

FISHERIES DIVISION SPECIAL REPORT

Number 15

July, 1995

A Fisheries Management Guide to Stream Protection and Restoration

Gaylord R. Alexander
Janice L. Fenske
and
David W. Smith



STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

**MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION**

Fisheries Special Report No. 15
July 1995

**A FISHERIES MANAGEMENT GUIDE TO
STREAM PROTECTION AND RESTORATION**

Gaylord R. Alexander
Janice L. Fenske
and
David W. Smith

TABLE OF CONTENTS

	Page
Introduction	3
Watershed Plan	4
Protection and Restoration Techniques	5
Water Management in the Uplands	5
<i>Increase groundwater recharge and create wetlands</i>	5
<i>Ditching and tiling</i>	6
<i>Vegetation management of uplands</i>	6
<i>Agriculture</i>	7
<i>Water withdrawals from aquifer</i>	8
<i>Pollution</i>	8
<i>Urbanization</i>	9
<i>Large rural land alterations and developments</i>	9
<i>Upland factors affecting water temperature</i>	10
Stream Corridor Management	10
<i>Vegetation management of corridor</i>	10
<i>Zoning</i>	11
<i>Ponds and canals in riparian corridor</i>	11
<i>Road crossings</i>	12
<i>Pipeline and utility crossings</i>	12
Channel Management	13
<i>Dams</i>	13
<i>Lake level controls</i>	14
<i>Beaver dams</i>	14
<i>Other factors affecting water temperature</i>	15
<i>Water withdrawals from streams</i>	16
<i>Seawalls and levees</i>	16
<i>Docks</i>	17
<i>Sediment control</i>	17
<i>Bank stabilization</i>	19
<i>Dredging and filling</i>	19
<i>Removal of obstructions to flow and navigation</i>	20
<i>Addition of fish cover</i>	20
<i>Addition of spawning gravel</i>	21
Aesthetics and Level of Public Use	21
<i>Aesthetics</i>	21
<i>Access sites</i>	22
<i>Management of recreational use</i>	22
<i>Fishery regulations</i>	23
Priority of Action and Implementation	23
References	25
Appendix A	29

Introduction

For most of Michigan's streams, the physical and ecological processes that determine channel conditions (or habitat for fish) have been degraded by human activities to the detriment of the fisheries. All of our streams and watersheds have been perturbed to some extent; many have been extensively damaged to the point where fisheries and aesthetic attributes have been severely diminished. Michigan Department of Natural Resources (MDNR), Fisheries Division seeks to:

Protect Michigan's streams from further degradation and restore, to the extent possible, their fish habitat, fish populations, and recreational potential.

This is best done by protecting and restoring flow dynamics, channel morphology, and sinuosity of streams. Restoration and protection programs should not be separated, because restoration programs must be coupled with perpetual protection of streams from new or ongoing degradation.

Michigan Chapter of the American Fisheries Society (MCAFS) developed a policy statement (Appendix A.) on stream protection and restoration in 1994. Their statement compliments this guide very well, and it is fully endorsed by MDNR, Fisheries Division. They defined *restoration* as movement of an ecosystem toward an approximation (not necessarily a re-creation) of its condition prior to disturbance. This definition acknowledges some of the realities of today's world. Clearly, it is impossible to restore all Michigan's river systems to their conditions prior to the arrival of European settlers. A number of fish and wildlife species have become extinct. Important genetic strains of surviving species have been lost and are probably unrecoverable. Many exotic species have been established and are thriving. Human population increases and related land-use activities have caused massive and relatively permanent changes to the landscape. However, it is still possible to improve the state of health and usefulness of all Michigan's river systems through well-planned restoration programs. Examples of restoration activities are: 1) providing fish passage in both directions at dams; 2) adding large woody debris, or a substitute cover material, if adequate amounts are not being produced and transported in the stream; or 3) modifying seasonal and daily stream flow patterns and total flow via water management in the streams' watershed. **The purpose of this report is to provide information to guide future stream protection and restoration efforts in Michigan, especially as they relate to the management of fisheries.**

To restore streams to healthy, functioning ecosystems, thus providing maximum fishery and aesthetic benefits, we need to emphasize management of the total watershed (Dewberry 1992; National Research Council 1992). We also need to adopt a broader watershed concept than is generally considered. For example, to most people watershed means "that land surface area which contributes surface water to lakes and streams". A broader concept would consider precipitation (rain and snow), vegetation, and human developments within the watershed. Our challenge is to manage the way human activities affect water in terms of overland flow, surface infiltration, subsurface groundwater flow, evaporation, evapotranspiration, and human water withdrawals.

Management activities that increase groundwater inputs and reduce surface runoff will benefit most streams in the midwestern United States, especially coldwater (trout) streams.

Streams whose flows have high ratios of groundwater to surface runoff tend to have the stable flow and temperature regimes which are beneficial to fish (Benson 1953, 1955; Hendrickson 1966; Hendrickson and Doonan 1972; Poff and Ward 1989, 1990; White et al. 1976). Maximizing groundwater input can be achieved by managing water so that the highest proportion possible of the annual precipitation infiltrates the ground to migrate slowly but steadily toward streams. Further, streams with relatively stable discharge patterns have lower rates of bank and bed erosion, everything else being equal. They are also less turbid than streams with high proportion of surface runoff, because surface runoff causes erosion and transports the displaced soil and debris particles to the stream.

The action plan for stream restoration and enhancement should be to correct problems and enhance conditions in the whole watershed. The first priority should be the uplands and the stream's headwaters. Conditions in the headwaters are the most important in determining the basic character and potential of the stream in terms of total discharge, discharge periodicity, and pollution load. Unsatisfactory conditions in the uplands can dominate and override satisfactory conditions in the stream corridor (lands adjacent to the stream channel) and channel. The next priorities in the action plan should be to improve the floodplains and corridors, and finally, the stream channels.

Watershed Plan

Completion and adoption of a comprehensive watershed management plan is the first step in stream restoration and enhancement. MDNR, Fisheries Division has developed an outline for preparing stream management plans focusing on fisheries. MDNR, Surface Water Quality Division (SWQD) has developed an outline for a watershed plan focusing on water quality (*Guidelines of Best Management Practices for Michigan Watersheds*). In general, comprehensive fisheries management oriented plans should contain the following components.

1. Assessments of the current and past conditions of the river and its watershed by tributary and stream segment, including the physical conditions (upland drainage patterns, channel conditions, water quality, and so on), as well as, the biological conditions (fish and other aquatic organisms).
2. Appraisals of a stream's fishery potential (based on the stream's physical and chemical characteristics).
3. Identifications of potential fishery management options. These may be different for tributaries or stream segments.
4. Recommendations of which fisheries management option(s) to pursue. For example, should management emphasize coldwater or coolwater species, free flowing stream habitat or impoundments, stream-resident fish or anadromous fish. Involvement of the agencies with jurisdiction in the watershed and all interested organizations and citizens is a critical component of this step.
5. Descriptions of what needs to be done to achieve the options (an action management plan).

Protection and Restoration Techniques

In the following section of this guide we will discuss the techniques and actions that may need to be done to collectively protect, restore, and enhance Michigan streams.

Stream protection techniques can not be conveniently separated from restoration techniques in most cases, because they are so interdependent. For example, erosion control techniques like stabilizing stream banks, applying vegetative filter strips along stream corridors, and designing grades and approaches of roads properly at stream crossings are *protection*, because they reduce sedimentation. But they could also be classified as restoration techniques if they are applied to repair past damage to a stream.

Thus, we will discuss techniques and actions that are generally needed to collectively protect and restore streams.

Water Management in the Uplands

Increase groundwater recharge and create wetlands

Streams with the most stable flow regimes produce more fish, given equal nutrient levels. The flow stability and seasonal discharge regime of a stream is highly correlated with the amount of groundwater input, which is related to the soil permeability and topographical relief within its watershed. Further, the proportion of the annual precipitation that falls on the watershed and infiltrates soils, varies with the extent and completeness of surface land drainage. For example, the best trout streams, the most stable of all streams, are located in areas with sandy and gravelly soils (light soils), irregular surface topography, and incomplete surface drainage. These watersheds contain hundreds of *groundwater recharge basins* (depressions, potholes, vernal ponds, and wetlands that serve as traps, sumps, or retention basins for rain or snow-melt water). In highly permeable soil areas, these natural land depressions, left as the last glacier receded, usually do not develop a surface-water outlet drain, because soil infiltration occurs faster than water input. By contrast, in watersheds with soils composed of relatively impermeable clay and loam soils (heavy soils), the depressions left by the glacier have, in most cases, filled to their brims and overflowed, forming a lake or marsh with a surface outlet drainage. Thus, drainages in impermeable soil watersheds are characterized by large numbers of small streams and intermittent drainages, with a high density of streams and other types of surface water per unit land area. By contrast, watersheds with more permeable soils have a low density of streams and surface water per land area, and streams are larger on the average.

Potential exists in most watersheds to increase groundwater recharge and/or increase the number and surface area of wetlands by rehabilitating old or developing new groundwater recharge basins and wetlands (Hendrickson 1966). Building dams in small valleys draining intermittent surface water (flowing mainly at spring runoff) could accomplish these objectives. These dams would be low fills, usually only a few feet high, fitted with an overflow tube or erosion resistant overspill. Ideally, most trapped and retained water would infiltrate to the groundwater. The proportion of trapped water infiltrating to the groundwater would depend upon the permeability of the basin's soils and evaporation rates. In less permeable soil areas permanent ponds and wetlands would be produced (Hendrickson 1966).

We believe that such projects could be accomplished as part of land management activities by foresters, highway planners, urban planners, agriculturalists, private land owners, and a watershed authorities. All land managers should look for opportunities to develop groundwater recharge basins and wetlands, with priority being given to the most permeable sites. The reconnaissance, planning, engineering, and construction of basins could be done collectively by the land managers. The wetlands created will not only enhance groundwater recharge, stream flow, and fish, but will also enhance vegetative diversity and habitat for many wildlife species.

Ditching and tiling

In keeping with the philosophy that streams are benefited most by reducing surface water runoff and increasing groundwater recharge and discharge to streams, we should discourage new land drainage projects such as ditching or tiling of any lands where it would result in less groundwater recharge. Where ditching or tiling must be used, it should only be used in combination with retention basins to reduce quick runoff into streams. We should also restore former wetlands that have been drained in the past by eliminating existing ditching and drain tile where possible. For example, former wetlands that were drained for agricultural purposes and are no longer used for that purpose should be considered for wetland restoration.

Wetlands further benefit streams in that they moderate flood frequency and magnitude by temporarily retaining water and releasing it slowly to the stream, and by reducing the amount of flood water through evaporation and evapotranspiration. Floods result in higher stream velocities, erosion, and bed scour and cause displacement of aquatic organisms including fish. Wetlands also trap sediments and biodegrade other pollutants, thus protecting the aquatic habitat, water quality, and biota of streams.

Vegetation management of uplands

The following section addresses vegetation management of the uplands beyond the riparian corridor (land immediately adjacent to the stream channel). The riparian corridor is addressed in a later section, *Vegetation management of the corridor*.

The amount and type of vegetative cover on the land affects the amount of precipitation that infiltrates the soil to become groundwater and the rate of surface runoff. Land with permeable soils that are covered with grass yields the greatest groundwater recharge and subsequent stream flow per land area (Bosch and Hewlett 1982; Rowe 1963; Johnson and Kouner 1956). If brushwood invades the grasslands, some recharge is lost through increased evapotranspiration. Larger trees use even more water. Coniferous species of trees reduce annual water yield to streams the greatest amount, because they use water earlier in the spring and later in the fall (Urie 1966a, 1977). Further, conifers trap more precipitation (particularly snow) in their crowns and part of it is lost to evaporation (Urie 1966b; Hansen 1969; Eschner and Satterlund 1963).

Research in Michigan and elsewhere has shown that grass-covered land on light soils yields as much as twenty percent more groundwater recharge than lands covered by

coniferous forests (Hibbert 1969; Hewlett and Hibbert 1961; Hoover 1944). This additional groundwater recharge translates into a proportional gain in stream discharge. Moreover, the annual stream flow periodicity for grasslands is different than for coniferous forestland. Grasslands produce higher summer flow and lower spring flood flow compared to coniferous forestland. This higher summer flow produced by grasslands also helps reduce average summer water temperature and range of daily temperature variation in streams, which is generally beneficial to coldwater fishes such as trout.

The amount of our watersheds covered in forest or brushwood has increased steadily since the late 1800's and early 1900's, when most virgin timber was removed, large forest fires occurred, and land was initially cleared for agriculture. According to the latest statewide survey (1993 Forest Survey of Michigan), the volume of wood in trees over five inches diameter at breast height (DBH) increased 33% since the 1980 survey. The increase since the 1935 survey has been approximately 200%. Much of the forests cleared for agriculture and timber harvest is now reverting back to forests via natural plant succession or through planned reforestation plantings. Based on previous studies (Hibbert 1969; Hewlett and Hibbert 1961; Hoover 1944), this increase in standing stock volume of woody vegetation is slowly reducing stream flows and altering seasonal flow patterns.

Because of the effects of vegetation on groundwater recharge and discharge to streams, we could manage stream flow to some degree by managing vegetation. We are not suggesting that we cut all trees and brush in Michigan to enhance stream flow for fish, but we do want to make people aware of the water-vegetation relationships and suggest a balanced management of both of these valuable resources.

If our overall resource management goal is to enhance stream discharge for fish, we should maintain large areas of watersheds with permeable soils in grassy fields and forest openings and keep conifer acreage (solid block monoculture) to a minimum. Conifer forest production should be intermingled with deciduous forest production (diverse hetero-culture species forest management) where practical and where soil and climate permit. Because water use by plants is highly correlated with leaf surface area per acre of land, it follows that clear cutting of forests will temporarily increase water yield until the new tree and brush growth re-establishes the original leaf mass. Thus, to enhance stream flow we should encourage the most rapid turnover cutting cycle practical for various timber types. To prevent erosion from timber harvest operations, best management practices should be implemented as described in MDNR, SWQD's manual, *Water Quality Management Practices on Forest Land; a Manual for Michigan's Forest Land Owners, Managers, and Users*.

Agriculture

Some agricultural practices have serious, adverse effects on Michigan streams. Increased surface water runoff and sediment delivery to streams from tilled lands probably have the biggest impact. Accelerating land drainage for agricultural purposes results in increased surface water runoff into streams (see *Ditching, and tiling*). In spite of years of agricultural research on soil conservation practices to prevent erosion and efforts to educate farmers, excessive soil erosion continues to occur. This erosion can and should be reduced. Soil losses reportedly vary from 2 to 15 tons per acre per year for crop land (USDA National

Resources Inventory, 1982). A significant fraction of the eroded soil reaches streams, where it adversely modifies water clarity, stream bed type, and channel morphology before it is eventually deposited in lakes, reservoirs, marshes, harbors, or the Great Lakes. Further, crop fertilizers (including animal waste), herbicides, and pesticides are draining into streams from agricultural lands. MDNR, SWQD has prepared a manual to help educate farmers in ways to reduce these problems, *Agricultural Best Management Practices Manual for Michigan's Non-point Source Pollution Program*. Other educational efforts, such as those undertaken by the Michigan State University Cooperative Extension Service, should continue to encourage farmers to voluntarily utilize best management practices. However, we think legislation is needed to require all farmers to apply best management practices, or at least to provide economic incentives to do so. Also needed is the development of technology to determine the extent of non-point source pollution that comes from a particular farm. Then, the land owner can be made aware of the magnitude of the pollution problem and take corrective action.

Water withdrawals from aquifer

Water withdrawals taken either directly from stream channels, or indirectly from aquifers supplying groundwater to streams, have the potential to adversely affect stream flows (Gowan and Kevern 1985; White 1975; White et al. 1976). Direct water withdrawals from streams, particularly during the low flow periods of summer and fall should be minimized (see later section on water withdrawals from streams). Agricultural withdrawals are increasing and projected to increase even more (Gowan and Kevern 1985; Bartholic et al. 1983). Truly necessary water withdrawals for residential, industrial, and agricultural use should, if possible, come from aquifers that minimally affect summer and fall stream flow. Increasing groundwater recharge through management techniques described in the two preceding sections of this paper could help to mitigate some water withdrawals. However, legislation is needed to allow for the determination and regulation of the minimum flow needs of stream systems to maintain fisheries and stream aesthetics.

Pollution

All types of pollution that degrade water quality should be eliminated to the extent possible. This includes thermal and sediment pollution, as well as, pollution from toxic chemicals or substances with a high biological oxygen demand. The latter includes pollution from domestic sewage, feed lots, farm fields, and urban storm drains. Such pollution can rob streams of oxygen and create excessive bacterial and weed growth, thereby significantly altering the stream fauna and aesthetic qualities. However, we need to remember that the level of certain nutrients (potassium, nitrogen, calcium, etc.) determine to a great extent the plant, benthos, and fish productivity of a stream. From the fish production standpoint, we want to have sufficient levels of these nutrients, but not excessive levels. Consult MDNR, SWQD's *Guidelines of Best Management Practices for Michigan Watersheds and Agricultural Best Management Practices Manual for Michigan's Non-point Source Pollution Program* for guidelines for the management of various pollutants.

Urbanization

Urbanization or any large land development project will have an impact on streams. Development projects increase surface water drainage (amount and rate) because they increase amounts of impermeable surfaces on the landscape, such as roads, parking lots, and buildings (Maurizi and Poillon 1992). Waters are usually conveyed via gutters, ditches, and storm sewers directly to the streams. Besides increasing surface water drainage, this direct runoff carries an array of pollutants to streams (sediment, oils, grease, pesticides, fertilizer, toxic metal ions, etc.). Developers should be required to implement storm water management plans that provides appropriate upland water retention, treatment, infiltration, and discharge. This includes regular maintenance of traps and retention basins is required, and if the pollutants collected present significant risks to aquatic life, they should be periodically removed and transported to disposal sites (see MDNR, SWQD's *Guidelines of Best Management Practices for Michigan Watersheds* for guidelines relating to construction site and runoff storage).

Urbanization and large developments also adversely affect streams by hindering groundwater recharge in the developed area. Most developments create extensive areas of non-permeable land surfaces (roads, parking lots, buildings, drives, tennis courts, etc.), thus preventing precipitation from infiltrating the ground to become groundwater.

Urbanization also brings bigger demands for water withdrawals for residential and industrial use. As urban areas grow, their water withdrawals from both streams and aquifers can significantly deplete stream flow. Augmenting low flows by pumping water from deep wells and discharging the water into the streams is possible, but expensive (Hendrickson 1966). However, this method could be used to mitigate damage to or enhance marginal trout streams. Pumping should only be done during the low flow, warm water period of the year. This procedure would not only increase summer flow, but would also lower water temperature because of the relatively low temperature of well water.

Large rural land alterations and developments

All construction projects and developments disturb vegetative cover and expose soils to erosion. Activities such as construction of new roads, harvest of timber, development of golf courses, construction of large subdivisions, operation of mines, and development of oil and gas wells can result in significant soil erosion if best management practices are not applied to prevent sedimentation to streams, lakes, and wetlands. Further, pollution of the ground and surface waters can occur from such projects. This pollution can be from operational waste, such as brines from oil and gas development, or tailings and spoil piles from mining operations. Pollution can also occur from grease and oil spills from heavy equipment or from breakage of transmission lines. Land use planning and growth control is needed to identify those areas within the watershed best suited for the various types of development. In addition, best management practices must be implemented during and after the construction process to prevent soil erosion from occurring (see MDNR, SWQD's *Guidelines of Best*

Management Practices for Michigan Watersheds and Water Quality Management Practices on Forest Land; a Manual for Michigan's Forest Land Owners, Managers and Users).

Upland factors affecting water temperature

Water temperatures should be maintained as cool (64-68° F) and stable in the summer as possible to benefit coldwater game fish, such as trout, but should be maintained as warm (75-85° F) and stable as possible for coolwater game fish, such as smallmouth bass. The goals for water temperature should be established based upon stream classification and temperature modeling. In many cases, we should try to increase groundwater yield and discharge to streams, thereby stabilizing stream temperatures. Practices which increase the amount of surface water run-off (drainage, ditching, tiling) can cause undesirable increases and fluctuations in summer water temperatures.

Stream Corridor Management

Vegetation management of corridor

Buffer strips of natural vegetation along the riparian corridor should be required for streams. We recommend a vegetation buffer strip one hundred feet wide to one hundred seventy-five feet, depending on slope, on each side of all streams (see MDNR, SWQD's *Water Quality Management Practices on Forest Land; a Manual for Michigan's Forest Land Owners, Managers and Users and Agricultural Best Management Practices Manual for Michigan's non-point source pollution program*). Vegetation buffers function as filter strips for sediments and biodegradable pollutants delivered via surface water runoff. Undisturbed vegetation stabilizes stream banks, which allows for stream meandering at normal rates. Large trees provide woody material for instream cover as they fall into the stream. A well vegetated floodplain and riparian zone protects stream water quality by reducing sediment and nutrient input from flooded lands. Vegetative buffer strips also function as corridors for movement of wildlife and serve as suitable and often critical habitat for many wildlife species. In addition, riparian vegetation screens development, thereby enhancing the natural and aesthetic quality of the river corridor.

Buffer strips of vegetation along stream corridors also help to maintain cool, stable water temperatures. Stream bank vegetation is important for shading (Meehan 1970; Swift and Messer 1971; Greene 1950; Pluhowski 1972; Patton 1973). Further, buffer strips with tall dense vegetation help reduce heat loss from streams in winter via radiation and convection. Narrower and deeper channels have cooler water temperatures because of smaller surface to volume ratios. Many of our stream channels are excessively wide. Thus we should establish stream side vegetation that narrows the stream, restoring cooler, and more stable temperatures.

Ditches in agricultural lands and road side ditches that deliver significant amounts of water to a river system can also deliver significant amounts of sediment and other pollutants (fertilizer, animal waste, pesticides, oils, grease, etc.). Vegetative buffer strips help to filter out and adsorb these pollutants before they reach the stream. For further information on

buffer/filter strips, see the following three documents written by MDNR, SWQD: *Guideline of BMP's for Michigan Watersheds, Water Quality Management Practices on Forest Land; a Manual for Michigan's Forest Land Owners, Managers and Users, and Agricultural Best Management Practices Manual for Michigan's non-point source pollution program.*

Zoning

Development adjacent to a stream has the potential to negatively affect the aquatic habitat (Berry 1992) and the aesthetic quality of the stream. There are a number of tools that can be used to reduce or eliminate such impacts. Acquiring lands adjacent to streams for public ownership and management is one method used to protect the resource because it usually minimizes development. Zoning of land use is another very powerful tool that can be used to protect water quality, fish habitat, and stream aesthetics.

There are two natural river zoning programs in Michigan that were developed to protect river resources. The laws that guide these programs are the federal Wild and Scenic River Act, P.L. 90-542 and Michigan's Natural River Act, P.A. 231 of 1970. A number of rivers and sections of rivers in Michigan have already been designated and others are under consideration for protection under these two programs. In addition, many local units of government incorporate special zoning along river corridors which restricts amount and type of development and includes vegetation buffer strips (greenbelts).

Ponds and canals in riparian corridor

The construction of artificial canals and channels branching from rivers has occurred in the past and new proposals are continually put forth. The purpose of the canals is usually for private developments to provide "key-hole access" to the river or to accommodate boat dockage facilities. These canals degrade water quality by discharging to the river water that has higher temperature, pesticide, and nutrient loadings. In addition, construction of these canals can modify the recreational usage of the river and result in boater congestion and other user conflicts. Future construction of such off-river canals and channels should be prohibited.

Another cause of stream water quality degradation from temperature and nutrients is the construction of ponds in the floodplain adjacent to the stream. In these ponds, stream water is often diverted into the upper end of the pond, and discharged as warmer, lower quality water from the lower end of the pond. Ponds in the floodplain which do not connect to the stream can also cause problems. During flood events, fish from the ponds can enter the stream, and may be a source of the introduction of diseases or exotic species into the system. In addition, these ponds may intercept groundwater which may be altered thermally or lost to evaporation. Serious consideration should be given to eliminating existing ponds in floodplains and construction of new pond in floodplains should be prohibited.

Road crossings

Road crossings of streams can deliver a significant amount of sediment and other pollutants to the streams, and thus, crossings should be kept to a minimum. Frequently, roads slope down toward the stream and cross at the lowest point of the roadway, thereby delivering surface water runoff directly to the stream.

Bridges are preferred over culverts. If culverts are used, placement should be well planned. Culverts that are too short result in steeply sloped roadside banks which are constant erosion problems. Improper alignment of culverts can also result in erosion at the crossing. Improper horizontal alignment combined with the natural downcutting of the streambed cause perched culverts, which are a barrier to the upstream migration of fish and other aquatic organisms. Inadequate culvert capacity is another problem. It causes excessively high water velocities, especially during high flows, thus hindering or blocking the upstream passage of fish. Culverts can also block navigation by boating enthusiasts. For the above reasons, single rather than multiple culverts should be used.

Design of bridges should consider the needs of the stream, as well as, the needs of the roadway. Bridges with insufficient span across a stream will impinge on the stream channel and encroach on the flood plain and associated wetlands. Insufficient bridge span can also impede the movement of wildlife species (including mammals, reptiles, and amphibians) which utilize the riparian edge of streams as travel routes.

MDNR has numerous documents containing design criteria which address the above concerns about road crossings. The reader is referred to SWQD's *Guideline of Best Management Practices for Michigan Watersheds* for the BMP's related to water course crossings and runoff conveyance and outlets. SWQD draft Forestry BMP's also has information on sediment control at road crossings. In addition, Fisheries Division's *Position Statement on Habitat Protection: Stream Crossings by Bridges and Culverts* gives further information.

Pipeline and utility crossings

Crossings of streams by pipelines and utilities can deliver significant quantities of sediment to streams. Poor installation techniques, and inadequate soil stabilization of the pipeline corridors contribute to the problem. In addition, these corridors are frequently traveled by all-terrain vehicles (ATV's) that continually disturb the stream bank. Some corridors are also used as fords by ATV's and other motor vehicles, causing erosion and pollution to the stream from oils and grease. Poorly maintained crossings diminish stream aesthetics.

Pipeline and utility crossings should be located at existing road crossings whenever feasible. Utility and pipeline companies should be required to consolidate their lines into a few corridors that would minimize the need for crossings of streams and wetlands, thus minimizing negative effects. The least disruptive construction techniques and sediment control techniques should be used throughout the construction process. Corridors should be stabilized immediately following construction, utilizing suitable erosion control materials and vegetation. Crossings should be constructed so as to prevent ATV's from crossing the streams, preferably with vegetation, but with other materials if necessary. (See SWQD's

Guideline of Best Management Practices for Michigan Watersheds for the best management practices relating to water course crossings and also Land and Water Management Division's (LWMD) *Stream Crossing Requirements for Pipelines and Utility Lines*. Also, the State's Natural River Section 15 Rules require most of the practices discussed above.)

Channel Management

Dams

The effects of dams on fisheries habitat depend on the size, gradient, and temperature of the stream. Dams have mostly negative effects on stream habitat and riverine and anadromous fish populations (Cushman 1985; Bain et al. 1988). There is a direct conversion of stream habitat in the impounded area to a pond environment with a corresponding shift in aquatic plant, invertebrate, and fish communities. Depending on the operation of a dam's water release, there can be both seasonal and daily alteration of flows downstream. On a seasonal basis, unnatural flow regimes below dams are produced whenever average water input to the reservoir is different from water output. Daily fluctuations in downstream flow occur with peaking operations (alternating storage and power generation on a daily schedule) at hydropower facilities and also with on/off operations of other dams. Fluctuations in flow destabilize habitat, frequently flooding and dewatering areas above and below the dam. Young fish and migrating fish are particularly vulnerable to the effects of flooding. Variation in discharge can cause bank destabilization and increased channel erosion rates downstream. Production of aquatic invertebrates and fish are significantly reduced in less stable flow streams (White 1975; White et al. 1976). Significant fish losses can also occur at hydropower facilities when fish are impinged on water intake grates or killed by mechanical and cavitation forces as they pass through turbines (entrainment mortality).

Dams also block the natural migration pattern of fish, both upstream and downstream, and result in the fragmentation of the river system. Water quality in impoundments is often lower than the original stream because of higher nutrient inputs and sometimes lower dissolved oxygen concentrations. For example, if the length of the shoreline of the impoundment is greater than the original river channel, more intensive shoreline development can result, which could lead to higher nutrient input from lawns and septic systems. Dams cause increases in water temperature during the summer months, both in the impoundment and downstream of the impoundment. This warming effect would be detrimental to coldwater fishes, such as trout. The water quality of the stream can be adversely affected for many miles downstream. Dams change the transport dynamics of both sediment and large woody debris. Deposition of sediment causes aggradation of the original river bed lying under the impoundment and a for a length of stream above the impoundment. The length of channel affected depends on stream gradient. Large woody debris is trapped in impoundments resulting in a paucity of large wood in the channel below dams.

To protect existing lotic habitat, construction of new dams on all rivers and permanent streams should be vigorously opposed. Existing dams should be removed when they are no longer used or maintained. All dams should allow for upstream and downstream passage of fish (when deemed desirable by fisheries managers). Hydropower dams should be operated at run-of-the-river flows (reservoir output equals reservoir input), and losses of the

downstream migrating fish should be minimized through operational changes or mechanical diversion of fish from water intake structures. All dams on coldwater streams should use bottom discharges to help maintain cold water temperatures in the stream below, and water aeration systems should be used where needed to maintain oxygen levels and improve water quality. In some cases, where streams have neither coldwater nor anadromous fish potential, impoundments may create habitat for lake-type fishes, wildlife, and recreational uses.

Lake level controls

Lake level control structures can have some of the same negative effects as other dams. The lakes are often located at the headwaters of the system, and therefore determine main channel conditions. Releases of water from these structures can have many temperature implications (see discussion under *Dams*). In addition, they are frequently opened rapidly in the spring of the year when stream levels are already high, creating abnormal flooding. This can result in habitat damage and lower survival rates of aquatic invertebrates and fish. As stated earlier, flooding is especially detrimental to young fish. Further, the naturally occurring high water levels of lakes can be important to the lake fisheries. For example, northern pike utilize flooded wetlands for spawning during spring, thus they benefit from these natural lake level fluctuations. These flooded wetlands are also important food production and rearing habitat for the young of many fish and wildlife species. In addition, lake level control structures impede the movement of organisms, sediment, and large woody debris.

Lake level controls can create problems by encouraging excessive construction and urbanization too close to the shoreline of lakes. Such development would not occur if lake levels fluctuated naturally. No new lake level control structures should be permitted and existing structures should be removed if possible. Where already in existence, structures should be operated at a fixed head with a structural design which accommodates peak flows (wide spillways). This method of operation will essentially equal run of the river flow and best protect the downstream habitat. Lake level control structures actually result in greater flooding on a system wide basis. Legal lake levels should not be established on any more lakes, and serious consideration should be given to repealing the Inland Lake Level Act (P.A. 146). It is poor public resource policy to abnormally stabilize lake levels to accommodate ill-advised development in the flood plain of a watershed.

Beaver dams

Beaver are native to Michigan and the presence of beaver dams on our streams is a natural condition. Beaver dams create impoundments which can be important habitat for many wildlife species. The effects of beaver dams on fisheries habitat depend on the size, gradient, and temperature of the stream. On coldwater streams, the effect of beaver dams on resident trout also depends on the total length of the stream system. For example, on cold streams with relatively short total stream length (e.g. short streams that discharge directly into the Great Lakes and large inland lakes), beaver ponds may actually enhance resident

trout by raising water temperatures, and thereby, increasing growth rates. However, these dams may interfere with anadromous fish runs.

Beaver dams differ from human-made dams in that they are generally present for fewer years (beaver dams last approximately 5 to 15 years). Also, upstream migrating fish are often able to pass over or through beaver dams. However, beaver dams can have some of the same negative effects on fisheries habitat described in the *Dams* section. The greatest potential for damage is in the low gradient headwater regions of streams, particularly trout streams. Beaver dams on trout streams are generally negative because they elevate summer water temperature. Detrimental warming effects of beaver dams in coldwater tributaries are often realized long distances downstream in mainstems. Further, beaver dams are relatively short lived, and when the dam deteriorates and collapses the stored sediment is released rapidly as a surge rather than as a normal, continuous transport. In streams with excessive sediment bedloads, this can result in degraded downstream channel morphology (Alexander and Hansen 1986). After such a sediment surge, it may take the stream years to re-establish good channel morphology for fish habitat if left to natural forces. However, a sand sediment trapping and removal project could be undertaken by managers to accelerate stream habitat recovery. Good channel morphology is also slow to re-establish in the former impounded area. The re-establishment of grasses and brush in the old pond bottom is a successional process that restores good channel morphology, but this process takes years.

In some areas, management action may be needed to control the beaver population. Such measures include liberalized beaver harvest regulations, beaver dam removals, and vegetative cover management to discourage beaver habitation of the area (Chuck Bassett, US Forest Service, Hiawatha National Forest, personal communication). Beaver populations are presently at an historic high level due to lower harvest rates by trappers. Also, in some cases, past timber cutting practices along streams have increased the abundance of tree species preferred by beaver (a change from spruce, fir, tamarack and pine to aspen, willow, and birch).

Other factors affecting water temperature

There are activities in addition to those discussed in previous sections which affect stream temperatures. Point source discharges of warm water, such as cooling water from industrial plants and storm water run-off from urban areas, can cause adverse effects on all streams. The technique of pumping water from deep wells discussed in the section on urbanization could be used to mitigate excessive water temperatures in streams where there is thermal pollution. Cooling ponds for thermal discharges are another possibility. Where appropriate conditions exist, bottom water withdrawals from lakes in the summer season can make stream temperatures more favorable for cold water species such as trout. This method requires that the lake be fitted with a water control structure at its outlet and a conduit pipe intake that extends out to the lake's deep cold water strata. As discussed above, lake-level control structures have adverse impacts on streams. Therefore, developing cold water discharges from natural lakes (as opposed to impoundments behind dams) by building new lake-level control structures should only be considered when the benefits outweigh the negative impacts.

Water withdrawals from streams

Water withdrawals for irrigation and other purposes decrease stream discharge and the amount of habitat available for fish and other aquatic organisms (Gowan and Kevern 1985; Bartholic et al. 1983). Further, withdrawals are generally done in summer when stream flows are lowest. The effects of the withdrawals are dependent on the amount, periodicity, and rate of removal compared to the size (discharge) of the stream. If sufficient volumes are withdrawn, the surface area to volume ratio could be changed, and the average depth would be decreased, resulting in increases in temperature and diurnal temperature fluctuations. Withdrawals also change the stability of the flow. Large water withdrawals should require a permit and these factors should be considered when water removal requests are reviewed. Many water removals do not require a permit (such as for purposes of irrigation). Although the effect of withdrawals by a single small user may be negligible, the cumulative effects of withdrawals by many users can be significant. Some streams in Michigan today are nearly completely dewatered by irrigation withdrawals. A reference list should be compiled of known withdrawals, including time (season) and amount of withdrawal, within all watersheds. This list would provide a way to estimate the cumulative effects on the streams in each watershed and form a basis for taking remedial action. Projects needing irrigation water should be encouraged to use water from deep wells that will not further deplete low summer stream flows. In addition, these users should be required to implement conservation irrigation methods to minimize water use. Legislation is needed to establish minimum stream flows in Michigan.

Seawalls and levees

Seawalls and levees along the stream banks, are generally less desirable than natural banks. Seawalls eliminate shallow water areas and the natural, irregular and diverse edge habitat that can be important for production of benthic invertebrates eaten by fish. Natural stream edge is also important larval fish habitat. Seawalls prevent water from entering the flood plain thereby increasing water velocity, sediment movement, bed scour, and abnormal downcutting. In addition, the slow recession of water from flooded areas is important in stream nutrient cycling. Seawalls decrease the natural stream meandering. They also impede or block animal (including mammals, birds, reptiles, amphibians, and invertebrates) access to and from the stream. Finally, seawalls impoverish and degrade the appearance of a stream.

Seawalls are often proposed to stabilize stream banks. Permits are required for the construction of seawalls. Through permitting processes, zoning procedures, and educational efforts, property owners should be encouraged or required to use less intrusive and more natural looking methods to stabilize eroding streambanks when stabilization is necessary. Methods for bank stabilization include vegetative plantings, log and whole tree revetments, and rock rip-rap. The primary advantage of these methods over seawalls is that they generally increase habitat for aquatic invertebrates and fish rather than reduce them. (See SWQD's *Guideline of Best Management Practices for Michigan Watersheds* for BMP's relating to stream bank stabilization and slope/shoreline stabilization.)

Levees prevent floodwaters from entering the floodplain and constrict the water flow, increasing flood peaks in areas downstream (Maurizi and Poillon 1992). They trap sediment and nutrients in the stream channel which normally would be deposited in the floodplain. Channel diversity is decreased with levee construction and aquatic species which utilize

stream edges are adversely affected. Levees also don't allow fish access to seasonally flooded areas which may be important for spawning and feeding.

The use of seawalls and levees is increasing to protect against elevated and more frequent floods. A better approach would be to try to treat the root cause of the increased flooding. The cause is more rapid drainage in the watershed due to poorly planned human developments in upstream areas, including building of seawalls and levees, agricultural ditching and tiling, urbanization, highway and road development, and other land uses that accelerate surface drainage. Construction of seawalls and levees should be discouraged or prohibited, and moving human development out of stream floodplains should be encouraged.

Docks

Some of the effects of docks are similar to seawalls, depending upon the construction design and size. In addition, docks can cover a significant portion of the stream width which can present hazards to navigation. Docks can provide some cover for fish depending on construction design.

The construction of docks should be discouraged through permitting processes and educational efforts. When allowed, dock size should be as small as possible. Design and location should minimize negative effects on aquatic habitat, stream aesthetics, and navigation. In some cases, upland docks adjacent to the river are feasible and preferred. Temporary docks are preferable over permanent structures.

Sediment control

Streams function to transport both water and sediment downstream, so the presence of sediment in streams is a natural, expected condition. However, many streams have excessive sedimentation due to current and past inputs caused by human activities. Current sources of sediment inputs include road systems, unstable stream banks, agricultural runoff, and storm water runoff from urban areas. Past sedimentation in Michigan was particularly pronounced during the logging era (Campbell and Bassett 1986). Much of this sediment is still present in stream channels, because these stream systems have low stream power to move heavy sediments (i.e. they are of low gradient and have low peak flows; stream power = discharge x gradient).

Both sediment in transport as suspended material or bedload, or occurring as accumulation on the streambed, has negative effects on aquatic invertebrate and fish habitat (Alexander and Hansen 1983, 1986). Fine clay particles in suspension cause turbidity and degrade the aesthetics of the streams. Some studies suggest that they also reduce fish and invertebrate health and survival (Herbert and Merkens 1961; Herbert et al. 1961; Herbert and Richards 1963). Larger inorganic particles, particularly sand, can reduce recruitment (natural reproduction) by plugging spawning gravels and adversely affecting egg development and/or larval fish emergence. Recruitment of gravel-spawning species can be adversely affected also by the sands abrading and burying gravels. Sand bedload also decreases food production by scouring or burying gravel substrates, and can decrease the amount of fish cover by filling in pools and burying logs (Alexander and Hansen 1983, 1986). Further, excess sediment levels stream bottom topography, thus producing more

laminar flow, which is less desirable for fish and other aquatic organisms. It lowers diversity of depth and water velocity in the stream channel, thus reducing retention time of terrestrial inputs of organic detrital material that serve as the energy source for aquatic invertebrates. Aquatic invertebrates are the basis for most fish food production. Sediment reduces riffle-to-pool frequency and stream sinuosity, and widens and reduces depth of the channel. It also decreases average stream cross sectional area, which increases average velocity. Another effect of sediment is the reduction of total static water volume of the stream, and thus total living space for aquatic organisms.

Research has demonstrated that sand sediment removal can substantially improve trout and aquatic invertebrate populations (Alexander and Hansen 1983, 1986). Sediment traps have proven to be very effective management tools to reduce stream sediment bedloads. In low gradient systems with a history of human-induced sediment problems, sediment traps will be needed to remove sand that has already accumulated in the stream channel. These streams have insufficient stream power to remove the sand through natural processes in any reasonable length of time. Sediment removal from stream beds and channels should be undertaken in conjunction with controlling upland and stream corridor sources of sediment input (road crossings, utility crossings, drains, agriculture drainage, eroding streambanks, construction sites, and so on). Generally, sediment traps are only practical for particles which are sand-sized and larger. Managers should refer to Hansen (1971) for guidelines for the location and construction of sediment traps.

Bank stabilization

The source of a significant portion of the instream bedload of sand in many streams is from excessive erosion of the stream banks. Erosion rates have generally increased because of human development accelerating runoff in the entire watershed as well as direct disturbance to stream banks and channel. Releases from peaking operations of hydroelectric dams and rapid releases of water from lake level control dams also cause abnormal bank erosion rates.

Stabilization projects to reduce this source of erosion have been undertaken for many years by resource managers. Stream bank stabilization has been proven to be a very effective tool in stream restoration efforts and managers should consider such projects. Erosion rates vary depending on the size of the bank, soil types present, moisture content of the bank, and stream flow stability. A report by Hansen (1971) presents a good discussion of erosion rates and recommends which types of banks to stabilize.

Methods that can be utilized to stabilize stream banks include the use of vegetation, log jams, log and whole tree revetments, rock rip-rap, and gabions. In some cases, reducing the steepness of the bank slope is advisable. The specific method used will depend on many factors, including stream flow stability, size and soil type of the bank, construction materials availability, ease of access, and stream setting (aesthetic aspect). Methods and materials which best absorb and dissipate stream energy rather than transferring the energy downstream should be selected when possible. Generally, vegetation functions best in this regard. Stream bank stabilization projects should be undertaken following a review of sediment sources throughout the entire watershed and in conjunction with control of upland inputs. (See SWQD's *Guideline of Best Management Practice's for Michigan Watersheds* for the guidelines relating to streambank stabilization.)

Dredging and filling

Alterations to rivers and adjacent wetlands are constantly being proposed for numerous purposes. Wetlands protect water quality and reduce and buffer flood flows. Spring flooded wetlands with submergent and emergent plants may be important fisheries spawning and rearing habitats and generally increase fish food production. Protection of wetlands is crucial to the health of river systems. Effects of in stream dredging are variable, but in general result in degradation of riverine habitat. Dredging projects that create sediment traps to control sand bedload or pools for fish cover are examples of the use of dredging for beneficial purposes.

Permits are required from MDNR for dredging and filling activities in inland waters (Inland Lakes and Streams Act, P.A. 346 of 1972), wetlands (Wetlands Protection Act, P.A. 203 of 1979), and floodplains (Floodplain Encroachment Act, P.A. 167 of 1968). Cooperation and assistance should be given to LWMD personnel in evaluating permit applications. In addition, we should identify sensitive and unique habitats for protection and possible public acquisition.

Removal of obstructions to flow and navigation

It has been common practice on many streams to systematically remove all obstructions within the stream channel, including fallen trees and log jams. The usual purpose of these removals is to prevent restriction to navigation, to drain storm water as quickly as possible, and to remove what some consider as unsightly messes. However, such action has severe negative effects on fisheries habitat. It removes critical fish cover and results in a stream channel morphology that is flat and devoid of complexity (Heede 1980). Further, it decreases stream cross sectional area and reduces diversity of water velocities and turbulence (more laminar flows). Such channels provide extremely poor habitat for fish and other aquatic organisms. In addition, pruning of sweepers (large trees leaning into streams) can degrade stream aesthetics. The American Fisheries Society, an organization of professional fisheries scientists and managers, has documented the importance of this woody material in streams, while recognizing that obstructions can cause stream flow problems in some instances. They have developed guidelines for removal of stream obstructions (Anonymous 1983).

There are no regulations prohibiting the removal of in-stream obstructions by landowners, if the work is done by hand, but such practices should be discouraged through education. On navigable streams, only the vegetation (fallen trees, sweepers, and so on) which causes navigational hazards should be removed, and only to the extent necessary to allow passage of watercraft. Generally, if a watercraft can pass under, over, or around the trees at normal stream flow, the obstruction would not be legally recognized as a hazard to navigation (D. Inman, MDNR, personal communication). Efforts should be undertaken to inform recreationists on rivers (canoeists, boaters, and livery owners) of the importance of large woody debris to the health of the aquatic system. Such users should be encouraged to view these obstructions as part of a recreational experience in a natural habitat. Further, we recommend legislation be adopted to regulate removal of these obstructions.

Addition of fish cover

Lack of cover in general is a factor limiting fish populations, and lack of large cover limits the number of larger fish. Cover is lacking in many streams for a number of reasons. Flooding, particularly on flashy streams, moves large woody debris from the stream channel to the floodplain. As the number of human development projects increase in a watershed, so does the magnitude and frequency of floods (Berry 1992). And this, in turn, accelerates the removal of large woody debris from stream channels. In addition, removal of large woody debris (desnagging) by river users and agricultural interests removes significant amounts of fish cover. Finally, lack of large trees in the riparian zones of streams means that the source for large woody debris is not available.

Fisheries managers have recognized the need for large woody debris. Cover for fish is critical in Michigan's streams, because most are low-gradient, run-type streams (rather than riffle/pool type streams) whose major source of habitat diversity is this woody debris. Various methods are used to increase needed fish cover in streams. Techniques that have been used include whole log covers, half logs, slab logs, log sod covers, log jams, fallen trees, boulders, lunker structures, sky boom structures, and pool excavation (White and

Brynildson 1967; Hunt 1986, 1988, 1991; Lyons 1990). When planning fish cover improvement projects, the character of the stream must be considered, including stream flows and winter icing conditions. It is best to keep cover beneath the water surface, because it reduces rot and ice damage. Further, it is more aesthetically pleasing and does not impede navigation. The maintenance of greenbelt buffer strips along streams will, in time, produce more natural large woody debris to serve as fish cover in streams. Canoeing and boating interests often remove excessive amounts of fish cover in streams to enhance navigation. This practice should be controlled.

Addition of spawning gravel

In some streams, recruitment of desirable fish populations is limited by a lack of suitable spawning habitat. In particular, trout and salmon (salmonids) and sturgeon require gravel and cobble in the streambed to successfully incubate their eggs. If gravel and cobble is scarce material in the natural stream corridor, it can be added to the stream to help increase natural reproduction potential of these fishes (Chuck Bassett, US Forest Service, Hiawatha National Forest, personal communication). The gravel should be placed in areas with highest gradients, near inputs of groundwater, and where sedimentation and migrating sand is not a problem. An excellent location to place spawning gravel is just downstream from a sediment trap.

Aesthetics and Level of Public Use

Aesthetics

Stream aesthetics is an important part of the fishing and other recreational pursuits on flowing waters. Many methods and materials have been used to restore stream habitat with little regard to aesthetics. In some states it was common practice to use such items as old car bodies and used tires for bank stabilization and fish cover projects. In Michigan, broken concrete and asphalt have been used to stabilize streams and cement abutments have been placed adjacent to streams to block ATV traffic on pipeline corridors. Use of these materials disrupts the natural appearance of the stream and degrades its aesthetics quality.

Natural materials (field stone, limestone, wood, whole trees, vegetative plantings, and so on) should be the primary material utilized with few exceptions. The use of local, parent material is best whenever possible. Use of materials such as clean broken concrete may be acceptable in certain urban settings, or if placed below the low water level, out of view.

As discussed in an earlier section, greenbelt zoning of all streams should be attempted for many reasons (see *Vegetation Management of the Corridor*), including the protection and enhancement of aesthetics.

Access sites

Human access sites are special areas of concern on streams, because human use is concentrated subjecting the stream to a number of potential problems including erosion, storm water runoff, and littering. Access sites are often large open areas, devoid of vegetation, and very unsightly. In addition, adequate funding is frequently unavailable for proper maintenance. Commercial use of access sites for canoe, tube, and boat launching can also be a problem when sites are not designed and maintained for such use.

Access sites need to be designed and constructed or rebuilt to minimize erosion and storm water runoff. Designs should incorporate greenbelts, storm water retention basins, traffic control devices (fencing, stairways, etc.), and bank stabilization at the launch area (runner logs, gravel, and so on). Construction plans should be designed for average rather than peak use. Some waiting at access sites during peak use (e.g. weekends during summer) is warranted to reduce the obtrusiveness of the site. On many streams, the most appropriate development is small scale (1-3 cars) access sites at multiple points along the stream rather than one large site.

Additional funding sources need to be found to properly maintain access sites. Commercial users of public access sites should be charged a user fee. Use of funding or labor from volunteers such as river restoration groups, youth organizations, or commercial livery operators are options that need to be explored.

Management of recreational use

The level of recreational use of a stream by humans can reach such a high point that stream habitat is degraded and conflicts arise between users. The most frequent problem occurs on rivers with very heavy watercraft traffic and significant angling pressure. Users entering and exiting the stream can cause bank erosion and trespass problems if private property is nearby. Heavy use often results in unauthorized, and indiscriminate removal of in-stream obstructions to facilitate navigation. The “obstructions” are important as fish cover and habitat (fallen trees, logs, brush, large rocks, overhanging vegetation, etc.). Anglers and canoeists often disrupt each other’s recreation. Many trout anglers maintain that the quality of the fishing experience is degraded considerably when heavy canoe traffic occurs on a river. On the other hand, some canoeists view wading anglers as obstacles to navigation.

In cases where intense recreational use of streams reduces habitat and aesthetic quality or causes significant user conflicts, the level of usage needs to be controlled. The specific type of control that is used depends on the problem and may include segregating the users by time restriction or limiting the number of users by a permit system. Controls of recreational use have rarely been exercised on Michigan rivers, because there is no specific law that permits control. Some control has been accomplished by placing restrictions at access sites, such as limiting size of sites, providing walk-in-only access, and opening and closing gates. However, as participation increases with human population size, we think legislation should be passed to establish legal authority to control levels of recreational use on our rivers, and where problems are anticipated, a long-term, recreational-use plan should be developed.

Fishery regulations

The level of angling activity on streams can increase to a point where key fishery values are reduced. For example, heavy harvest of fish could reduce numbers and/or size structure of the fish population. Fishing regulations are management tools that can be used to protect and restore fish populations by limiting the participation and/or harvest by anglers (Clark and Alexander 1985, 1992; Clark et al. 1981). Managers can also use special fishing regulations on streams to meet angler demand for unique fisheries. Special fishing regulations are different, usually more restrictive regulations, than those in effect on a statewide level. They are generally tailored to improve opportunities for catching larger fish and may completely prohibit harvest of fish, such as no-kill regulations, or restrict harvest to only very large fish, such as trophy regulations (Clark and Alexander 1992). As human population levels increase and participation in fishing increases, the need for and interest in special fishing regulations will also increase. Managers need to carefully analyze the fishery potential of a given stream and the recreational values of anglers to determine the management objectives for that stream. Public meetings of the angler clientele and other recreational interests, including riparian owners, local governments, and the business community, should be held prior to implementing special fishing regulations.

Priority of Action and Implementation

The most critical step in stream protection and restoration is the planning process. As discussed previously, the entire watershed must be managed to most effectively protect and improve the volume and quality of water in a river system. The first step toward managing the watershed is to develop an inventory that describes the present status of water quality, quantity, fish habitat, fishery, human land use, and so on. The next step is to define fishery management objectives, based on the potential of the stream, and to identify the actions necessary to reach those objectives. The final step in the planning process is the development of an action plan. Determination of the priority of attack should be based on location within the watershed (uplands and headwater areas first), severity of the problem, and an analysis of the costs and benefits.

Because protection of water quality and quantity involves management of the entire watershed, development of the management plan must allow input by all government organizations that have jurisdiction within the watershed and all affected citizen or private groups, including both the public and private sectors. An effective approach to developing and implementing such a plan is to form a watershed advisory group or council. Participants should include divisions of MDNR (such as the Fisheries, Wildlife, Forestry, SWQD, and LWMD), divisions of Michigan Department of Agriculture, divisions of U.S. Department of Agriculture (such as the Forest Service, Natural Resources Conservation Service, and Resource, Conservation, and Development Council), local government organizations (such as, counties, townships, municipalities, and councils of government), and citizen and private groups (such as, watershed councils, river associations, industries and sportsmen's clubs). In addition to planning and decision making, two key functions of watershed management groups are: 1) educating to help generate better public support for the project; and 2) seeking financing to help support the costs of putting the plan into action.

We believe that the best way to assure the successful implementation of a river watershed management plan is to create a watershed management authority. Such a body should have legal and financial powers to implement the proposals outlined in the plan. Further, they need to continue to maintain improvements that are made to assure a continued river quality. The management authority should have the power to tax, regulate, and manage all aspects of the management plan. The Local River Management Act (P.A. 253 of 1964) enables local units of government to organize watershed authorities or councils of this type in order to coordinate watershed management planning and implementation. We strongly support enactment of new legislation which would substantially increase the authority of river basin councils.

References

- Alexander, G.R., and E.A. Hansen. 1983. Sand sediments in a Michigan trout stream. Part II. Effects of reducing sand bedload on a trout population. *North American Journal of Fisheries Management* 3:365-372.
- Alexander, G.R., and E.A. Hansen. 1986. Sand bed load in a brook trout stream. *North American Journal of Fisheries Management* 6:9-23.
- Anonymous. 1983. *Stream Obstruction Removal Guidelines*. AFS, Bethesda, Md.
- Bain, Mark B., J.T. Finn, and H.E. Booke. 1988. Streamflow regulation and fish community structure. *Ecology*, 69(2):382-392.
- Bartholic, J.F., R.L. Cook, K.D. Bernard, and F.M. D'Mtri. 1983. Impact evaluation of increased water use by agriculture in Michigan. Research report 449, Mich. State Univ. Agriculture Exper. Stn., E. Lansing, Mich.
- Benson, N.G. 1953. The importance of groundwater to trout populations in the Pigeon River, Michigan. Reprinted from *Transactions of the Eighteenth North American Wildlife Conference*, 1953:269-281.
- Benson, N.G. 1955. Observations on anchor ice in a Michigan trout stream. Reprinted from *Ecology* 36(3):529-530.
- Berry, Thomas. 1992. Land use and stream discharge in Michigan's cold water streams. Master's theses. University of Michigan, Ann Arbor.
- Bosch, J.M. and J.D. Hewlett. 1982. A review of catchment experiments to determine the effects of vegetation changes on water yield and evapotranspiration. *Journal of Hydrology*, 55:3-23.
- Campbell, D., and C. Bassett. 1986. *Rivers of sand: A perspective of river restoration rehabilitation for improved fish habitat on major rivers of the Hiawatha National Forest*.
- Clark, Richard D., Jr., and G.R. Alexander. 1992. Evaluation of catch-and-release trout fishing regulations on the South Branch of the Au Sable River, Michigan. Mich. Dep. Natl. Resour. Fish. Res. Rep. 1987. Ann Arbor, Michigan.
- Clark, Richard D., Jr., and G.R. Alexander. 1985. Effects of a slotted size limit on a multispecies trout fishery. Mich. Dep. Natl. Resour. Fish. Res. Rep. 1926, Ann Arbor, Michigan.
- Clark, Richard D., Jr., G.R. Alexander, and H. Gowing. 1981. A history and evaluation of regulations for brook trout and brown trout in Michigan streams. *N. Am. J. Fish. Manage.* 1:1-14.

- Cushman, Robert M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. *N. Am. J. Fish. Manage.*, 5:330-339.
- Dewberry, T.C. 1992. Protecting the biodiversity of riverine and riparian ecosystems: the national river public land policy development project. *Trans. of the 57th N.A. Wildl. and Nat. Res. Conf.*, pp.424-432.
- Eschner, A.R. and D.R. Satterlund. 1963. Snow deposition and melt under different vegetative covers in central New York. *USDA For. Ser. Res. Note NE-13*, 6p. Northeast. For. Exp. Stn., Upper Darey, Penn.
- Greene, G.E. 1950. Land use and trout streams. *Journal of Soil and Water Conservation* 5:125-126.
- Gowan, C. and N.R. Kevern. 1985. An assessment of the impact of irrigation withdrawals on trout habitat in a southern Michigan stream. *Papers of the Mi. Acad. of Science Arts and Letters*. 17(2:149-155).
- Hansen, Edward A. 1969. Relation of snowpack accumulation to red pine stocking. *USDA For. Ser. Res. Note NC-85*. North Cent. For. Exp. Stn., St. Paul, Minnesota.
- Hansen, Edward A. 1971. Sediment in a Michigan trout stream, its source, movement and some effects on fish habitat. *USDA For. Ser. Res. Paper NC-59*. North Cent. For. Exp. Stn., St. Paul, Minnesota.
- Heede, Burchard H. 1980. Stream dynamics: an overview for land managers. *USDA For. Ser. General Tech. Rep. RM-72*, 26p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.
- Hendrickson, G.E. 1966. Michigan's Au Sable River - today and tomorrow. *Michigan Dept. Conservation, Geological Survey Bull.* 3, Lansing.
- Hendrickson, G.E., and C.J. Doonan. 1972. *Hydrology and Recreation on the Coldwater Rivers of Michigan's southern Peninsula*. U.S. Geological Survey, 83pp.
- Herbert, D.W.M., and J.C. Merkens. 1961. The effect of suspended mineral solids on the survival of trout. *International Journal of Air and Water Pollution* 5:46-55.
- Herbert, D.W.M., J.S. Alabaster, M.C. Dart, and R. Lloyd. 1961. The effect of china-clay wastes on trout streams. *International Journal of Air and Water Pollution* 5:56-74.
- Herbert, D.W.M., and J.M. Richards. 1963. The growth and survival of fish in some suspensions of solids of industrial origin. *International Journal of Air and Water Pollution* 7:297-302.

- Hewlett, J.D., and A.R. Hibbert. 1961. Increases in water yield after several types of forest cutting. *Quart. Bull. Int. Ass. Sci. Hydrol.*, 6:5-17.
- Hibbert, A.R. 1969. Water yield changes after converting a forested catchment to grass. *Water Resources Research*. 5:(3)634-640.
- Hoover, M.D. 1944. Effect of removal of forest vegetation upon water yields. *Trans. Am. Geophys. Union*, Part 6, 40pp.
- Hunt, Robert L. 1986. An evaluation of brush bundles and half-logs to enhance carrying capacity of two brown trout streams. Pages 31-62 in J. G. Miller, J. A. Arway, and R. F. Carline, eds. *Fifth Trout Stream Habitat Workshop, Proc. of a Conf. at Lock Haven, Penn.*
- Hunt, Robert L. 1988. A compendium of 45 trout stream habitat development evaluations in Wisconsin during 1953-1985. *Wisc. Dep. Nat. Resour. Tech. Bull. No. 162*. Madison.
- Hunt, Robert L. 1991. Habitat improvement remedies for sick trout streams. Pages 165-174 in Thorne Ecological Institute, *Proc. V: Issues and Technology in the Management of Impacted Wildlife, Snowmass Resort, Colorado*.
- Johnson, E.A., and J.L. Kouner. 1956. Effect on streamflow of cutting a forest understory. *Forest Sci.*, 2:82-91.
- Leopold, L. 1968. *Hydrology for urban land planning - a guidebook on hydrologic effects of urban land use*. USGS, Circ. 554.
- Lyons, J. and C. C. Courtney. 1990. A review of fisheries habitat improvement projects in warmwater streams, with recommendations for Wisconsin. *Wisc. Dep. Nat. Resour. Tech. Bull. No. 169*. Madison.
- Maurizi, Susan, and F. Poillon, editors. 1992. *Restoration of Aquatic Ecosystems*. National Academy Press, Washington, D.C.
- Meehan, W.R. 1970. Some effects of shade cover on stream temperature in southwest Alaska. *USDA Forest Service Research Note PNW-113*. Pacific Northwest Forest Range Experiment Station. Portland, Oregon.
- National Research Council. 1992. *Restoration of Aquatic Ecosystems*. National Academy Press, Washington, D.C.
- Patton, D.R. 1973. A literature review of timber-harvesting effects on stream temperatures. *USDA Forest Service Research Note RM 249*. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

- Pluhowski, E.J. 1972. Clear-cutting and its effect on the water temperature of a small stream in northern Virginia. U.S. Geol. Survey Prof. paper 800-C, pages 257-262.
- Poff, N.L., and J.V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. *Can. J. Fish. Aquat. Sci.* 46:1805-1818.
- Poff, N.L., and J. V. Ward. 1990. Physical habitat template of lotic systems: recovery in the context of historical pattern of spatiotemporal heterogeneity. *Environmental Management* Vol.14, No.5,629-645.
- Rowe, P.E. 193. Streamflow increases after removing woodland riparian vegetation from a southern California Watershed. *J. Forestry*, 61:365-370.
- Swift, L.W., and J.B. Messer. 1971. Forest cuttings raise temperatures of small streams in the southern Appalachians. *Jour. of Soil and Water Conservation* 26:(3)111-116.
- Urie, Dean H. 1966a Influence of forest cover on ground-water recharge, timing, and use. In *Int. Forest Hydrology Symp. Proc.* p.313-324, Pennsylvania State Univ.
- Urie, Dean H. 1966b. Influence of forest cover on snowpack and ground-water recharge. *Ground Water* Vol.3, No.1.
- Urie, Dean H. 1977. Groundwater differences on pine and hardwood forests of the Udell Experimental Forest in Michigan. *USDA For. Ser. Res. Pap. NC-145.* North Cent. For. Exp. Stn., St. Paul, Minnesota.
- White, R.J. 1975. Trout population responses to streamflow fluctuation and habitat management in Big Roche-a-Cri Creek, Wisconsin.
- White, R.J. and O.M. Brynildson. 1967. Guidelines for management of trout stream habitat in Wisconsin. *Wisc. Dep. Nat. Resour. Res. Rep. No. 39*, 64pp.
- White, R.J., E.A. Hansen, and G.R. Alexander. 1976. Relationship of trout abundance to stream flow in midwestern streams. In *Instream flow Needs.* Vol. II, American Fisheries Society, Bethesda, Maryland.

Appendix A.

STREAM PROTECTION AND RESTORATION POLICY STATEMENT

by

Michigan Chapter of the American Fisheries Society
Rivers and Streams Committee
Troy G. Zorn, Chairperson

In natural stream ecosystems, the stream channel is in dynamic equilibrium with the water and sediment it receives. The native stream biota evolved to perpetuate themselves under the original channel conditions. Human activities have altered natural processes and communities in Michigan streams. Restoration of lost physical processes and biotic communities to these stream ecosystems is desirable.

Concepts from the National River Public Land Policy Development Project (Dewberry 1992) and the book *Restoration of Aquatic Ecosystems* (National Research Council 1992) provide the basis for our policy. **Restoration is defined as movement of an ecosystem toward an approximation (not a re-creation) of its condition prior to disturbance.** The goal of stream protection and restoration in Michigan is:

To protect and restore the natural ecological integrity of riverine landscapes.
(Dewberry 1992)

The riverine landscape consists of the network of stream channels and riparian areas within the watershed. *Natural ecological integrity* includes species composition, diversity, and functional organization which are comparable to that found in the natural habitat prior to its disturbance. Maintenance of integrity in stream ecosystems centers on the principles of connectedness, natural variability and resiliency.

Connectedness is needed longitudinally (upstream-downstream), laterally (stream channel-riparian zones and floodplains), and vertically (riparian wetlands - groundwater table). Longitudinal connections allow free transport of organic and inorganic matter in a downstream direction (e.g. the River Continuum Concept; Vannote et al. 1980), and unhindered movement of organisms (and their genetic material) in either direction. Lateral connections allow for natural channel-shaping processes, and movements of water, matter, and organisms between the channel and its riparian and floodplain areas. Vertical connections between the groundwater table and riparian wetlands or floodplains provide water storage during wet periods and enhance summer baseflows.

Stream systems are dynamic. Restoration programs should allow for natural variations in channel morphology and position over time. Finally, restoration efforts should take advantage of the natural resiliency of streams, i.e. their ability to repair themselves.

Stream Protection

Strong protection measures are needed to prevent further degradation and insure the success of stream restoration programs in Michigan. The following actions should be taken in order to protect and restore the natural ecological integrity of stream ecosystems (from Dewberry 1992).

1. ***Protect and restore headwater streams, riparian areas and floodplains, and reconnect streams with floodplains where possible.*** Headwater streams play an important role in controlling the delivery of water and sediment to downstream reaches. Upland management strategies should minimize changes in basin hydrology so that precipitation and eroding sediment enter the stream at natural rates. Healthy riparian areas contain all age and size classes of vegetation. Only management activities which do not compromise the integrity of these areas should be allowed. Large woody debris must be left in riparian areas (where it maintains habitat complexity) and floodplains (where it serves as a supply of woody debris to the stream).
2. ***Establish a state-wide system of aquatic refuges.*** Few watersheds with high natural integrity remain in Michigan, particularly in the southern Lower Peninsula. Stream reaches representing various stream types should be identified and preserved. These will serve as ecological “benchmarks” for similar streams and as species banks. Stream ecosystem refuges should include stream channels and their riparian floodplains and wetlands.
3. ***Perform watershed assessments and historical reconstructions.*** Watershed assessments provide an ecological framework for the development of protection and restoration programs. Assessments should follow a hierarchical sequence, beginning at the landscape level, and proceeding towards the stream reach and site levels. Each assessment should document hydrological and ecological processes of the watershed, highlighting significant aspects such as flow characteristics, or important spawning rapids or marshes, and discuss significant changes that have occurred through time. These assessments should be based on historical reconstructions (e.g. Zorn and Seelbach 1992; Trautman 1957) and integrated with current knowledge of stream community structure and functional processes.

Stream Restoration

Stream restoration efforts should be based on the following principles described in the National River Public Land Policy Development Project (Dewberry 1992):

1. Restoration should be based on a long term, whole basin perspective.
2. The goal should be to restoration of stream function, i.e. the natural downstream processing of water, sediment, and nutrients.

3. Restoration plans should be designed to minimize the need for future human maintenance.
4. Restoration plans should focus on the source of the degradation, not the symptoms.

Objectives of stream restoration programs should be prioritized as suggested by the National Research Council (1992):

1. Restore the natural sediment and water regime; specifically, restore natural rates and patterns of water and sediment delivery, including the annual-to-decadal patterns of floods and droughts.
2. Restore the natural channel geometry, if restoration of the water and sediment regimes alone will not.
3. Restore the riparian plant community.
4. If desired, restore native plants and animals within the stream.

Components of Protection and Restoration Projects

Based on the above guidelines, restoration projects should feature the following steps:

1. Assess status of the stream ecosystem based on existing data and historical reconstructions. See the Huron River Basin Assessment (Hay-Chmielewski et al. 1993) as an example.
2. Identify non-degraded reaches and develop strategies for their protection.
3. Identify major changes that have occurred to the stream ecosystem and develop a prioritized list of restoration objectives.
4. Develop strategies to be used in attaining the primary objectives. Strategies employed in the plan should provide details regarding:
 - A. Level of involvement of participants (representatives of agencies, watershed councils, drain commissions, local communities, riparian landowners, angler groups, etc.).
 - B. Techniques used (policies, equipment, human resources, funding costs and sources, etc.).
 - C. Plans for monitoring and evaluating ecosystem responses to the restoration effort. Response variables that should be monitored include stream discharge, sediment load, and channel morphology.
5. Evaluate effectiveness of the restoration project; addressing ecosystem response over time, effectiveness of methods and technologies used, and costs.

Literature Cited

- Dewberry, T.C. 1992. Protecting the biodiversity of riverine and riparian ecosystems: the National River Public Land Policy Development Project. Transactions of the 57th North American Wildlife and Natural Resources Conference (1992). pp. 424-432.
- Hay-Chmielewski, E.M., P.W. Seelbach, G.E. Whelan, and D.B. Jester, Jr. 1993. Huron River watershed plan. Michigan Department of Natural Resources Fisheries Division.
- National Research Council. 1992. Restoration of Aquatic Ecosystems. pp. 206-208. National Academy of Sciences.
- Trautman, M.B. 1957. The fishes of Ohio. Ohio State University Press. Columbus, Ohio.
- Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.
- Zorn, T.G. and P.W. Seelbach. 1992. A historical perspective of the Clinton River, its watershed and fish communities. Michigan Department of Natural Resources Fisheries Division Technical Report Number 92-10.

This policy statement was approved by vote of Michigan Chapter of the American Fisheries Society members at Spring Meeting, March 25, 1994.

This guide, now in its second edition, provides some of the basics and specifics that concerned citizens need to help lakes survive and thrive. It describes how lakes work, how various lake problems occur, what individuals and groups can do to protect and improve lakes, and where advice and assistance can be obtained. These three terms “stewardship, management, and restoration” are related but not interchangeable.

1. Lake and Watershed Stewardship: An Attitude. “Treat the Earth well.” Lake restoration is not just a yearly process of adding chemicals to an affected lake. With \$2 billion spent annually on stream restoration worldwide, there is a pressing need for guidance in this area, but until now, there was no comprehensive text on the subject. Filling that void, this unique text covers both new and existing information following a stepwise approach on theory, planning, implementation, and evaluation methods for the restoration of stream habitats.
- 1.5 History of stream and watershed restoration, 5.
- 1.6 Key steps for planning and implementing restoration, 7.
- 1.7 References, 8.
- 2 Watershed Processes, Human Impacts, and Process-based Restoration, 11.
- 2.1 Introduction, 11.
- 5.4.3 Riparian buffers and protection, 167.
- 5.5 Habitat improvement and creation techniques, 167.
- 5.5.1 Instream habitat improvement techniques, 167.