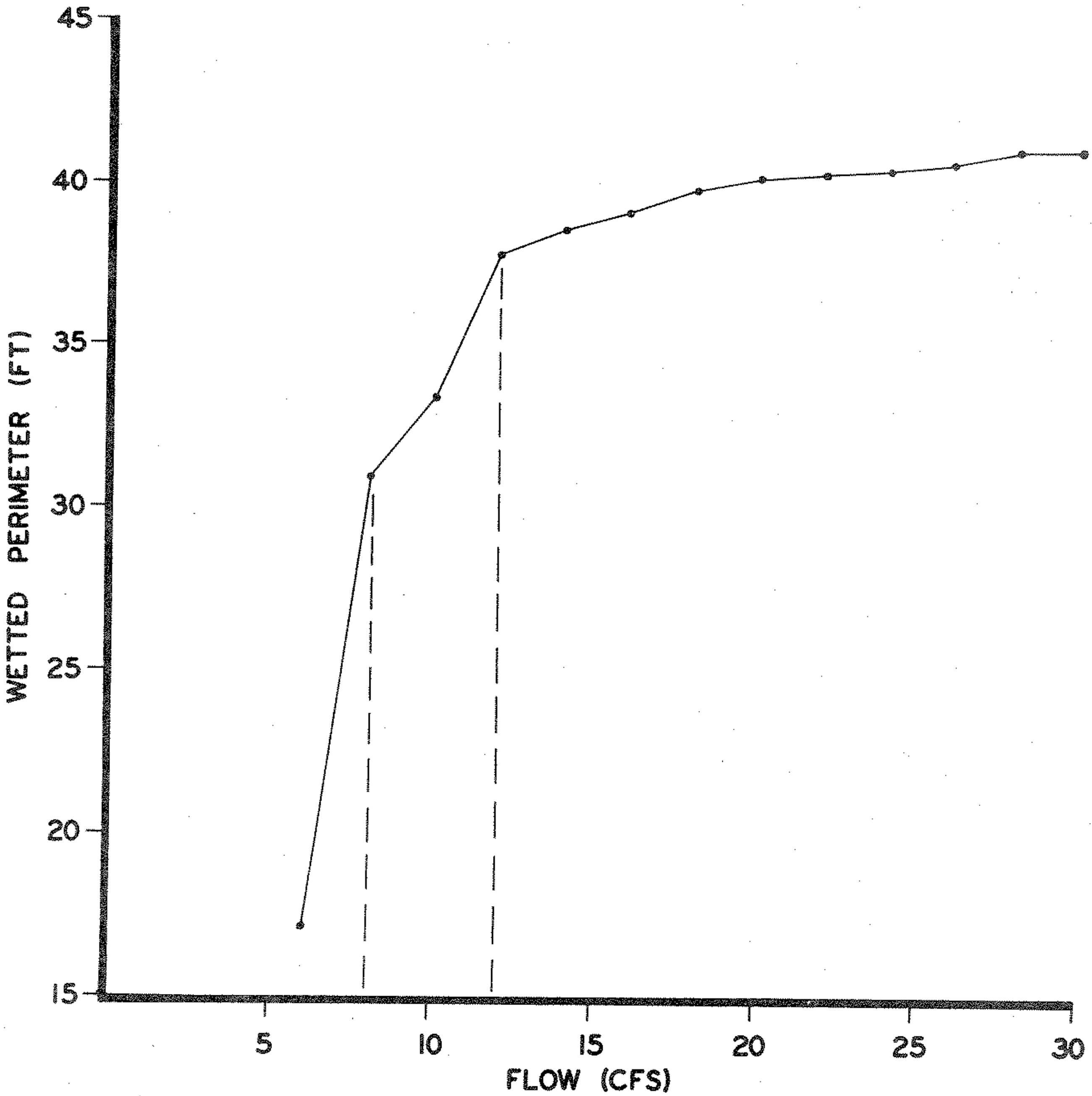

Figure 3. An example of a relationship between wetted perimeter and flow for a riffle cross-section.

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 nonexistent 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 habitat 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 thusly combines a field methodolgy (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.

While the underlying assumptions of the wetted perimeter/inflection point method appear valid, it cannot yet be said that the method enables the biologist to accurately predict the effects of flow reductions on the fish standing crops and the carrying capacity of the aquatic habitat. Presently, a study evaluating the method for small trout streams is being completed at the Cooperative Fisheries Research Unit, Montana State University, as a thesis project. An innovative approach in which stream sections are isolated with weirs and wild rainbow trout added during the high flow period, saturating the habitat, is used. Changes in carrying capacity as determined by the movement of trout out of the sections, are measured as the flow decreases. Preliminary study results support the use of riffle wetted perimeter as a reliable index of carrying capacity.

Method for 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 at least two sets of stage (water surface elevation) measurements taken at different known discharges (flows) to establish a least-squares fit of log-stage versus log-discharge. 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 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 (Figure 4).

The WETP program can be run using only two sets of stage-discharge data. This practice is not recommended since substantial "two-point" error can result. However, when only two data sets are obtainable, the higher discharge should be at least twice as high as the lower discharge.

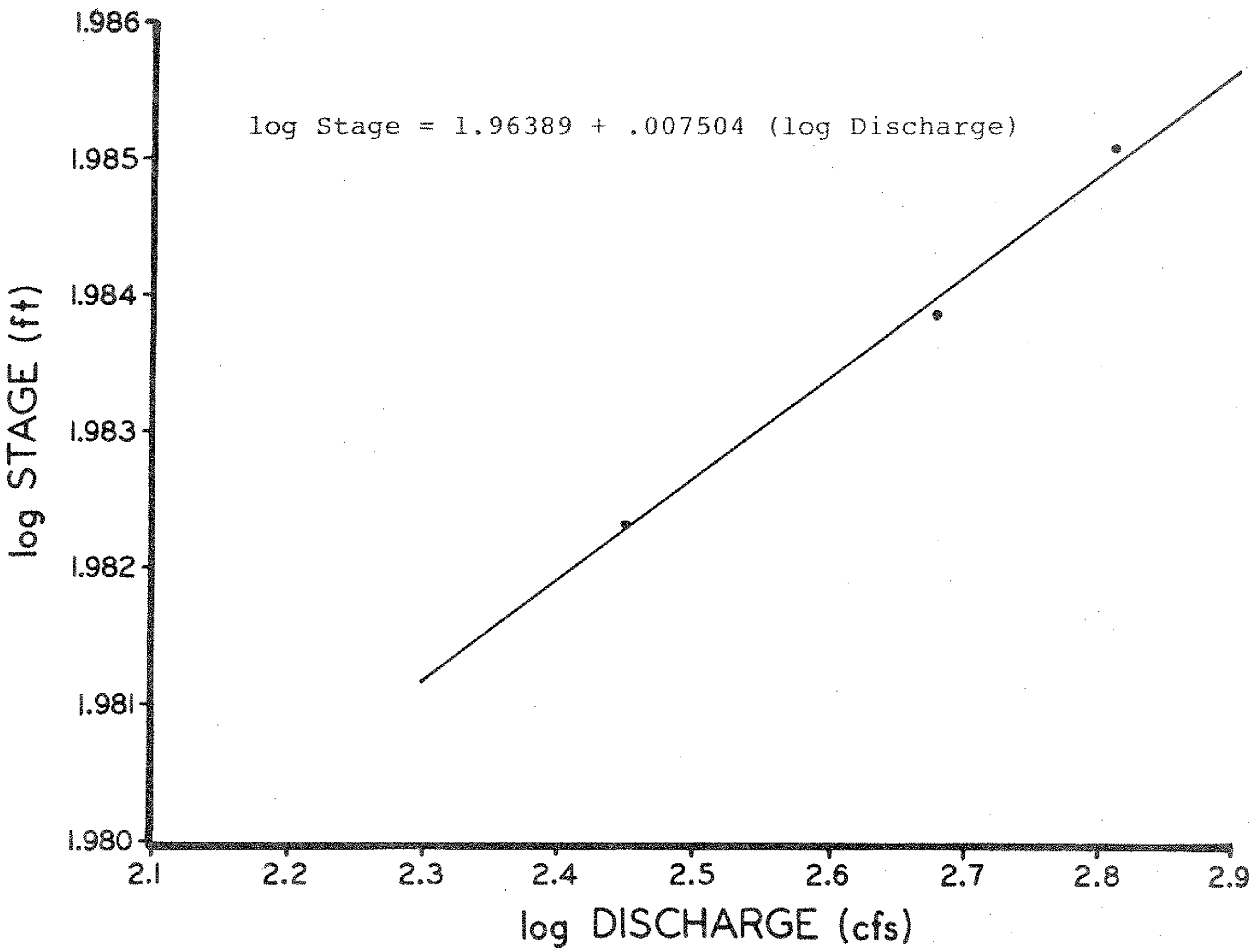

Figure 4. An example of a "three point" stage-discharge rating curve for a riffle cross-section.

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. 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.

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. Two sets will satisfy the program requirements; however, a minimum of three is recommended.

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. Labeled 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 NAK1 is preferred).

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

3. 100-500 ft canyon line or other suitable measuring tape.

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.

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 prior 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. Other critical habitat types can also be used, depending on your chosen methodology.

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. This will require the use of a 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.

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. Bench marks should be well marked and described in your field notebook so they can be easily located. 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.

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.

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, an approximate 0.2 - 0.3 ft difference is allowable. Average these two measurements to obtain the water surface elevation that is entered in the WETP program.

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. 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 0.1 ft. 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 95.26 ft and at 3.2 ft from the headstake the water depth is 1.9 ft, then the bottom elevation at this distance is 93.36 ft (95.26 ft minus 1.9 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 <u>will not</u> 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 A. 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.

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 (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

If the cross-sectional profile and stage-discharge data are entered in the above manner, decimal points are not 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. Two point stage-discharge rating curve

   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. Three point (or greater) stage-discharge rating curve

   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.

WETP Data Output

The output for the input example in Appendix A is given in Appendix B. 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 red 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, r^2 values are automatically 1.00 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.

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

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 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 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 WAGD 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 WAGD 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 $\geq$ 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 nine years of continuous USGS gage records for deriving high flow recommendations, so cannot be applied to most streams.

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702/G

APPENDIX A

Example of WETP input format

Title and location of study area

IBM 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 1-31-83

1 4

FORTRAN STATEMENT

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										
QARD	70										
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

Number of forms per pad may vary slightly

IBM FORTRAN Coding Form

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

Bear Creek

2 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

IBM FORTRAN Coding Form

Bear Creek

3 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								
CAL2	3		9626		113								
CAL3	3		9590		38								
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												
	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

} Calibration flows
Without decimal points, reads as 33.4, 11.3 and 3.8 cfs

IBM FORTRAN Coding Form GX28-7327-6 U/M 050 Printed in U.S.A.

Bear Creek 4 4

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 PØØL entries as needed.

Mandatory Entry
Prints results for each cross-section as well as the average for all cross-sections.

Width-at-given-depth option
Up to 10 depths allowed.
Separate depths of interest with single space.
In this example, asking for length of top width having depths ≥ .4 ft and 1.0 ft.

APPENDIX B

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. 1-83 (1 Feb. 1983)

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
```

B-2

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	Y
.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						
.0	.00	.0	.00	.0	.00	27.2	97.48	.0	.00						
.0	.00	.0	.00	.0	.00	27.8	97.63	.0	.00						

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

.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	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	92.83	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 = A + B * LOG Q

1		2		3		4		5							
A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1.966	.004	1.968	.003	1.980	.003	1.984	.003	1.984	.002						
R2		R2		R2		R2		R2		R2		R2		R2	
1.000		1.000		1.000		.997		.995							

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	5.02	4.32	5.54	5.72	8.45	.00	.00	.00	.00	.00	5.81
DBAR	.13	.11	.26	.09	.26	.00	.00	.00	.00	.00	.17
VBAR	2.40	3.42	1.10	2.79	.70	.00	.00	.00	.00	.00	2.08
WDTH	4.97	4.14	5.35	5.69	8.24	.00	.00	.00	.00	.00	5.68
AREA	.62	.44	1.37	.54	2.14	.00	.00	.00	.00	.00	1.02
STGE	92.51	92.95	95.59	96.38	96.53	.00	.00	.00	.00	.00	94.79
DMAX	.28	.22	.44	.22	.38	.00	.00	.00	.00	.00	.30
WTOT .4	.00	.00	.77	.00	.00	.00	.00	.00	.00	.00	.15
WMAX	.00	.00	.45	.00	.00	.00	.00	.00	.00	.00	.09
PTOT	.00	.00	14.34	.00	.00	.00	.00	.00	.00	.00	2.87
PMAX	.00	.00	8.46	.00	.00	.00	.00	.00	.00	.00	1.69
WTOT 1.0	.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	5.66	4.98	6.13	6.44	8.69	.00	.00	.00	.00	.00	6.38
DBAR	.21	.18	.33	.15	.32	.00	.00	.00	.00	.00	.24
VBAR	1.73	2.38	1.05	2.08	.74	.00	.00	.00	.00	.00	1.60
WDTH	5.58	4.69	5.85	6.38	8.42	.00	.00	.00	.00	.00	6.18
AREA	1.15	.84	1.91	.96	2.69	.00	.00	.00	.00	.00	1.51
STGE	92.61	93.03	95.68	96.45	96.59	.00	.00	.00	.00	.00	94.87
DMAX	.38	.30	.53	.29	.44	.00	.00	.00	.00	.00	.39
WTOT .4	.00	.00	2.21	.00	2.20	.00	.00	.00	.00	.00	.88
WMAX	.00	.00	2.21	.00	1.77	.00	.00	.00	.00	.00	.80
PTOT	.00	.00	37.85	.00	26.11	.00	.00	.00	.00	.00	12.79
PMAX	.00	.00	37.85	.00	21.03	.00	.00	.00	.00	.00	11.78
WTOT 1.0	.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	6.46	5.13	6.45	8.52	8.83	.00	.00	.00	.00	.00	7.08
DBAR	.25	.25	.38	.16	.37	.00	.00	.00	.00	.00	.28
VBAR	1.55	2.15	1.06	1.82	.80	.00	.00	.00	.00	.00	1.48
WDTH	6.35	4.74	6.11	8.46	8.51	.00	.00	.00	.00	.00	6.83
AREA	1.61	1.16	2.35	1.37	3.12	.00	.00	.00	.00	.00	1.92
STGE	92.68	93.10	95.76	96.50	96.64	.00	.00	.00	.00	.00	94.94

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

DMAX		.45	.37	.61	.34	.49	.00	.00	.00	.00	.00	.45
WTOT	.4	.54	.00	3.00	.00	4.29	.00	.00	.00	.00	.00	1.57
WMAX		.54	.00	3.00	.00	2.69	.00	.00	.00	.00	.00	1.25
PTOT		8.54	.00	49.11	.00	50.39	.00	.00	.00	.00	.00	21.61
PMAX		8.54	.00	49.11	.00	31.61	.00	.00	.00	.00	.00	17.85
WTOT	1.0	.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

												AVG
XSEC		1	2	3	4	5						
WETP		7.09	6.01	6.83	9.18	8.95	.00	.00	.00	.00	.00	7.61
DBAR		.29	.26	.43	.19	.40	.00	.00	.00	.00	.00	.32
VBAR		1.47	2.07	1.10	1.70	.86	.00	.00	.00	.00	.00	1.44
WDTH		6.95	5.57	6.43	9.11	8.59	.00	.00	.00	.00	.00	7.33
AREA		2.04	1.45	2.73	1.76	3.48	.00	.00	.00	.00	.00	2.29
STGE		92.75	93.16	95.82	96.54	96.69	.00	.00	.00	.00	.00	94.99
DMAX		.52	.43	.67	.38	.54	.00	.00	.00	.00	.00	.51
WTOT	.4	1.76	1.57	3.79	.00	4.80	.00	.00	.00	.00	.00	2.38
WMAX		1.76	1.57	3.79	.00	4.80	.00	.00	.00	.00	.00	2.38
PTOT		25.38	28.25	58.94	.00	55.91	.00	.00	.00	.00	.00	33.70
PMAX		25.38	28.25	58.94	.00	55.91	.00	.00	.00	.00	.00	33.70
WTOT	1.0	.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

												AVG
XSEC		1	2	3	4	5						
WETP		7.28	6.43	7.16	12.16	9.05	.00	.00	.00	.00	.00	8.42
DBAR		.34	.29	.46	.18	.44	.00	.00	.00	.00	.00	.34
VBAR		1.45	2.03	1.14	1.62	.93	.00	.00	.00	.00	.00	1.43
WDTH		7.11	5.95	6.72	12.09	8.65	.00	.00	.00	.00	.00	8.10
AREA		2.41	1.72	3.07	2.17	3.78	.00	.00	.00	.00	.00	2.63
STGE		92.80	93.21	95.87	96.58	96.72	.00	.00	.00	.00	.00	95.04
DMAX		.57	.48	.72	.42	.57	.00	.00	.00	.00	.00	.55
WTOT	.4	2.57	1.69	4.48	.32	5.36	.00	.00	.00	.00	.00	2.88
WMAX		2.57	1.69	4.48	.32	5.36	.00	.00	.00	.00	.00	2.88
PTOT		36.11	28.42	66.67	2.68	62.02	.00	.00	.00	.00	.00	39.18
PMAX		36.11	28.42	66.67	2.68	62.02	.00	.00	.00	.00	.00	39.18
WTOT	1.0	.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

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

PMAX	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
FLOW=	4.0 CFS										
XSEC	1	2	3	4	5						AVG
WETP	7.45	6.66	7.43	13.30	9.14	.00	.00	.00	.00	.00	8.80
DBAR	.38	.32	.49	.19	.47	.00	.00	.00	.00	.00	.37
VBAR	1.46	2.03	1.18	1.56	.99	.00	.00	.00	.00	.00	1.44
WDTH	7.25	6.14	6.94	13.22	8.70	.00	.00	.00	.00	.00	8.45
AREA	2.75	1.97	3.38	2.57	4.05	.00	.00	.00	.00	.00	2.94
STGE	92.85	93.25	95.92	96.61	96.75	.00	.00	.00	.00	.00	95.08
DMAX	.62	.52	.77	.45	.60	.00	.00	.00	.00	.00	.59
WTOT .4	4.27	1.79	4.90	.81	7.02	.00	.00	.00	.00	.00	3.76
WMAX	4.27	1.79	4.90	.81	7.02	.00	.00	.00	.00	.00	3.76
PTOT	58.81	29.20	70.52	6.13	80.64	.00	.00	.00	.00	.00	49.06
PMAX	58.81	29.20	70.52	6.13	80.64	.00	.00	.00	.00	.00	49.06
WTOT 1.0	.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										
XSEC	1	2	3	4	5						AVG
WETP	7.73	6.90	7.72	14.11	9.29	.00	.00	.00	.00	.00	9.15
DBAR	.44	.38	.55	.24	.51	.00	.00	.00	.00	.00	.42
VBAR	1.51	2.09	1.28	1.52	1.11	.00	.00	.00	.00	.00	1.50
WDTH	7.49	6.30	7.15	14.01	8.79	.00	.00	.00	.00	.00	8.75
AREA	3.32	2.40	3.90	3.30	4.49	.00	.00	.00	.00	.00	3.48
STGE	92.93	93.32	95.99	96.67	96.80	.00	.00	.00	.00	.00	95.14
DMAX	.70	.59	.84	.51	.65	.00	.00	.00	.00	.00	.66
WTOT .4	5.13	2.61	5.36	3.12	7.52	.00	.00	.00	.00	.00	4.75
WMAX	5.13	1.96	5.36	3.12	7.52	.00	.00	.00	.00	.00	4.62
PTOT	68.48	41.41	74.96	22.30	85.60	.00	.00	.00	.00	.00	58.55
PMAX	68.48	31.17	74.96	22.30	85.60	.00	.00	.00	.00	.00	56.50
WTOT 1.0	.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										
XSEC	1	2	3	4	5						AVG
WETP	7.95	7.59	9.99	14.40	9.94	.00	.00	.00	.00	.00	9.98
DBAR	.50	.40	.47	.28	.52	.00	.00	.00	.00	.00	.43
VBAR	1.58	2.17	1.36	1.53	1.23	.00	.00	.00	.00	.00	1.57
WDTH	7.66	6.94	9.33	14.28	9.37	.00	.00	.00	.00	.00	9.52
AREA	3.80	2.77	4.41	3.93	4.87	.00	.00	.00	.00	.00	3.96

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

STGE	92.99	93.37	96.05	96.71	96.84	.00	.00	.00	.00	.00	95.19
DMAX	.76	.64	.90	.55	.69	.00	.00	.00	.00	.00	.71
WTOT .4	5.48	4.52	5.74	3.79	7.87	.00	.00	.00	.00	.00	5.48
WMAX	5.48	2.35	5.74	3.79	7.87	.00	.00	.00	.00	.00	5.05
PTOT	71.57	65.12	61.54	26.54	83.96	.00	.00	.00	.00	.00	61.75
PMAX	71.57	33.84	61.54	26.54	83.96	.00	.00	.00	.00	.00	55.49
WTOT 1.0	.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	8.11	8.21	10.87	14.64	10.42	.00	.00	.00	.00	.00	10.45
DBAR	.54	.41	.49	.31	.53	.00	.00	.00	.00	.00	.46
VBAR	1.66	2.25	1.42	1.57	1.34	.00	.00	.00	.00	.00	1.65
WDTH	7.75	7.52	10.11	14.50	9.80	.00	.00	.00	.00	.00	9.94
AREA	4.22	3.11	4.92	4.47	5.21	.00	.00	.00	.00	.00	4.39
STGE	93.04	93.42	96.10	96.75	96.88	.00	.00	.00	.00	.00	95.24
DMAX	.81	.69	.95	.59	.73	.00	.00	.00	.00	.00	.76
WTOT .4	5.85	4.67	5.91	4.35	8.04	.00	.00	.00	.00	.00	5.77
WMAX	5.85	4.67	5.91	4.35	8.04	.00	.00	.00	.00	.00	5.77
PTOT	75.50	62.16	58.47	30.02	82.06	.00	.00	.00	.00	.00	61.64
PMAX	75.50	62.16	58.47	30.02	82.06	.00	.00	.00	.00	.00	61.64
WTOT 1.0	.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	8.24	9.23	11.47	14.89	10.76	.00	.00	.00	.00	.00	10.92
DBAR	.58	.41	.51	.34	.55	.00	.00	.00	.00	.00	.48
VBAR	1.75	2.31	1.49	1.62	1.45	.00	.00	.00	.00	.00	1.72
WDTH	7.84	8.49	10.63	14.75	10.10	.00	.00	.00	.00	.00	10.36
AREA	4.58	3.46	5.38	4.94	5.52	.00	.00	.00	.00	.00	4.78
STGE	93.09	93.46	96.15	96.78	96.91	.00	.00	.00	.00	.00	95.28
DMAX	.86	.73	1.00	.62	.76	.00	.00	.00	.00	.00	.79
WTOT .4	6.41	4.71	6.05	5.77	8.18	.00	.00	.00	.00	.00	6.23
WMAX	6.41	4.71	6.05	5.77	8.18	.00	.00	.00	.00	.00	6.23
PTOT	81.85	55.46	56.98	39.15	80.94	.00	.00	.00	.00	.00	62.87
PMAX	81.85	55.46	56.98	39.15	80.94	.00	.00	.00	.00	.00	62.87
WTOT 1.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

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	8.36	9.33	12.02	15.12	11.10	.00	.00	.00	.00	.00	11.19
DBAR	.62	.44	.52	.36	.56	.00	.00	.00	.00	.00	.50
VBAR	1.83	2.39	1.55	1.68	1.55	.00	.00	.00	.00	.00	1.80
WDTH	7.91	8.55	11.09	14.96	10.41	.00	.00	.00	.00	.00	10.58
AREA	4.91	3.77	5.81	5.37	5.80	.00	.00	.00	.00	.00	5.13
STGE	93.13	93.50	96.19	96.81	96.94	.00	.00	.00	.00	.00	95.31
DMAX	.90	.77	1.04	.65	.79	.00	.00	.00	.00	.00	.83
WTOT .4	6.90	4.74	6.26	6.11	8.29	.00	.00	.00	.00	.00	6.46
WMAX	6.90	4.74	6.26	6.11	8.29	.00	.00	.00	.00	.00	6.46
PTOT	87.26	55.44	56.40	40.85	79.66	.00	.00	.00	.00	.00	63.92
PMAX	87.26	55.44	56.40	40.85	79.66	.00	.00	.00	.00	.00	63.92
WTOT 1.0	.00	.00	.76	.00	.00	.00	.00	.00	.00	.00	.15
WMAX	.00	.00	.45	.00	.00	.00	.00	.00	.00	.00	.09
PTOT	.00	.00	6.81	.00	.00	.00	.00	.00	.00	.00	1.36
PMAX	.00	.00	4.02	.00	.00	.00	.00	.00	.00	.00	.80
FLOW=	10.0 CFS										
XSEC	1	2	3	4	5						AVG
WETP	8.59	9.42	12.55	15.32	11.41	.00	.00	.00	.00	.00	11.46
DBAR	.64	.47	.54	.38	.57	.00	.00	.00	.00	.00	.52
VBAR	1.92	2.47	1.61	1.74	1.65	.00	.00	.00	.00	.00	1.88
WDTH	8.10	8.60	11.55	15.15	10.68	.00	.00	.00	.00	.00	10.82
AREA	5.20	4.05	6.21	5.76	6.05	.00	.00	.00	.00	.00	5.45
STGE	93.17	93.53	96.22	96.84	96.96	.00	.00	.00	.00	.00	95.34
DMAX	.94	.80	1.07	.68	.81	.00	.00	.00	.00	.00	.86
WTOT .4	7.01	4.77	6.44	6.32	8.36	.00	.00	.00	.00	.00	6.58
WMAX	7.01	4.77	6.44	6.32	8.36	.00	.00	.00	.00	.00	6.58
PTOT	86.56	55.43	55.76	41.69	78.29	.00	.00	.00	.00	.00	63.54
PMAX	86.56	55.43	55.76	41.69	78.29	.00	.00	.00	.00	.00	63.54
WTOT 1.0	.00	.00	1.47	.00	.00	.00	.00	.00	.00	.00	.29
WMAX	.00	.00	.87	.00	.00	.00	.00	.00	.00	.00	.17
PTOT	.00	.00	12.76	.00	.00	.00	.00	.00	.00	.00	2.55
PMAX	.00	.00	7.53	.00	.00	.00	.00	.00	.00	.00	1.51
FLOW=	15.0 CFS										
XSEC	1	2	3	4	5						AVG
WETP	9.62	10.49	15.02	15.98	12.58	.00	.00	.00	.00	.00	12.74
DBAR	.71	.55	.58	.46	.60	.00	.00	.00	.00	.00	.58
VBAR	2.34	2.89	1.89	2.06	2.11	.00	.00	.00	.00	.00	2.26
WDTH	8.99	9.48	13.77	15.79	11.74	.00	.00	.00	.00	.00	11.95

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

AREA	6.41	5.20	7.92	7.29	7.10	.00	.00	.00	.00	.00	6.78
STGE	93.31	93.65	96.36	96.94	97.06	.00	.00	.00	.00	.00	95.46
DMAX	1.08	.92	1.21	.78	.91	.00	.00	.00	.00	.00	.98
WTOT .4	7.44	6.16	7.07	9.01	8.53	.00	.00	.00	.00	.00	7.64
WMAX	7.44	6.16	7.07	9.01	8.53	.00	.00	.00	.00	.00	7.64
PTOT	82.74	64.94	51.30	57.09	72.67	.00	.00	.00	.00	.00	65.75
PMAX	82.74	64.94	51.30	57.09	72.67	.00	.00	.00	.00	.00	65.75
WTOT 1.0	.79	.00	3.00	.00	.00	.00	.00	.00	.00	.00	.76
WMAX	.79	.00	3.00	.00	.00	.00	.00	.00	.00	.00	.76
PTOT	8.81	.00	21.81	.00	.00	.00	.00	.00	.00	.00	6.13
PMAX	8.81	.00	21.81	.00	.00	.00	.00	.00	.00	.00	6.13

FLOW= 20.0 CFS

XSEC	1	2	3	4	5						AVG
WETP	10.18	10.67	16.25	16.41	12.83	.00	.00	.00	.00	.00	13.27
DBAR	.78	.63	.63	.52	.66	.00	.00	.00	.00	.00	.64
VBAR	2.72	3.31	2.14	2.38	2.54	.00	.00	.00	.00	.00	2.62
WDTH	9.46	9.52	14.82	16.18	11.92	.00	.00	.00	.00	.00	12.38
AREA	7.34	6.04	9.35	8.41	7.88	.00	.00	.00	.00	.00	7.81
STGE	93.41	93.74	96.46	97.01	97.12	.00	.00	.00	.00	.00	95.55
DMAX	1.18	1.01	1.31	.85	.97	.00	.00	.00	.00	.00	1.06
WTOT .4	7.70	6.59	9.42	12.53	8.65	.00	.00	.00	.00	.00	8.98
WMAX	7.70	6.59	7.44	12.53	8.65	.00	.00	.00	.00	.00	8.58
PTOT	81.34	69.27	63.54	77.43	72.58	.00	.00	.00	.00	.00	72.83
PMAX	81.34	69.27	50.20	77.43	72.58	.00	.00	.00	.00	.00	70.16
WTOT 1.0	2.70	1.53	4.31	.00	.00	.00	.00	.00	.00	.00	1.71
WMAX	2.70	1.53	4.31	.00	.00	.00	.00	.00	.00	.00	1.71
PTOT	28.54	16.10	29.07	.00	.00	.00	.00	.00	.00	.00	14.74
PMAX	28.54	16.10	29.07	.00	.00	.00	.00	.00	.00	.00	14.74

FLOW= 25.0 CFS

XSEC	1	2	3	4	5						AVG
WETP	10.62	10.81	16.40	16.64	13.00	.00	.00	.00	.00	.00	13.49
DBAR	.82	.70	.71	.57	.71	.00	.00	.00	.00	.00	.70
VBAR	3.09	3.73	2.39	2.69	2.94	.00	.00	.00	.00	.00	2.97
WDTH	9.83	9.55	14.84	16.39	12.03	.00	.00	.00	.00	.00	12.53
AREA	8.10	6.70	10.47	9.30	8.50	.00	.00	.00	.00	.00	8.61
STGE	93.49	93.81	96.53	97.06	97.17	.00	.00	.00	.00	.00	95.61
DMAX	1.26	1.08	1.38	.90	1.02	.00	.00	.00	.00	.00	1.13
WTOT .4	7.83	7.43	10.43	13.54	8.72	.00	.00	.00	.00	.00	9.59
WMAX	7.83	7.43	7.82	13.54	8.72	.00	.00	.00	.00	.00	9.07
PTOT	79.73	77.84	70.26	82.63	72.52	.00	.00	.00	.00	.00	76.60
PMAX	79.73	77.84	52.71	82.63	72.52	.00	.00	.00	.00	.00	73.09
WTOT 1.0	4.82	1.70	4.99	.00	1.65	.00	.00	.00	.00	.00	2.63

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

WMAX	4.82	1.70	4.99	.00	1.41	.00	.00	.00	.00	.00	2.59
PTOT	49.04	17.86	33.62	.00	13.68	.00	.00	.00	.00	.00	22.84
PMAX	49.04	17.86	33.62	.00	11.76	.00	.00	.00	.00	.00	22.46

FLOW= 30.0 CFS

XSEC	1	2	3	4	5						AVG
WETP	10.80	11.35	16.52	16.83	13.13	.00	.00	.00	.00	.00	13.73
DBAR	.88	.73	.77	.61	.74	.00	.00	.00	.00	.00	.74
VBAR	3.44	4.14	2.64	2.99	3.33	.00	.00	.00	.00	.00	3.31
WDTH	9.92	9.99	14.86	16.56	12.12	.00	.00	.00	.00	.00	12.69
AREA	8.73	7.25	11.38	10.03	9.01	.00	.00	.00	.00	.00	9.28
STGE	93.55	93.87	96.59	97.11	97.22	.00	.00	.00	.00	.00	95.67
DMAX	1.32	1.14	1.44	.95	1.07	.00	.00	.00	.00	.00	1.18
WTOT .4	8.00	8.50	11.16	14.25	8.96	.00	.00	.00	.00	.00	10.18
WMAX	8.00	8.50	8.14	14.25	8.76	.00	.00	.00	.00	.00	9.53
PTOT	80.72	85.15	75.08	86.09	73.94	.00	.00	.00	.00	.00	80.19
PMAX	80.72	85.15	54.76	86.09	72.32	.00	.00	.00	.00	.00	75.81
WTOT 1.0	5.29	1.85	5.38	.00	3.05	.00	.00	.00	.00	.00	3.11
WMAX	5.29	1.85	5.38	.00	2.17	.00	.00	.00	.00	.00	2.94
PTOT	53.30	18.48	36.17	.00	25.15	.00	.00	.00	.00	.00	26.62
PMAX	53.30	18.48	36.17	.00	17.92	.00	.00	.00	.00	.00	25.17

FLOW= 40.0 CFS

XSEC	1	2	3	4	5						AVG
WETP	11.10	12.52	16.94	17.13	13.34	.00	.00	.00	.00	.00	14.21
DBAR	.97	.74	.85	.67	.80	.00	.00	.00	.00	.00	.80
VBAR	4.11	4.89	3.12	3.57	4.08	.00	.00	.00	.00	.00	3.95
WDTH	10.09	11.00	15.16	16.82	12.26	.00	.00	.00	.00	.00	13.06
AREA	9.74	8.18	12.83	11.21	9.81	.00	.00	.00	.00	.00	10.35
STGE	93.65	93.96	96.69	97.18	97.28	.00	.00	.00	.00	.00	95.75
DMAX	1.42	1.23	1.54	1.02	1.13	.00	.00	.00	.00	.00	1.27
WTOT .4	8.65	8.64	12.42	14.69	9.81	.00	.00	.00	.00	.00	10.84
WMAX	8.65	8.64	8.66	14.69	8.83	.00	.00	.00	.00	.00	9.90
PTOT	85.78	78.60	81.94	87.35	80.04	.00	.00	.00	.00	.00	82.74
PMAX	85.78	78.60	57.12	87.35	72.03	.00	.00	.00	.00	.00	76.18
WTOT 1.0	5.98	4.31	5.86	.23	4.77	.00	.00	.00	.00	.00	4.23
WMAX	5.98	2.23	5.86	.23	4.77	.00	.00	.00	.00	.00	3.81
PTOT	59.28	39.16	38.68	1.39	38.90	.00	.00	.00	.00	.00	35.48
PMAX	59.28	20.26	38.68	1.39	38.90	.00	.00	.00	.00	.00	31.70

FLOW= 50.0 CFS

XSEC	1	2	3	4	5						AVG
WETP	11.55	12.95	17.32	17.34	13.51	.00	.00	.00	.00	.00	14.53
DBAR	1.01	.79	.90	.71	.84	.00	.00	.00	.00	.00	.85
VBAR	4.74	5.59	3.58	4.12	4.79	.00	.00	.00	.00	.00	4.56

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

WDTH	10.48	11.36	15.46	17.00	12.37	.00	.00	.00	.00	.00	13.33
AREA	10.54	8.95	13.98	12.13	10.45	.00	.00	.00	.00	.00	11.21
STGE	93.73	94.03	96.76	97.23	97.33	.00	.00	.00	.00	.00	95.82
DMAX	1.50	1.30	1.61	1.07	1.18	.00	.00	.00	.00	.00	1.33
WTOT .4	9.10	9.47	14.80	15.10	10.35	.00	.00	.00	.00	.00	11.76
WMAX	9.10	9.47	14.80	15.10	8.96	.00	.00	.00	.00	.00	11.49
PTOT	86.81	83.38	95.76	88.82	83.67	.00	.00	.00	.00	.00	87.69
PMAX	86.81	83.38	95.76	88.82	72.40	.00	.00	.00	.00	.00	85.43
WTOT 1.0	6.90	4.68	6.14	1.05	5.62	.00	.00	.00	.00	.00	4.88
WMAX	6.90	4.68	6.14	1.05	5.62	.00	.00	.00	.00	.00	4.88
PTOT	65.89	41.21	39.71	6.19	45.46	.00	.00	.00	.00	.00	39.69
PMAX	65.89	41.21	39.71	6.19	45.46	.00	.00	.00	.00	.00	39.69

FLOW= 60.0 CFS

XSEC	1	2	3	4	5						AVG
WETP	11.92	13.13	17.58	17.51	13.72	.00	.00	.00	.00	.00	14.77
DBAR	1.04	.84	.95	.75	.87	.00	.00	.00	.00	.00	.89
VBAR	5.35	6.25	4.02	4.65	5.47	.00	.00	.00	.00	.00	5.15
WDTH	10.80	11.47	15.65	17.15	12.54	.00	.00	.00	.00	.00	13.52
AREA	11.22	9.60	14.94	12.89	10.97	.00	.00	.00	.00	.00	11.93
STGE	93.80	94.08	96.83	97.27	97.37	.00	.00	.00	.00	.00	95.87
DMAX	1.57	1.35	1.68	1.11	1.22	.00	.00	.00	.00	.00	1.39
WTOT .4	9.40	9.49	14.82	15.43	10.83	.00	.00	.00	.00	.00	11.99
WMAX	9.40	9.49	14.82	15.43	9.06	.00	.00	.00	.00	.00	11.64
PTOT	86.98	82.75	94.65	89.95	86.36	.00	.00	.00	.00	.00	88.14
PMAX	86.98	82.75	94.65	89.95	72.23	.00	.00	.00	.00	.00	85.31
WTOT 1.0	7.10	4.73	6.46	3.22	7.25	.00	.00	.00	.00	.00	5.75
WMAX	7.10	4.73	6.46	3.22	7.25	.00	.00	.00	.00	.00	5.75
PTOT	65.71	41.21	41.27	18.78	57.81	.00	.00	.00	.00	.00	44.95
PMAX	65.71	41.21	41.27	18.78	57.81	.00	.00	.00	.00	.00	44.95

FLOW= 70.0 CFS

XSEC	1	2	3	4	5						AVG
WETP	12.81	13.24	17.80	17.66	14.02	.00	.00	.00	.00	.00	15.11
DBAR	1.01	.88	1.00	.78	.89	.00	.00	.00	.00	.00	.91
VBAR	5.92	6.90	4.44	5.17	6.13	.00	.00	.00	.00	.00	5.71
WDTH	11.65	11.52	15.82	17.28	12.81	.00	.00	.00	.00	.00	13.82
AREA	11.82	10.15	15.76	13.54	11.42	.00	.00	.00	.00	.00	12.54
STGE	93.85	94.13	96.88	97.31	97.41	.00	.00	.00	.00	.00	95.92
DMAX	1.62	1.40	1.73	1.15	1.26	.00	.00	.00	.00	.00	1.43
WTOT .4	9.65	9.51	14.83	15.65	11.24	.00	.00	.00	.00	.00	12.18
WMAX	9.65	9.51	14.83	15.65	9.15	.00	.00	.00	.00	.00	11.76
PTOT	82.80	82.54	93.73	90.56	87.73	.00	.00	.00	.00	.00	87.47
PMAX	82.80	82.54	93.73	90.56	71.40	.00	.00	.00	.00	.00	84.21

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

WTOT	1.0	7.26	5.27	6.76	3.79	7.59	.00	.00	.00	.00	.00	6.13
WMAX		7.26	5.27	6.76	3.79	7.59	.00	.00	.00	.00	.00	6.13
PTOT		62.31	45.76	42.74	21.92	59.24	.00	.00	.00	.00	.00	46.40
PMAX		62.31	45.76	42.74	21.92	59.24	.00	.00	.00	.00	.00	46.40

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	5.54	5.72	8.45	.00	.00	.00	.00	.00	6.57
DBAR	.00	.00	.26	.09	.26	.00	.00	.00	.00	.00	.20
VBAR	.00	.00	1.10	2.79	.70	.00	.00	.00	.00	.00	1.53
WDTH	.00	.00	5.35	5.69	8.24	.00	.00	.00	.00	.00	6.43
AREA	.00	.00	1.37	.54	2.14	.00	.00	.00	.00	.00	1.35
STGE	.00	.00	95.59	96.38	96.53	.00	.00	.00	.00	.00	96.16
DMAX	.00	.00	.44	.22	.38	.00	.00	.00	.00	.00	.34
WTOT .4	.00	.00	.77	.00	.00	.00	.00	.00	.00	.00	.26
WMAX	.00	.00	.45	.00	.00	.00	.00	.00	.00	.00	.15
PTOT	.00	.00	14.34	.00	.00	.00	.00	.00	.00	.00	4.78
PMAX	.00	.00	8.46	.00	.00	.00	.00	.00	.00	.00	2.82
WTOT 1.0	.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	6.13	6.44	8.69	.00	.00	.00	.00	.00	7.08
DBAR	.00	.00	.33	.15	.32	.00	.00	.00	.00	.00	.27
VBAR	.00	.00	1.05	2.08	.74	.00	.00	.00	.00	.00	1.29
WDTH	.00	.00	5.85	6.38	8.42	.00	.00	.00	.00	.00	6.88
AREA	.00	.00	1.91	.96	2.69	.00	.00	.00	.00	.00	1.85
STGE	.00	.00	95.68	96.45	96.59	.00	.00	.00	.00	.00	96.24
DMAX	.00	.00	.53	.29	.44	.00	.00	.00	.00	.00	.42
WTOT .4	.00	.00	2.21	.00	2.20	.00	.00	.00	.00	.00	1.47
WMAX	.00	.00	2.21	.00	1.77	.00	.00	.00	.00	.00	1.33
PTOT	.00	.00	37.85	.00	26.11	.00	.00	.00	.00	.00	21.32
PMAX	.00	.00	37.85	.00	21.03	.00	.00	.00	00	.00	19.63
WTOT 1.0	.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	6.45	8.52	8.83	.00	.00	.00	.00	.00	7.93
DBAR	.00	.00	.38	.16	.37	.00	.00	.00	.00	.00	.30
VBAR	.00	.00	1.06	1.82	.80	.00	.00	.00	.00	.00	1.23
WDTH	.00	.00	6.11	8.46	8.51	.00	.00	.00	.00	.00	7.69
AREA	.00	.00	2.35	1.37	3.12	.00	.00	.00	.00	.00	2.28
STGE	.00	.00	95.76	96.50	96.64	.00	.00	.00	.00	.00	96.30

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

DMAX	.00	.00	.61	.34	.49	.00	.00	.00	.00	.00	.48
WTOT .4	.00	.00	3.00	.00	4.29	.00	.00	.00	.00	.00	2.43
WMAX	.00	.00	3.00	.00	2.69	.00	.00	.00	.00	.00	1.90
PTOT	.00	.00	49.11	.00	50.39	.00	.00	.00	.00	.00	33.17
PMAX	.00	.00	49.11	.00	31.61	.00	.00	.00	.00	.00	26.91
WTOT 1.0	.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	6.83	9.18	8.95	.00	.00	.00	.00	.00	8.32
DBAR	.00	.00	.43	.19	.40	.00	.00	.00	.00	.00	.34
VBAR	.00	.00	1.10	1.70	.86	.00	.00	.00	.00	.00	1.22
WDTH	.00	.00	6.43	9.11	8.59	.00	.00	.00	.00	.00	8.04
AREA	.00	.00	2.73	1.76	3.48	.00	.00	.00	.00	.00	2.66
STGE	.00	.00	95.82	96.54	96.69	.00	.00	.00	.00	.00	96.35
DMAX	.00	.00	.67	.38	.54	.00	.00	.00	.00	.00	.53
WTOT .4	.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	58.94	.00	55.91	.00	.00	.00	.00	.00	38.28
PMAX	.00	.00	58.94	.00	55.91	.00	.00	.00	.00	.00	38.28
WTOT 1.0	.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	7.16	12.16	9.05	.00	.00	.00	.00	.00	9.46
DBAR	.00	.00	.46	.18	.44	.00	.00	.00	.00	.00	.36
VBAR	.00	.00	1.14	1.62	.93	.00	.00	.00	.00	.00	1.23
WDTH	.00	.00	6.72	12.09	8.65	.00	.00	.00	.00	.00	9.15
AREA	.00	.00	3.07	2.17	3.78	.00	.00	.00	.00	.00	3.01
STGE	.00	.00	95.87	96.58	96.72	.00	.00	.00	.00	.00	96.39
DMAX	.00	.00	.72	.42	.57	.00	.00	.00	.00	.00	.57
WTOT .4	.00	.00	4.48	.32	5.36	.00	.00	.00	.00	.00	3.39
WMAX	.00	.00	4.48	.32	5.36	.00	.00	.00	.00	.00	3.39
PTOT	.00	.00	66.67	2.68	62.02	.00	.00	.00	.00	.00	43.79
PMAX	.00	.00	66.67	2.68	62.02	.00	.00	.00	.00	.00	43.79
WTOT 1.0	.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

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

PMAX	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
FLOW=	4.0 CFS										
XSEC	1	2	3	4	5						AVG
WETP	.00	.00	7.43	13.30	9.14	.00	.00	.00	.00	.00	9.96
DBAR	.00	.00	.49	.19	.47	.00	.00	.00	.00	.00	.38
VBAR	.00	.00	1.18	1.56	.99	.00	.00	.00	.00	.00	1.24
WDTH	.00	.00	6.94	13.22	8.70	.00	.00	.00	.00	.00	9.62
AREA	.00	.00	3.38	2.57	4.05	.00	.00	.00	.00	.00	3.33
STGE	.00	.00	95.92	96.61	96.75	.00	.00	.00	.00	.00	96.43
DMAX	.00	.00	.77	.45	.60	.00	.00	.00	.00	.00	.61
WTOT .4											
WTOT	.00	.00	4.90	.81	7.02	.00	.00	.00	.00	.00	4.24
WMAX	.00	.00	4.90	.81	7.02	.00	.00	.00	.00	.00	4.24
PTOT	.00	.00	70.52	6.13	80.64	.00	.00	.00	.00	.00	52.43
PMAX	.00	.00	70.52	6.13	80.64	.00	.00	.00	.00	.00	52.43
WTOT 1.0											
WTOT	.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										
XSEC	1	2	3	4	5						AVG
WETP	.00	.00	7.72	14.11	9.29	.00	.00	.00	.00	.00	10.38
DBAR	.00	.00	.55	.24	.51	.00	.00	.00	.00	.00	.43
VBAR	.00	.00	1.28	1.52	1.11	.00	.00	.00	.00	.00	1.30
WDTH	.00	.00	7.15	14.01	8.79	.00	.00	.00	.00	.00	9.98
AREA	.00	.00	3.90	3.30	4.49	.00	.00	.00	.00	.00	3.90
STGE	.00	.00	95.99	96.67	96.80	.00	.00	.00	.00	.00	96.49
DMAX	.00	.00	.84	.51	.65	.00	.00	.00	.00	.00	.67
WTOT .4											
WTOT	.00	.00	5.36	3.12	7.52	.00	.00	.00	.00	.00	5.34
WMAX	.00	.00	5.36	3.12	7.52	.00	.00	.00	.00	.00	5.34
PTOT	.00	.00	74.96	22.30	85.60	.00	.00	.00	.00	.00	60.96
PMAX	.00	.00	74.96	22.30	85.60	.00	.00	.00	.00	.00	60.96
WTOT 1.0											
WTOT	.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										
XSEC	1	2	3	4	5						AVG
WETP	.00	.00	9.99	14.40	9.94	.00	.00	.00	.00	.00	11.45
DBAR	.00	.00	.47	.28	.52	.00	.00	.00	.00	.00	.42
VBAR	.00	.00	1.36	1.53	1.23	.00	.00	.00	.00	.00	1.37
WDTH	.00	.00	9.33	14.28	9.37	.00	.00	.00	.00	.00	11.00
AREA	.00	.00	4.41	3.93	4.87	.00	.00	.00	.00	.00	4.41

BEAR CREEK - BIG HOLE DRAINAGE - SW, SE, SEC 34, T2N, R12W

STGE	.00	.00	96.05	96.71	96.84	.00	.00	.00	.00	.00	96.54
DMAX	.00	.00	.90	.55	.69	.00	.00	.00	.00	.00	.72
WTOT .4	.00	.00	5.74	3.79	7.87	.00	.00	.00	.00	.00	5.80
WMAX	.00	.00	5.74	3.79	7.87	.00	.00	.00	.00	.00	5.80
PTOT	.00	.00	61.54	26.54	83.96	.00	.00	.00	.00	.00	57.35
PMAX	.00	.00	61.54	26.54	83.96	.00	.00	.00	.00	.00	57.35
WTOT 1.0	.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	10.87	14.64	10.42	.00	.00	.00	.00	.00	11.98
DBAR	.00	.00	.49	.31	.53	.00	.00	.00	.00	.00	.44
VBAR	.00	.00	1.42	1.57	1.34	.00	.00	.00	.00	.00	1.44
WDTH	.00	.00	10.11	14.50	9.80	.00	.00	.00	.00	.00	11.47
AREA	.00	.00	4.92	4.47	5.21	.00	.00	.00	.00	.00	4.87
STGE	.00	.00	96.10	96.75	96.88	.00	.00	.00	.00	.00	96.58
DMAX	.00	.00	.95	.59	.73	.00	.00	.00	.00	.00	.76
WTOT .4	.00	.00	5.91	4.35	8.04	.00	.00	.00	.00	.00	6.10
WMAX	.00	.00	5.91	4.35	8.04	.00	.00	.00	.00	.00	6.10
PTOT	.00	.00	58.47	30.02	82.06	.00	.00	.00	.00	.00	56.85
PMAX	.00	.00	58.47	30.02	82.06	.00	.00	.00	.00	.00	56.85
WTOT 1.0	.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	11.47	14.89	10.76	.00	.00	.00	.00	.00	12.38
DBAR	.00	.00	.51	.34	.55	.00	.00	.00	.00	.00	.46
VBAR	.00	.00	1.49	1.62	1.45	.00	.00	.00	.00	.00	1.52
WDTH	.00	.00	10.63	14.75	10.10	.00	.00	.00	.00	.00	11.82
AREA	.00	.00	5.38	4.94	5.52	.00	.00	.00	.00	.00	5.28
STGE	.00	.00	96.15	96.78	96.91	.00	.00	.00	.00	.00	96.61
DMAX	.00	.00	1.00	.62	.76	.00	.00	.00	.00	.00	.79
WTOT .4	.00	.00	6.05	5.77	8.18	.00	.00	.00	.00	.00	6.67
WMAX	.00	.00	6.05	5.77	8.18	.00	.00	.00	.00	.00	6.67
PTOT	.00	.00	56.98	39.15	80.94	.00	.00	.00	.00	.00	59.02
PMAX	.00	.00	56.98	39.15	80.94	.00	.00	.00	.00	.00	59.02
WTOT 1.0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
WMAX	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

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	12.02	15.12	11.10	.00	.00	.00	.00	.00	12.75
DBAR	.00	.00	.52	.36	.56	.00	.00	.00	.00	.00	.48
VBAR	.00	.00	1.55	1.68	1.55	.00	.00	.00	.00	.00	1.59
WDTH	.00	.00	11.09	14.96	10.41	.00	.00	.00	.00	.00	12.15
AREA	.00	.00	5.81	5.37	5.80	.00	.00	.00	.00	.00	5.66
STGE	.00	.00	96.19	96.81	96.94	.00	.00	.00	.00	.00	96.65
DMAX	.00	.00	1.04	.65	.79	.00	.00	.00	.00	.00	.83
WTOT .4	.00	.00	6.26	6.11	8.29	.00	.00	.00	.00	.00	6.89
WMAX	.00	.00	6.26	6.11	8.29	.00	.00	.00	.00	.00	6.89
PTOT	.00	.00	56.40	40.85	79.66	.00	.00	.00	.00	.00	58.97
PMAX	.00	.00	56.40	40.85	79.66	.00	.00	.00	.00	.00	58.97
WTOT 1.0	.00	.00	.76	.00	.00	.00	.00	.00	.00	.00	.25
WMAX	.00	.00	.45	.00	.00	.00	.00	.00	.00	.00	.15
PTOT	.00	.00	6.81	.00	.00	.00	.00	.00	.00	.00	2.27
PMAX	.00	.00	4.02	.00	.00	.00	.00	.00	.00	.00	1.34
FLOW= 10.0 CFS											
XSEC	1	2	3	4	5						AVG
WETP	.00	.00	12.55	15.32	11.41	.00	.00	.00	.00	.00	13.09
DBAR	.00	.00	.54	.38	.57	.00	.00	.00	.00	.00	.49
VBAR	.00	.00	1.61	1.74	1.65	.00	.00	.00	.00	.00	1.67
WDTH	.00	.00	11.55	15.15	10.68	.00	.00	.00	.00	.00	12.46
AREA	.00	.00	6.21	5.76	6.05	.00	.00	.00	.00	.00	6.01
STGE	.00	.00	96.22	96.84	96.96	.00	.00	.00	.00	.00	96.67
DMAX	.00	.00	1.07	.68	.81	.00	.00	.00	.00	.00	.85
WTOT .4	.00	.00	6.44	6.32	8.36	.00	.00	.00	.00	.00	7.04
WMAX	.00	.00	6.44	6.32	8.36	.00	.00	.00	.00	.00	7.04
PTOT	.00	.00	55.76	41.69	78.29	.00	.00	.00	.00	.00	58.58
PMAX	.00	.00	55.76	41.69	78.29	.00	.00	.00	.00	.00	58.58
WTOT 1.0	.00	.00	1.47	.00	.00	.00	.00	.00	.00	.00	.49
WMAX	.00	.00	.87	.00	.00	.00	.00	.00	.00	.00	.29
PTOT	.00	.00	12.76	.00	.00	.00	.00	.00	.00	.00	4.25
PMAX	.00	.00	7.53	.00	.00	.00	.00	.00	.00	.00	2.51
FLOW= 15.0 CFS											
XSEC	1	2	3	4	5						AVG
WETP	.00	.00	15.02	15.98	12.58	.00	.00	.00	.00	.00	14.53
DBAR	.00	.00	.58	.46	.60	.00	.00	.00	.00	.00	.55
VBAR	.00	.00	1.89	2.06	2.11	.00	.00	.00	.00	.00	2.02
WDTH	.00	.00	13.77	15.79	11.74	.00	.00	.00	.00	.00	13.77

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

AREA	.00	.00	7.92	7.29	7.10	.00	.00	.00	.00	.00	7.44
STGE	.00	.00	96.36	96.94	97.06	.00	.00	.00	.00	.00	96.78
DMAX	.00	.00	1.21	.78	.91	.00	.00	.00	.00	.00	.96
WTOT .4	.00	.00	7.07	9.01	8.53	.00	.00	.00	.00	.00	8.20
WMAX	.00	.00	7.07	9.01	8.53	.00	.00	.00	.00	.00	8.20
PTOT	.00	.00	51.30	57.09	72.67	.00	.00	.00	.00	.00	60.35
PMAX	.00	.00	51.30	57.09	72.67	.00	.00	.00	.00	.00	60.35
WTOT 1.0	.00	.00	3.00	.00	.00	.00	.00	.00	.00	.00	1.00
WMAX	.00	.00	3.00	.00	.00	.00	.00	.00	.00	.00	1.00
PTOT	.00	.00	21.81	.00	.00	.00	.00	.00	.00	.00	7.27
PMAX	.00	.00	21.81	.00	.00	.00	.00	.00	.00	.00	7.27

FLOW= 20.0 CFS

XSEC	1	2	3	4	5						AVG
WETP	.00	.00	16.25	16.41	12.83	.00	.00	.00	.00	.00	15.16
DBAR	.00	.00	.63	.52	.66	.00	.00	.00	.00	.00	.60
VBAR	.00	.00	2.14	2.38	2.54	.00	.00	.00	.00	.00	2.35
WDTH	.00	.00	14.82	16.18	11.92	.00	.00	.00	.00	.00	14.31
AREA	.00	.00	9.35	8.41	7.88	.00	.00	.00	.00	.00	8.55
STGE	.00	.00	96.46	97.01	97.12	.00	.00	.00	.00	.00	96.86
DMAX	.00	.00	1.31	.85	.97	.00	.00	.00	.00	.00	1.04
WTOT .4	.00	.00	9.42	12.53	8.65	.00	.00	.00	.00	.00	10.20
WMAX	.00	.00	7.44	12.53	8.65	.00	.00	.00	.00	.00	9.54
PTOT	.00	.00	63.54	77.43	72.58	.00	.00	.00	.00	.00	71.18
PMAX	.00	.00	50.20	77.43	72.58	.00	.00	.00	.00	.00	66.74
WTOT 1.0	.00	.00	4.31	.00	.00	.00	.00	.00	.00	.00	1.44
WMAX	.00	.00	4.31	.00	.00	.00	.00	.00	.00	.00	1.44
PTOT	.00	.00	29.07	.00	.00	.00	.00	.00	.00	.00	9.69
PMAX	.00	.00	29.07	.00	.00	.00	.00	.00	.00	.00	9.69

FLOW= 25.0 CFS

XSEC	1	2	3	4	5						AVG
WETP	.00	.00	16.40	16.64	13.00	.00	.00	.00	.00	.00	15.34
DBAR	.00	.00	.71	.57	.71	.00	.00	.00	.00	.00	.66
VBAR	.00	.00	2.39	2.69	2.94	.00	.00	.00	.00	.00	2.67
WDTH	.00	.00	14.84	16.39	12.03	.00	.00	.00	.00	.00	14.42
AREA	.00	.00	10.47	9.30	8.50	.00	.00	.00	.00	.00	9.42
STGE	.00	.00	96.53	97.06	97.17	.00	.00	.00	.00	.00	96.92
DMAX	.00	.00	1.38	.90	1.02	.00	.00	.00	.00	.00	1.10
WTOT .4	.00	.00	10.43	13.54	8.72	.00	.00	.00	.00	.00	10.90
WMAX	.00	.00	7.82	13.54	8.72	.00	.00	.00	.00	.00	10.03
PTOT	.00	.00	70.26	82.63	72.52	.00	.00	.00	.00	.00	75.14
PMAX	.00	.00	52.71	82.63	72.52	.00	.00	.00	.00	.00	69.29
WTOT 1.0	.00	.00	4.99	.00	1.65	.00	.00	.00	.00	.00	2.21

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

WMAX	.00	.00	4.99	.00	1.41	.00	.00	.00	.00	.00	2.14
PTOT	.00	.00	33.62	.00	13.68	.00	.00	.00	.00	.00	15.77
PMAX	.00	.00	33.62	.00	11.76	.00	.00	.00	.00	.00	15.13
FLOW= 30.0 CFS											
XSEC	1	2	3	4	5						AVG
WETP	.00	.00	16.52	16.83	13.13	.00	.00	.00	.00	.00	15.49
DBAR	.00	.00	.77	.61	.74	.00	.00	.00	.00	.00	.70
VBAR	.00	.00	2.64	2.99	3.33	.00	.00	.00	.00	.00	2.99
WDTH	.00	.00	14.86	16.56	12.12	.00	.00	.00	.00	.00	14.51
AREA	.00	.00	11.38	10.03	9.01	.00	.00	.00	.00	.00	10.14
STGE	.00	.00	96.59	97.11	97.22	.00	.00	.00	.00	.00	96.97
DMAX	.00	.00	1.44	.95	1.07	.00	.00	.00	.00	.00	1.15
WTOT .4	.00	.00	11.16	14.25	8.96	.00	.00	.00	.00	.00	11.46
WMAX	.00	.00	8.14	14.25	8.76	.00	.00	.00	.00	.00	10.38
PTOT	.00	.00	75.08	86.09	73.94	.00	.00	.00	.00	.00	78.37
PMAX	.00	.00	54.76	86.09	72.32	.00	.00	.00	.00	.00	71.06
WTOT 1.0	.00	.00	5.38	.00	3.05	.00	.00	.00	.00	.00	2.81
WMAX	.00	.00	5.38	.00	2.17	.00	.00	.00	.00	.00	2.52
PTOT	.00	.00	36.17	.00	25.15	.00	.00	.00	.00	.00	20.44
PMAX	.00	.00	36.17	.00	17.92	.00	.00	.00	.00	.00	18.03
FLOW= 40.0 CFS											
XSEC	1	2	3	4	5						AVG
WETP	.00	.00	16.94	17.13	13.34	.00	.00	.00	.00	.00	15.80
DBAR	.00	.00	.85	.67	.80	.00	.00	.00	.00	.00	.77
VBAR	.00	.00	3.12	3.57	4.08	.00	.00	.00	.00	.00	3.59
WDTH	.00	.00	15.16	16.82	12.26	.00	.00	.00	.00	.00	14.75
AREA	.00	.00	12.83	11.21	9.81	.00	.00	.00	.00	.00	11.28
STGE	.00	.00	96.69	97.18	97.28	.00	.00	.00	.00	.00	97.05
DMAX	.00	.00	1.54	1.02	1.13	.00	.00	.00	.00	.00	1.23
WTOT .4	.00	.00	12.42	14.69	9.81	.00	.00	.00	.00	.00	12.31
WMAX	.00	.00	8.66	14.69	8.83	.00	.00	.00	.00	.00	10.73
PTOT	.00	.00	81.94	87.35	80.04	.00	.00	.00	.00	.00	83.11
PMAX	.00	.00	57.12	87.35	72.03	.00	.00	.00	.00	.00	72.17
WTOT 1.0	.00	.00	5.86	.23	4.77	.00	.00	.00	.00	.00	3.62
WMAX	.00	.00	5.86	.23	4.77	.00	.00	.00	.00	.00	3.62
PTOT	.00	.00	38.68	1.39	38.90	.00	.00	.00	.00	.00	26.32
PMAX	.00	.00	38.68	1.39	38.90	.00	.00	.00	.00	.00	26.32
FLOW= 50.0 CFS											
XSEC	1	2	3	4	5						AVG
WETP	.00	.00	17.32	17.34	13.51	.00	.00	.00	.00	.00	16.05
DBAR	.00	.00	.90	.71	.84	.00	.00	.00	.00	.00	.82
VBAR	.00	.00	3.58	4.12	4.79	.00	.00	.00	.00	.00	4.16

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

WDTH	.00	.00	15.46	17.00	12.37	.00	.00	.00	.00	.00	14.94
AREA	.00	.00	13.98	12.13	10.45	.00	.00	.00	.00	.00	12.19
STGE	.00	.00	96.76	97.23	97.33	.00	.00	.00	.00	.00	97.11
DMAX	.00	.00	1.61	1.07	1.18	.00	.00	.00	.00	.00	1.29
WTOT .4	.00	.00	14.80	15.10	10.35	.00	.00	.00	.00	.00	13.42
WMAX	.00	.00	14.80	15.10	8.96	.00	.00	.00	.00	.00	12.95
PTOT	.00	.00	95.76	88.82	83.67	.00	.00	.00	.00	.00	89.41
PMAX	.00	.00	95.76	88.82	72.40	.00	.00	.00	.00	.00	85.66
WTOT 1.0	.00	.00	6.14	1.05	5.62	.00	.00	.00	.00	.00	4.27
WMAX	.00	.00	6.14	1.05	5.62	.00	.00	.00	.00	.00	4.27
PTOT	.00	.00	39.71	6.19	45.46	.00	.00	.00	.00	.00	30.45
PMAX	.00	.00	39.71	6.19	45.46	.00	.00	.00	.00	.00	30.45

FLOW= 60.0 CFS

XSEC	1	2	3	4	5						AVG
WETP	.00	.00	17.58	17.51	13.72	.00	.00	.00	.00	.00	16.27
DBAR	.00	.00	.95	.75	.87	.00	.00	.00	.00	.00	.86
VBAR	.00	.00	4.02	4.65	5.47	.00	.00	.00	.00	.00	4.71
WDTH	.00	.00	15.65	17.15	12.54	.00	.00	.00	.00	.00	15.12
AREA	.00	.00	14.94	12.89	10.97	.00	.00	.00	.00	.00	12.94
STGE	.00	.00	96.83	97.27	97.37	.00	.00	.00	.00	.00	97.16
DMAX	.00	.00	1.68	1.11	1.22	.00	.00	.00	.00	.00	1.34
WTOT .4	.00	.00	14.82	15.43	10.83	.00	.00	.00	.00	.00	13.69
WMAX	.00	.00	14.82	15.43	9.06	.00	.00	.00	.00	.00	13.10
PTOT	.00	.00	94.65	89.95	86.36	.00	.00	.00	.00	.00	90.32
PMAX	.00	.00	94.65	89.95	72.23	.00	.00	.00	.00	.00	85.61
WTOT 1.0	.00	.00	6.46	3.22	7.25	.00	.00	.00	.00	.00	5.64
WMAX	.00	.00	6.46	3.22	7.25	.00	.00	.00	.00	.00	5.64
PTOT	.00	.00	41.27	18.78	57.81	.00	.00	.00	.00	.00	39.29
PMAX	.00	.00	41.27	18.78	57.81	.00	.00	.00	.00	.00	39.29

FLOW= 70.0 CFS

XSEC	1	2	3	4	5						AVG
WETP	.00	.00	17.80	17.66	14.02	.00	.00	.00	.00	.00	16.49
DBAR	.00	.00	1.00	.78	.89	.00	.00	.00	.00	.00	.89
VBAR	.00	.00	4.44	5.17	6.13	.00	.00	.00	.00	.00	5.25
WDTH	.00	.00	15.82	17.28	12.81	.00	.00	.00	.00	.00	15.30
AREA	.00	.00	15.76	13.54	11.42	.00	.00	.00	.00	.00	13.58
STGE	.00	.00	96.88	97.31	97.41	.00	.00	.00	.00	.00	97.20
DMAX	.00	.00	1.73	1.15	1.26	.00	.00	.00	.00	.00	1.38
WTOT .4	.00	.00	14.83	15.65	11.24	.00	.00	.00	.00	.00	13.91
WMAX	.00	.00	14.83	15.65	9.15	.00	.00	.00	.00	.00	13.21
PTOT	.00	.00	93.73	90.56	87.73	.00	.00	.00	.00	.00	90.67
PMAX	.00	.00	93.73	90.56	71.40	.00	.00	.00	.00	.00	85.23

BEAR CREEK - BIG HOLE DRAINAGE - SW,SE, SEC 34, T2N, R12W

WTOT	1.0	.00	.00	6.76	3.79	7.59	.00	.00	.00	.00	.00	6.05
WMAX		.00	.00	6.76	3.79	7.59	.00	.00	.00	.00	.00	6.05
PTOT		.00	.00	42.74	21.92	59.24	.00	.00	.00	.00	.00	41.30
PMAX		.00	.00	42.74	21.92	59.24	.00	.00	.00	.00	.00	41.30

APPENDIX F

CONCEPTUAL IDEAS

FOR

MINIMUM FLOW PASSAGE DIVERSION STRUCTURES

Prepared for

Montana Department of Fish, Wildlife & Parks

by

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June 30, 1983

At the request of the Montana Department of Fish, Wildlife and Parks, we were to prepare drawings of working concepts for diverting stream water to small hydroelectric generating facilities. Design criteria as set by the Department for the diversion structures are: 1) structure must automatically pass the minimum flow for the particular stream, and 2) structure must be able to pass the bedload carried by the stream.

Being bound by the two design conditions stated above, one is limited to placing the floor of the minimum flow channel at the bottom of the stream. This configuration will also enable the passing of the bedload carried by the stream. Any obstructions such as energy dissipators must be placed so as to accommodate the passage of the largest bedload component expected for the particular stream.

Plates I and II are conceptual design drawings for diversion structures that address the two design conditions. Please note that these drawings are for ideas only. They are subject to site specific requirements for minimum flows and bedload passage. Each design will be discussed with attention pointed to advantages and disadvantages of the structures.

It is not going to be an easy task for the developer of small hydro projects to design and build a diversion structure that will satisfy the requirements placed on him by the state agencies and, at the same time, satisfy the requirements needed to produce an efficient generating facility. The requirements of automatically passing the minimum flows and bedload are the main concern of the Montana Department of Fish, Wildlife and Parks. Satisfying those requirements will insure the stream's integrity and fish habitat.

The Plates included with this report are two conceptual designs that will satisfy the requirements set forth. These designs are only concepts that should help the developer see what is required of him to satisfy minimum flow and bedload passage. There are advantages and disadvantages of both designs shown, which will be addressed in the following discussion.

PLATE I

The design shown on Plate I is only a conceptual idea that must be modified for specific stream application. Dimensions of the entire structure must be engineered to handle the design flows for the minimum flows required for stream preservation, maximum flows to the generation facility, and the maximum annual flow above that needed for generation. The configuration for the outlet pipe will probably have to be modified to allow for the most efficient entry of water into the pipe. Of course, the stilling basin may have to be enlarged to handle the silt washed through the primary trash rack.

Modification to the gate structure may include radial gates or automatic slide gates. These modifications may or may not be more efficient than the type shown. It is all going to depend on the size of the stream and the developer's desires.

PLATE II

The design shown on Plate II is also a conceptual idea. Modifications to this design are also needed, depending on the stream utilized. As shown, the operation of this facility should be self explanatory. Excess water flows into the catch basin and then settles out the silt in the stilling basin. From there the water flows into the outlet pipe to the generating facility.

There are some definite advantages to the design shown on Plate I over the design on Plate II. As an overview, the advantages are as follows:

1. Ability to divert all excess water to generating facility

2. Ability to bypass all water in the event of failure at the power house

3. Two stage trash cleaning

4. More positive silt settlement

5. Ability to clean stilling basin

6. Ability to adjust flows with gates

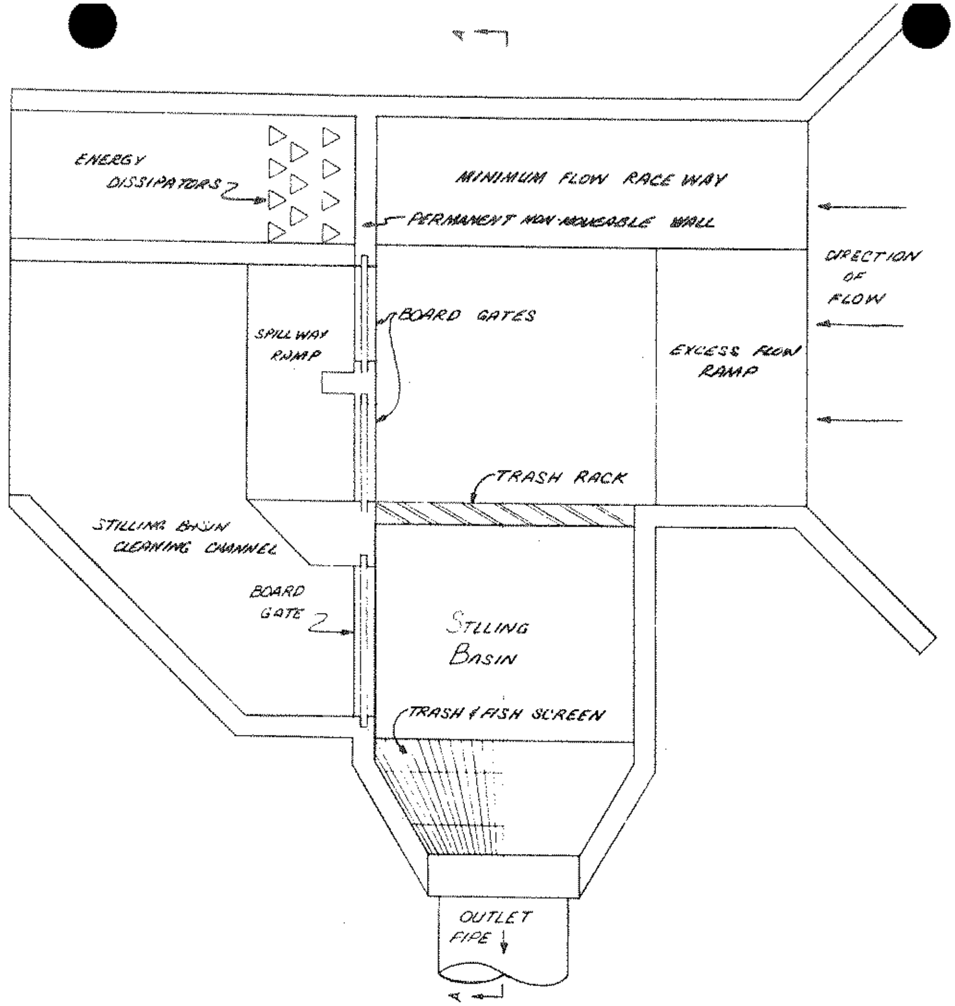
7. Suitable for large streams

The disadvantages of the design on Plate I compared with the design on Plate II are as follows:

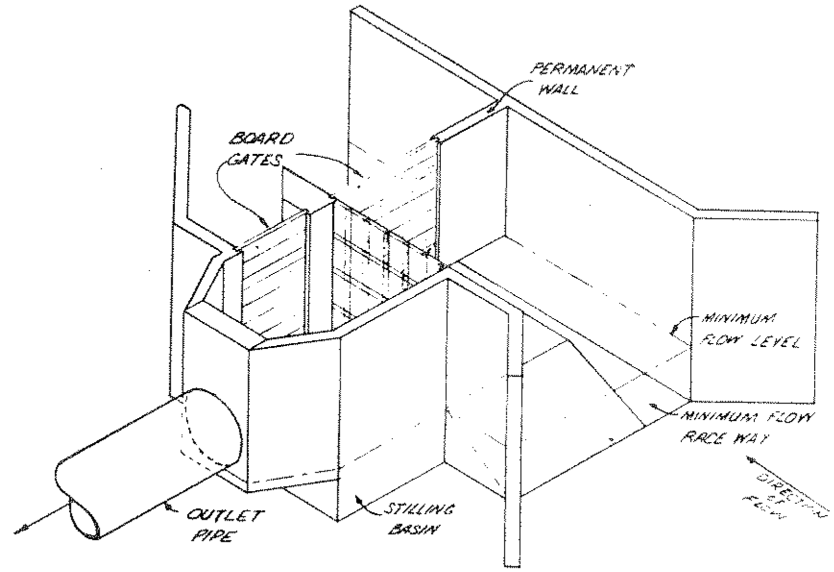
1. Constant monitoring of flow is required at gates

2. Velocities under the permanent wall will increase as the head increases

As stated earlier, the designs shown are only for the developer to visualize what must be done to guarantee the stream and fish preservation.

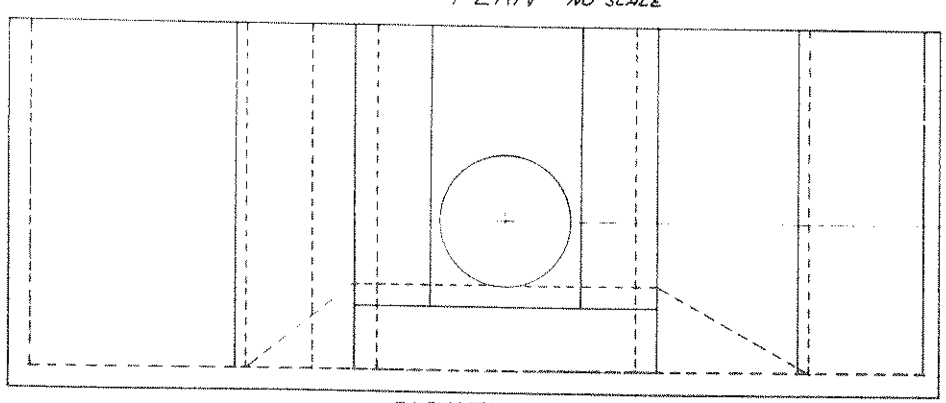


PLAN NO SCALE



ISOMETRIC VIEW
NO SCALE

PLATE I



ELEVATION
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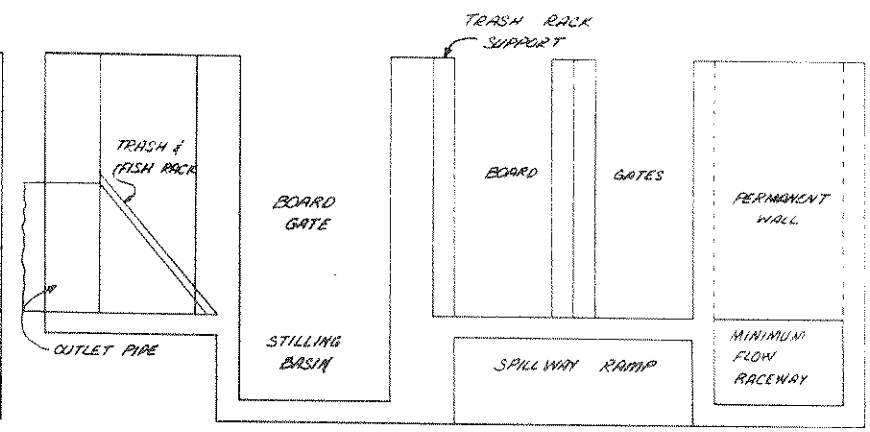

SECTION A-A
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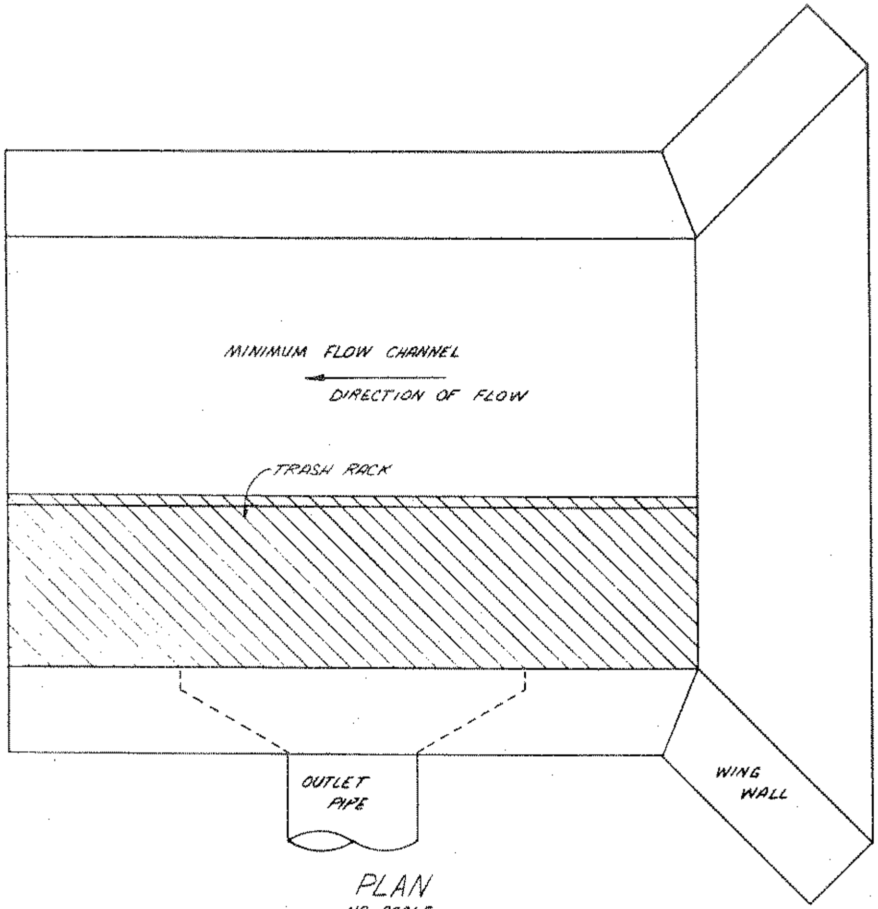

PLAN
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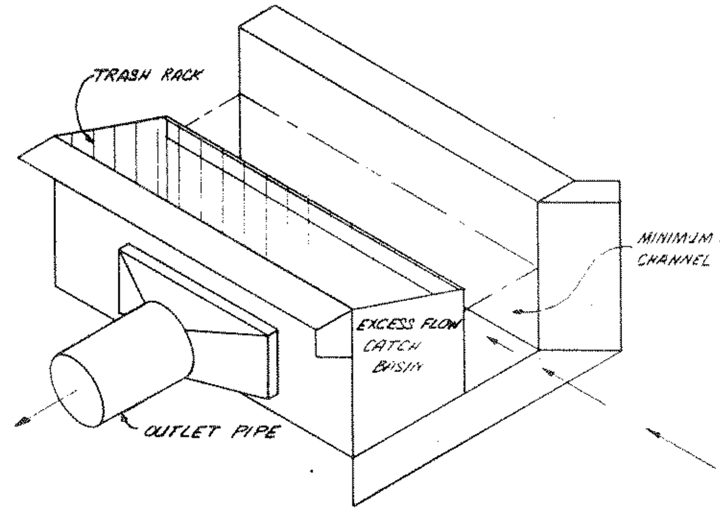
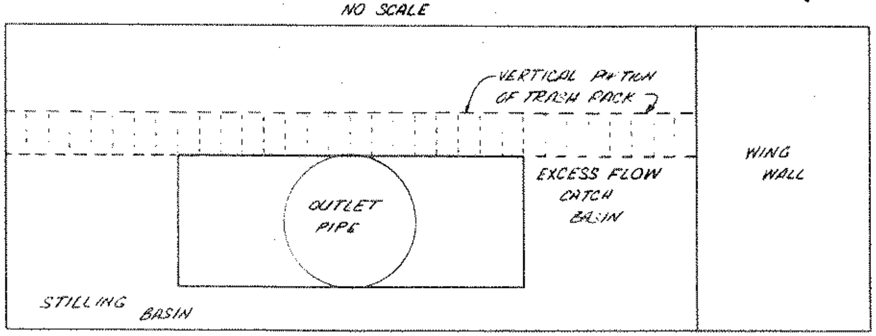


ISOMETRIC VIEW
NO SCALE

PLATE II



SIDE ELEVATION
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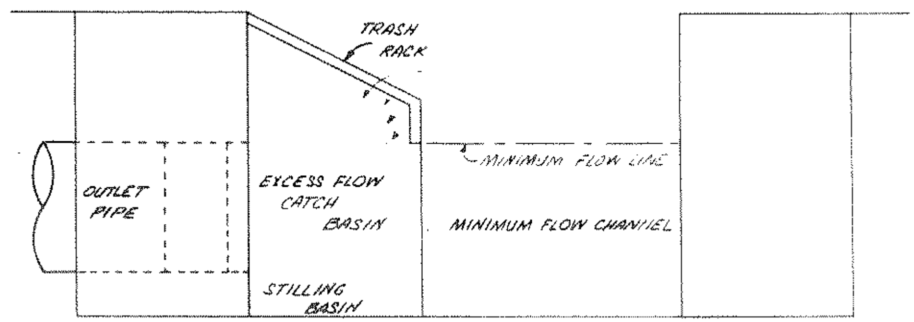

FRONT ELEVATION
NO SCALE