INSTREAM FLOW REGIMENS FOR FISH, WILDLIFE, RECREATION AND RELATED ENVIRONMENTAL RESOURCES

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ABSTRACT

A quick, easy methodology is described for determining flows to protect the aquatic resources in both warmwater and coldwater streams, based on their average flow. Biologists do their analysis with aid of hydrological data provided by the U.S. Geological Survey (USGS). Detailed field studies were conducted on 11 streams in 3 states between 1964 and 1974, testing the "Montana Method." This work involved physical, chemical, and biological analyses of 38 different flows at 58 cross-sections on 196 stream-miles, affecting both coldwater and warmwater fisheries. The studies, all planned, conducted, and analyzed with the help of state fisheries biologists, reveal that the condition of the aquatic habitat is remarkably similar on most of the streams carrying the same portion of the average flow. Similar analyses of hundreds of additional flow regimens near USGS gages in 21 different states during the past 17 years substantiated this correlation on a wide variety of streams. Ten percent of the average flow is a minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic life forms.Thirty percent is recommended as a base flow to sustain good survival conditions for most aquatic life forms and general recreation. Sixty percent provides excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreational uses.

Introduction

Natural, free-flowing streams are one of the world's most beautiful and valuable resources. Before the coming of Christ, the Roman Emperor Justinian said: "By the law of nature certain things are common property; for example, the air, running water, and the sea." America's late Senator Norris from Nebraska said: "The streams that are flowing downhill were given us by a creator. They do not belong to any special interest or to any individual. They belong to the people and ought to be utilized for the benefit of all of them."

Few streams in the United States have escaped degradation from land use practices or altered flows by some kind of man-made "water development" project. Some recognition is finally being given to instream flow regimens to protect the natural environment. Scientists from many disciplines are seeking reliable, practical methods for derermining streamflow requirements to protect fishes, waterfowl, furbearers, reptiles, amphibians, molluscs, other aquatic invertebrates, and related life forms from all the various people competing for our Nation's water.

With the help of several hydrologists and many State and Federal biologists, this quick, easy method was developed for determining flows to protect the aquatic resources in both warmwater and coldwater streams. This methodology evolved over the past 17 years from work on hundreds of streams in the states north of the Mason-Dixon Line between the Atlantic Ocean and the Rocky Mountains. This work has been cited in a score of publications and is best known as the "Montana Method."

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Method

The Montana Method is so brief it can be typed on a 3" x 5" card. It can be applied rapidly to many segments of thousands of streams by referring to Table 1 of this paper and surface water records of the USGS.

Table 1. Instream flow regimens for fish, wildlife, recreation, and related environmental resources.

Narrative description of flows [a]	Recommended base flow regimens Oct.-Mar.	Apr.-Sept.
Flushing or maximum	200% of the average flow	
Optimum range	60%-100% of the average flow	
Outstanding	40%	60%
Excellent	30%	50%
Good	20%	40%
Fair or degrading	10%	30%
Poor or minimum	10%	10%
Severe degradation	10% of average flow to zero flow	

[a] Most appropriate description of the general condition of the stream flow for all parameters listed in the title of this paper.

The following intensive use of this method will produce a factual, conclusive streamflow study on any stream. First, determine the average annual flow of the stream at the location(s) of interest (listed as AVERAGE DISCHARGE by USGS and hereinafter called *average flow*). If the average flow is not published by the USGS, it can quickly be calculated for you. Visit the stream and observe, photograph, sample, and study flow regimens approximating 10%, 30%, and 60% of the average flow. Other flows can be studied, but these three regimens will cover a flow range from about the minimum to near the maximum that can normally be justified and recommended to protect the natural environment on most streams.

The average flow of a stream (or any given portion or percent of the average flow) is a composite manifestation of the size of the drainage area, geomorphology, climate, vegetation, and land use. These relationships have been evaluated and reported also by other biologists and hydrologists. (Rantz 1964; Tennant 1957-1975).

On uncontrolled streams, study USGS records for daily, monthly, and annual flow patterns; then go to the field and check their gages until you can view and study natural flows approximating 10%, 30%, and 60% of the average flow.

If flows are controlled, begin by having the highest flow you wish to study released first; then regulate so that each succeeding lower flow will begin the following midnight. Photos taken early the next morning will reveal the difference in exposed substrate or wetted perimeter (Fig. 1). This is photographic "regression analysis." An interval of 8-10 hours will normally be sufficient to negate any appreciable differences in flow levels due to bank storage.

Figure 1. Missouri River below Holter Dam, Montana, showing differences between flows of 3,000 cfs (55% of the average flow) and 2,000 cfs (37% of the average flow). The vertical drop was 7 inches. Flows reduced about midnight will clearly reveal differences in wetted substrate when photographed the next morning (photographic "regression analysis").

Pictures may be the best data you will collect for selling your recommendations to the general public, administrators of construction agencies managing water development projects, and judges or juries adjudicating water laws. Black and white photographs and 35 mm slides of key habitat types (e.g., riffles, runs, pools, islands and bars) from elevated vantage points like bridges and high stream banks will give results superior to ground level shots or photos from aircraft high above the stream. Record appropriate, vital information on all photographs and slides as soon as they are received.

USGS monthly measurements of width, depth, and velocity cover a variety of flows at most of their stream gage or cable crossings. Obtain cross-sectional data on width, depth, and velocity measurements from the local USGS field office for flow regimens under study. Use this information to plot and compare water widths, depths, and velocities to known requirements for aquatic resources. As manpower and money permit, USGS will make specific cross-sectional measurements of width, depth, and velocity for government agencies at any point on any stream. It requires proper experience, equipment, and plenty of time for others to make the necessary cross-sectional measurements. Study average daily, monthly, and annual stream-flow regimen tables and previous historic low-flow data published by USGS to learn the base flow patterns of the climatic year and help determine flows that mimic nature and justify your final recommendations. Recommend the most appropriate and reasonable flow(s) that can be justified to provide protection and habitat for all aquatic resources.

Results

Detailed field studies were conducted on 11 streams in 3 states between 1964 and 1974 testing the Montana Method (Table 2). This work involved physical, chemical, and biological analyses of 38 different flows at 50 cross-sections on 196 stream miles, affecting both coldwater and warmwater fisheries. Reports or publications on 6 study streams are available as indicated in

Table 2. Detailed studies of instream flow regimens using the Montana Method.

Name of Stream	State	Date	Miles Studied	Number of Stations	Different Flows	Parameters Studied[a]	Type of Fishery[b]	Reference
Republican R.	Nebraska	1964	40	3	4	W,D,V,S,B,C,T,F	WW	25
Wind-Bighorn R.	Wyoming	1968	50	10	3	W,D,S,B,C,T,F	CW & WW	24
Marias R.	Montana	1968	67	9	3	W,D,V,S,B,C,T,F	CW & WW	
Missouri R.	Montana	1970	15	8	4	W.D.V.S.B,C,I,F	CW & WW	
Blacks Fork R.	Wyoming	1971	16	4	3	W,D,V,S,C,I	CW	31
Shoshone Creek	Wyoming	1971	1	2	9	W,D,V,S,B,C,F	CW	
Ruby R.	Montana	1971	1	4	3	W,D,V,S,B,C,F	CW	10
W. Fk. Bitterroot	Montana	1971	1	5	3	W,D,V,S,B,C,F	CW	10
W. Rosebud R.	Montana	1971	3	3	4	W,D,V,S,B,C,F	CW	10
N. Platte R.	Wyoming	1974	2	10	2	W,D,V,S,B,C,F	CW & WW	
Totals			196	58	38			

[a]Parameters Studied: W, Width; D, Depth; V, Velocity; S, Substrate & Sidechannels; B, Bars & Islands; C, Cover; M, Migration; T, Temperature; I, Invertebrates; F, Fishing & Floating; E, Esthetics & Natural Beauty.
[b]Type Fishery: WW, Warmwater; CW, Coldwater.

(INSTREAM FLOW—)

Table 2. Numerous black and white photos and 35 mm slides were taken of all the flow stages studied at each cross-section. The studies, all planned, conducted, and analyzed with the help of state fisheries biologists, reveal that the condition of the aquatic habitat is remarkably similar on most streams carrying the same portion of the average flow.

Width, depth, and velocity are physical instream flow parameters vital to the well-being of aquatic organisms and their habitat. Sixteen hundred measurements of these parameters for 48 different flows on 10 of the streams cited in Table 2 show that they all increase with flow, and that changes are much greater at the lower levels of flow (Fig. 2). Width, depth, and velocity all changed more rapidly from no flow to a flow of 10% of the average than in any range thereafter.

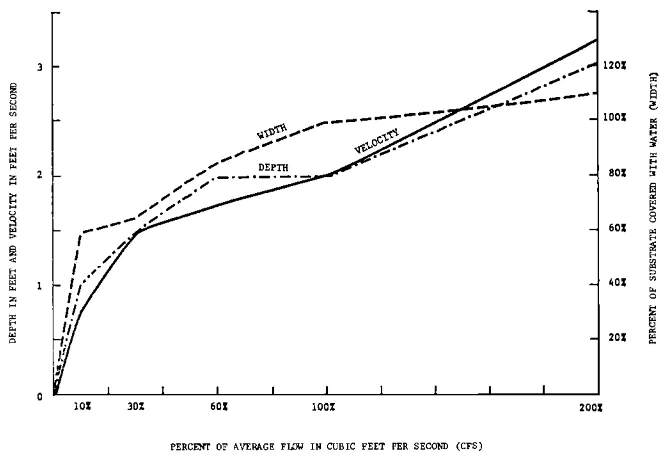

Figure 2. Average width, depth, and velocity from ten field tests of instream flow regimens using the Montana Method and the USGS hydrology data.

Ten percent of the average flow covered 60% of the substrates. depths averaged 1 foot, and velocities averaged 0.75 foot per second. Studies show that these are critical points or the lower limits for the well-being of many aquatic organisms, particularly fishes. This substantiates the conclusion that this is the area of most severe degradation or that 10% is a minimum short-term survival flow at best. Flows from 30% to 100% of average result in a gain of 40% for wetted substrate, average depth increases from 1.5 to 2 feet, and average velocities rise from 1.5 to 2 feet per second. These are within good to optimum ranges for aquatic organisms; however, it requires 3 to 10 times the amount of water needed for a short-term minimum or good base flow, and gains or benefit/cost ratios may become questionable. Increasing flow frim 100% of average to 200% of average (doubled) only increases average wetted substrate by 10%, average depth increases from 2 to 3 feet, and average velocity rises from 2 to 3.5 feet per second. Velocities averaging 3.5 feet per second are probably too high for the general well-being of most aquatic organisms but good for moving sidiment, bedload, and white water boating, In all 11 field tests of the Montana Method, water depth appeared adequate for aquatic organisms whenever velocities were satisfactory.

Analyses of hundreds of additional flow regimens near USGS gages in 21 different states during the past 17 years substantiate these correlations between similar flows on a wide variety of streams. Running waters studied ranged from small precipitous brooks high in the Rocky Mountains, to large, low-gradient rivers out on the prairies of mid-America and streams along the coastal plains. This phenomenon of nature is dicumented with hundreds of black and white photographs and 35 mm slides that are registered and filed with the U.S. Fish and Wildlife Service (FWS) in Billings, Montana; Grand Island, Nebraska; and Denver, Colorado.

Application of the Montana Method

Using the Montana Method it is easy to adjust to above or below water years and maintain stream flows that are appropriate portions of monthly, quarterly, or annual instream supplies of water. This helps fish, wildlife, and aquatic resources share surpluses and shortages of water equitably with other users.

With the Montana Method, USGS measures the hydraulic characteristics of the stream, and biologists interpret the biological responses. This saves considerable precious time that biologists can use on a more complete ecological analysis of streamflow needs.

There is significant hydrological and biological evidence that the Montana Method can be used successfully on streams throughout the United States and in other parts of the world (Rantz 1964: Whelan and Wood 1962). USGS data from cross-sectional measurements is subject to computer analysis with predicted flow parameters for width, depth, velocity, hydraulic radius, etc. at any desired water stage between zero and historic peak discharge.

USGS is considering the revision of stream flow data programs for most of the states (U.S. Department of Interior). The majority of existing gages may be discontinued under its future program. Techniques like measuring channel geometry, interpolation from a known flow to an unknown flow, and correlations with adjacent streams will be used to provide stream flow information at any point on any stream. Simple channel geometry measurements have produced average flow data as accurate as 10 years of continuous gage records (Hedman and Kastner 1974). The standard errors were lowest for mountain regions and in competition with 5 to 10 years of gaged records for the plains region. There is very little variation when results are compared between channel width and average flow (Fig. 3).

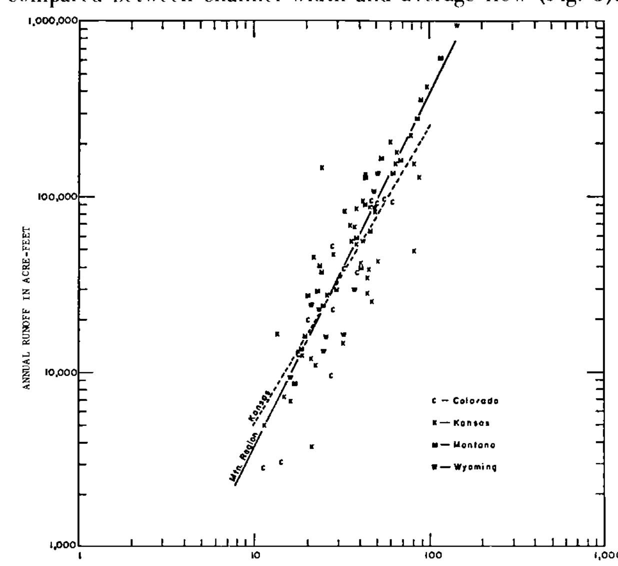

Figure 3. Correlation between average flow and channel width for streams in the mountain and plains regions of Colorado, Kansas, Montana, and Wyoming. Used with the permission of E.R. Hedman.

Mean annual discharge is one of the few criteria that will be routinely provided by this future program. Therefore, the Montana Method can still be used with this new program, since it is based primarily on knowledge of the mean annual discharge or average flow. The ability to provide the average flow at any point on any stream at any time would actually facilitate the use of the Montana Method in the future.

Adopting the metric system would not require conversion tables or other problems since this method is based on percentages of the average flow however it is expressed.

Conclusions

Ten percent of the average flow: This is a minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic life forms. Channel widths, depths, and velocities will all be significantly reduced and the aquatic habitat degraded (Figs. 2,4). The stream substrate or wetted perimeter will be about half exposed, except in wide, shallow riffle or shoal areas where exposure could be higher. Side channels will be severely or totally dewatered. Gravel bars will be substantially dewatered, and islands will usually no longer function as wildlife nesting, denning, nursery, and refuge habitat. Streambank cover for fish and fur animal denning habitat will be severely diminished. Many wetted areas will be so shallow they no longer will serve as cover, and fish will be crowded into the deepest pools. Riparian vegetation may suffer from lack of water. Large fish will have difficulty migrating upstream over riffle areas. Water temperature often becomes a limiting factor, especially in the lower reaches of streams in July and August. Invertebrate life will be severly reduced. Fishing will often be bery good in the deeper pools and runs since fish will be concentrated. Many fishermen prefer this level of flow. However, fish may be vulnerable to overharvest. Floating is difficult even in a canoe or rubber raft. Natural beauty and stream esthetics are badly degraded. Most streams carry less than 10% of the average flow at times, so even this low level of flow will occasionally provide some enhancement over a natural flow regimen.

Figure 4. Republican River below Hardy Bridge, Nebraska, showing a flow of 12 cfs (10% of the average flow). Water depths were adequate to provide some fish cover, living space, movement, and fishing. Temperatures were within tolerable limits. This is a *minimum* instantaneous flow recommended to sustain short-term survival habitat for most aquatic life forms.

Thirty percent of the average flow: This is a base flow recommended to sustain good survival habitat for most aquatic life forms. Widths, depths, and velocities will generally be satisfactory (Figs. 2,5). The majority of the substrate will be covered with water, except for very wide, shallow riffle or shoal areas. Most side channels will carry some water. Gravel bars will be partially covered with water and many islands will provide wildlife nesting, denning, nursery, and refuge habitat. Streambanks will provide cover for fish and wildlife denning habitat in many reaches. Many runs and most pools will be deep enough to serve as cover for fishes. Riparian vegetation will not suffer from lack of water. Large fish can move over riffle areas. Water temperatures are not expected to become limiting in most stream segments. Invertebrate life is reduced but not expected to become a limiting factor in fish production. Water quality and quantity should be good for fishing, floating, and general recreation, especially with canoes, rubber rafts, and smaller shallow draft boats. Stream esthetics and natural beauty will generally be satisfactory.

Figure 5. Bighorn River below Boysen Dam, Wyoming, showing a flow of 100 cfs (30% of the average flow). Water depth was adequate for trout movement, spawning, incubation, and winter survival in most run and pool areas for a distance of 45 car miles downstream. This is a base flow recommended to sustain *good* survival habitat for most aquatic life forms.

Sixty percent of the average flow: This is a base flow recommended to provide excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreational uses. Channel widths, depths, and velocities will provide excellent aquatic habitat (Figs. 2,6). Most of the normal channel substrate will be covered with water, including many shallow riffle and shoal areas. Side channels that normally carry water will have adequate flows. Few gravel bars will be exposed, and the majority of islands will serve as wildlife nesting, denning, nursery, and refuge habitat. The majority of streambanks will provide cover for fish and safe denning areas for wildlife. Pools, runs, and riffles will be ade-

Donald L. Tennant

Figure 6. North Fork Shoshone River near Wapiti, Wyoming, showing a flow of 456 cfs (approximately 60% of the average flow). Water widths, depths, and velocities very good for fish and fishing in all riffles, runs and pools. This is a base flow recommended to provide *excellent* to *outstanding* habitat for most aquatic life forms during their primary periods of growth and for the majority of recreational uses.

quately covered with water and provide excellent feeding and nursery habitat for fishes. Riparian vegetation will have plenty of water. Fish migration is no problem in any riffle areas. Water temperatures are not expected to become limiting in any reach of the stream. Invertebrate life forms should be varied and abundant. Water quality and quantity is excellent for fishing and floating canoes, rafts, and larger boats, and for general recreation. Stream esthetics and natural beauty will be excellent to outstanding.

A flow of two to three times the average flow is often best for kayaks and whitewater canoeing. A flow of this magnitude is also preferable for larger boats with inboard or outboard motors, like those many people use on the annual Missouri and Yellowstone River floats held in June and July in Montana.

Recommendations

1. Request "instantaneous flows" to prevent flow releases from dams and diversion structures that are averaged over a day, month, or year, which permits erratic releases or even no flow at times.
2. Recommend that dual or multiple outlets to all dams be designed and constructed so that minimum flows of an appropriate temperature and quality to protect the aquatic environment can be by-passed at all times, including during drawdowns for safety inspections and emergency repairs.
3. Insist that costs for providing of instream flows to protect the aquatic environment downstream below dams be project costs, including costs for unforeseen emergency repairs and routine maintenance over the life of the project.
4. Justify only that portion of a stream flow required to fulfill specific instream needs. If fish need a flow of 100 cfs in a segment of stream where there are already legal requirements of 25 cfs for municipal water, 15 cfs for irrigation water transport, and 10 cfs for a U.S. Environmental Protection Agency water quality requirement, you logically and legally should have to justify a flow of only 50 cfs. Planners of water development projects may ask you to justify and apply benefit/cost ratios for fish to the 100 cfs flow because this makes their "project purpose" look more favorable on a comparable benefit/cost basis.
5. Stipulate that the downstream flow will not be less than the inflow to impoundments, whenever operators of water development projects cannot provide specific flow requirements. Make this an integral part of every flow regimen recommendation, preferably part of the same sentence.
6. Reduced releases to a stream should not exceed a vertical drop of 6 inches in 6 hours. Fluctuations greater than this may significantly degrade aquatic resources.
7. Request that maximum flows released from dams not exceed twice the average flow. Prolonged releases of clear water greater than this will cause severe bank erosion and degrade the downstream aquatic environment.
8. Use "undepleted" USGS hydrology data for flow recommendations that relate to the stream in its pristine conditions (e.g., before dams, diversion, pumps, etc.). Otherwise, recommendations from the Montana Method may relate to depleted stream conditions and result in less than ideal flows.
9. Avoid recommending minimum instantaneous stream flow regimens less than 10% of the average flow since they will result in catastrophic degradation to fish and wildlife resources and harm both the aquatic and riparian environments. Encourage lawmakers to pass legislation that would prevent diversions or regulation at dams, whenever it would reduce streamflow below this level. If water development projects cannot make it on 90% of the water carried by a stream, use of the remaining 10% probably won't justify their projects. Philosophically, it is a crime against nature to rob a stream of that last portion of water so vital to the life forms of the aquatic environment that developed there over eons of time.

Note: Complete copies of this report can be obtained free by writing U.S. Fish and Wildlife Service, Federal Building, Billings, Montana 59101.

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