Date of Report: July 1, 1995
LCMR Research Work Program 1993 - Abstract - Research
I. Project Title: STREAM FLOW PROTECTION

Program Manager: Ian Chisholm
Agency Affiliation: Minnesota Department of Natural Resources
Division of Fish and Wildlife
Address: Ecological Services Section
Box 25, 500 Lafayette Road
St. Paul, Minnesota 55155-4025
Phone: (612) 296-0781

A. Legal Citation M.L. 93 Chpt. 172, Sec. 14, Subd. 11(d)

Statement of Objectives:

We collect stream habitat data, use it to model the stream, and combine this stream habitat data with information on the habitat requirements of the aquatic community which is collected by our program under a different funding source. Ultimately, we will determine how much water needs to remain in a stream for aquatic life. These habitat-based protected flows will be established for all watersheds and monitored statewide.

Overall Project Results

Sampling Overview: We have completed data collection at 14 sites located in 8 of Minnesota's 39 major watersheds. The data sets for each of these sites include all of the information necessary to develop computer-based models of the physical habitat at each site. In general, data sets include hydraulic and physical information for three flows (high, medium, and low). Over the course of our project we have sampled at total of 51 flows (high, medium, or low) at 22 sites in 14 watersheds. We attempt to gather information from 2 sites within each watershed before developing our recommendations. From those 14 completed sites only three watersheds have enough information to develop recommendations at this time. Because of the variation in size and complexity of the watersheds in Minnesota, in many cases information from more than two sites within a watershed may be needed to properly protect aquatic habitat.

Modeling Overview: We have modeled a total of 9 sites, from 5 watersheds. Of those 9 sites, 2 were in the Yellow Medicine River watershed, 1 was in the Buffalo River watershed, 4 were in the Red Lake River watershed, 1 was in the Otter Tail River watershed, and one site was in the St. Croix River watershed. The 2 sites modeled in the Yellow Medicine River watershed represent all of the information needed to complete our stream flow protection recommendations.

Project Results Use and Dissemination: An important objective of this project is to enhance water management and policy activities, particularly in decisions involving protected flow levels for our streams. The groundwork for this has already begun through the Department task force dealing with instream flow issues. We have completed several major reports that deal directly with stream flow protection issues.

Yellow Medicine Watershed Package: The Yellow Medicine Watershed Package will be used cooperatively by the Department of Natural Resources' Divisions of Fish and Wildlife, and Waters. The package will be used to guide rule revisions to establish biologically sound streamflow protection levels for the Yellow Medicine Watershed. In various forms, the package will be distributed to user groups such as irrigators, anglers, and environmental groups to help them understand the issues relating to stream flow in the watershed. Resource managers will receive copies of the watershed package as an aid to help them make better decisions related to the resources of the Yellow Medicine Watershed.

St Croix Report: This report is being used by 1) the Winged Mapleleaf Recovery Team to help identify threats to *Q. fragosa* and to develop recommendations to minimize or eliminate these threats, 2) the Wisconsin Department of Natural Resources, who obtained funding for this project from the U.S. Fish and Wildlife Service, to help establish a flow regime from the hydroelectric dam that addresses the instream flow needs of the downstream aquatic community, and 3) the Minnesota Department of Natural Resources' Stream Habitat Program for setting protected flows in the Lower St. Croix River Watershed. Results from this study were presented at the July 1994 conference "Sustaining the Ecological Integrity of Large Floodplain Rivers" in LaCrosse, WI and will be presented at future national, regional, and state scientific meetings. These results will also be submitted for publication in peer-reviewed scientific journals.

Red Lake River Instream Flow Study: This instream flow study will be used by the U.S. Corp of Engineers to develop a more environmentally sound operation of the Red Lake dam on Lower Red Lake. It will also be incorporated into the watershed package for the Red Lake River watershed.

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Total Biennial LCMR Budget: $280,000
Balance: $0

This appropriation is from the future resources fund to the commissioner of natural resources to collect stream habitat data (width, depth, velocity, substrate, water elevation) in up to 39 watersheds to develop community-based flows that protect stream resources. This project must comply with the data compatibility requirements set forth in subdivision 14.

B. Data Compatible Language: Subd. 14; During the biennium ending June 30, 1995, the data collected by the projects funded under this section that have common value for natural resource planning and management must conform to information architecture as defined in guidelines and standards adopted by the information policy office. Data review committees may be established to develop or comment on plans for data integration and distribution and shall submit semiannual status reports to the legislative commission on Minnesota resources on their findings. In addition, the data must be provided to and integrated with the Minnesota land management information center's geographic databases with the integration costs borne by the activity receiving funding under this section.

C. Status of Match Requirement: Not Applicable

II. Project Summary:

We will collect stream habitat data, use it to model the stream, and combine this stream habitat data with information on the habitat requirements of the aquatic community which is collected by our program under a different funding source. Ultimately, we will determine how much water needs to remain in a stream for aquatic life. These habitat-based protected flows will be established for all watersheds and monitored statewide. Our results will be presented in the form of 'watershed packages' which are intended to summarize all pertinent information relating to watershed management activities on each river.

III. Statement of Objectives:

A. Begin collecting stream habitat information on the 39 major watersheds.
B. Begin developing community-based protected flows on the 39 major watersheds.

IV. Research Objectives

A. **Title of Objective**: Begin collecting stream habitat information on the 39 major watersheds

A.1. **Activity**: Select study sites on representative streams in selected watersheds and collect hydraulic and habitat data.

A.1.a. **Context within the project:** The Instream Flow Incremental Methodology (IFIM) will be used to assess the instream flow needs of aquatic communities in each of the 39 major watersheds. Because of the amount of data required for hydraulic modeling, this 2-year portion of the project will only begin to collect the necessary data in selected watersheds. Representative streams and appropriate sites will be selected from each of the 39 major watersheds. Streams in agricultural watersheds with significant present appropriations or which are prone to increasing future appropriations will be assessed first (Figure 1).

A.1.b. **Methods:** We will collect habitat and hydraulic data on each study stream. Field data will be collected in the following sequence: 1) establish transects describing habitat and hydraulic features, benchmark and headstakes; 2) survey headstake elevations; 3) survey water surface elevations at each transect; 4) measure velocity, depth, substrate and cover along each transect; 5) survey stream bed elevations at each transect; 6) sketch study site and take measurements needed to prepare site map; and, 7) determine station index values, assign weighing factors and photograph each transect.

Transects will be located to characterize both the hydraulic and microhabitat conditions of the study sites. At a minimum, five to seven transects will be established at each study site. Field measurements will be made at three or more flows (low, medium, and high) and stream discharge will be calculated for each transect.

A.1.c. **Materials:** Field materials necessary to accomplish this objective include: vehicles, velocity meters with top setting rods, tape(s), surveying equipment, waders, staff gages, headstakes, and data forms. A boat and transect cable with reel may be required for some larger rivers.

A.1.d. **Budget:** $188,000 **Balance:** $0

A.1.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Site Scoping	*****		*****		
Fieldwork	********	**********			****
Analysis and Report	**********	**********			

A. Status

Sampling Overview: We have completed data collection at 14 sites. The data sets for each of these sites include all of the information necessary to develop computer-based models of the physical habitat at each site. In general, data sets include hydraulic and physical information for three flows (high, medium, and low). The 14 sites are located in 8 of Minnesota's 39 major watersheds. From those 14 completed sites only three watersheds have enough information to develop recommendations at this time. Because of the variation in size and complexity of the watersheds in Minnesota, in many cases information from more than two sites within a watershed may be needed to properly protect aquatic habitat.

Total Sampling Effort: Over the course of our project we have sampled at total of 51 flows (high, medium, or low) at 22 sites in 14 watersheds . This represents a substantial effort under this objective, however only 3 watersheds currently have enough information to develop flow protection recommendations, or in other words, are considered completed watersheds. We anticipated that we would have completed 9 study sites, and would have enough information on the 9 watersheds to recommend protected flow regimes. However, a combination of high-flow water years and misjudging the amount of work necessary to adequately represent some of the large, complex watersheds, have demonstrated that our plans for completing 9 watersheds were unrealistic. Nevertheless, we have sampled many more study sites than we expected to, even with two sites (RedWood and Lac Qui Parle) having to be abandoned after 1993 flood flows significantly altered the channels.

Unpredictable Nature of Sampling: Because our sampling effort is contingent on certain naturally occurring events, it is difficult to predict and subsequently sample these events when they do occur. We target three flows at which we will collect information on the physical nature of Minnesota's streams and rivers. These flows may or may not occur in a given year. In a wet year, such as 1993, low flows may never occur or occur for only a very brief period, making it very difficult to plan sampling efforts. As a result it is difficult to reliably predict when sampling on any one watershed will be completed.

Future Efforts: During FY96-97, we will continue collecting data on stream habitat information (depth, velocity, substrate, width, water surface elevations, etc.,) for three flow ranges (low, medium, high), on representative streams in 4 of the 39 major watersheds. At this time, our targeted watersheds are: the Pomme de Terre, Wild Rice, Pelican River Subbasin of the Otter Tail, and the Cottonwood. The additional stream habitat information will complete modeling and recommendations for the 5 targeted watersheds.

B. Title of Objective: Begin developing community-based protected flows on the 39 major watersheds.

B.1. Activity: Model stream habitat data to predict changes in fish habitat with changes in flow.

B.1.a. Context within the project: Field data was be analyzed from representative streams to develop protected flows for aquatic communities on a watershed basis. A collection of models, developed by the US Fish and Wildlife Service, was used to predict changes in stream habitat with changes in flow at each of our study sites. Results from each site will be related to available USGS stream gages by watershed drainage area and other watershed characteristics.

B.1.b. Methods: Hydraulic and habitat modeling can be executed using any number of models and model options. Our general strategy will be to run various models and model combinations and compare their outputs to determine which is most appropriate for specific study sites. Once the hydraulic model is developed, criteria describing habitat types will be input into the model to predict how habitat changes in relation to changes in discharge. In addition, suitability criteria for appropriate representatives (game and nongame-fish, invertebrate, and amphibian species which are found in the river system) will be input into the model to determine relationships between suitable habitat for a species and discharge. Existing community characteristics and species composition will be determined from DNR and other (such as university) stream surveys and our own sampling done concurrently with collection of hydraulic data.

Protected flow recommendations will be based on the following criteria: 1) Protection of habitat and biodiversity of the aquatic community, 2) protection of habitat for rare and endangered species and, 3) protection of habitat for important game species. Prioritization of these criteria will be specific for each watershed. Community-based recommendations will be developed by examining the habitat-discharge relationships for appropriate habitat guild representatives and identifying a flow that yields the most diversity of habitat types for all species considered (Leonard and Orth 1988).

B.1.c. Materials: Materials necessary to accomplish this objective consist of high capacity computers and the software programs developed by the USFWS. The major equipment is in place and in use. Most of the staff has taken the training necessary to run the computer models competently and are experienced in analyzing the data.

B.1.d. Budget: $92,000 **Balance:** $0

B.1.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Data Analysis	**********	**********	**********	**********	**********
Develop Flows		**********	**********	******	
Interpretation and Report			**********	**********	**********

B. Status:

Modeling Overview: We have modeled a total of 9 sites, from 5 watersheds. Of those 9 sites, 2 were in the Yellow Medicine River watershed, 1 was in the Buffalo River watershed, 4 were in the Red Lake River watershed, 1 was in the Otter Tail River watershed, and one site was in the St. Croix River watershed. The 2 sites modeled in the Yellow Medicine River watershed represent all of the information needed to complete our stream flow protection recommendations.

Yellow Medicine Watershed Package: The Yellow Medicine Watershed Package has been completed. The important findings and recommendations taken directly from the report are as follows.

Bracketed Approach: The following bracket system has been established to determine when appropriations will be limited or suspended. When the discharge at the USGS gage is greater than 150% of the recommended flow, appropriators will be permitted to withdraw their full permitted amount. Total appropriations will be limited when the discharge is at or between 50% and 150% of the recommended flow. Within this bracket, appropriators within a watershed will be permitted to withdraw up to a total of 20% of the recommended flow. Below 50% of the recommended flow, all appropriations will be suspended.

Flow Recommendation: Under the bracket system, full appropriations will be permitted within the Yellow Medicine Watershed from 1 April through 15 May when the flow at the USGS gage is above 293 cfs. Appropriators can withdraw up to a combined total of 39 cfs (20% of 195 cfs) when the discharge is between 98 cfs and 293 cfs. Individual appropriators will be allowed to take their full permitted amounts at flows over 98 cfs if the total appropriations do not exceed 39 cfs. If the flow at the gage is less than 98 cfs, all withdrawals will be suspended. From 16 May through 31 March, during which the protected flow is 57 cfs, full appropriations will be allowed when the flow at the gage exceeds 86 cfs. Twenty percent of the recommended flow, or 11 cfs, can be withdrawn when the discharge at the gage is between 29 cfs and 86 cfs. Currently, the total permitted amount does not exceed 11 cfs; therefore, appropriators permitted at the present time will be able to take their full permitted amount at flows greater than 29 cfs. No appropriations would be allowed when the discharge at the gage drops below 29 cfs.

Summary of Recommendations: The following points summarize the recommendations made in this report for the Yellow Medicine Watershed:

- implement protected flows and enforce them according to the proposed bracket system

- consider the impacts of groundwater withdrawals within the riparian zone equal to impacts of surface water withdrawals
- protect channel-shaping and bankfull flows
- protect seasonal floodplain habitat
- protect connectivity within the watershed
- restore channelized reaches
- decrease sedimentation by improving land use practices

Implications: As discussed earlier, the Yellow Medicine frequently has very low flows which make it an unreliable source of water for irrigation. Flows tend to be very high following heavy rains or snowmelt when there is little need for irrigation and very low during dry periods when demand for irrigation is high. Because of common low flows, any future appropriations would compete directly with instream resources, and new protected flows will further limit periods during which water could be removed for irrigation and other uses.

St Croix Report: Results from this instream flow study are presented in the February 1995 report "Instream Flow Requirements of *Quadrula fragosa* and the Aquatic Community in the Lower St. Croix River Downstream of the Northern States Power Hydroelectric Dam at St. Croix Falls, Wisconsin.".

Introduction: A study was initiated in 1992 to examine the instream flow needs of *Quadrula fragosa* (winged mapleleaf), a federally endangered freshwater mussel, and the aquatic community in the Lower St. Croix River. The only known population of *Q. fragosa* in the world inhabits a 12-mile reach of the Lower St. Croix River downstream of the Northern States Power (NSP) hydroelectric peaking dam at St. Croix Falls, WI. The most important habitat for this rare mussel has been identified as a riffle in the east channel at Folsum Island, Interstate State Park. Flows in the Lower St. Croix River are highly regulated by the dam and much of the stream channel at Interstate State Park is dewatered daily during winter peaking operations. Concern among resource agencies that *Q. fragosa* and other mussels were being exposed to desiccation, freezing, predation, and ice abrasion during winter peaking operations provided the impetus for this instream flow study.

Results and Discussion: The availability of suitable mussel habitat in the Lower St. Croix River is strongly influenced by stream flow. Suitable mussel habitat is relatively abundant over the natural range of summer and winter flows (2000 to 4000 cfs). These flows also provide good habitat conditions for the macroinvertebrate and fish communities, as well as providing a diversity of habitat types. During peaking operations, flows rapidly fluctuate between low impounding flows (less than 2000 cfs) and high generation flows (greater than 4000 cfs); consequently, flows between 2000 and 4000 cfs occur only briefly. These daily fluctuations in flow typically exceed the most extreme natural seasonal flow fluctuations, especially low flow extremes. As flows drop below 2000 cfs, the availability of mussel habitat decreases sharply and rapid dewatering of the stream channel begins to occur. At 800 cfs, the minimum winter release from the dam, mussel habitat is severely limited due to low velocities, shallow depths, low habitat diversity, and a large loss of wetted area. The distribution of

mussels at Interstate Park appears to be restricted to areas that are not dewatered at a dam release of 800 cfs.

Based on 1) the hydrology of the Lower St. Croix River, 2) the relations between habitat availability and discharge, and 3) the impacts of peaking flows, a run-of-river flow regime was recommended to protect and restore the habitat of *Q. fragosa* and to protect the integrity of the aquatic community in the Lower St. Croix River downstream of the hydroelectric dam at St. Croix Falls, WI.

Instream Flow Study For the Red Lake River Near Lower Red Lake, MN: One site in the Red Lake River watershed has been used to address instream flow issues related to the operation of the Red Lake Dam, the study will be used as one component in the Red Lake River Watershed Package. In cooperation with the U.S. Corp of Engineers (USCOE), we conducted an instream flow study on the Red Lake River near lower Red Lake in Clearwater County, MN. The USCOE initiated the study as part of their evaluation and revision of the Operations Manual for the Red Lake Dam. The work will be used to help determine a more ecologically sound operation of the Red Lake Dam. In addition to addressing the operation of the Red Lake dam, the modeling and results will be used in the Red Lake River Watershed Package. Data were collected for us by the USCOE according to standard instream flow data collection practices. The data were analyzed by us as described in section B.1.b above.

Our analysis indicated the inadequacy of the aquatic habitat of the channelized reach of the Red Lake River for fish and mussels. We concluded that developing flow protection recommendations from channelized portions of rivers is ureliable due to the lack of habitat diversity in those reaches, and that stream flow protection of channelized reaches should be accomplished by relating results from unchannelized reaches to the channelized reaches.

We recommended that the dam not be operated for flood control or water supply purposes and that the channelized reach of the Red Lake River be restored to provide habitat for fish and mussels that was lost due to channelization.

Future Efforts: Final watershed packages will be complete for the St. Croix and Red Lake River watersheds by winter 1995. The emphasis for the FY96-97 biennium will be on completing the modeling and analysis of data collected during the first biennium using a habitat guild approach to the Instream Flow Incremental Methodology (IFIM). With the stream habitat information we have collected previously and that we will finish collecting this biennium, along with habitat suitability information also collected by the Division, we will model habitat relationships to flow. Our goal is to have final reports, with flow recommendations and supporting information, for 5 additional watersheds, (total of 8 watersheds) by the end of FY97. The targeted watersheds will be: the Otter Tail, Buffalo, Wild Rice, Cottonwood and Pomme de Terre.

V. **Evaluation:** For the FY94-95 biennium, this program can be evaluated by its ability to: 1) begin collecting data on representative streams in the 39 major watersheds. Our goal was to have complete data sets on 9 watersheds by the end of the first biennium. As originally proposed, this entailed collecting data on at least one stream per watershed, at two sites and 3 flows (low, medium and high) per stream. We have completed sampling at 14 sites, covering 8 watersheds. These watersheds are: Yellow Medicine, Red Lake, St. Croix, Otter Tail, Buffalo, Wild Rice, Pomme de Terre, and Cottonwood. Large, complex watersheds, like the Red Lake and Otter Tail necessitated multiple study sites for better representation of the watershed, as indicated under Section 'A. Status'. Because of high water years during the biennium, additional field work will be necessary during the FY96-97 on the Otter Tail, Wild Rice, Pomme de Terre and Cottonwood watersheds. Additionally, this project can be evaluated by its ability to 2) assess flows in these selected watersheds in terms of habitat requirements for fish species; and, 3) recommend protected flow levels for fish and wildlife in selected watersheds. For evaluation item 2): we have modeled 9 study sites. Along with the Yellow Medicine watershed package, we are presenting two studies with water management recommendations for the St. Croix River and the Red Lake River. These last two studies were prepared to guide multi-agency water management decisions on those river systems. The work for the St. Croix and Red Lake rivers will be converted to watershed package format for use in DNR flow recommendations by the end of 1995. In the long-term, the project should be evaluated on its ability to successfully use the information collected to implement an instream flow protection program that incorporates biological values in our state's water management decisions.

VI. **Context Within Field.** The ultimate goal of instream flow recommendations should be to maintain the integrity of the aquatic biota (Moyle and Baltz 1985). Efforts to protect integrity must recognize the diverse habitat needs of aquatic communities as well as the importance of seasonally dynamic flow regimes of stream ecosystems.

Since species diversity is related to both habitat diversity (Schlosser 1982) and flow regime (Horowitz 1978), protection of our diverse stream biota requires an approach which recognizes both the temporal and spacial diversity of habitat which natural streams provide. Aquatic biota have adapted their spawning, feeding and migratory strategies to natural flow regimes, and alterations of these flow regimes can have numerous negative effects on the stream ecosystem (Sparks 1992). The method we are using is widely accepted, from a scientific and legal basis, for establishing protected flows in streams based on their resource values (Reiser et al. 1989) and incorporates the seasonally changing flow and habitat needs of the stream ecosystem.

This project is aimed at changing the way we directly manage water appropriation from our river systems; providing a fundamental step towards biologically based decision-making. The information collected and developed by the project will serve as a basis, within the Department, to begin the rulemaking process for establishing protected flows on our streams. Additional benefits in defining the relationships between various vertebrate and invertebrate species, stream habitat characteristics and flow may result when the data are integrated with

a state GIS, but are considered secondary to the primary study objective of developing community-based protected flows on a statewide basis.

VII. Benefits: During the drought of 1976, protected flows were established on more than 30 streams in Minnesota based only on hydrologic statistics. The more recent drought in 1987 has shown that these emergency measures are inadequate to protect aquatic life in our streams. The funding is being used to provide stream data that is integral to our overall stream protection efforts. Developing data on the habitat requirements of stream organisms, coordinating program activities and implementing protected flows are other components of the overall stream protection program that this project serves. Information collected will begin a process to integrate biology into water management decisions affecting stream flows. This initiative is the first statewide program in the US designed to use a community approach with IFIM to develop protected flows for warmwater streams.

Habitat for the entire aquatic community will become a primary decision criteria in establishing protected flows on streams, thereby protecting stream community diversity. Our Yellow Medicine Watershed Package is the template for future presentations of our results and is intended to furnish the information necessary to establish ecologically meaningful and defendable instream flow recommendations. The watershed packages propose a 'bracketed approach' to managing water withdrawals, where appropriation is allowed within the bracket, but at a level that minimizes impact to the resource, and include an analysis of impacts to current users that reviews the historical record, and shows the percent time users will be impacted. Using the watershed packages and the IFIM, we will be able to develop recommended flows in a framework that allows tradeoff analysis between in-stream and off-stream uses. Results from this work will provide the legal and institutional systems with information to realistically evaluate water appropriations and control intra- and inter-state water diversions. In addition, we have used the data collected under this project to guide decision-makers in related issues of water management for regulation of Lower Red Lake Dam and the St. Croix Falls dam.

VIII. Dissemination: An important objective of this project is to enhance water management and policy activities, particularly in decisions involving protected flow levels for our streams. The groundwork for this has already begun through the Department task force dealing with instream flow issues.

As detailed in section B: Status above, we have completed several major reports (copies enclosed with the Detailed Report and available from Program Manager). Each deals directly with stream flow protection issues as discussed in this final report.

Yellow Medicine Watershed Package: The Yellow Medicine Watershed Package will be used cooperatively by the Department of Natural Resources' Divisions of Fish and Wildlife, and Waters. The package will be used to guide rule revisions to establish biologically sound streamflow protection levels for the Yellow Medicine Watershed. In various forms, the pac[illegible] will be distributed to user groups such as irrigators, angl[illegible] and environmental

groups to help them understand the issues relating to stream flow in the watershed. Resource managers will receive copies of the watershed package as an aid to help them make better decisions related to the resources of the Yellow Medicine Watershed.

St Croix Report: This report is being used by 1) the Winged Mapleleaf Recovery Team to help identify threats to *Q. fragosa* and to develop recommendations to minimize or eliminate these threats, 2) the Wisconsin Department of Natural Resources, who obtained funding for this project from the U.S. Fish and Wildlife Service, to help establish a flow regime from the hydroelectric dam that addresses the instream flow needs of the downstream aquatic community, and 3) the Minnesota Department of Natural Resources' Stream Habitat Program for setting protected flows in the Lower St. Croix River Watershed.

Red Lake River Instream Flow Study: This instream flow study will be used by the U.S. Corp of Engineers to develop a more environmentally sound operation of the Red Lake dam on Lower Red Lake. It will also be incorporated into the watershed package for the Red Lake River watershed.

IX. Time: Stewardship of our watersheds requires an extensive commitment. The intent of this project is to establish a data collection program that will be operable for a minimum of 9-12 years at this funding level. Funding beyond the FY96-97 biennium will continue to be requested from LCMR.

X. Cooperation:
Dr. Luther Aadland, Instream Flow Team
Fergus Falls, Minnesota Department of Natural Resources

A fisheries research biologist with extensive instream flow experience, Dr. Aadland's primary role will be to coordinate all field activities of the project and direct the data analysis.

XI. Reporting Requirements:
Semi-annual reports will be submitted not later than January 1, 1994, July 1, 1994, January 1, 1995, and a final status report by June 30, 1995.

XII. Literature Cited:

Horowitz, R.J. 1978. Temporal variability patterns and the distributional patterns of stream fishes. Ecological Monographs 48:307-321.

Leonard, P.M. and D.J. Orth. 1988. Use of habitat guilds of fishes to determine instream flow requirements. North American Journal of Fisheries Management 8 (4):399-409.

Moyle, P.B., and D.M. Baltz. 1985. Microhabitat use by an assemblage of California stream fishes: developing criteria for instream flow determinations. Transactions of the American Fish[illegible] Society 114:695-704.

Reiser, D.W., T.A. Wesche, and C. Estes. 1989. Status if instream flow legislation and practices in North America. Fisheries 14(2):22-29.

Schlosser, I.J. 1982. Trophic structure, reproductive success, and growth rate of fishes in a natural and modified headwater streams. Canadian Journal of Fisheries and Aquatic Sciences. 39:968-978.

Sparks, R.E. 1992. Risks of altering the hydrologic regime of large river. Pages 119-152 in J. Cairns, Jr., B.R. Niederlehner, and D.R. Orvos, eds. Predicting Ecosystem Risk. Advances in Modern Environmental Toxicology. Volume XX. Princeton Scientific Publishing Company, Inc. Princeton, NJ. 347 p.

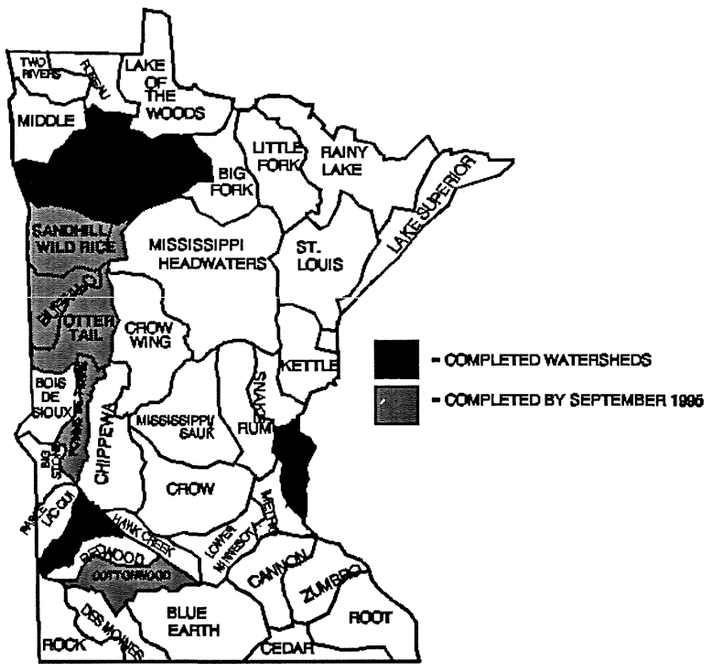

Figure 1. Map of the 39 major watersheds of Minnesota, showing the study watersheds and status of data collection. The watersheds where data collection is complete are (clockwise, from top left to bottom left): Red Lake, St. Croix, and Yellow Medicine.

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Red Lake River Instream Flow Study: This instream flow study will be used by the U.S. Corp of Engineers to develop a more environmentally sound operation of the Red Lake dam on Lower Red Lake. It will also be incorporated into the watershed package for the Red Lake River watershed.

I. Project Title: STREAM FLOW PROTECTION

Program Manager: Ian Chisholm
Agency Affiliation: Minnesota Department of Natural Resources
Division of Fish and Wildlife
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A. Legal Citation M.L. 93 Chpt. 172, Sec. 14, Subd. 11(d)

Total Biennial LCMR Budget: $280,000
Balance: $0

This appropriation is from the future resources fund to the commissioner of natural resources to collect stream habitat data (width, depth, velocity, substrate, water elevation) in up to 39 watersheds to develop community-based flows that protect stream resources. This project must comply with the data compatibility requirements set forth in subdivision 14.

B. Data Compatible Language: Subd. 14; During the biennium ending June 30, 1995, the data collected by the projects funded under this section that have common value for natural resource planning and management must conform to information architecture as defined in guidelines and standards adopted by the information policy office. Data review committees may be established to develop or comment on plans for data integration and distribution and shall submit semiannual status reports to the legislative commission on Minnesota resources on their findings. In addition, the data must be provided to and integrated with the Minnesota land management information center's geographic databases with the integration costs borne by the activity receiving funding under this section.

C. Status of Match Requirement: Not Applicable

II. Project Summary:

Introduction: In 1976, Minnesota went through a drought that stimulated legislation to manage our surface waters. At that time, river management in the US as a whole was largely an art, not a science (Stalnaker 1994). As a consequence, we established protected flows using hydrologic statistics, like the currently used 90% exceedence flow, that had little or no relation to the values we were trying to protect. However, as Dr. Tom Waters, of the University of Minnesota noted, "To preserve river values, our streams must be deliberately managed for diversity - not just for the canoeist, not just for the species of fish that provide sport to the angler, but rather for the myriad life forms that, living interdependently, are unique to flowing waters." (Waters 1977). The current Stream Flow Protection Program strives to protect the riverine habitat of Minnesota's rivers and streams by quantifying and protecting habitat diversity. Most of Minnesota's rivers and streams have suffered from habitat degradation of one form or another. The range of human activities that are potentially damaging to river systems is staggering (Boon 1992). Of these, few are decreasing in intensity or remaining stable. One avoidable way that these riverine habitats have been degraded in Minnesota is through the withdrawal of water for off-stream uses such as agriculture and industry. When we withdraw water from our rivers, we generally lessen the amount of riverine habitat and affect the processes, physical and biological, that are occurring within them.

Summary: To preserve river systems and the values they provide, protected flows are established. Protected flows refer to the amount of water left in a stream for fish and other instream values. Quantifying the habitat lost by water withdrawals allows managers to examine tradeoffs between uses and the most widely recognized method for developing instream flow recommendations is the Instream Flow Incremental Methodology (IFIM). There are two primary data collection elements necessary for establishing IFIM based protected flows: 1) collection of stream data to enable modeling of stream conditions, and 2) collection of habitat requirements for targeted stream fish and invertebrates. This LCMR program is designed to accomplish item (1). Under this funding we will collect stream habitat data, use it to model the stream, and combine this stream habitat data with information on the habitat requirements of the aquatic community which is collected by our program under a different funding source. Ultimately, we will determine how much water needs to remain in a stream for aquatic life. These habitat-based protected flows will be established for all watersheds and monitored statewide. Our results will be presented in the form of 'watershed packages' which are intended to summarize all pertinent information relating to watershed management activities on each river.

III. Statement of Objectives:

A. Begin collecting stream habitat information on the 39 major watersheds.
B. Begin developing community-based protected flows on the 39 major watersheds.

IV. Research Objectives

A. Title of Objective: Begin collecting stream habitat information on the 39 major watersheds

A.1. Activity: Select study sites on representative streams in selected watersheds and collect hydraulic and habitat data.

A.1.a. Context within the project: The Instream Flow Incremental Methodology (IFIM) will be used to assess the instream flow needs of aquatic communities in each of the 39 major watersheds. Because of the amount of data required for hydraulic modeling, this 2-year portion of the project will only begin to collect the necessary data in selected watersheds. Representative streams and appropriate sites will be selected from each of the 39 major watersheds. Streams in agricultural watersheds with significant present appropriations or which are prone to increasing future appropriations will be assessed first (Figure one).

A.1.b. Methods: We will collect habitat and hydraulic data on each study stream. Field data will be collected in the following sequence: 1) establish transects describing habitat and hydraulic features, benchmark and headstakes; 2) survey headstake elevations; 3) survey water surface elevations at each transect; 4) measure velocity, depth, substrate and cover along each transect; 5) survey stream bed elevations at each transect; 6) sketch study site and take measurements needed to prepare site map; and, 7) determine station index values, assign weighing factors and photograph each transect.

Transects will be located to characterize both the hydraulic and microhabitat conditions of the study sites. At a minimum, five to seven transects will be established at each study site. Field measurements will be made at three or more flows (low, medium, and high) and stream discharge will be calculated for each transect.

A.1.c. Materials: Field materials necessary to accomplish this objective include: vehicles, velocity meters with top setting rods, tape(s), surveying equipment, waders, staff gages, headstakes, and data forms. A boat and transect cable with reel may be required for some larger rivers.

A.1.d. Budget: $188,000 **Balance:** $0

A.1.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Site Scoping	*****		*****		
Fieldwork	********	**********			****
Analysis and Report	**********		**********		

A. Status

Sampling Overview: We have completed data collection at 14 sites. The data sets for each of these sites include all of the information necessary to develop computer-based models of the physical habitat at each site. In general, data sets include hydraulic and physical information for three flows (high, medium, and low). The 14 sites are located in 8 of Minnesota's 39 major watersheds. As mentioned previously, we attempt to gather information from 2 sites within each watershed before developing our recommendations (Objective B). From those 14 completed sites only three watersheds have enough information to develop recommendations at this time. Because of the variation in size and complexity of the watersheds in Minnesota, in many cases information from more than two sites within a watershed may be needed to properly protect aquatic habitat. For example, the Red Lake River watershed is very large and complex, it has two main rivers that need to be incorporated into a protection regime for the watershed as a whole. Because the Red Lake Watershed has two main tributaries, the Red Lake and Clearwater rivers, each with a somewhat different character, we need to place two study sites on each river.

Total Sampling Effort: Over the course of our project we have sampled at total of 51 flows (high, medium, or low) at 22 sites in 14 watersheds (Table 1). This represents a

substantial effort under this objective, however only 3 watersheds currently have enough information to develop flow protection recommendations, or in other words, are considered completed watersheds. We anticipated that we would have completed 9 study sites, and would have enough information on the 9 watersheds to recommend protected flow regimes. However, a combination of high-flow water years and misjudging the amount of work necessary to adequately represent some of the large, complex watersheds, have demonstrated that our plans for completing 9 watersheds were unrealistic. Nevertheless, we have sampled many more study sites than we expected to, even with two sites (RedWood and Lac Qui Parle) having to be abandoned after 1993 flood flows significantly altered the channels.

Unpredictable Nature of Sampling: Because our sampling effort is contingent on certain naturally occurring events, it is difficult to predict and subsequently sample these events when they do occur. We target three flows at which we will collect information on the physical nature of Minnesota's streams and rivers. These flows may or may not occur in a given year. In a wet year, such as 1993, low flows may never occur or occur for only a very brief period, making it very difficult to plan sampling efforts. As a result it is difficult to reliably predict when sampling on any one watershed will be completed. Although it may be difficult to complete a sampling effort for one watershed because of persistent high or low water, it is often possible to work in other watersheds, ones that have either not yet been sampled or that need additional information to begin modeling.

Future Efforts: During FY96-97, we will continue collecting data on stream habitat information (depth, velocity, substrate, width, water surface elevations, etc.,) for three flow ranges (low, medium, high), on representative streams in 4 of the 39 major watersheds. At this time, our targeted watersheds are: the Pomme de Terre, Wild Rice, Pelican River Subbasin of the Otter Tail, and the Cottonwood. The additional stream habitat information will complete modeling and recommendations for the 5 targeted watersheds.

B. Title of Objective: Begin developing community-based protected flows on the 39 major watersheds.

B.1. Activity: Model stream habitat data to predict changes in fish habitat with changes in flow.

B.1.a. Context within the project: Field data was be analyzed from representative streams to develop protected flows for aquatic communities on a watershed basis. A collection of models, developed by the US Fish and Wildlife Service, was used to predict changes in stream habitat with changes in flow at each of our study sites. Results from each site will be related to available USGS stream gages by watershed drainage area and other watershed characteristics.

B.1.b. Methods: Hydraulic and habitat modeling can be executed using any number of models and model options. Our general strategy will be to run various models and model combinations and compare their outputs to determine which is most appropriate for specific study sites. Once the hydraulic model is developed,

criteria describing habitat types will be input into the model to predict how habitat changes in relation to changes in discharge. In addition, suitability criteria for appropriate representatives (game and nongame-fish, invertebrate, and amphibian species which are found in the river system) will be input into the model to determine relationships between suitable habitat for a species and discharge. Existing community characteristics and species composition will be determined from DNR and other (such as university) stream surveys and our own sampling done concurrently with collection of hydraulic data.

Protected flow recommendations will be based on the following criteria: 1) Protection of habitat and biodiversity of the aquatic community, 2) protection of habitat for rare and endangered species and, 3) protection of habitat for important game species. Prioritization of these criteria will be specific for each watershed. Community-based recommendations will be developed by examining the habitat-discharge relationships for appropriate habitat guild representatives and identifying a flow that yields the most diversity of habitat types for all species considered (Leonard and Orth 1988).

B.1.c. Materials: Materials necessary to accomplish this objective consist of high capacity computers and the software programs developed by the USFWS. The major equipment is in place and in use. Most of the staff has taken the training necessary to run the computer models competently and are experienced in analyzing the data.

B.1.d. Budget: $92,000 **Balance:** $0

B.1.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Data Analysis	**********	**********	**********	**********	**********
Develop Flows		**********	**********	******	
Interpretation and Report			**********	**********	**********

B. Status:

Modeling Overview: We have modeled a total of 9 sites, from 5 watersheds. Of those 9 sites, 2 were in the Yellow Medicine River watershed, 1 was in the Buffalo River watershed, 4 were in the Red Lake River watershed, 1 was in the Otter Tail River watershed, and one site was in the St. Croix River watershed. The 2 sites modeled in the Yellow Medicine River watershed represent all of the information needed to complete our stream flow protection recommendations. We will need to complete sampling on another site in the Buffalo River watershed before we can recommend a protected flow regime for that watershed. Although we have already completed modeling on four sites within the Red Lake River watershed, because of the size and complexity of the watershed, we felt that modeling from an additional site was needed. Within the Red Lake River watershed there are two main tributaries, the Red Lake and the Clearwater Rivers, as described previously, the character of the two rivers is

sufficiently different to warrant placing study sites on each river. Although a recommendation will be made for the watershed as a whole, it is important to understand the nature of the watersheds flow regime, habitat, and aquatic community to recommend a flow regime that will provide adequate protection to the entire watershed.

Yellow Medicine Watershed Package: The Yellow Medicine Watershed Package has been completed and is included with this final report as Attachment A. The important findings and recommendations taken directly from the report are as follows.

Bracketed Approach: Abruptly shutting off all appropriators within a watershed as soon as the flow at the USGS gage drops down to the recommended flow is not ideal for appropriators, the riverine ecosystem, or regulators. Therefore, the following bracket system has been established to determine when appropriations will be limited or suspended. When the discharge at the USGS gage is greater than 150% of the recommended flow, appropriators will be permitted to withdraw their full permitted amount. Total appropriations will be limited when the discharge is at or between 50% and 150% of the recommended flow. That bracket width was chosen because: 1) it is sufficiently wide to be useful as a management tool, 2) it encompasses flows which provide the most habitat for most species, and 3) it simultaneously allows for some water use while protecting stream resources. Within this bracket, appropriators within a watershed will be permitted to withdraw up to a total of 20% of the recommended flow. The 20% cap is based on analyses of historic flow data, comparison of various appropriation scenarios, and resulting changes to the stream hydrograph. Below 50% of the recommended flow, all appropriations will be suspended.

Flow Recommendation: Under the bracket system, full appropriations will be permitted within the Yellow Medicine Watershed from 1 April through 15 May when the flow at the USGS gage is above 293 cfs. Appropriators can withdraw up to a combined total of 39 cfs (20% of 195 cfs) when the discharge is between 98 cfs and 293 cfs. Individual appropriators will be allowed to take their full permitted amounts at flows over 98 cfs if the total appropriations do not exceed 39 cfs. If the flow at the gage is less than 98 cfs, all withdrawals will be suspended. From 16 May through 31 March, during which the protected flow is 57 cfs, full appropriations will be allowed when the flow at the gage exceeds 86 cfs. Twenty percent of the recommended flow, or 11 cfs, can be withdrawn when the discharge at the gage is between 29 cfs and 86 cfs. Currently, the total permitted amount does not exceed 11 cfs; therefore, appropriators permitted at the present time will be able to take their full permitted amount at flows greater than 29 cfs. No appropriations will be allowed when the discharge at the gage drops below 29 cfs.

Summary of Recommendations: The following points summarize the recommendations made in this report for the Yellow Medicine Watershed:

- implement protected flows and enforce them according to the proposed bracket system
- consider the impacts of groundwater withdrawals within the riparian zone equal to impacts of surface water withdrawals
- protect channel-shaping and bankfull flows
- protect [illegible]al floodplain habitat

- protect connectivity within the watershed
- restore channelized reaches
- decrease sedimentation by improving land use practices

Implications: As discussed earlier, the Yellow Medicine frequently has very low flows which make it an unreliable source of water for irrigation. Flows tend to be very high following heavy rains or snowmelt when there is little need for irrigation and very low during dry periods when demand for irrigation is high. Because of common low flows, any future appropriations would compete directly with instream resources, and new protected flows will further limit periods during which water could be removed for irrigation and other uses. Based on historical flows and our recommended protected flows, appropriators in the past would have been allowed to withdraw water from the Yellow Medicine River 70% of the time in late May, 66% in June, 52% in July, and 31% in August. These percentages do not, however, give a true picture of flow availability and reliability. For instance, during June, July, and August of 1932-1937, average stream flow was 3.9 cfs and appropriators would have been allowed to irrigate only 2% of the time under the recommended protected flows. In contrast, during the same months of 1990-1992, stream flow averaged 384 cfs and appropriators would have been allowed to irrigate 100% of the time. This instability of stream flow makes any future reliance on the Yellow Medicine River for irrigation tenuous with or without flow protection.

St Croix Report: Results from this instream flow study are presented in the February 1995 report "Instream Flow Requirements of *Quadrula fragosa* and the Aquatic Community in the Lower St. Croix River Downstream of the Northern States Power Hydroelectric Dam at St. Croix Falls, Wisconsin.", included in this final report as Attachment B.

Introduction: A study was initiated in 1992 to examine the instream flow needs of *Quadrula fragosa* (winged mapleleaf), a federally endangered freshwater mussel, and the aquatic community in the Lower St. Croix River. The only known population of *Q. fragosa* in the world inhabits a 12-mile reach of the Lower St. Croix River downstream of the Northern States Power (NSP) hydroelectric peaking dam at St. Croix Falls, WI. The most important habitat for this rare mussel has been identified as a riffle in the east channel at Folsum Island, Interstate State Park. Flows in the Lower St. Croix River are highly regulated by the dam and much of the stream channel at Interstate State Park is dewatered daily during winter peaking operations. Concern among resource agencies that *Q. fragosa* and other mussels were being exposed to desiccation, freezing, predation, and ice abrasion during winter peaking operations provided the impetus for this instream flow study.

Methods: The instream flow needs of *Q. fragosa* and the aquatic community were assessed using the standard application of the IFIM and PHABSIM as described in section B.1.b above. Two PHABSIM hydraulic study sites were selected: one at Interstate State Park, MN and WI, and the other at Franconia, MN. The Interstate State Park site was selected to encompass the critical riffle area located in the east channel at Folsum Island, and the Franconia site was selected to represent the 12-mile

stretch of the St. Croix River where *Q. fragosa* have been found. Site-specific mussel habitat suitability criteria were developed from mussel habitat-use data collected at Interstate State Park by Hornbach (1992).

Results and Discussion: The availability of suitable mussel habitat in the Lower St. Croix River is strongly influenced by stream flow. Suitable mussel habitat is relatively abundant over the natural range of summer and winter flows (2000 to 4000 cfs). These flows also provide good habitat conditions for the macroinvertebrate and fish communities, as well as providing a diversity of habitat types. During peaking operations, flows rapidly fluctuate between low impounding flows (less than 2000 cfs) and high generation flows (greater than 4000 cfs); consequently, flows between 2000 and 4000 cfs occur only briefly. These daily fluctuations in flow typically exceed the most extreme natural seasonal flow fluctuations, especially low flow extremes. As flows drop below 2000 cfs, the availability of mussel habitat decreases sharply and rapid dewatering of the stream channel begins to occur. At 800 cfs, the minimum winter release from the dam, mussel habitat is severely limited due to low velocities, shallow depths, low habitat diversity, and a large loss of wetted area. The distribution of mussels at Interstate Park appears to be restricted to areas that are not dewatered at a dam release of 800 cfs.

Based on 1) the hydrology of the Lower St. Croix River, 2) the relations between habitat availability and discharge, and 3) the impacts of peaking flows, a run-of-river flow regime was recommended to protect and restore the habitat of *Q. fragosa* and to protect the integrity of the aquatic community in the Lower St. Croix River downstream of the hydroelectric dam at St. Croix Falls, WI.

Instream Flow Study For the Red Lake River Near Lower Red Lake, MN: One site in the Red Lake River watershed has been used to address instream flow issues related to the operation of the Red Lake Dam, the study has been included with this report as Attachment C, and will be used as one component in the Red Lake River Watershed Package forthcoming. In cooperation with the U.S. Corp of Engineers (USCOE), we conducted an instream flow study on the Red Lake River near lower Red Lake in Clearwater County, MN. The study was initiated by the USCOE as part of their evaluation and revision of the Operations Manual for the Red Lake Dam. The study will be used to help determine a more environmentally friendly operation of the Red Lake Dam. In addition to addressing the operation of the Red Lake dam, the modeling and results will be used in the Red Lake River Watershed Package. Data were collected for us by the USCOE according to standard instream flow data collection practices. The data were analyzed by us as described in section B.1.b above.

Our analysis indicated the inadequacy of the aquatic habitat of the channelized reach of the Red Lake River for fish and mussels. We concluded that developing flow protection recommendations from channelized portions of rivers is unreliable due to the lack of habitat diversity in those reaches, and that stream flow protection of channelized reaches should be accomplished by relating results from unchannelized reaches to the channelized reaches.

We recommended that the dam not be operated for flood control or water supply purposes and that the channelized reach of the Red Lake River be restored to provide habitat for fish and mussels that was lost due to channelization.

Future Efforts: Final watershed packages will be complete for the St. Croix and Red Lake River watersheds by winter 1995. The emphasis for the FY96-97 biennium will be on completing the modeling and analysis of data collected during the first biennium using a habitat guild approach to the Instream Flow Incremental Methodology (IFIM). With the stream habitat information we have collected previously and that we will finish collecting this biennium, along with habitat suitability information also collected by the Division, we will model habitat relationships to flow. Our goal is to have final reports, with flow recommendations and supporting information, for 5 additional watersheds, (total of 8 watersheds) by the end of FY97. The targeted watersheds will be: the Otter Tail, Buffalo, Wild Rice, Cottonwood and Pomme de Terre.

V. **Evaluation:** For the FY94-95 biennium, this program can be evaluated by its ability to: 1) begin collecting data on representative streams in the 39 major watersheds. Our goal was to have complete data sets on 9 watersheds by the end of the first biennium. As originally proposed, this entailed collecting data on at least one stream per watershed, at two sites and 3 flows (low, medium and high) per stream. We have completed sampling at 14 sites, covering 8 watersheds. These watersheds are: Yellow Medicine, Red Lake, St. Croix, Otter Tail, Buffalo, Wild Rice, Pomme de Terre, and Cottonwood. Large, complex watersheds, like the Red Lake and Otter Tail necessitated multiple study sites for better representation of the watershed, as indicated under Section 'A. Status'. The specific river sites are identified, and the status of data collection at each site is furnished in Table 1, at the end of this report. Because of high water years during the biennium, additional field work will be necessary during the FY96-97 on the Otter Tail, Wild Rice, Pomme de Terre and Cottonwood watersheds. Additionally, this project can be evaluated by its ability to 2) assess flows in these selected watersheds in terms of habitat requirements for fish species; and, 3) recommend protected flow levels for fish and wildlife in selected watersheds. For evaluation item 2): we have modeled 9 study sites. The 2 sites modeled in the Yellow Medicine River represent all of the information needed to complete our stream flow protection recommendations for this watershed. In addition to this watershed package, we are presenting two studies with water management recommendations for the St. Croix River and the Red Lake River. These last two studies were prepared to guide multi-agency water management decisions on those river systems. The work for the St. Croix and Red Lake rivers will be converted to watershed package format for use as a DNR flow recommendation by the end of 1995. In the long-term, the project should be evaluated on its ability to successfully use the information collected to implement an instream flow protection program that incorporates biological values in our state's water management decisions.

VI. **Context Within Field.** The ultimate goal of instream flow recommendations should be to maintain the integrity of the aquatic biota (Moyle and Baltz 1985). Efforts to protect integrity must recognize the diverse habitat needs of aquatic communities as well as the importance of seasonally dynamic flow regimes of stream ecosystems.

Minnesota's streams harbor a diversity of fish, mussels, and other aquatic organisms which have specific habitat and stream flow requirements (Phillips et al. 1982; Cummings and Mayer 1992; Aadland 1993; Hart 1995). Since habitat in streams is a function of flow (Leopold et al.1964; Bovee 1982; Leonard and Orth 1988; Aadland 1993), extraction, regulation, and other anthropogenic alterations in flow directly alter habitat availability. Loss of or changes in habitat as a result of flow alteration and other factors can cause subsequent changes in abundance of fish (Orth and Maughan 1982; Schlosser 1985), mussels (Miller et al. 1984) and other invertebrates (Gislason), changes in fish community structure (Schlosser 1982; Schlosser 1985), and ultimately extinction of species of fish (Miller et al. 1989) and mussels (Williams et al. 1993).

Since species diversity is related to both habitat diversity (Schlosser 1982) and flow regime (Horowitz 1978), protection of our diverse stream biota requires an approach which recognizes both the temporal and spacial diversity of habitat which natural streams provide. Aquatic biota have adapted their spawning, feeding and migratory strategies to natural flow regimes, and alterations of these flow regimes can have numerous negative effects on the stream ecosystem (Sparks 1992). The method we are using is widely accepted, from a scientific and legal basis, for establishing protected flows in streams based on their resource values (Reiser et al. 1989; Trihey and Stalnaker 1985; Gordon et al. 1992) and incorporates the seasonally changing flow and habitat needs of the stream ecosystem.

Our work is not intended to supplant protection of our wetlands or restoration of watersheds through integrated resource management. This project is aimed at changing the way we directly manage water appropriation from our river systems; providing a fundamental step towards biologically based decision-making. The information collected and developed by the project will serve as a basis, within the Department, to begin the rulemaking process for establishing protected flows on our streams. Additional benefits in defining the relationships between various vertebrate and invertebrate species, stream habitat characteristics and flow may result when the data are integrated with a state GIS, but are considered secondary to the primary study objective of developing community-based protected flows on a statewide basis.

VII. **Benefits:** During the drought of 1976, protected flows were established on more than 30 streams in Minnesota based only on hydrologic statistics. The more recent drought in 1987 has shown that these emergency measures are inadequate to protect aquatic life in our streams. The funding is being used to provide stream data that is integral to our overall stream protection efforts. Developing data on the habitat requirements of stream organisms, coordinating program activities and implementing protected flows are other components of the overall stream protection program that this project serves. Information collected will begin a process to integrate biology into water management decisions affecting stream flows. This initiative is the first statewide program in the US designed to use a community approach with IFIM to develop protected flows for warmwater streams.

Habitat for the entire aquatic community will become a primary decision criteria in establishing protected flows on streams, thereby protecting stream community diversity. Our Yellow Medicine Watershed Package is the template for future presentations of our results

and is intended to furnish the information necessary to establish ecologically meaningful and defendable instream flow recommendations. The watershed packages propose a 'bracketed approach' to managing water withdrawals, where appropriation is allowed within the bracket, but at a level that minimizes impact to the resource, and include an analysis of impacts to current users that reviews the historical record, and shows the percent time users will be impacted. Using the watershed packages and the IFIM, we will be able to develop recommended flows in a framework that allows tradeoff analysis between in-stream and off-stream uses. Results from this work will provide the legal and institutional systems with information to realistically evaluate water appropriations and control intra- and inter-state water diversions.

In addition, we have used the data collected under this project to guide decision-makers in related issues of water management for regulation of Lower Red Lake Dam and the St. Croix Falls dam. These accomplishments demonstrate that this program is actively integrating with other facets of the MNDNR mission to protect or enhance the resources of Minnesota.

VIII. Dissemination: Results from this project will be presented at national, regional and state scientific meetings to peers in the fisheries and water management fields. Following presentations, the results will be published, in various forms, in peer-reviewed scientific journals. An important objective of this project is to enhance water management and policy activities, particularly in decisions involving protected flow levels for our streams. The groundwork for this has already begun through the Department task force dealing with instream flow issues.

As detailed in section B: Status above, we have completed several major reports. Each deals directly with stream flow protection issues as discussed in this final report.

Yellow Medicine Watershed Package: The Yellow Medicine Watershed Package will be used cooperatively by the Department of Natural Resources' Divisions of Fish and Wildlife, and Waters. The package will be used to guide rule revisions to establish biologically sound streamflow protection levels for the Yellow Medicine Watershed. In various forms, the package will be distributed to user groups such as irrigators, anglers, and environmental groups to help them understand the issues relating to stream flow in the watershed. Resource managers will receive copies of the watershed package as an aid to help them make better decisions related to the resources of the Yellow Medicine Watershed.

St Croix Report: This report is being used by 1) the Winged Mapleleaf Recovery Team to help identify threats to *Q. fragosa* and to develop recommendations to minimize or eliminate these threats, 2) the Wisconsin Department of Natural Resources, who obtained funding for this project from the U.S. Fish and Wildlife Service, to help establish a flow regime from the hydroelectric dam that addresses the instream flow needs of the downstream aquatic community, and 3) the Minnesota Department of Natural Resources' Stream Habitat Program for setting protected flows in the Lower St. Croix River Watershed.

Results from this study were presented at the July 1994 conference "Sustaining the Ecological Integrity of Large Floodplain Rivers" in LaCrosse, WI and will be presented at future national, regional, and state scientific meetings. These results will also be submitted for publication in peer-reviewed scientific journals.

Red Lake River Instream Flow Study: This instream flow study will be used by the U.S. Corp of Engineers to develop a more environmentally sound operation of the Red Lake dam on Lower Red Lake. It will also be incorporated into the watershed package for the Red Lake River watershed.

IX. Time: Stewardship of our watersheds requires an extensive commitment. The intent of this project is to establish a data collection program that will be operable for a minimum of 9-12 years at this funding level. Funding beyond the FY96-97 biennium will continue to be requested from LCMR.

X. Cooperation:

Dr. Luther Aadland, Instream Flow Team
Fergus Falls, Minnesota Department of Natural Resources

A fisheries research biologist with extensive instream flow experience, Dr. Aadland's primary role will be to coordinate all field activities of the project and direct the data analysis.

XI. Reporting Requirements:

Semi-annual reports will be submitted not later than January 1, 1994, July 1, 1994, January 1, 1995, and a final status report by June 30, 1995.

XII. Literature Cited:

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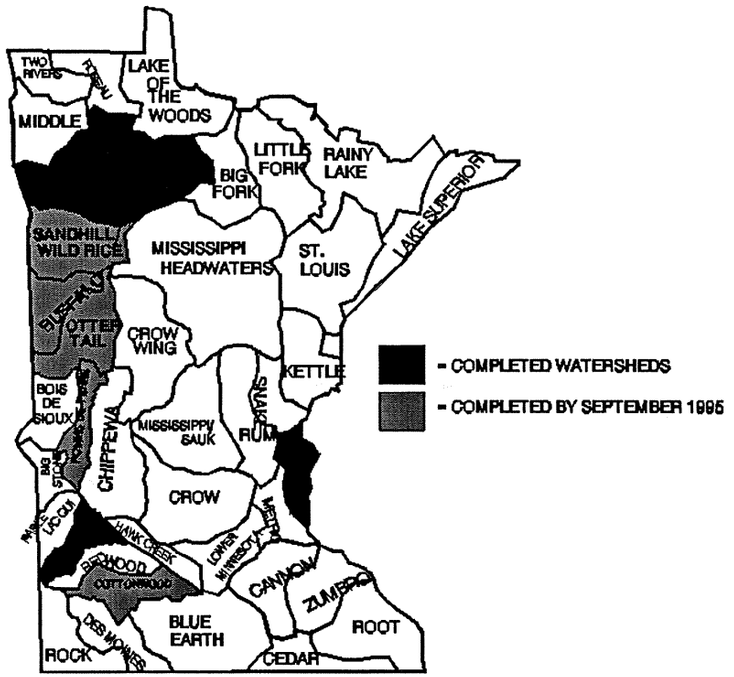

Figure 1. Map of the 39 major watersheds of Minnesota, showing the study watersheds and status of data collection. The watersheds where data collection is complete are (clockwise, from top left to bottom left): Red Lake, St. Croix, and Yellow Medicine.

Table 1. List of sites within watersheds detailing the stream habitat data collected for each site.

Updated 6/28/95 = those sites which are completed

RIVER	WATERSHED	FLOW	MEAN ANNUAL Q	IDEAL Qs	0.4 X IDEAL Qs	2.5 X IDEAL Qs	DATE	MEAS'D Qs	0.4 X MEAS'D Qs	2.5 X MEAS'D Qs	PERIOD OF RECORD	DRAINAGE AREA (sq mi)	GAGE ID NUMBER	GAGE LOCATION	USGS GAGE
Buffalo Downstream	Buffalo	LOW	71.9	17.98	7.19	44.94	6/06/91	14.15	5.66	35.38	1945 - present	322	05061000	Hawley	n/a
		MED.		44.94	17.98	112.34	7/09/91	62.09	24.84	155.24					n/a
		HIGH		71.90	28.76	179.75	8/15/91	98.30	39.32	245.74					n/a
Buffalo Upstream	Buffalo	LOW	71.9	17.98	7.19	44.94			0.00	0.00	1945 - present	322	05061000	Hawley	
		MED.		44.94	17.98	112.34	8/11/94	48.00	19.20	120.00					
		HIGH		71.90	28.76	179.75	6/29/94	75.00	30.00	187.50					
Yellow Med. downstream	Yellow Medicine	LOW	121.0	30.25	12.10	75.63	10/1/92	15.97	6.39	39.93	1931 - present (Some Time Periods Missing)	653	05313500	Granite Falls	n/a
		MED.		75.63	30.25	189.06	8/3/92	113.77	45.51	284.43					135.6
		HIGH		121.00	48.40	302.50	7/16/92	266.72	106.69	666.80					269.5
Yellow Medicine Upstream	Yellow Medicine	LOW	121	30.25	12.10	75.63	7/26/94	7.30	2.92	18.25					
		MED.		75.63	30.25	189.06	10/11/94	12.20	4.88	30.50					
		HIGH		121.00	48.40	302.50	8/24/94	23.90	9.56	59.75					
Lil. Cottonwood	Cottonwood	LOW	54.5	13.63	5.45	34.06			0.00	0.00	1973-present	230	05317200	Courtland	
		MED.		34.06	13.63	85.16	10/27/92	58.86	23.54	147.13					n/a
		HIGH		54.50	21.80	136.25	7/14/92	139.32	55.73	348.30					114.7
Otter Tail #1 Orwell	Otter Tail	LOW	320.0	80.00	32.00	200.00	10/29/92	150.00	60.00	375.00	1930 - present	1830	05046000	Orwell Dam	n/a
		MED.		200.00	80.00	500.00	7/20/94	450.00	180.00	1125.00					
		HIGH		320.00	128.00	800.00	5/19/93	660.00	264.00	1650.00					n/a
Otter Tail #2 Broken Down Dam	Otter Tail	LOW			0.00	0.00	9/24/92	54.67	21.87	136.68	1930 - present	1830	05046000	Orwell Dam	none
		MED.			0.00	0.00	6/22/92	130.00	52.00	325.00					
		HIGH			0.00	0.00	5/10/93	290.00	116.00	725.00					none
Pelican	Otter Tail	LOW	75.6	18.90	7.56	47.25			0.00	0.00	1909-1912,1942-1966	482		Fergus Falls	n/a
		MED.		47.25	18.90	118.13	8/15/94	82.00	32.80	205.00					n/a
		HIGH		75.60	30.24	189.00	6/6/94	143.00	57.20	357.50					n/a
Lac Qui Parle	Lac Qui Parle	LOW	130.0	32.50	13.00	81.25			0.00	0.00	1910-1914,1931-present	983	05300000	Lac qui Parle	
		MED.		81.25	32.50	203.13	7/30/92	14.68	5.87	36.69					413.5
		HIGH		130.00	52.00	325.00			0.00	0.00					
Pomme de Terre Upstream	Pomme de Terre	LOW		0.00	0.00	0.00	8/17/92	5.45	2.18	13.62	1986 - 1991	340	05293371	Elbow Lake	
		MED.		0.00	0.00	0.00	9/23/93	12.26	4.91	30.70					
		HIGH		0.00	0.00	0.00	7/1/93	39.50	15.80	98.75					
			The site was vegetated at low flow but not at the other two flows												
Pomme de Terre Downstream	Pomme de Terre	LOW	111	27.75	11.10	69.38			0.00	0.00	1931-1935,1935-present	905	05294000	Appleton	
		MED.		69.38	27.75	173.44	8/23/94	56.00	22.40	140.00					
		HIGH		111.00	44.40	277.50	6/13/95	239.00	95.60	597.50					
Wild Rice	Wild Rice	LOW	171.0	42.75	17.10	106.88	8/14/91	12.00	4.80	30.00	09-17, 30-83, 89-preser	888	05062500	Twin Valley	
		MED.		106.88	42.75	267.19	7/17/91	50.00	20.00	125.00					85.6
		HIGH		171.00	68.40	427.50	5/06/92	145.00	58.00	362.50					218.4
Sandhill	Wild Rice	LOW	70.6	17.65	7.06	44.13			0.00	0.00	1943-1984,1985-present	426	05069000	Climax	
		MED.		44.13	17.65	110.31			0.00	0.00					
		HIGH		70.60	28.24	176.50			0.00	0.00					

Table 1. Continued

Updated 8/28/95 = those sites which are completed

RIVER	WATERSHED	FLOW	MEAN ANNUAL Q	IDEAL Qs	0.4 X IDEAL Qs	2.5 X IDEAL Qs	DATE	MEAS'D Qs	0.4 X MEAS'D Qs	2.5 X MEAS'D Qs	PERIOD OF RECORD	DRAINAGE AREA (sq mi)	GAGE ID NUMBER	GAGE LOCATION	USGS GAGE
Clearwater #1	Red Lake	LOW	173.0	43.25	17.30	108.13	6/19/91	47.00	18.80	117.50	1939-1979,1982-present	512	09078000	Plummer	n/a
Downstream		MED		108.13	43.25	270.31	8/20/91	139.00	55.60	347.50					n/a
Plummer		HIGH		173.00	69.20	432.50	6/21/93	270	108.00	675.00					n/a
Clearwater #2	Red Lake	LOW	173.0	43.25	17.30	108.13	9/18/91	40.00	16.00	100.00	1939-1979,1982-present	512	09078000	Plummer	none
Upstream		MED		108.13	43.25	270.31	7/7/93	65.00	26.00	162.50					none
		HIGH		173.00	69.20	432.50	7/09/92	102.00	40.80	255.00					none
Red Lake	Red Lake	LOW	543.0	135.75	54.30	339.38	10/03/91	49.00	19.60	122.50	1929-present	2300	09075000	High Landing	264.0
Middle		MED		339.38	135.75	848.44	07/07/92	94.00	37.60	235.00					424.0
		HIGH		543.00	217.20	1357.50	08/25/92	286.00	114.40	715.00					485.0
Red Lake	Red Lake	LOW	543.0	135.75	54.30	339.38	10/10/91	65.00	26.00	162.50	1929-present	2300	09075000	High Landing	n/a
Downstream		MED		339.38	135.75	848.44	4/19/94	350.00	140.00	875.00					
TRF		HIGH		543.00	217.20	1357.50	8/26/92	460.00	184.00	1150.00					485.0
Red Lake	Red Lake	LOW	468.0	117.00	46.80	292.50	6/23/94	184.00	73.60	460.00	1933-present	1950	5074500	Red Lake	
Upstream		MED		292.50	117.00	731.25	7/26/94	425.80	170.32	1064.50					
		HIGH		468.00	187.20	1170.00	8/17/94	656.70	262.68	1641.75					
Deer	Lake Superior	LOW	7.4	1.84	0.74	4.60			0.00	0.00	1976-present	8	04024098	Holyoke	
		MED		9.20	3.68	23.00	4/23/91	11.00	4.40	27.50					n/a
		HIGH		46.00	18.40	115.00			0.00	0.00					
Rum	Rum	LOW		0.00	0.00	0.00			0.00	0.00					
		MED		0.00	0.00	0.00			0.00	0.00					
		HIGH		0.00	0.00	0.00			0.00	0.00					
Snake	Snake	LOW		0.00	0.00	0.00			0.00	0.00					
		MED		0.00	0.00	0.00			0.00	0.00					
		HIGH		0.00	0.00	0.00			0.00	0.00					
Knife	Snake	LOW		0.00	0.00	0.00			0.00	0.00					
		MED		0.00	0.00	0.00			0.00	0.00					
		HIGH		0.00	0.00	0.00			0.00	0.00					
Redwood	Redwood	LOW	55.4	13.85	5.54	34.63			0.00	0.00	1940 - present	259	05315000	Marshall	
		MED		34.63	13.85	86.56	7/8/92	30.75	12.30	76.88					n/a
		HIGH		55.40	22.16	138.50			0.00	0.00					
Two Rivers	Two Rivers	LOW	84.6	21.15	8.46	52.88			0.00	0.00	1928-36,1937,1941-43	444	05094000	Lake Bronson	
		MED		52.88	21.15	132.19			0.00	0.00	1944,1945-47,1953-81			(S BR Two Rivers)	
		HIGH		84.60	33.84	211.50			0.00	0.00	1985-PRESENT				
St. Croix	Lower St. Croix	LOW	4312	1078.00	431.20	2695.00			0.00	0.00	1902-present	6240	05340500	St. Croix Falls, WI	
Folsum Island		MED		2695.00	1078.00	6737.50	8/31/92	1800.00	720.00	4500.00					3913.9
		HIGH		4312.00	1724.80	10780.00	10/13/92	3200.00	1280.00	8000.00					n/a
St. Croix	Lower St. Croix	LOW	4312	1078.00	431.20	2695.00			0.00	0.00	1902-present	6240	05340500	St. Croix Falls, WI	
Franconia		MED		2695.00	1078.00	6737.50	8/23/93	1700.00	680.00	4250.00					
		HIGH		4312.00	1724.80	10780.00	11/11/92	3200.00	1280.00	8000.00					n/a

Ideal flows are determined as follows: low = (2.5*(0.1*MAF)), high = MAF, medium = something in b[illegible]n that allows for overlap between the range of simulated flows.