1999

A vision for the future: Chemical physical and biological goals for the Clark Fork-Pend Oreille basin

Bonnie Gestring
The University of Montana

Maureen and Mike
MANSFIELD LIBRARY

The University of **MONTANA**

Permission is granted by the author to reproduce this material in its entirety, provided that this material is used for scholarly purposes and is properly cited in published works and reports.

*** Please check "Yes" or "No" and provide signature ***

Yes, I grant permission ✓

No, I do not grant permission ____

Author's Signature Bonnie Gersting

Date 5-28-99

Any copying for commercial purposes or financial gain may be undertaken only with the author's explicit consent.

A Vision For The Future:

Chemical, Physical and Biological Goals for the Clark Fork-Pend Oreille Basin

By
Bonnie Gestring

B.S., Montana State University, 1987

Presented in partial fulfillment of the
requirements for the degree of
Master of Science
The University of Montana
1999

Approved by:

Vicki Watson
Chairperson

Dean, Graduate School

5-28-99
Date

Gestring, Bonnie J., M.S., May 1999
Environmental Studies

A Vision For The Future: Chemical, Physical and Biological Goals For The Clark Fork River Basin (199 pp.)

Chairperson: Dr. Vicki Watson VW

ABSTRACT

Many areas of the Clark Fork River Basin in western Montana suffer degradation. For this reason, the Clark Fork Pend Oreille Coalition, a basin-wide citizens group, has developed a Vision Document which outlines a set of goals and recommendations for action collectively called Watershed CPR: conservation, preservation and restoration. This paper serves as the technical support document for the Vision Document. It reviews, summarizes, and interprets the broad array of research that has been conducted on the Clark Fork River Basin. Existing laws and rules are evaluated in light of watershed science. Policy changes and other actions are recommended to better protect the health and integrity of the aquatic ecosystems of the Clark Fork River Basin. Part I focuses on chemical goals. It describes the existing framework of state water quality standards and nondegradation laws, summarizes causes and sources of impairment throughout the basin, and proposes chemical conditions expected to protect human health and aquatic life. Part II identifies physical goals for the Clark Fork beginning with the stream channel and expanding to riparian and upland areas. Part III recognizes that the ultimate objective of chemical and physical goals is to protect biological communities. It identifies biological goals for the Clark Fork in terms of algae, macroinvertebrate and fish communities. Finally, to assess whether watershed CPR is being achieved, Part IV outlines elements for a watershed monitoring plan.

TABLE OF CONTENTS

FIGURE LIST

List of Tables

INTRODUCTION

The Clark Fork River begins its life as snow melt in the Northern Rockies. Numerous tiny headwater streams gather into creeks which combine to form rivers. The mainstem of the Clark Fork begins near Butte, Montana where three small tributaries converge--Silver Bow, Mill-Willow and Warm Springs Creeks. As it winds its way north and west through the valleys and foothills, tributaries such as the Blackfoot, Bitterroot and Flathead Rivers add to its power and volume. By the time it reaches the state border, it has grown to Montana's largest river. Across the border the mighty Clark Fork widens into the deep, clear waters of Lake Pend Oreille, Idaho, and ultimately continue its journey to the Pacific via the Columbia River.

The Clark Fork-Pend Oreille Basin encompasses 25,000 square miles and supports some 250,000 inhabitants. Bound by the same great watershed, citizens of northern Idaho and western Montana share a common stake and a common responsibility in the river's well being.

Streams, lakes and rivers shape, and are shaped by the watershed through which they flow. We can view them as the watershed's "bottom line", where all land and water uses are reflected in water quality, quantity, habitat and aquatic life. These aquatic ecosystems are characterized by their physical (e.g. channel shape, substrate, flows) and chemical nature (e.g. pH, dissolved oxygen). These, in turn, shape the biological community.

While some areas of the basin are in good condition due to good land stewardship or their remote location, many other areas suffer degradation. Evidence for this is clearly reflected in the basin's waters. Only a quarter of the stream reaches assessed in the basin can fully support their beneficial uses (MTDHES 1994). Over 560 stream miles are chronically dewatered (MTDFWP 1995). Native bull trout have disappeared from 58% of their native range, and westslope cutthroat from 73% of theirs (Thomas 1992; Liknes 1983). Nuisance algae plague the upper and middle Clark Fork River (Weber 1986; Watson & Gestring 1996), and over 120 stream miles and 13,000 floodplain acres are poisoned by toxic mine waste (MTNRDP, 1995). The precarious position of native fish and the impaired condition of many streams and rivers are a clear indication of the inadequacy of existing resource protection measures. Traditional water quality protection programs focus almost entirely on controlling the release of chemical contaminants and fail to address physical and biological impacts such as dewatering, introduced species, stream channel straightening or increased sediment yield.

Furthermore, existing watershed protection efforts are often fragmented and uncoordinated. Over a dozen organizations are involved in research, restoration, reclamation and protection efforts throughout the basin. Yet, there exists no clear and comprehensive vision for the watershed that integrates these efforts and provides specific chemical, physical and biological goals.

With this in mind, the Clark Fork Pend Oreille Coalition, a basin-wide citizens group, has developed a Vision Document for the basin based on watershed and ecosystem science, and on concern for natural and human communities. The vision document

outlines a set of goals and recommendations for action collectively called Watershed CPR: conservation, preservation and restoration.

This paper serves as a technical support document to the vision document. It reviews, summarizes and interprets the vast volumes of research that provide the basis for the vision document. It also evaluates existing laws and rules in light of watershed science. Finally, I recommend policy changes and other actions that I feel would better protect the health and integrity of the aquatic ecosystems of the Clark Fork-Pend Oreille Basin.

Part I focuses on chemical goals. It describes the existing framework of state water quality standards and nondegradation laws, summarizes causes and sources of impairment throughout the basin, and proposes chemical conditions expected to protect human health and aquatic life. Part II identifies physical goals for the Clark Fork beginning with the stream channel and expanding to riparian and upland areas. Part III recognizes that the ultimate objective of chemical and physical goals is to protect biological communities. It identifies biological goals for the Clark Fork in terms of algae, macroinvertebrate and fish communities. Finally, to assess whether watershed CPR is being achieved, Part IV outlines elements for a watershed monitoring plan.

This paper was written primarily in 1996. While various issues were updated in 1999, some major new developments occurred in the iterim, and are not discussed throughly in this paper.

If there is magic on this planet, it is contained in water.
-Loren Eiseley

Section I. CHEMICAL GOALS

In 1969, the Montana Water Quality Act was passed to provide water quality protection for Montana's streams, lakes and rivers. This law directs the state "to conserve water by protecting, maintaining and improving the quality and potability of water for public water supplies, fisheries, recreational, agricultural, industrial and other beneficial uses" (MCA 75-5-101). Protection of these beneficial uses occurs primarily through state water quality standards and Montana's nondegradation law.

All too often, however, state water quality standards provide only the minimum of protection for aquatic life. Existing standards assume that people, fish and wildlife are exposed to only one pollutant from only one source. Ignored are simultaneous, perhaps additive or synergistic impacts from multiple pollutants and from multiple sources such as air, water or food (Adler et al. 1993). For example, research has shown that the combination of ammonia and copper are far more toxic than either substance individually (Rand and Petrocelli 1985).

The establishment of standards does not take into account how some substances reach levels harmful to aquatic life after accumulating in sediments or concentrating in the food chain. For example, mining activities have contaminated bed sediments in the upper Clark Fork river with toxic metals (MTNRDP, 1993). Aquatic insects which live and feed on the river bottom are an important toxic pathway by which fish are contaminated

(Woodward, 1994 & 1995). Over time, these toxic metals concentrate in fish tissue at a level that causes reduced growth, health impairment or death.

Water quality standards operate as if crystal clear, distilled water running through a concrete channel is the goal, because they focus almost entirely on chemical parameters (Karr, 1995). They ignore many of the critical physical elements necessary to provide high quality habitat for fish and other aquatic life. A good trout stream needs fallen trees and branches to form deep cold pools, stable streambanks for sediment-free spawning beds, and healthy streamside vegetation to provide shade and leaves for hungry aquatic insects. Despite the state's narrow focus on protecting chemical water quality, the Montana Legislative Audit Bureau concluded even these laws and rules are not well enforced (MTLAB 1994).

Furthermore, numerical criteria are often set based on laboratory tests on standard organisms. Local aquatic life and below optimum physical, and chemical conditions are generally not taken into consideration. For all these reasons, water quality standards must be set with a wide margin of safety and decisions based on these standards should err on the side of caution.

A. State Water Quality Standards and Nondegradation Laws

State water quality standards consist of two elements: 1) designated uses and 2) the conditions required to support those uses. Every water body in the state has been classified according to its designated use (e.g. drinking water, fisheries, recreation, industrial, agriculture). Although the state has some flexibility in establishing these uses, the U.S. Environmental Protection Agency (EPA) requires that, at a minimum, streams are

"fishable and swimmable" unless that would result in "substantial and widespread economic and social impact" (CWA Section 101). Use designations are critical because they determine the level of water quality protection that will ultimately be required. In general, four designated uses require the highest water quality requirements: drinking water, aquatic life support, cold water fisheries and swimming.

Surface waters are classified under four basic categories (A, B, C, and I), and each category corresponds to specific designated uses (MTDHES 1994). Class A represents the highest quality waters, and Class I (Impacted) represents the most severely impaired. Class A and B are suitable for drinking, while Class C is not. The B and C classification are further subdivided into cold water fisheries (B-1& C-1), marginal coldwater fisheries (B-2 & C-2) and warm water fisheries (B-3, C-3). Streams classified as C-3 are naturally high in total dissolved solids. Hence, they are marginal for drinking, agricultural and industrial uses.

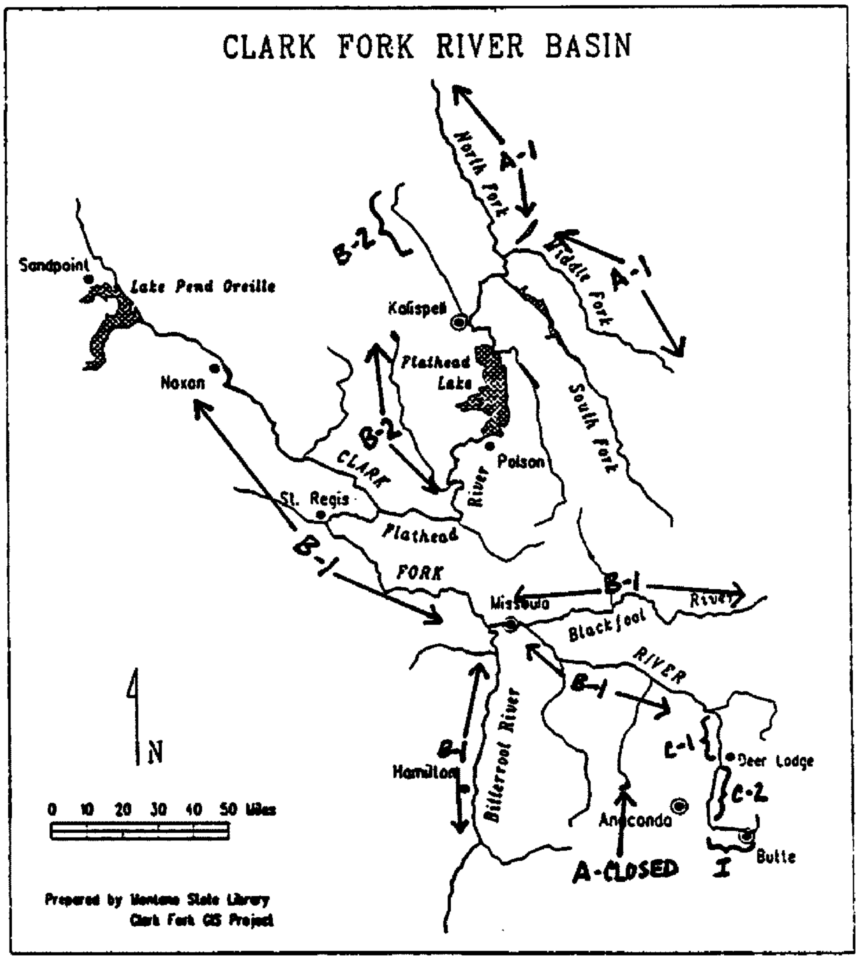
Table 1. Designated uses relative to use-classifications (MTDHES, 1994).

Designated Uses	A-closed	A-1	B-1	B-2	B-3	C-1	C-2	C-3
Bathing, swimming & recreation.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Agricultural & industrial.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NM
Drinking, culinary & food processing.	Yes, after simple disinfection	Yes, after conventional treatment	Yes, after conventional treatment	Yes, after conventional treatment	Yes, after conventional treatment	No	No	NM
Growth and propagation of fish& assoc. aquatic life, waterfowl & furbearers.	Salmonids	Salm.	Salm.	MPS	Non - Salm.	Salm.	MPS	Non-Salm.

NM = Naturally Marginal - high in dissolved solids. MPS = marginal propagation of salmonids Source: ARM 16.20

I (Impacted) - These streams were impacted by an activity which would not allow the stream to fully support drinking, recreation or fishery uses at the time the stream was classified. The goal of the state is to have these waters fully support all of the above uses.

Figure 1. Various Use-Classifications in the Clark Fork River Basin (ARM 16.20.604).



The federal EPA publishes criteria (guidelines) which are the conditions presumed to support the designated uses. States adopt enforceable standards based on these criteria. These may be numeric standards (such as the limit of acceptable concentrations of toxic metals) or they may be narrative standards (such as prohibiting discharges which will produce odors, colors or other conditions which create a nuisance). Many narrative standards state that no changes from natural conditions will be allowed (e.g. temperature or sediment levels), but since natural levels are very variable and not well characterized, these are difficult to enforce. In addition to the standards in this table, standards for additional chemicals are summarized in a document called WQB-7.

Table 2. Various Water Quality Standards relative to use-classifications (ARM 16.20.616-624).

	Coliform Bacteria	pH Max. Change	Temp. Max. Change	Turbidity Max. Inc.	Color Max. Inc.	Dissolved Oxygen Minimum (mg/l)	
Class	#/100ml	pH Units	Deg. F	Turbidity Units	Color Units	Early*** Life Stage	Other**** Life Stage
A-Closed	50	NC	NI	NI	NI	NC	NC
A-1	"	0.5*	1	NI	2	9.5	5
B-1	200	"	"	5	5	"	"
B-2	"	0.5**	"	10	"	"	"
B-3	"	"	3	"	"	6	4
C-1	"	0.5*	1	5	"	9.5	5
C-2	"	0.5**	"	10	"	"	"
C-3	"	"	3	"	"	6	"
I	"	3	NI	NI	NI	"	"

*must be maintained between 6.5 and 8.5 ** must be maintained between 6.5 and 9.0. ***7 day mean * ***7 day mean minimum
NI=No Increase above "natural" condition. NC=No change from "natural" condition.

In addition to designated uses and water quality conditions, federal policy and Montana law require that water not be degraded. Montana's nondegradation law requires that "any state waters whose existing quality is higher than the established water quality standards be maintained at that high quality unless it has been affirmatively demonstrated that a change is justifiable...and will not preclude present and anticipated use of those waters" (MCA 75-5-303). This is perhaps Montana's most powerful tool for protecting water quality and supporting aquatic life.

The nondegradation law applies to all waters classified as "high quality". Until 1995, all state waters were considered high quality as long as they supported one or more of their designated uses. However, in 1995 the legislature redefined high quality waters as all state waters except those "that are not capable of supporting any one of the designated

uses for their classification" (MCA 75-5-103(9)). If this definition is interpreted to mean high quality waters must be capable of fully supporting all of their uses, over 1,750 miles of streams may lose their nondegradation protection. This is the number of assessed stream miles that are not supporting all of their beneficial uses according to the Montana Dept. of Health and Environmental Science (1994). Although human impact is, for the most part, what prevents these waters from supporting their designated uses, these streams will no longer be considered "high quality" waters and can be degraded right up to the standard for any substance regardless of whether that substance is responsible for the use violations. The Dept. of Env. Quality, however, maintains the position that state waters that support one or more uses are "high quality", until the courts dictate otherwise (A. Horpestead, 1996 pers. comm.).

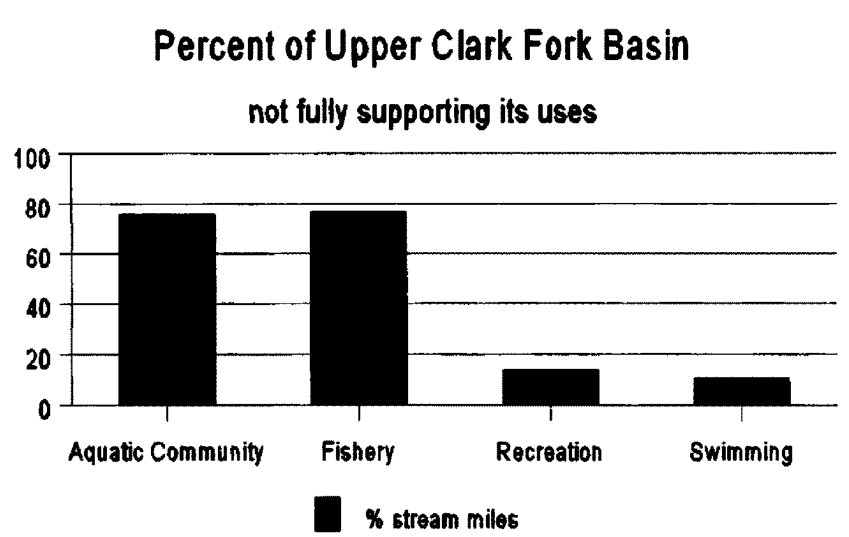
The 1995 amendments to the nondegradation law also restrict most Montanans from legally challenging an authorization to degrade. It provides legal standing only to those people who demonstrate they have property, business interests, or water rights that will be affected (MCA 75-5-103 (11)). Montana's streams and rivers are "waters of the state" and, by law, held in trust for all Montanans. Not only do all Montanans have a stake in a clean and healthy environment, the Montana Constitution gives all Montanans this responsibility and right: "the state and each person shall maintain and improve a clean and healthful environment in Montana for present and future generations...and the legislature shall provide adequate remedies for the protection of the environmental life support system from degradation" (Mont. Const. Art. 9, Section 1).

Waterbody Assessment

The Federal Clean Water Act directs the EPA (or the state agency it designates) to assess all streams, rivers and lakes throughout Montana to determine whether or not water quality standards and beneficial uses are being supported. Streams are classified as either: 1) Fully supporting, 2) Threatened (a new activity or an increase in existing activities may result in water quality standard violations or use impairments), 3) Partially supporting (impaired but not violating water quality standards) or, 4) Not supporting (water quality violations have occurred).

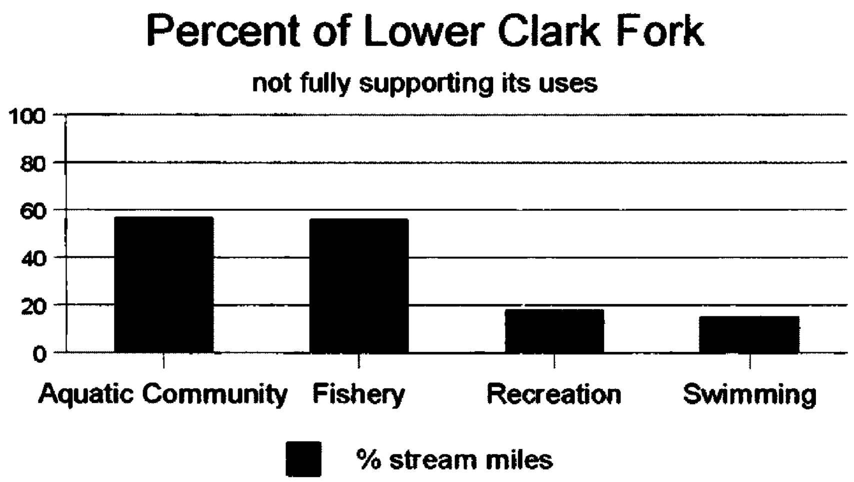
To date, 206 stream and river segments representing 2,315 stream miles have been assessed throughout the Clark Fork River basin; 1,005 miles in the lower Clark Fork basin and 1,335 in the upper Clark Fork basin. Initial efforts have focussed primarily on evaluating stream reaches that have been impacted. Figures 2 and 3 illustrate the number of assessed stream miles supporting each beneficial use in the upper and lower Clark Fork.

Figure 2: Beneficial use support in the upper Clark Fork River Basin. Source of data MTDHES (1994).



Figures 2:

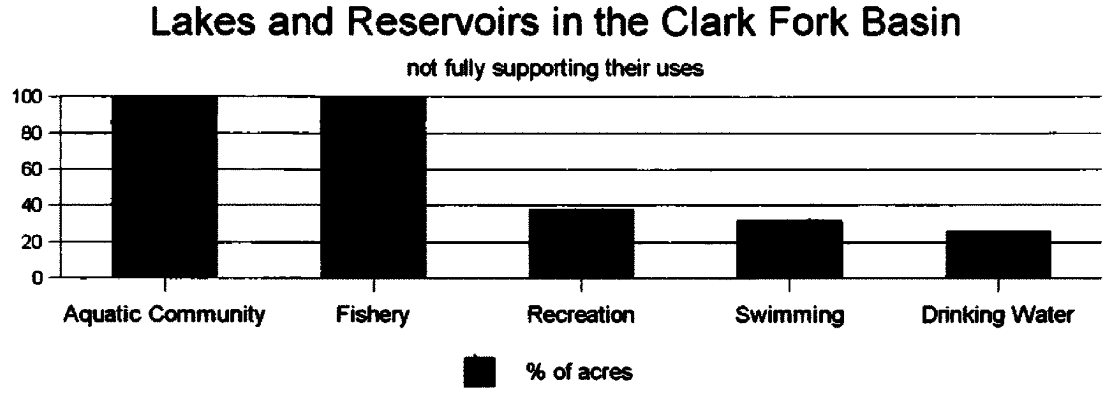
Figure 3: Beneficial use support in the lower Clark Fork River Basin. Source of data MTDHES (1994).



Of the 2,315 assessed stream miles in the Clark Fork river basin, 701 stream miles (30%) are described as fully supporting their beneficial uses, 1,511 stream miles (66%) partially support their beneficial uses, and 103 stream miles (4%) do not support their beneficial uses. However, of the 701 stream miles fully supporting their beneficial uses, all are categorized as having a threatened fishery. Hence, every stream assessed in the Clark Fork Basin is listed as either threatened, partially supporting or not supporting cold water fisheries.

Only a few lakes and reservoirs in the Clark Fork Basin have been assessed: Noxon Reservoir, Georgetown Lake, Salmon Lake and Seeley Lake. None of these waterbodies fully support two beneficial uses - fishery and aquatic community support.

Figure 4. Beneficial use support of lake and reservoir acresin the Clark Fork Basin. Source of data MTDHES (1994).



Three causes are responsible for the most of the impairment of streams and rivers throughout the basin - siltation, changes in flow and habitat alteration. However, nutrients, thermal alterations and metals also cause numerous impacts. Many waterbodies are impacted by more than one cause, hence, the percent in different categories sums to more than 100%.

Figure 5. Causes of use impairment in assessed rivers and streams in the upper Clark Fork basin. Source of data MTDHES (1994).

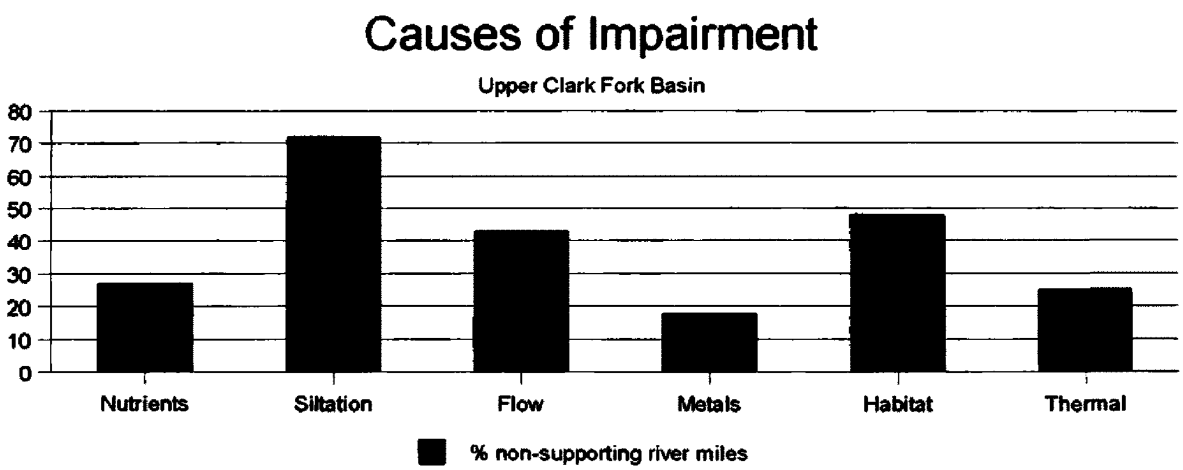


Figure 6. Causes of use impairment in assessed streams and rivers in the lower Clark Fork River Basin. Source: MTDHES (1994).

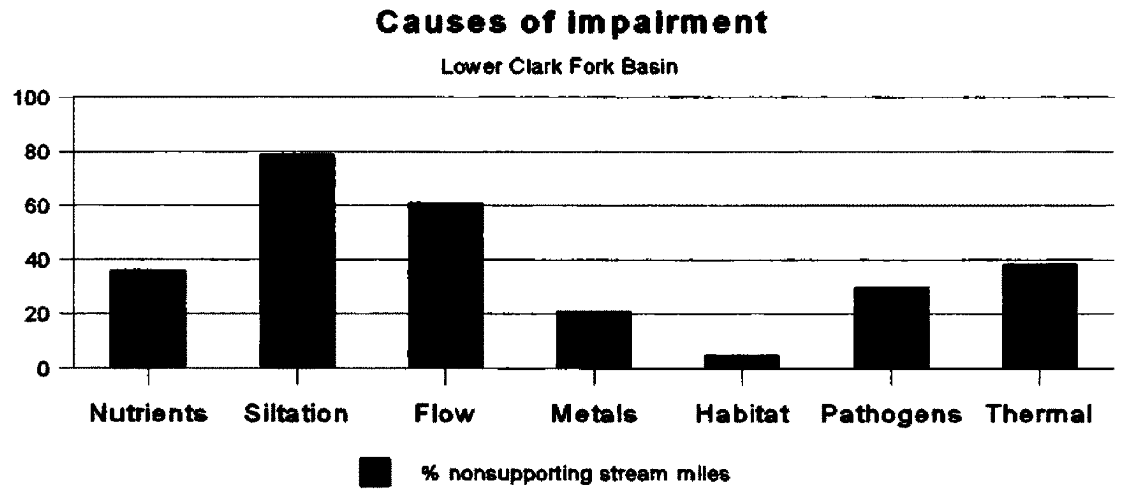
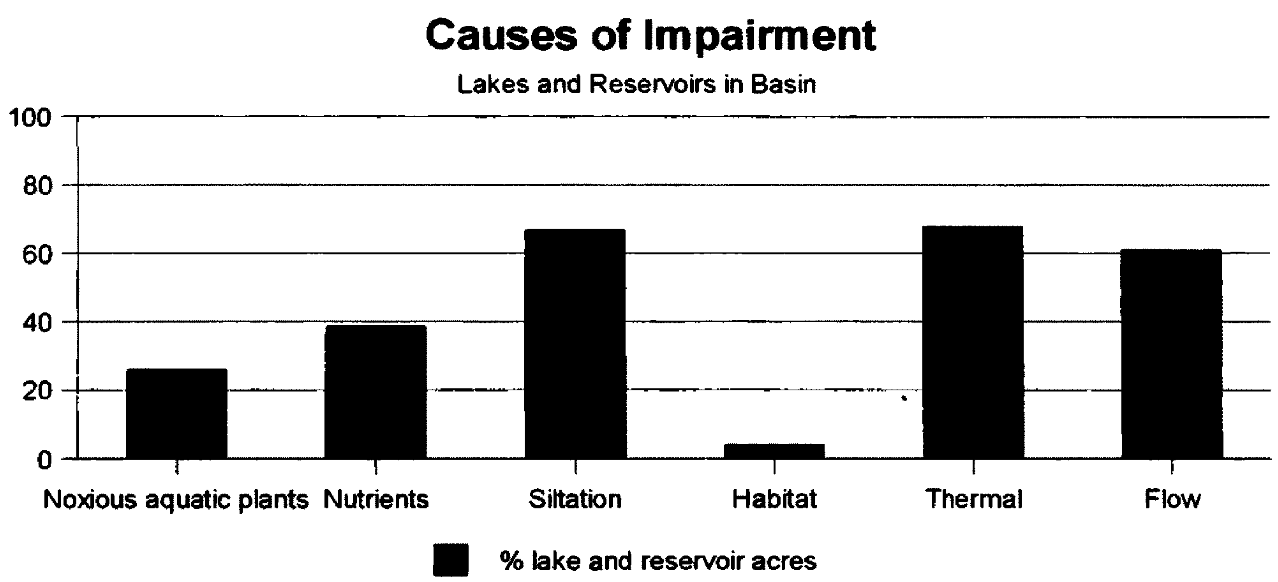


Figure 7. Causes of use impairment in assessed lakes and reservoirs in the Clark Fork Basin. Source: MTDHES (1994).

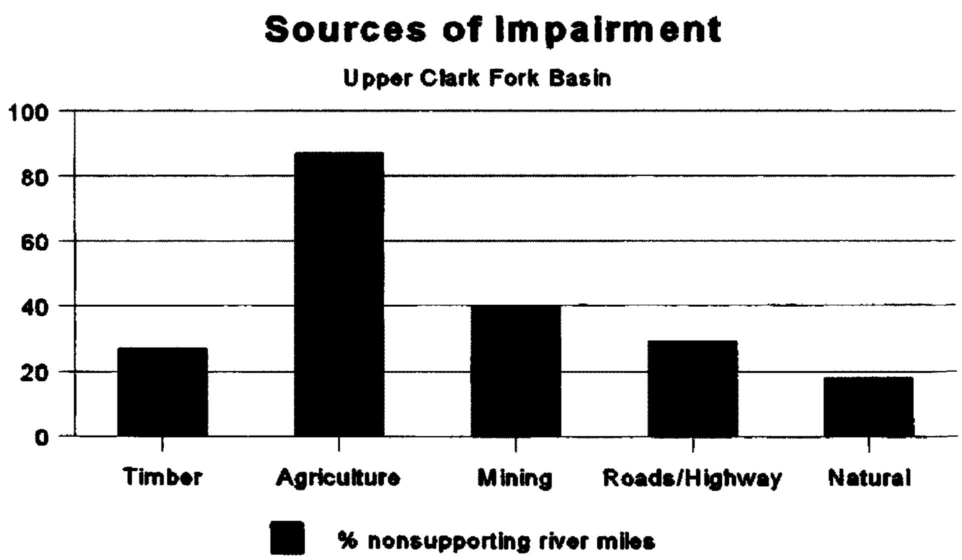


Sources of pollution loading are often divided into two types: point and non-point. Point sources are direct inputs such as discharge from wastewater treatment plants. Non-point sources are diffuse inputs including runoff from disturbed land or leakage from many underground storage tanks, waste sites, pipelines, etc.

Point source dischargers are required by the Clean Water Act to use Best Available Technology (BAT) to control their effluent. For example, sewage treatment plants are required to use certain treatment systems to reduce nutrient levels before water is discharged. Non-point sources, on the other hand, are controlled primarily through Best Management Practices (BMPs). For example, the U.S. Forest Service has BMP's governing road design and construction in order to reduce the amount of sediment eroding into nearby streams. However, BMPs have not been completely successful at protecting aquatic systems against degradation because they have not been developed for all land use practices, violations are common and BMPs are largely voluntary on private lands.

Nonpoint sources are responsible for the majority of impacts in streams and rivers not fully supporting their beneficial uses. Agriculture (including nonirrigated and irrigated crops, pasture, range, feedlots, and animal holding/management areas) is responsible for the greatest number of impacts in the Clark Fork basin.

Figure 8. Sources of impairment to assessed streams and rivers in the upper Clark Fork Basin. Source of data MTDHES (1994).



In the lower Clark Fork basin, dam operation and timber harvesting are the next most frequently cited sources of impairment, whereas, in the upper basin, mining and roads are next in importance. The greatest sources of impairment to lakes and reservoirs are timber harvesting and dam operations.

Figure 9. Sources of impairment in assessed river and stream miles in the lower Clark Fork Basin. Source of data MTDHES (1994).

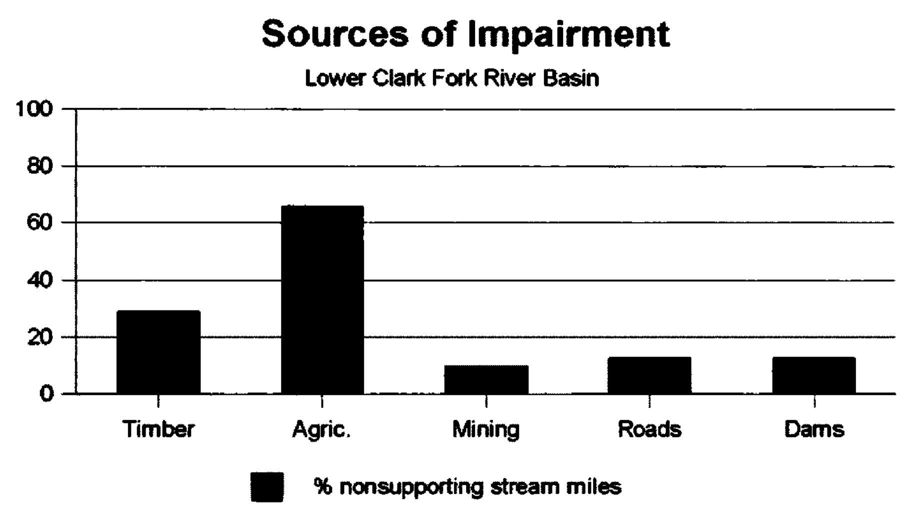
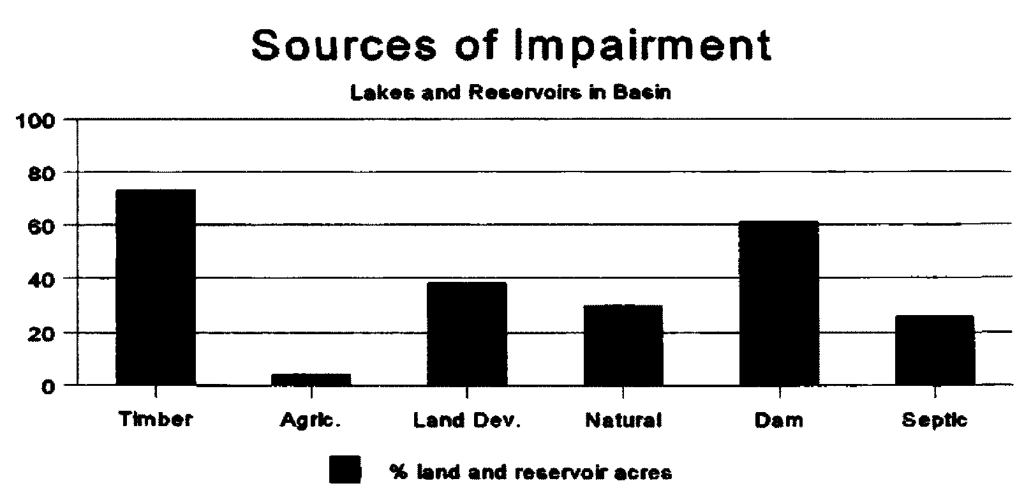


Figure 10. Sources of impairment of assessed lakes and reservoirs in the Clark Fork Basin. Source of data MTDHES (1994)



CHEMICAL GOALS FOR LAWS & ENFORCEMENT: All streams, rivers, lakes and reservoirs should be restored and conserved to fully support their beneficial uses, and high quality waters should be preserved at that high quality.

RECOMMENDED ACTIONS: Return the definition for high quality waters to its pre-1995 definition. That is, waterbodies that support one or more of their beneficial uses should be considered high quality.

*To prevent degradation of high quality waters by pollution load, states must: 1) Improve enforcement of all water quality and nondegradation laws. 2) Vigorously enforce Best Available Technology to control point source pollution. 3) Develop Best Management Practices for all significant nonpoint sources and pursue vigorous education programs.. 4) Require mandatory BMP's where there is evidence of degradation, or where uses are not fully supported. 5) Return legal standing to all Montana citizens to challenge authorizations to degrade.

*To prevent degradation of high quality waters by habitat degradation, states must: 1) Pursue vigorous landowner education campaigns concerning BMP's. 2) Enforce nondegradation rules and review water

permits accordingly. 3) Expand the Streamside Management Zone Act and Streambank Protection Act (see Physical Section) to require BMPS for all activities in the streamside management zone, not just forestry. 4) Prohibit any new development in the 100-year floodplain.

***To restore and conserve water bodies that no longer support their uses, states must: 1) Ensure that all required BAT's are in compliance. 2) Require mandatory Best Management Practices. 3) Conduct a watershed analysis if water quality is still limited. Identify the most cost-effective load reductions, and require all pollution sources contribute towards achieving those reductions. Sources may contribute voluntarily to efforts to reduce loads until uses are supported. 4) Conduct the required Total Maximum Daily Load and Waste Load Allocation process if voluntary efforts are not sufficient. 5) Adopt a basin closure if dewatering contributes significantly to inability to support uses.**

B. Conditions Necessary to Support Uses and Protect Integrity of Surface and Ground Waters

DISSOLVED OXYGEN

Montana's state water quality standards establish certain levels for dissolved oxygen (DO). In most of the rivers and streams in Western Montana (waters classified A-1, B-1, B-2, C-1 and C-2), dissolved oxygen levels must not be reduced below a 7 day mean of 9.5 mg/l when early life stages of fish are present nor below a minimum of 5 mg/l

if early life stages are not present (Circular WQB-7, 1994). Early life stages are defined as all fish eggs, embryonic and larval stages and all juvenile forms up to 30 days following hatching.

Fish embryos are especially sensitive to low concentrations of DO during the early stages of development because they take up oxygen by diffusion through skin rather than through more efficient gills. Many fish in western Montana spawn in the fall when cold water holds high levels of dissolved oxygen, so DO levels are not a problem. However, native westslope cutthroat (*Oncorhynchus clarki lewisi*) spawn in the spring. Shepard (1984) found that the incubation period for Westslope cutthroat embryos in the upper Flathead River basin extends from mid-May through August depending on the time of spawning and water temperature. Thus, early life stages of cutthroats are present in the gravel when high water temperatures and low flows may reduce dissolved oxygen concentrations to critical levels.

The Westslope cutthroat has been listed as a "Class A" species of special concern in Montana and as a sensitive species by USFS Regions 1 and 4. A "Class A" designation means that the species has limited numbers and/or limited habitats both in Montana and elsewhere in North America; elimination from Montana would be a significant loss to the gene pool of the species or subspecies (Hunter 1994). As a result, restoration of native Westslope cutthroat has been declared a high priority. To restore cutthroats to more of their former range, the tougher DO standard (9.5 mg/l) must be enforced for streams that currently support these trout, as well as for streams that historically supported Westslope cutthroat.

Several factors are responsible for dissolved oxygen depletion in the Clark Fork Basin. Water temperature plays an important role. Cold water holds much higher concentrations of dissolved oxygen than warm water. Thus, sufficient instream flows and healthy riparian zones for shade are critical for maintaining dissolved oxygen levels.

Excess attached algae growth may also cause severe oxygen depletion. The benthic, or stream bottom community, is made up of algae, bacteria, and aquatic insects. As algal mass increases, the amount of bacteria and aquatic insects also increases, causing greater demands for oxygen. During the day, algal photosynthesis produces enough oxygen to satisfy the community's respiration demands. However, at night, respiration continues without photosynthesis, and oxygen levels drop to their lowest levels by early morning. The 1994 standard for DO of 7 mg/l was violated frequently in the upper Clark Fork River during past low-flow years (Braico 1973, Kerr 1987, Watson 1985, 1989 a&b).

GOALS: Surface waters which currently support or historically supported populations of Westslope cutthroat trout (*O. c. lewisi*) must meet dissolved oxygen standards for early life stages (9.5 mg/l) through summer low flows.

RECOMMENDED ACTIONS: Focus fishery restoration efforts on restoring healthy riparian zones, instream flows and reducing nuisance algae levels.

SUSPENDED SEDIMENTS

Each year spring runoff brings a rush of sediment down through the Clark Fork River and its tributaries. Fish and aquatic life are adapted to these natural, short bursts. However, disturbances to the watershed which increase the amount and duration of high sediment loads in the stream may harm fish and other aquatic life, and interfere with water treatment, irrigation, and aesthetics.

Predatory fish, such as trout, depend on good visibility for finding food (and fishermen's lures). In addition, many species of game fish exhibit complex reproductive and social behaviors that depend on visual cues. Hence, a reduction in visibility reduces reproduction. Lloyd (1987) lists numerous studies that found suspended solid concentrations of 35 mg/l harm salmonids.

Fish exude a protective mucus on their skin and gills that traps and continually flushes particles away. However, this protective mechanism requires energy and causes stress on the fish at the same time that turbidity reduces its ability to find food. Suspended sediment may also reduce primary production and the abundance of benthic macroinvertebrates (Lloyd et al 1987). Eventually, sediment settles onto the stream or river bottom where it may interfere with spawning (see physical section - substrate size).

Suspended Sediment Levels

Tralles (1992) evaluated streams throughout the Clark Fork Basin and found that more than 2/3 of the assessed streams in the upper Clark Fork and Blackfoot River basins, were rated as impaired. Sedimentation problems affected 85% of the reaches. Land use

activities in impaired drainages were dominated by grazing (75% of all reaches), followed by road construction (44%) and mining, logging and irrigation (20%).

Guidelines for suspended sediment levels have been outlined by the USEPA (1973). They are as follows:

High Level of Protection: suspended sediment concentrations < 25 mg/l.
Moderate Level of Protection: suspended sediment conc. between 25-80 mg/l.
Low Level of Protection: suspended sediment concentrations > 80 mg/l.

These guidelines do not address duration of exposure to suspended sediment concentrations. Suspended sediment levels in the Clark Fork Basin relative to these criteria are illustrated in the following graphs.

Figure 11: Suspended sediment levels in the upper Clark Fork River and several tributaries from 1985-1993. Source: (U.S.G.S. unpub.)

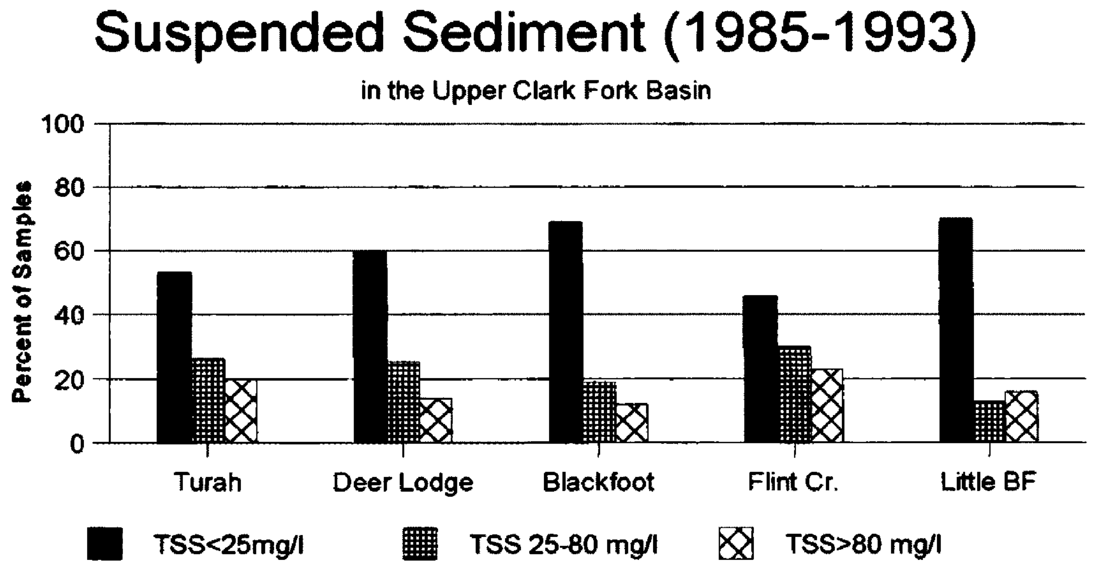
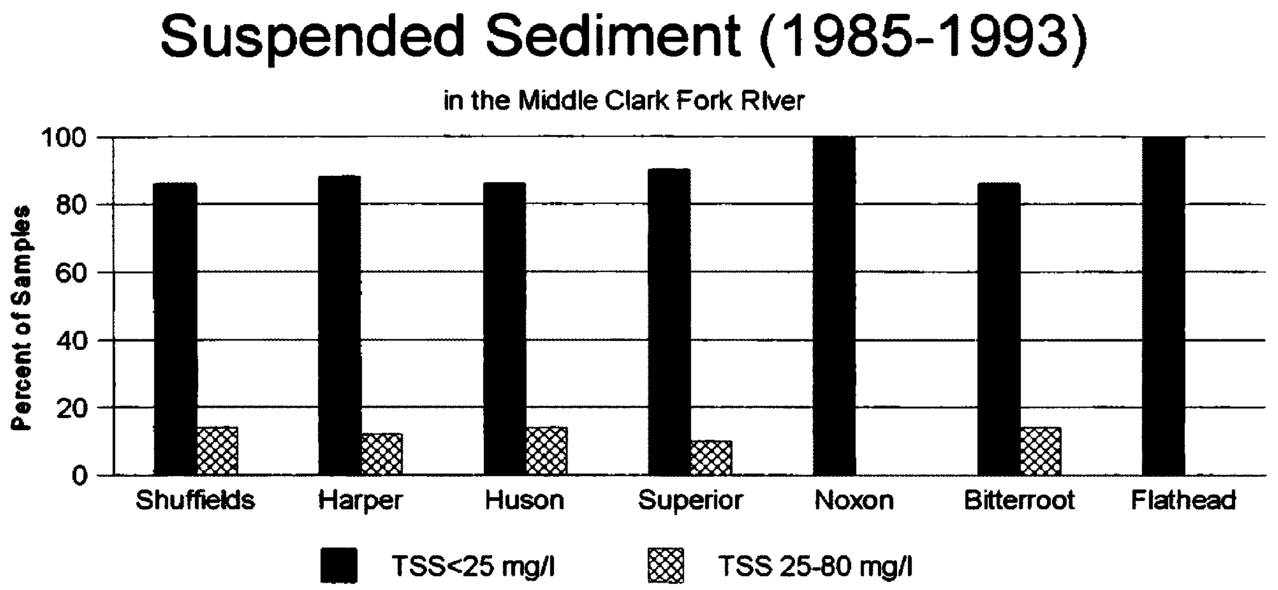


Figure 12: Suspended sediment levels in the middle and lower Clark Fork River and tributaries from 1985-1992. Source: MTDHES unpub.



Highest suspended sediment levels occur in the upper Clark Fork. Streamside mine wastes are presumably the primary cause. In many reaches, toxic metals prevent the growth of healthy riparian vegetation which would otherwise stabilize streambanks and prevent erosion. Grazing is also responsible for destabilized banks and increased suspended sediment levels.

During most years, suspended sediment concentrations in the middle Clark Fork are fairly low. The Milltown Reservoir traps some sediment, however, almost 80% of the Clark Fork's current sediment load passes through because of the reservoir's small size and the volume of material behind it (MTNRDP, 1995). The Bitterroot River, which carries lower levels of suspended sediment than the Clark Fork, dilutes the concentrations as well.

Suspended sediment concentrations in the lower Clark Fork are generally very low. The Flathead River more than doubles the volume of the Clark Fork and generally transports very low levels of suspended sediment. In addition, the Noxon Rapids, Cabinet Gorge and Thompson Falls Reservoirs act as settling basins for sediments and reduce suspended sediment concentrations even further.

State water quality standards state that no increases are allowed above naturally occurring concentrations of sediment which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish or other wildlife (A.R.M. 16.20.619 & 16.20.621). However, since natural levels are largely unknown and are very variable, this standard is difficult to enforce. A standard that incorporates a measure of duration as well as intensity such as the Stress Index of Newcombe & MacDonald (1991) would be helpful.

GOAL: Suspended sediment levels should provide a high level of fishery protection (<25 ppm) except during short periods of spring runoff.

***RECOMMENDED ACTIONS: Where suspended sediment levels frequently exceed 25 ppm other than during spring runoff, Best Management Practices (BMPs) should be mandatory. BMPs should include provisions for limiting the area of watershed disturbance as in the Watershed Resource Management Standards proposed by the Montana Division of Forestry (1995).**

***Public land managers and state and local governments should make protecting and restoring riparian vegetation a high priority. Public land managers should develop a comprehensive landscape-level road management plan which removes ail unnecessary roads (especially those near streams and considered substandard for water quality protection) and plans road density around wildlife and water quality protection. Remaining roadless areas should be protected from road building.**

***Standards for suspended sediment should be developed that incorporate measurements of duration as well as intensity.**

pH

The concentration of hydrogen ions in the water column, or pH, is important to aquatic life. pH measurements indicate whether a solution is acidic (pH values, <7), neutral (pH values =7) or basic (pH values >7).

Streams generally have pH values measuring anywhere from 6 to 9. However, each individual stream has a narrower range of pH values, and the life it supports has adapted to that pH level. Trout are among the organisms most sensitive to changes in pH. As pH levels increase, smaller amounts of ammonia are needed to reach a level that is toxic to fish (Rand and Petrocelli, 1985).

On the other hand, as pH levels drop, many heavy metals previously in particulate form are dissolved (Rand & Petrocelli, 1985). In addition, at lower pH more of the dissolved metals are in their most toxic free ion form. Lambing (1995) observed that

elevated levels of dissolved rather than particulate forms of metals have been responsible for fish kills in the upper Clark Fork River.

Mining activities are the primary cause of acidic waters in the Clark Fork. Metals such as copper and gold are often found in sulfide-bearing ores. Dewatering mine shafts and disposing of waste rock and tailings at the surface exposes the sulfides in these materials to oxygen. When sulfide is exposed to oxygen and water, sulfuric acid is formed. Sulfuric acid is a powerful acid which can dissolve certain minerals and release sulfate, metals, and metalloids to the environment.

Respiration and photosynthesis also influence pH levels. Respiration of the aquatic community constantly uses oxygen. During the day, photosynthesis produces more than enough oxygen to meet this demand, but at night, photosynthesis ceases, oxygen levels drop and CO_2 levels increase. Increases in CO_2 create carbonic acid, decreasing pH. In summer 1994, the Clark Fork at Deer Lodge exhibited daily pH fluctuations from 8.2 to 8.7 (Brick and Moore, 1995). Measurements were taken upstream of the Deer Lodge sewage treatment plant. Hence, more extreme fluctuations might be expected downstream.

State water quality standards prohibit discharges from changing pH by more than 0.5 pH units where pH falls within the range of 6.5 to 8.5 (for waters classified as A-1, B-1, and C-1) and within the range of 6.5 to 9.0 (for waters classified as B-2, B-3, C-2 and C-3). Natural pH outside this range must not be worsened. Natural pH above 7.0 must be maintained above 7.0. In waters classified as A-closed, no changes from natural pH is allowed (A.R.M. 16.20.618 & 621).

GOAL: pH levels should be maintained within the natural range of each waterbody.

RECOMMENDED ACTIONS: With this in mind, algal levels should be reduced to a level which eliminates wide fluctuations in pH. Acid mine drainage and acid rock drainage from tailings and waste rock piles must be remediated and avoided in the future.

METAL LEVELS

In response to severe environmental degradation and threats to human health resulting from past mining and smelting operations, the upper Clark Fork River was designated a Superfund Site in 1983. Superfund law requires contaminated sites be cleaned up to state and federal standards. It also allows states to sue for damages to resources caused by contamination. The upper Clark Fork is the subject of a Natural Resource Damage lawsuit filed by the State of Montana against the primary responsible party, the Atlantic Richfield Company (ARCO). This lawsuit will take clean-up efforts one step further by allowing the State to recover damages for use in restoring the area to pre-mining conditions. The Montana Natural Resource Damage Assessment Program (MTNRDP) has conducted extensive studies throughout the upper Clark Fork in its efforts to quantify injuries to natural resources in relation to baseline conditions.

A settlement between the State of Montana and ARCO was reached in 1999 which, if approved by the court, will provide the State $200 million in compensation.

There are three restoration claims, however, which have not yet been settled. These amount to an additional $206 million. Any damages which are recovered from these lawsuits are required by law to be used to “restore, replace or acquire the equivalent of the natural resources that were lost or injured.” 42 U.S.C. Section 9607(f). Futhermore, federal law requires that Natural Resource Damage claims only be spent pursuant to a restoration plan.

In the Clark Fork River, an estimated 100 million tons of mine and smelting waste were dispersed along the river's channel and flood plains from 1880 to 1982 (Andrews, 1987). Erosion of these contaminated sediments provides a constant source of potential toxicity to aquatic life, because metals are commonly adsorbed to sediment particles and transported through river systems this way.

From 1985-1990, the USGS sampled four mainstem and four tributary sites in the upper Clark Fork Basin for metals (dissolved and particulate forms) and correlated metal levels with suspended sediment samples (Lambing, 1995). Their results confirmed that most metals are transported in particulate form attached to suspended sediment in the Clark Fork River. Comparison of the dissolved and total recoverable (dissolved and particulate) concentrations of copper at various sampling sites revealed that, in general, the percentage of copper in suspended sediment ranged from about 50% in the Clark Fork at Rock Creek to more than 80% in the Clark Fork near Bonner. Strong associations with suspended sediments were also observed for iron, lead, manganese and zinc.

The source of these contaminated sediments extends throughout the upper Clark Fork --in the floodplain, riverbed, Warm Springs Ponds and Milltown Reservoir.

MTNRDP estimated the areal extent of floodplain contamination in the upper Clark Fork Basin at over 13,000 acres (MTNRDP 1995). More than 4,500 floodplain acres contain exposed tailings, mainly in the reach between Warm Springs Ponds and Drummond. Metals enriched soils cover approximately 9,000 additional acres of floodplain extending along the entire length of the river between Warm Springs and Milltown Reservoir.

Water quality data and daily streamflow records were used to estimate annual loads (in tons) of suspended sediment and metals transported past various sites along the upper Clark Fork Basin and into Milltown Reservoir (Lambing, 1995). In general, the Clark Fork Basin upstream from Galen, including the headwater mining and smelting area, currently supplies only moderate quantities of copper (10%), lead (2%) and zinc (11%) to Milltown Reservoir's annual load. The 21.5 mile reach of the mainstem between Galen and Deer Lodge contributed higher quantities; copper (16%), lead (7%) and zinc (19%). The largest percent was contributed by the 91 mile reach between Deer Lodge and Turah Bridge; copper (56%), lead (56%), and zinc (50%).

Toxicity Levels in the upper Clark Fork River

Instream metal concentrations are compared to state water quality standards designed to protect freshwater aquatic life (WQB-7). These standards are expressed in terms of acute (1-hour average) and chronic (4-day average) criteria. Aquatic life uses are not supported if acute or chronic criteria are violated more than once in a three-year period (USEPA, 1991).

Silver Bow Creek, a headwater stream to the Clark Fork River, is extremely degraded by toxic metals. From 1985-1991, 100% of samples exceeded both acute and chronic copper criteria (MTNRDP, 1993).

Copper appears to pose the greatest threat to aquatic organisms in the upper Clark Fork mainstem because it exceeds standards by the greatest amount for the longest time. Periodic sampling (5-8 times/year during hydrologic conditions ranging from base flow to peak runoff) from 1985-1990 by the U.S.G.S. revealed that copper concentrations exceeded acute toxicity criteria at all upper Clark Fork mainstem stations (Lambing 1995). In the Clark Fork at Deer Lodge and Bonner, copper concentrations exceeded acute criteria in more than 50% of the samples. Zinc rarely exceeded acute toxicity criteria, and arsenic and lead never exceeded acute toxicity criteria. Chronic criteria for copper and lead were exceeded frequently at many stations in the upper Clark Fork (Table 3).

Table 3. Estimated percent of time that trace element concentrations exceeded aquatic life criteria for chronic toxicity in the upper Clark Fork basin 1985-90. Source: (Lambing 1995)

Station Name	Arsenic	Copper	Lead	Zinc
Clark Fork near Galen	<.01	71	1	<.1
Clark Fork at Deer Lodge	<.1	81	7	1
Little Blackfoot River near Garrison	<.1	<.1	6	<.1
Flint Creek near Drummond	<.1	1	82	.2
Rock Creek near Clinton	<.1	3	--	<.1
Clark fork at Turah Bridge, near Bonner	<.1	59	59	2
Blackfoot River near Bonner	<.1	24	--	<.1
Clark Fork above Missoula	--	3	3	--

Although acute toxicity has been responsible for numerous fish kills, chronic toxicity also profoundly affects aquatic communities in the Clark Fork River. Water quality data collected 7 times per year from 1988-1992 indicate that dissolved metal concentrations at locations over the entire length of the Clark Fork River continue to exceed concentrations that cause avoidance and impair growth in fish (Woodward, 1994 & 1995).

Metal Fluctuations in the upper Clark Fork River

Release of metals from bed sediments was once thought to be confined largely to springtime runoff. Recent research, however, reveals that metal levels in the upper Clark Fork River fluctuate on a daily basis in response to fluctuations in pH and dissolved oxygen, and possibly macroinvertebrate activity (Brick and Moore, 1995).

Dissolved forms of manganese and zinc, as well as acid soluble particulate copper, aluminum, and iron show 2-3 fold increases in concentrations at night. In the case of copper, total acid-soluble concentrations were well below the EPA's chronic toxicity limit for aquatic life during the day but exceeded it for several hours at night. While these daily events are small relative to seasonal cycles, they nonetheless expose aquatic life to higher concentrations of metals on a more regular basis than was previously thought.

Furthermore, daytime sampling may result in consistent underestimations of contamination. This is especially crucial in the Clark Fork River where high algal levels exacerbate the daily fluctuations of dissolved oxygen and pH.

Warm Springs Ponds

Warm Springs Ponds are located at the headwaters of the Clark Fork River just above the confluence of Mill Willow Bypass and Warm Springs Creek. The three treatment ponds were constructed in 1911, 1916 and 1959 to settle out mining wastes from Silver Bow Creek before it reached the Clark Fork River. Although wastes are no longer released directly into Silver Bow Creek, the ponds are still used as a settling basin for sediments and as a precipitation unit for removal of dissolved metal contaminants (USEPA 1990). Mine wastes along the Silver Bow Creek continue to erode and travel down the creek, especially during high flows and floods.

Milltown Reservoir

Approximately 6.6 million cubic yards of contaminated sediments are stored behind the Milltown Reservoir; filling it almost to capacity. MTNRDP (1995) estimates that almost 80% of the annual sediment load currently carried by the Clark Fork River passes through the dam. In February, 1996, ice jams and flooding forced a drawdown of Milltown reservoir, resulting in significant metals transport downstream. Samples downriver from the dam showed copper levels up to 770 ppb (compared to an aquatic life standards of 18 ppb), zinc levels of 1,310 ppb (compared to 120 ppb) and arsenic at 97 ppb (compared to a human health standard of 18 ppb). Instream metal concentrations were higher than those responsible for fish kills in the past (MTNRDP, 1995).

GOALS: Restoration efforts should strive to reduce dissolved and suspended metal levels in the Clark Fork River to the baseline conditions of appropriate reference streams as outlined in MTNRDP (1993). If this cannot be achieved, then, at a minimum, restoration efforts must restore water quality to the point of meeting all State Water Quality Standards.

RECOMMENDED ACTIONS: Remove streamside mine tailings from the Silver Bow Creek and upper Clark Fork floodplain, particularly those that are 1) saturated by groundwater during any part of the year, 2) thicker than six inches and do not have underlying native soils that can act as a buffer between the tailings and groundwater, 3) are located where they may be eroded into the creek system through normal stream meandering or 100-year flood events and 4) have high arsenic content.

***Treat the remaining contaminated areas with STARS technology, a treatment system which includes neutralizing the soils to immobilize certain metals and replanting with metal resistant and drought resistant grasses.**

***While the Warm Springs Ponds are functioning to treat Silver Bow Creek, they should be considered industrial treatment ponds, hence, only the**

discharge be required to meet state water quality standards. If the ponds are left in place once they are no longer needed to treat Silver Bow Creek, the ponds and their discharge should meet state water quality standards. In addition, the ponds should support a biotic community similar to other ponds in the region.

*To protect the Clark Fork River downstream of Milltown Dam, the source of contamination must be removed. A permanent remedy should be emphasized rather than institutional controls.

*Monitoring for metals, pH and DO should be conducted at night in summer in the upper Clark Fork River when metal levels are at their highest concentrations in order to evaluate compliance with standards and effect on the river community.

*Criteria should be developed for determining allocation of Natural Resource Damage Claim funds. High priority should be given to those projects which emphasize permanent remedies and provide restoration of resources rather than replacement of services.

Toxicity levels in the Blackfoot River

The Blackfoot River has also experienced a long history of mining. Water quality investigations in 1988 & 89 determined that heavy metals and acid mine drainage associated with early mining operations in the headwaters were the major source of water quality problems in the upper Blackfoot River (Ingman et al., 1990). The source of these metals includes streamside deposits of mine wastes (tailings) and mine adit discharges associated with these abandoned mines: the Mike Horse, Carbonate, Anaconda, Paymaster, Edith and Mary P (McCulley et al. 1994). A severe impact occurred in 1975 when the Mike Horse tailings dam was breached by a flood, and its toxic contents were spilled into the headwaters of the Blackfoot.

Research indicates that Mike Horse Creek, downstream of the Mike Horse mine, has the highest instream concentration of metals in the upper Blackfoot (McCulley et al. 1994). Beartrap Creek, below its confluence with Mike Horse Creek, also contains elevated levels of various metals including aluminum, zinc, cadmium and manganese.

Zinc was the most problematic metal in the Blackfoot mainstem, followed by copper, cadmium and then lead. Water samples in 1988 and 89 revealed instream zinc concentrations exceeded toxicity criteria values in the upper 10-12 miles of the river during high flows and up to 5 miles downstream during low flows (Ingman et al. 1990). Concentrations of copper, lead and cadmium exceeded aquatic life toxicity criteria levels in the upper five to seven miles of the Blackfoot River during spring runoff.

The Upper Blackfoot Mining Complex is currently being remediated under a voluntary cleanup by the ASARCO & ARCO Corporations. The remediation plan calls

for treatment of acid mine drainage in an oxidation pond and series of constructed wetlands. An MPDES permit was issued in 1993 with the provision that operations come into compliance with state Water Quality Standards within 5 years.

GOAL: Restoration and remediation efforts on the upper Blackfoot River must reduce instream metal concentrations to meet state water quality standards.

Groundwater

Acid mine drainage is responsible for vast amounts of groundwater contamination in western Montana. The following table illustrates the volume and extent of groundwater contamination in the upper Clark Fork Basin Superfund sites:

Table 4. Contaminated Groundwater Resources in the upper Clark Fork Superfund Complex.

Site	Volume (acre-feet)	Flux or Yield (acre-feet/year)
Butte	205,000	14,105
Anaconda	327,400	9,100-10,100
Milltown	4,100	117,100
Montana Pole	350	22
Rocker	202	1.8
*Source: MTNRDP 1993		

Butte Groundwater Resource Area. Both bedrock and overlying alluvial aquifers have been contaminated in this area (MTNRDP, 1995). Contaminated groundwater in the Butte Hill bedrock aquifer occurs within the fractures, joints, and faults in the bedrock and in the underground mine workings. Much of this contaminated groundwater has flowed into the Berkely Pit. Bedrock groundwater in the Butte Hill area exceeds drinking water standards for pH, sulfate, TDS, aluminum, arsenic, cadmium, copper, iron, fluoride, lead, manganese, nickel silver and zinc.

Contaminated groundwater in the alluvial aquifer occurs primarily in the upper 40 feet of the aquifer near the Berkely Pit and between the Pit and Silver Bow Creek. The alluvial groundwater in the Butte Hill area contains iron, cadmium and sulfate that exceed drinking water standards. Furthermore, contaminated groundwater discharges to sections of Silver Bow Creek.

Anaconda Groundwater Resource Area. This area, located in the Deer Lodge Valley, includes portions of Anaconda, opportunity Ponds and Warm Springs Ponds. There are two injured aquifers: the bedrock aquifer under Smelter Hill and the alluvial aquifer underlying a large area from Anaconda to Warm Springs Ponds (MTNRDP, 1995).

Median concentrations of hazardous substances found in groundwater in the Smelter Hill/Old Works/Anaconda Ponds area, exceed primary and secondary drinking water standards for aluminum, arsenic, cadmium, chromium, fluoride, iron, manganese, mercury, sulfate, and zinc. Contaminated groundwater discharging to the Opportunity Ponds area exceeds drinking water standards for arsenic, cadmium, fluoride, iron,

manganese, sulfate, and zinc. In the Warm Springs Ponds area, groundwater exceeds drinking water standards for arsenic, cadmium, fluoride, iron, manganese and sulfate.

Discharge of contaminated groundwater from Warm Springs Pond #1 is estimated to be approximately 1,100 acft/yr and discharge from the Opportunity Ponds is estimated to be between 8,000 and 9,000 acre feet/year.

Milltown Groundwater Resource Area. This area, located adjacent to Milltown Dam about five miles east of the City of Missoula, includes the dam's reservoir area and a portion of the town of Milltown (MTNRDP, 1995). The injured groundwater is contained in the reservoir sediments and in the sand, gravel and cobble aquifer underneath these sediments and Milltown. Over six million cubic yards of contaminated sediments are currently trapped behind the dam. Over 110,990 acre feet of contaminated groundwater flows from the reservoir to the adjacent sand and gravel aquifer annually. Median contaminant concentrations exceed drinking water standards for dissolved arsenic, iron, manganese, sulfate and total dissolved solids.

GOAL: High quality groundwater should be maintained at that high quality, and contaminated groundwater should be cleaned up to standards by the most cost effective method.

RECOMMENDED ACTIONS: Contaminated groundwater should be treated by removing the source of the contamination and permitting the

groundwater to gradually cleanse itself. However, when groundwater is currently used for drinking water, pump and treatment may be necessary because alternative sources of clean drinking water are generally very costly to find.

***Groundwater contamination that limits future development of an area should be addressed through pump and treatment or paying compensation and damages.**

Proposed Mines

The proposed ASARCO mine near Rock Creek (a tributary to the lower Clark Fork river) has the potential to cause serious groundwater degradation. ASARCO plans to pile its leftover crushed ore, or tailings, as well as its excess mill water in an impoundment just 400 yards from the river (ASARCO, 1994). The impoundment will be the permanent location for about 300 million tons of waste. The plan of operations does not call for a liner for the impoundment. As a result, contaminated seepage from the mine tailings impoundment will likely pollute groundwater destined for Rock Creek and the Clark Fork river.

GOAL: Do not permit the ASARCO mine as proposed.

Arsenic

Arsenic is an element of great concern in our rivers because it exhibits both acute and chronic effects to aquatic life and is carcinogenic to humans. Many experts believe there is no threshold or safe level for any carcinogen because only the slightest alteration in the genetic molecule may begin the chain of events which causes a cancerous growth. Moreover, standards are based on exposure to one chemical at a time and do not consider possible synergistic or even additive effects and multiple exposure. Therefore, standards for carcinogenic substances should be set with a wide margin of safety.

The 1995 legislature (MCA 75-5-301) weakened Montana's water quality standards from the level expected to produce 1 cancer/ million people to 1 cancer/100,000 people for all carcinogens except arsenic. For arsenic, the standard was weakened to the level associated with 1 cancer/1,000 people. These risk levels are based on lifetime exposure. In other words, if all 850,000 Montanas were exposed to carcinogens at the new standard levels for their lifetime, the state might have 850 more cancer deaths a year from arsenic and another 800 or so from the other 100+ carcinogens.

Advocates for these changes claim that the old arsenic standards were below detection levels and that some waters in the state are naturally high in arsenic. While it is true that the old arsenic standards couldn't be measured reliably, instream concentrations could be calculated effectively by sampling arsenic concentrations in the effluent and calculating the degree of dilution. Although Yellowstone basin does have naturally high arsenic levels, most Montana streams and rivers do not. This does not justify dumping arsenic generated through human activity into waters with naturally low arsenic levels.

GOAL: Montana's state water quality standards for arsenic and other carcinogens should be returned to the level associated with one additional cancer case per million. Site specific standards can be adopted for surface waters that are naturally high in arsenic; however, those using these waters should be informed of the risk.

Cyanide

Cyanide is a chemical of great concern for the Clark Fork Basin's groundwater given the scope of a proposed heap leach gold mine in the Blackfoot River Basin. Sodium cyanide is used in massive quantities to extract silver, gold and other heavy metals from low-grade ores. The proposed McDonald mine at the headwaters of the Blackfoot River would use an estimated 9.4 million pounds of cyanide a year in the leaching process.

Although cyanide is toxic to humans, it poses the greatest threat to fish, especially salmonids such as trout (Erickson et al 1990). The lethal dose for trout is only 100 ppb. A trout's swimming ability may be permanently altered at one-tenth the lethal dose 10 ppb, and fish reproduction may be prohibited at one-twentieth of the lethal dose (5 ppb). Standards to protect aquatic life have been established by the EPA and adopted by the state of Montana. Instream concentrations must not exceed a one-hour acute criteria of 22 ppb and/or a four-day chronic criteria of 52 ppb.

Cyanide usually does not persist in surface waters for long periods of time because sunlight and soil microorganisms quickly break it down. However, in groundwater, there is little light or oxygen, and cyanide can persist much longer. The concern for

groundwater contamination from heap leach mining is not unfounded. Two-thirds to three-fourths of the mines that have used cyanide to process ore in Montana have had documented releases (MTDHES, 1994).

OEA, a Helena environmental consulting firm was hired by the Clark Fork Pend-Oreille Coalition to evaluate the proposed McDonald mine. OEA (1995) concluded that "the potential for cyanide toxicity problems in the upper Blackfoot River would be fairly high, given 1) the close proximity of the leach pads to the river; 2) the low pH and stream discharge rate of the river during summer; 3) the extent of surface water/groundwater connections near McDonald Meadows; 4) the difficulty of designing, installing and maintaining a perfectly-sealed liner system while continuously adding 30,000 tons of crushed ore per day to the pads; 5) the small, potentially undetectable, volume of seepage from the pads that could become toxic to the River's aquatic life and 6) the history of groundwater contamination associated with most, if not all, cyanide leach pad operations in Montana and elsewhere in the U.S."

GOAL: The McDonald mine as proposed must not be permitted due to the high potential for cyanide toxicity and other effects.

NUTRIENTS

Nitrogen and phosphorus are nutrients necessary for the survival and growth of aquatic plants. Many human activities increase nutrient loads to aquatic systems in a

process called cultural eutrophication. With increased nutrient loading, algal growth may be stimulated - sometimes to excessive levels.

Guidelines to prevent degradation of surface waters are specified in Montana's nondegradation rules. Any increases in instream concentrations greater than the following trigger values are defined as degradation: nitrogen as nitrates (NO_3) and nitrites (NO_2) - 10 ppb, nitrogen as nitrites - 4 ppb, and inorganic phosphorus - 1 ppb (WQB-7).

The Clark Fork River from its headwaters to the confluence with the Flathead River has been declared water-quality-limited based on excess levels of algae. That is, the river does not meet all its ambient standards even though all discharge permits are generally in compliance. Acting under the Clean Water Act, the U.S. EPA has ordered that the river's total maximum daily load (TMDL) for nutrients be determined. This is the load the river can assimilate and still support its uses and meet all standards. Furthermore, the EPA ordered that steps be taken to reduce nutrient loads to the river.

Wastewater discharges are responsible for 50% of the annual load of soluble phosphorus entering the Clark Fork River (USEPA, 1993). Most of these nutrients come from just four sources -- the Missoula, Butte and Deer Lodge municipal wastewater treatment plants, and the Stone Container Corporation kraft mill at Frenchtown. The other 50% of soluble phosphorus in the Clark Fork River comes from nonpoint sources.

However, nitrogen has a somewhat different origin. Nonpoint sources are responsible for 75% of the annual load of soluble nitrogen in the Clark Fork River (USEPA 1993). Wastewater discharge is responsible for the other 25%. Non point sources are primarily agriculture related, including cattle wastes, irrigation return flows

and overgrazed rangelands. Other sources include runoff from roads, logged sites, leaking septic tanks and urban fertilizer.

In the summer months, wasewater discharges are responsible for about 40% of the nutrients available for uptake by algae in the Upper Clark Fork (Ingman, 1992). The Deer Lodge sewage lagoon contributes about 80% of the wastewater nutrient loading to that reach in summer. In the middle Clark Fork, about 73% of the nutrients in summer come from wastewater discharges. Of that total, about 97% comes from the City of Missoula.

Lake Pend Oreille has experienced increased nearshore eutrophication problems in recent years (EPA 1993). In accordance with the 1987 reauthorization of the Clean Water Act, the Tri State Implementation Council is currently in the process of determining the total maximum daily load (TMDL) of nutrients that Lake Pend Oreille can receive daily without causing degradation. Any further increase in nutrient loading to the lake from a new point source would clearly be a contradiction of the objectives of these efforts.

Nutrient Levels in the Clark Fork River

Ingman (1995) evaluated long term trends in nutrient levels throughout the Clark Fork mainstem. As a result of phosphorus detergent bans and improved industrial waste treatment (figures 13, 14, & 15), phosphorus concentrations show a significant downward trend (figure 16). Nitrogen discharge from the Missoula WWTP has increased however (figure 17).

Figure 13. Missoula Waste Water Treatment Plant Phosphorus Discharge from 1984-1995 (Ingman, 1995).

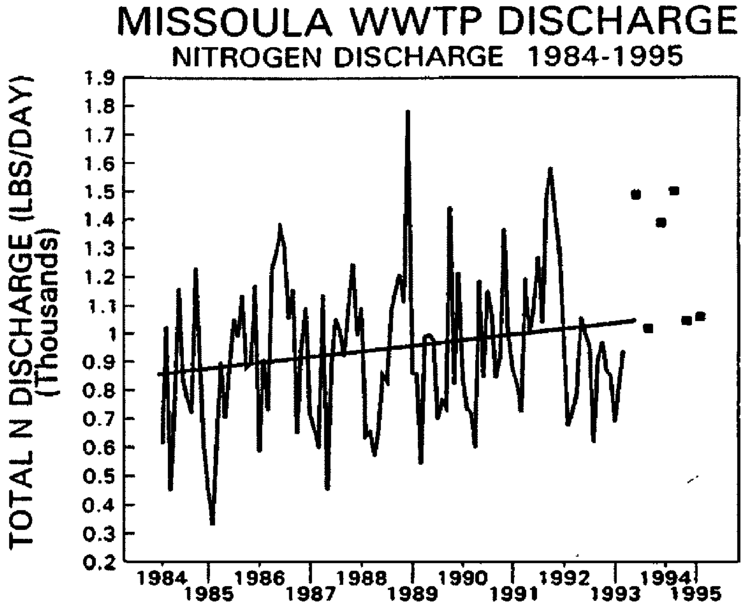


Figure 14. Butte Metro WWTP Phosphorus Discharge 1987-1995 (Ingman 1995).

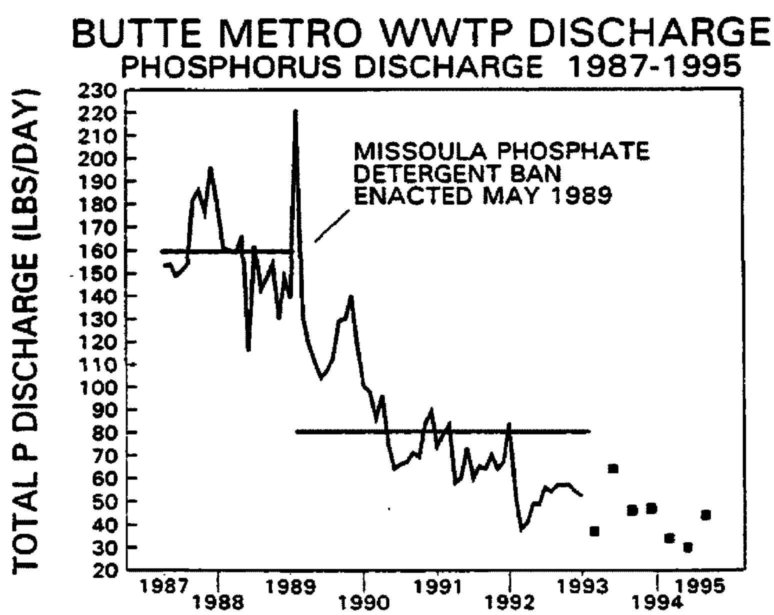


Figure 15. Stone Container Corp. Direct Phosphorus Discharge 1985-1993 (Ingman 1995).

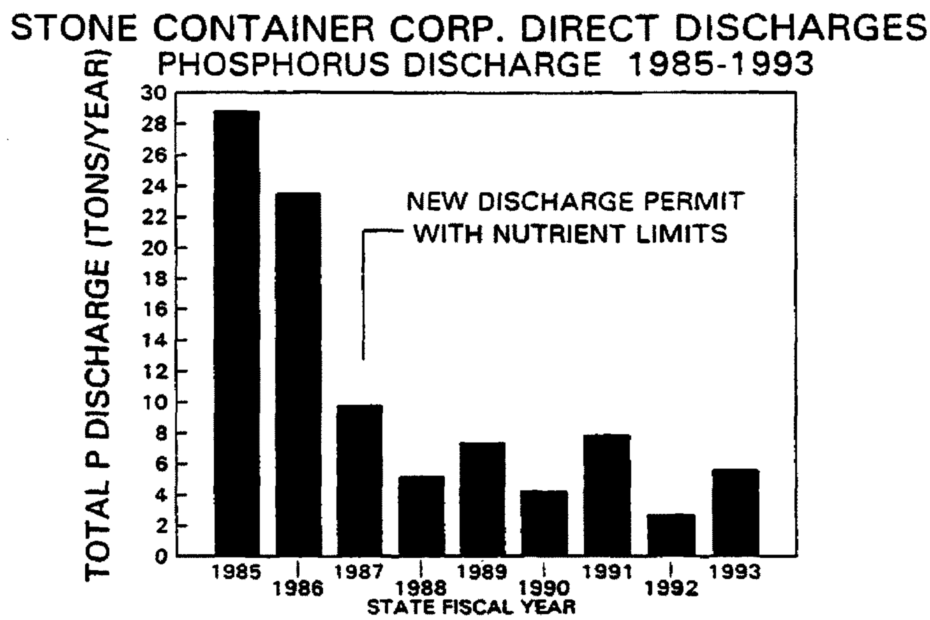
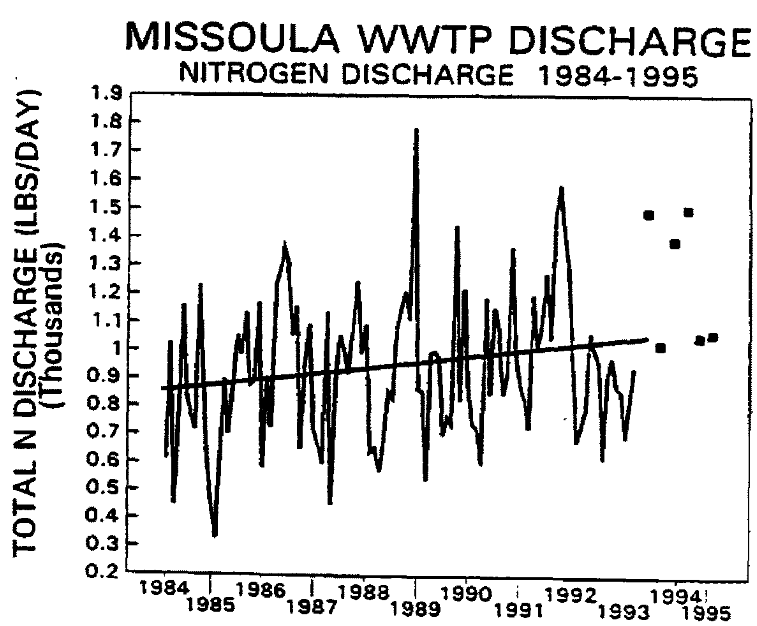


Figure 16. Nitrogen Discharge from the Missoula WWTP (1985-1995). Source: Ingman (1995).



What Nutrient Concentrations Reduce Algae Levels To Acceptable Levels?

Algae communities in the middle and lower Clark Fork River are dominated primarily by diatoms. Diatom growth rates (divisions per day) are nutrient limited only at very low nutrient levels - (<1 ppb soluble phosphorus and <10 - 20 ppb soluble nitrogen) (Bothwell 1988, 1989). Although higher levels of nutrients do not increase growth rates, they may increase algal biomass (standing crop). Diatom standing crop continues to increase in response to nutrient increases up to 30 ppb soluble phosphorus (Bothwell 1989) and 250 ppb soluble nitrogen (Watson 1990). These levels are considered the "saturation" points beyond which algal accumulation will not increase further with increases in nutrient concentration.

Nutrient levels which limit diatom growth rates are found only in the lower Clark Fork River below the confluence of the Flathead River. However, nutrient concentrations low enough to limit standing crop are consistently found throughout the Clark Fork River with the exception of the reach is directly downstream of the Butte and Deer Lodge sewage treatment plants (Ingman 1992). As a result, reductions in soluble phosphorus and/or nitrogen have a good chance of reducing diatom levels. Conversely, increases in phosphorus or nitrogen could increase diatom levels unless some other factor is more limiting. However, due to great natural variability in algal levels, reductions in algal growth may not be detectable, at least until nutrient concentrations are very low. A fairly labor intensive algal sampling program is needed to provide sufficient data for trend analysis (see monitoring).

Cladophora, a filamentous green algae, dominates most of the upper Clark Fork River. Its bright green strands have grown to 2-3 meters long and filled the entire upper Clark Fork river channel. Nutrient levels which limit Cladophora growth rates are considered to be < 9-25 ppb soluble phosphorus (Horner 1983). There is much less information on nitrogen concentrations which limit Cladophora growth rates. Growth rates of many algal species appear to be limited at soluble nitrogen concentrations <50 ppb (Caperon and Meyer 1972; Eppley et al. 1969; Goldman and McCarthy 1978).

Yet, some of the heaviest growths of Cladophora are consistently found where summertime instream soluble nitrogen levels are well below 20 ppb and annual soluble nitrogen levels are as low as 50 ppb. Its ability to thrive in these conditions suggests that nitrogen-fixing algae supply some of its growth needs. Some of these algal species live symbiotically on Cladophora, and are common in the upper Clark Fork (Bahls, 1995).

The nutrient concentrations which limit Cladophora standing crop are uncertain, however, they are probably similar to the concentration which limit growth due to its filamentous nature. Many forms of filamentous algae grow to massive lengths only in fairly strong currents or turbulent waters. Thus, the filament is more readily saturated by instream nutrients than the bottom layer of a dense mat of diatoms.

Phosphorus and nitrogen concentrations throughout the upper Clark Fork River are frequently below this growth saturation point with the exception of the reach directly downstream of the Deer Lodge sewage treatment plant. Once again, reductions in nutrient levels have a good chance of reducing Cladophora levels in most parts of the Clark Fork River.

Though N:P ratios in the Clark Fork are quite low, suggesting N limitation, it is essential that both phosphorus and nitrogen concentrations be controlled. Cladophora dominance is often associated with low N:P ratios (Dodds 1991). Control of nitrogen without control of phosphorus might reduce N:P ratios and favor Cladophora over diatoms. Unlike Cladophora which is unpalatable to most invertebrate grazers, diatoms are generally very palatable. Thus the invertebrate population may help to control diatom algal growth. Furthermore, diatoms are less of an aesthetic concern because of their growth form.

Nutrient Target Levels

In 1994, a Nutrient Target Subcommittee was established by the Tri-State Implementation Council (Council) to determine nutrient target levels and a basin-wide nutrient source reduction program to meet those targets. The committee established summer instream nutrient targets at: 300 ppb total nitrogen; 39 ppb total phosphorus downstream of Missoula and 20 ppb total phosphorus upstream of Missoula, where Cladophora is often a problem (Tri-State Implementation Council, 1998).

These target levels were based on a database analysis, conducted by an independent third party review, of nutrient and algal levels in approximately 200 rivers. Dodds, Smith and Zander (1996) concluded that total nutrients were a better predictor of algal levels than soluble nutrients and that total nitrogen was a better predictor than

phosphorus because high soluble nutrient loads may be rapidly depleted to very low levels by algal uptake where algal levels are high.

Using the database, Dodds et al. (1996) predicted that algal levels are unlikely to exceed algal targets (discussed under biological goals) when TN is below 300 ppb. In addition, algae was seldom observed to be a problem in the Clark Fork when TN is less than 300 ppb. Once the target level for total N was determined, the target level for total phosphorus (39 ppb TP) was set based on the weight ratio of N:P typically found in algae - 7:1 according to (Redfield 1958). However, in reaches where Cladophora grows to nuisance levels, the nutrient target for total phosphorus was set at 20 ppb to provide a high N:P ratio of 15:1 which it was hoped would discourage Cladophora growth. The Reserve Street bridge in Missoula was selected as the border because Cladophora is a problem mainly upstream of this point.

Figure 17. Average Summer Total Phosphorus levels in the Clark Fork River relative to target levels. Source of data: MTDHES (unpub.)

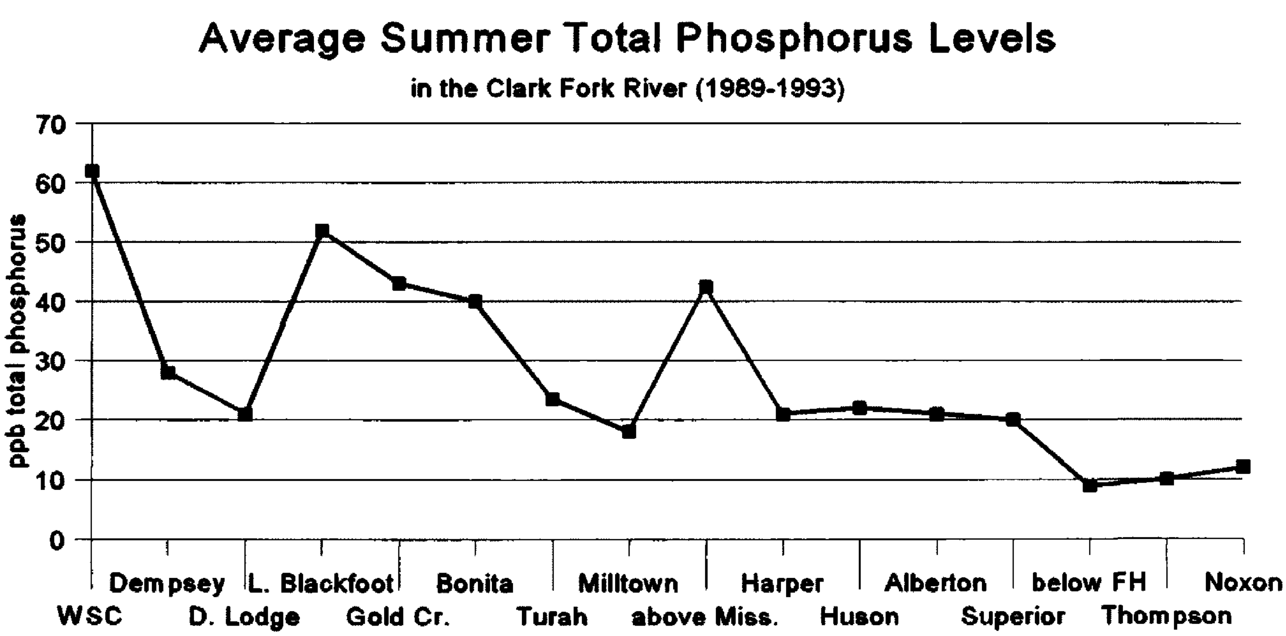
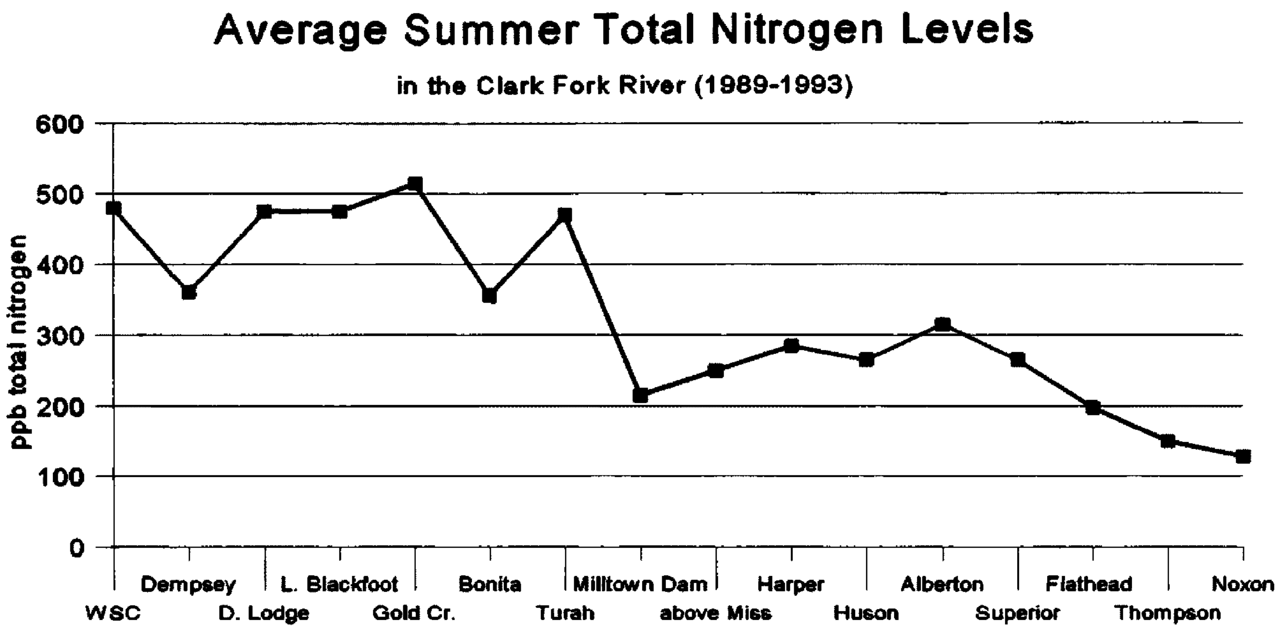


Figure 18. Average Summer Total Nitrogen levels in the Clark Fork River relative to target levels. Source of data: MTDHES (unpub.)



Figures 17 and 18 indicate that phosphorus and nitrogen must be controlled in the upper Clark Fork River. Phosphorus should be controlled just below Missoula and little nitrogen control is needed below the confluence with the Blackfoot River. However, the time period depicted in these figures does not include any low flow years when nutrients are most concentrated. The TMDL is designed to address nutrient concentrations during these low flow years.

In 1998, a ten-year Voluntary Nutrient Reduction Program was completed for the basin. It outlines site-specific measures to be taken by each of the four key point source dischargers and significant reductions in key nonpoint sources. A Memorandum of Understanding (MOU) was signed by the Department of Environmental Quality, Butte Silver Bow, City of Deer Lodge, City of Missoula, Stone Container Corporation, Clark

Fork Pend Oreille Coalition, Missoula City county Health Department Board of Health, and the Board of Missoula County Commissioners. Progress will be evaluated on three year intervals.

To achieve nutrient reduction in the Clark Fork Basin, the members of the MOU agreed to the following (Tri-State Implementation Council 1998):

Montana Department of Environmental Quality

- Implementation of procedures to address new and other existing discharge permits;
- Implementation of appropriate subdivision review procedures to reduce water quality impacts;
- Working with the City of Missoula, Missoula County and the City-County Health Department to address septic effluent and groundwater-to-surface water issues in Missoula and surrounding areas;
- Working with the Council on a prioritization and implementation strategy to reduce impacts from nonpoint sources in the upper Clark Fork;
- Serving as a repository for the Clark Fork model and working with the subcommittee to continue to refine the model; and
- Continued coordination with the Council's nutrient target subcommittee.

Butte-Silver Bow:

- Meeting in-stream nutrient and algae targets just below Warm Springs ponds through:
  -installation of an effluent pump at the Metro sewer plant;
  -flow augmentation of Warm Springs Creek from Silver Lake water;
  -a combination of other possible options outlined in the Bureau of Reclamation study;
  -continued implementation of voluntary phosphate detergent ban; and
- Continued participation on nutrient target subcommittee.

City of Deer Lodge:

- Meeting in-stream nutrient and algae targets by reducing loading by 100% through construction of a land application system; and
- continued implementation of phosphate detergent ban.

City of Missoula:

- Reducing loading to meet in-stream nutrient and algae targets through:
  -continued biological nutrient removal experimentation at present wastewater treatment facility;

-biological nutrient removal upgrade to wastewater treatment plant;
-capacity upgrade at wastewater treatment plant;

City of Missoula; Missoula City/County Health Department and Missoula County

- Working to address septic-effluent/groundwater-to-surface water issues in the Missoula valley both inside and outside of sewer service areas; through actions that include:
  -reviewing state and local regulations with the goal of removing disincentives and/or offering incentives for connecting new and existing septic systems to public sewage collection and treatment facilities that will remove nutrients;
  -modifying state subdivision regulations as appropriate to encourage clustering and smaller lots in new subdivisions and provide for the economically feasible, orderly and timely connection of new subdivisions in the area onto public sewer;
  -encouraging development of alternatives to municipal wastewater disposal to reduce nutrients from new development (such as land application, wetlands, and nutrient removal septic systems;)
  -connecting 50% of the existing 6,780 septic systems in the Missoula urban area, resulting in an estimated reduction of approximately 130 kg/day nitrogen discharged to the Bitterroot and Clark Fork Rivers.
  -continuing to connect existing septic systems in the Missoula area to public sewage treatment facilities at a rate approximately equivalent to the number of new septic system permits.
  -limiting nutrient loading from septic systems outside the Missoula WWTP service area;
- Working to control other nutrient sources in the Missoula area;
- Continued implementation of phosphate ban.

Stone Container Corporation:

- Reducing loading to meet in-stream nutrient and algae targets through:
  -early start-up of the color removal plant at flow at or below 4000 cfs;
  -no direct discharge to the river during July and August at flow below 4000 cfs;
  -summer use of storage ponds farthest from river to reduce seepage;
  -researching additional nutrient reduction techniques;

Tri-State Implementation Council:

- Providing coordination and administration of the VNRP to ensure program effectiveness;
- Overseeing the nutrient target subcommittee's responsibilities to implement, monitor, evaluate and address progress of the VNRP measures;
- Coordinating the monitoring subcommittee's in-stream data with the nutrient target subcommittee's efforts;
- Working with other parties in the watershed to expand nonpoint and other point source awareness and participating in nutrient reduction measures;

- Hiring a VNRP coordinator to assist the nutrient target subcommittee in carrying out the VNRP; and
- Reporting to EPA and the public on VNRP progress.

To meet VNRP goals, the subcommittee also outlined steps to address nutrient loading from nonpoint sources. Brown and Caldwell (1997) estimated nonpoint source nitrogen and phosphorus loading to the Clark Fork River from its five major contributing tributaries based on landuse, area and loading factors. The committee will use these estimates to prioritize nonpoint efforts throughout the basin.

The committee's initial goal is to reduce nitrogen and phosphorus loading from existing nonpoint sources by 20%. These efforts will begin in the Upper Clark Fork and Bitterroot drainages where established groups and projects are already underway.

GOALS: Restore beneficial uses and eliminate nuisance algae levels in the Clark Fork River from its headwaters to the Flathead River confluence.

RECOMMENDED ACTIONS: Reduce instream nutrient concentrations to those target levels identified by the Tri-State Implementation Council:

<300 ppb total nitrogen;

<39 ppb total phosphorus below Missoula;

<20 ppb total phosphorus above Missoula.

***Manage both nitrogen and phosphorus since both appear limiting at various times and places on the river.**

***Monitor and manage both total and soluble forms of nutrients to give the best picture of bioavailability and of loads from point and nonpoint sources.**

***Evaluate instream nutrient concentrations every three years to determine if nutrient reductions are occurring, and evaluate algal levels every summer to assess whether nutrient reductions are having the desired effects.**

***Require major point sources to report their nutrient loads.**

***Adopt nutrient control strategy and nutrient reduction actions of the Voluntary Nutrient Reduction Program (1998).**

Lake Pend Oreille

Water quality has become a concern in Lake Pend Oreille. Although no significant change in clarity in the deep-water portion of the lake has been detected since the mid-1950's, researchers have discovered increasing algae levels and decreasing water clarity in the nearshore littoral zone. The higher nearshore algae levels have been consistently

correlated to shorelines with significant residential development (and high phosphorus loadings) (USEPA 1993). Pack River and Sand Creek discharge the highest phosphorus loads per unit of land area to the lake. Lightning Creek, Pack River, and Sand Creek contribute the largest nitrogen loads (USEPA 1993).

Although current nearshore eutrophication has been directly correlated with shoreline residential development, nutrient loading from the Clark Fork river must also be considered. The Clark Fork is responsible for more than 90% of the water and 85% percent of the total phosphorus entering the lake. In order to maintain current open lake water quality, nutrient discharges from the Clark Fork River must be maintained at or below their present levels (USEPA, 1993).

GOAL: Prevent lake-wide eutrophication and reduce attached algal levels.

RECOMMENDED ACTIONS: Reduce, or at least prevent, increases in nutrient loads from the Clark Fork River into Pend Oreille Lake. Reduce nutrient concentrations in the lake to those concentrations found at "undeveloped" sites: 2 ppb soluble phosphorus or 5 ppb total phosphorus.

***New development should be set back from the lake and stream banks. Centralized sewer or land application systems should be installed as part of development plans.**

Blackfoot River

Research conducted during a low and high flow year (1988 & 89) indicates that nutrient levels in the Blackfoot drainage are generally low except during runoff events (Ingman et al., 1990). The average soluble phosphorus concentration during August, 1988 (a low-flow year) was 1 ppb with a range of <1-3 ppb, and the average soluble nitrogen concentration was 36 ppb with a range of 10-95 ppb. During spring runoff in April, 1989 (a high-flow year) soluble phosphorus concentrations averaged 58 ppb with a range of <1-147 ppb and soluble nitrogen concentrations averaged 182 ppb with a range of 65-225 ppb. During the spring of 89 the tributaries Landers Fork, Nevada Creek, the North Fork, and Elk and Union Creeks also contained elevated phosphorus concentrations relative to other tributaries. Soluble phosphorus ranged from 65-155 ppb. High levels of algae downstream from Nevada Creek also suggest elevated nutrient levels.

Landers Fork, the East Fork of Chamberlain Creek and Elk Creek contained elevated nitrogen levels compared to the other tributaries. Soluble nitrogen levels were low, 10-25 ppb, but total nitrogen concentrations ranged from 600-1210 ppb.

The primary nutrient sources in the Blackfoot River are considered to be nonpoint sources originating from land use activities. The elevated nutrients suggest agricultural runoff enriched with fertilizer, soil particles and animal wastes (Ingman 1990). Logged watersheds also contribute nutrients (Hauer and Blum (1991).

GOAL: Protect the Blackfoot River from any increase in nutrient concentrations.

RECOMMENDED ACTIONS: Work with landowners to reduce nutrient inputs from nonpoint sources.

Nitrates in Groundwater

Groundwater is a critical resource throughout the Clark Fork Basin. Not only is it used for irrigation, livestock and industry, but 54% of Montanans rely on groundwater exclusively for their domestic water supply (MTDHES, 1994).

The most important sources of groundwater in Montana are the alluvial aquifers which occupy the river valleys. Alluvial aquifers are made up of loosely compacted gravel, sand, silt and clay deposited by streams and rivers. Generally, these alluvial aquifers provide abundant, high quality water. Yet, because they are composed of coarse-grained material and the groundwater is close to the surface, they are also very vulnerable to contamination.

The Missoula Aquifer, for example, is the major source of ground water in the Missoula Valley and the sole source of drinking water for area residents. It supplies two municipal water systems, over 30 small community systems, several large industrial users and numerous individual wells (MTDHES 1994). Protecting the high quality of this aquifer is of utmost importance.

Septic system failure connected to rural development is degrading groundwater and creating a potential threat to public health in the Missoula and Swan Valleys (VerHey, 1987; Woessner et al, 1995). Originally, septic tanks were designed for low-density rural areas where there was sufficient open space and soil volume to treat and dilute septic

waste. However, in areas with shallow groundwater and thin soils underlain by coarse alluvial sand and gravel, little if any treatment occurs. Many rural households obtain drinking water from wells penetrating the same groundwater system. As a result, they may be contaminating the aquifer from which they obtain their drinking water supplies.

The Missoula Valley contains about 10% of Montana's population, and has been experiencing a growth rate of 8.9% in the last few years (U.S. Census Bureau). It is estimated that over 30,600 septic systems are currently in use in Missoula County. Current subdivision regulations and rural property development regulations often allow two septic systems per acre. Older regulations have allowed portions of the county to contain six or seven systems per acre.

Woessner et al. (1995) conducted research to determine the impact of septic tanks on groundwater in Missoula County. This research indicated that little or no "treatment" of wastes occurs before it reaches the groundwater. Furthermore, septic system density of one to two homes per acre creates a cumulative impact to the groundwater quality. The most elevated concentrations were located in areas where a number of septic systems were consecutively aligned with a groundwater flowpath. This resulted in an overlap of multiple plumes. Field identified plumes were often about 50 to 100 ft wide and extended at least 200 feet down-gradient from the drainfield source.

Septic system wastes may cause several human health hazards. Nitrate concentrations over 10 mg/l are known to cause "blue baby" syndrome. Also known as methemoglobinemia, this disease oxidizes the hemoglobin in the blood, making it unable to transport oxygen. Confined largely to infants less than 3 months old, it can result in brain

damage or death. This is the basis for the drinking water standard of 10 ppm.

High concentrations of nitrate have also been connected to cancer. Nitrate converts to nitrite in the digestive system of humans and animals. Nitrite may subsequently combine with amines to form nitrosamines, a class of compounds shown to cause cancer (Smith 1978, Tannenbaum et al., 1978).

Elevated nitrate concentrations are a health concern in their own right, but they also indicate the presence of other harder to detect hazardous substances associated with sewage such as bacteria, parasites and viruses. These substances, especially viruses, are much more expensive and difficult to detect. Therefore, nitrates and coliform bacteria are often used as indicators.

Bacteria can cause waterborne diseases such as typhoid and gastroenteritis. Viruses are an even greater concern than bacteria because they are much longer-lived, infective at lower numbers, and far smaller in size. Bacteria may persist weeks or months, whereas viruses may remain viable for months and even years. Viruses (.02 to .08 um) are considerably smaller than bacteria (1 to 10 um), therefore, filtration has not been an effective way of treating viruses. Cliver (1981) indicates that "media coarser than sand are unlikely to be effective in removing viruses from septic tank effluents, and saturation of the medium appears to allow viruses to persist and to be transported over considerable distances in an infectious condition." Keswick and Gerba (1980) found that virus movement in groundwater can penetrate to a depth of 67 meters and migrate as far as 408 meters horizontally.

Over 100 different viruses are known to be excreted in human waste products, according to Tyler (1985). Only one or two of viral infective units are needed to cause illness, whereas, a much higher dosage of bacteria is needed for illness to occur. However, once infection occurs, one million viral infective units can be shed per gram of feces which results in concentrations of 100,000 units per liter of sewage. Yates et al (1985) cite several researchers as stating that "consumption of contaminated groundwater is responsible for most of the outbreaks of waterborne disease in the U.S. and that viruses probably are the etiologic agents in most cases". Keswick and Gerba (1980) found that 65% of documented outbreaks of waterborne disease from 1946 to 1977 can be attributed to viruses. This number probably represents only a fraction of the actual number of virus-caused outbreaks because of the difficulties involved in proving its origin.

The 1995 legislature changed Montana's nondegradation laws to allow degradation of groundwater just short of the drinking water standard (10 ppm). Nitrate levels may be increased up to 5.0 mg/l using standard septic systems, and up to 7.5 mg/l using more effective systems (MCA 75-5-301). Because declining trends in groundwater are slow to be detected and reversed, it is likely that groundwater allowed to degrade to these levels will continue to degrade to the standard.

Furthermore, if nitrate levels are allowed to increase, other harmful substances (i.e. viruses, bacteria, parasites) will increase as well. Woessner et al. (1995) sampled two sites in the summer of 1995 for viruses: one in Frenchtown and another west of Reserve Street in Missoula. Although no harmful organisms were detected at the Frenchtown site, the Missoula site contained fecal coliforms, plaque-forming-units of male-specific coliphage,

and human enterovirus at 1 virus per 402 liters. Suggested drinking water standards are not more than 1 virus per 10,000,000 liters.

Allowing increased nitrates in groundwater degrades surface waters also. In Montana, many aquifers are located along streams. They are unconfined, vulnerable to contamination and connected to surface water. For example, groundwater seepage from the Missoula area contributes up to half of the nitrogen in the lower Bitterroot River during summer months (MTDHES, 1994).

Despite the connection between surface and groundwater, state law was also changed in 1995 to state that "standards for the protection of aquatic life do not apply to groundwater" (MCA 75-5-301(B)(2)). This makes it more difficult to prevent surface water pollution caused by discharges to groundwater. The Clark Fork River, already beset by nutrient problems, provides an example. Increases in groundwater nitrate levels in the Missoula valley and at proposed mines will increase nutrient loads to the Clark Fork and its tributaries.

Nitrate levels are also of concern to lakes such as Flathead Lake where nearshore development is high. Increased nitrate levels may result in unwanted plant growth and reduced clarity. To properly protect water quality, impacts of groundwater discharges upon surface water need to be considered and vice versa.

GOAL: Prevent degradation of groundwater to the nitrate drinking water standard (10 ppm).

RECOMMENDED ACTIONS: For groundwater used or with potential to be used for drinking water, Montana should adopt water quality standards for nitrates which provide a preventative action limit of 1 ppm. At this concentration, the change in groundwater quality should be considered significant and the Board of Environmental Review should direct the Dept. of Environmental Quality to determine the cause of degradation and take action to prevent any further increase in nitrate concentrations.

*Further development in areas where groundwater nitrate levels have reached 1 ppm should be either limited, sewered or best available septic systems required. High density unsewered areas in the valley bottoms should be connected to sewage treatment facilities, especially if nitrates reach 1 ppm.

*Where groundwater is connected to surface water, any increase in groundwater concentrations that could raise surface water concentrations above the trigger values of 1 ppb P and 10 ppb N (as defined in Montana's Numeric Water Quality Standards Circular WQB-7) should be treated as significant degradation. The increase in nutrient loading to surface water should be determined, and potential increase in eutrophication problems estimated and considered in any permit decisions.

**The river is, in effect, the "bottom line"
where the cumulative effects of all land and water uses are reflected
in water quality, quantity, habitat, and aquatic life.**
**- Upper Clark Fork River Basin
Steering Committee**

Section II. PHYSICAL GOALS

Streams are far more than a sparkling ribbon of flowing water. They are an integral part of the entire watershed. All the things which create a stream--water, nutrients, bed sediment, leaf litter, woody debris and channel shape--are a product of the drainage basin it flows through. Chemical criteria are an essential part of state water quality standards, but by themselves they cannot protect our streams and rivers because they fail to account for physical impacts such as stream channel straightening, dewatering, and increased water and sediment yield caused by land use practices. This is clearly important in Montana, where non-point pollution sources such as agriculture, forest practices, mining, dams, and habitat alterations are responsible for about 90 percent of the impaired waterbodies. Point source discharges from municipal and industrial wastewater treatment plants account for only 10 percent (MTDHES 1992).

Land-use practices throughout the watershed affect stream quality by influencing the amount and pattern of water and sediment yield; however, the most critical area is the streamside or riparian zone. A thriving population of bull trout, for example, requires far more than crystal clear water. It relies on overhanging branches for shade during the warm summer months, fallen branches and trees to form deep, cold pools for hiding and resting, stable stream banks to maintain sediment-free spawning gravels, and fallen leaves

to feed the aquatic insects that juvenile bull trout prey upon. As a result, conservation, preservation and restoration efforts must reach beyond the stream to include riparian and even certain aspects of upland areas.

A. In the Stream

INSTREAM FLOWS

Water quantity is as critical as water quality for aquatic life. In fact, these two cannot be separated. The Montana Dept. of Fish Wildlife and Parks has determined that 560 miles of streams are chronically dewatered in the Clark Fork Basin due to irrigation withdrawals (MTDFWP, 1994). An additional 5.3 miles in the Flathead Basin are dewatered due to dam regulation. These streams experience dewatering sufficient to degrade fish habitat nearly every year during the summer months.

Table 5. Chronically dewatered streams in the Clark Fork River Basin (MTDFWP, 1994).

River Basin	Miles
Upper Clark Fork Basin	224.8
Blackfoot River Basin	82.4
Flint Creek Basin	66.8
Little Blackfoot River Basin	75.2
Rock Creek Basin	21.9
Bitterroot River Basin	64.5
Flathead River Basin	24.3
Lower Clark Fork	6

Dewatering often results in increased water temperatures, increased concentrations of dissolved minerals including nutrients and lower dissolved oxygen levels. In addition, reduced streamflows seasonally limit the ability of the Clark Fork to dilute its present pollution load down to acceptable levels (MTDFWP, 1986).

Although dewatering may only be a seasonal occurrence, its impacts to the stream community has year round implications. If spawning or rearing areas for trout become dry for a few days or even hours, the resulting mortality to young-of-the year-individuals can remove an entire age class from the population. Adequate flow is critical at specific times in life cycles for spawning, rearing and migration. For example, the Bitterroot River Fisheries Management Plan identifies July as a critical time of the year for sufficient flows because young-of-the-year trout are moving from the tributaries to the main river (MTDFWP 1991).

Desired Instream Flows

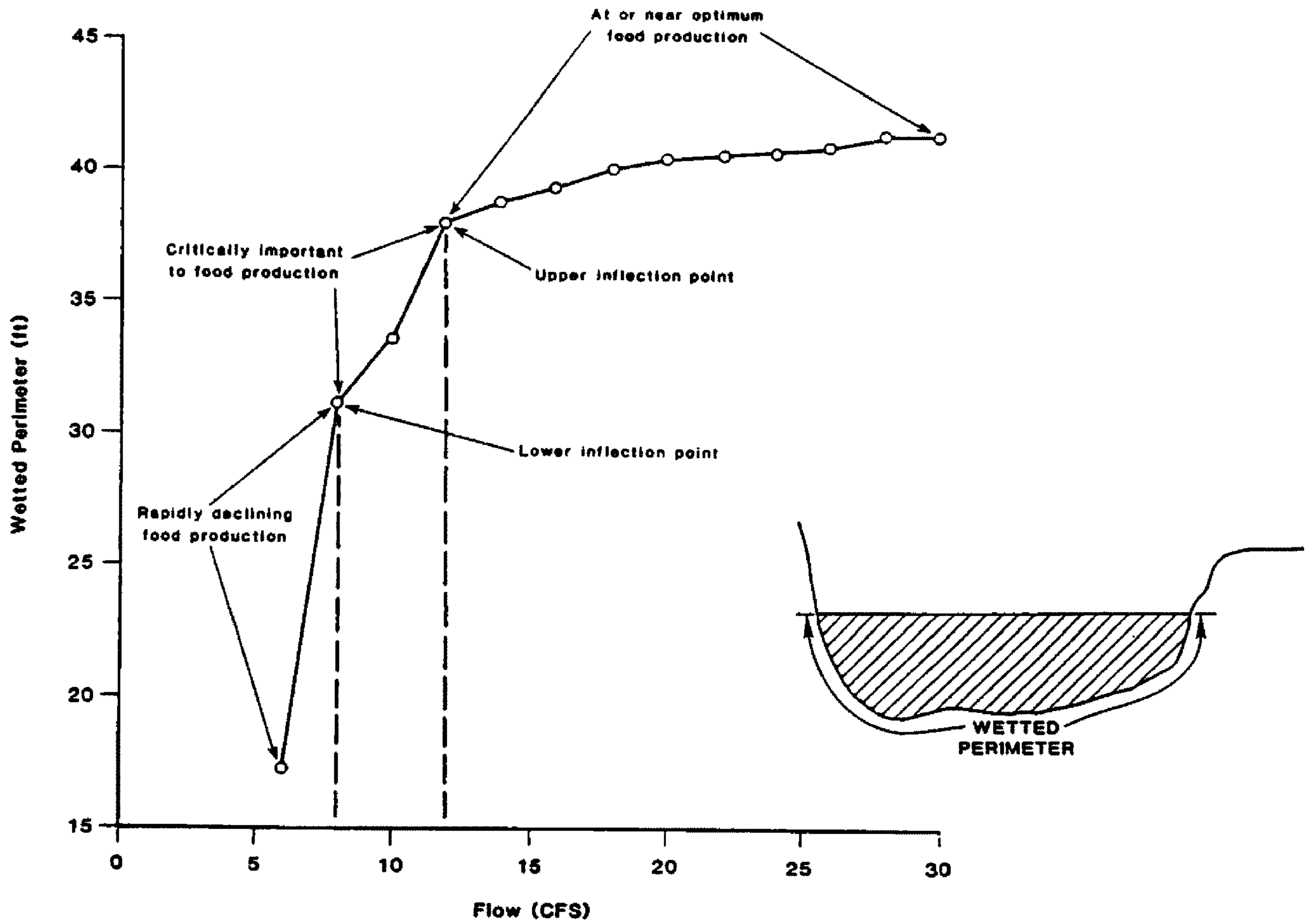
Prior to the Water Use Act of 1973, a permit system for the acquisition of new water rights in Montana did not exist. There was little control over the amount of water claimed by users relative to the actual amount of water available in the stream. As a result, the total water demand claimed in water rights in many areas of the Clark Fork Basin exceeds the mean annual flow. In low flow years fish are left "high and dry".

In 1973, Montana's Water Use Act made water reservations available to state agencies, municipalities, or other public entities as a way of keeping in the stream water

gained through a water right (MCA 85-2-316). The purpose of a water reservation is to preserve instream beneficial uses, primarily recreation, fish and wildlife values. Instream reservations establish a level below which new consumptive uses cannot further deplete the river. In 1986, the Montana Dept. of Fish Wildlife and Parks applied for water reservations to maintain instream flows in the upper Clark fork River and various tributary streams (MTDFWP, 1986). To determine a range of desired instream flows for the upper Clark Fork Basin, the Montana Dept. of Fish, Wildlife and Parks used the Wetted Perimeter Inflection Method (MTDFWP, 1986). This method is based on two assumptions: 1) the number of fish a stream can support is most limited by the abundance of food, and 2) food abundance depends on the presence of adequate aquatic invertebrate habitat. Riffles (shallow areas) are measured because they are the primary habitat for aquatic invertebrates.

Wetted perimeter is the distance along the bottom and sides of a channel cross-section that is in contact with water (Figure 20). As streamflow increases, the wetted perimeter also increases - although not at an equal rate. At first, the length of the wetted perimeter increases sharply as the water covers the wetted perimeter unrestricted by channel walls. Once the channel walls are reached, the wetted perimeter increases at a slower rate. The point at which this rate slows is called the lower inflection point. Eventually the lengthening of the wetted perimeter reaches a plateau because the stream's maximum width, except for floods, has been reached. The point where this plateau begins is the upper inflection point. The final flow recommendation is generally selected between the two inflection points.

Figure 19. The relationship between wetted perimeter and flow, and their relationship to fish food production. Source: MTDFWP (1986).



Factors considered in selecting the final instream flow reservation include: (1) the level of recreational use, (2) the existing level of environmental degradation, (3) water availability and (4) the magnitude and composition of existing fish populations. If species of "special concern" are present (i.e. bull trout, westslope cutthroat and arctic grayling), a higher flow level is selected. Specific flow levels are recommended for the Upper Clark Fork River and its tributaries by the Montana Dept. of Fish, Wildlife and Parks (1986).

In streams where field studies have not been conducted, MTDFWP uses 10% of the mean annual flow as a general rule of thumb for the absolute minimum instantaneous flow to provide short term sustenance for fisheries. This "rock bottom" value is based on

research by Tennant (1976) in which trout habitat conditions are described at 60, 30 and 10% of mean annual flows.

In response to severe dewatering within the upper Clark Fork, the 1991 Montana Legislature issued a basin closure for the Upper Clark Fork Basin, preventing any new surface water rights from being issued. Groundwater, however, was excluded. Therefore, streams may still be dewatered by pumping nearby groundwater. In addition, the upper Clark Fork River Basin Steering Committee is in the process of developing a drought management plan for the upper Clark Fork Basin.

According to Montana's nondegradation rules, activities that would increase or decrease the mean monthly flow of a surface water by less than 15% or the 7-day 10 year low flow by less than 10% are considered nonsignificant (ARM 16.20.712). If the cumulative effects of water withdrawals since passage of these rules exceeds those levels of change, it could be considered significant degradation and a petition to degrade might be required.

High Flows

Although low flows generally receive the greatest attention, high flows are also important to river systems. The capacity to scour is a function of flow, therefore, most reworking of stream channels occurs during floods of moderate frequency. Periodic high-flows also scour away nuisance algae and flush out the accumulation of fine particles, thereby restoring spawning habitat for trout or salmon (Milhous, 1990). On the other hand, high flows which have been greatly increased due to poor land use practices can

erode banks and downcut streams. Restoration of the natural flow regime is one of the most neglected yet important aspects of stream and river restoration.

Impacts From Dams

Dams completely transform a river system both upstream and downstream of the dam. The reservoir of water behind the dam may become stratified by temperature: the deeper layer is cool, oxygen-poor and generally too dark to support plant growth; the upper layer is better oxygenated, but often too warm for native aquatic species. Depending on whether water is released from the top or bottom of the dam, downstream temperatures may be warmer or colder than the river's natural temperature.

Water level manipulations can harm shallow inshore habitat. The average drawdown at the Hungry Horse dam reduces reservoir volume to 50%, exposing vast expanses of reservoir bottom. Downstream flows are often altered from their historic seasonal pattern, especially where water is released in response to irrigation or electricity needs. Dams also change natural sedimentation processes. Sediments are trapped behind the impoundment, causing the "sediment hungry" water released from the dam to erode downstream riverbanks and destroy instream island habitat. Because dams are frequently managed to moderate high flows, downstream bed sediments may become choked with fine sediments and rooted plants which were once flushed clean by periodic flood events.

The Integrated Rule Curves Concept (IRCs) is a reservoir management strategy developed to protect reservoir aquatic communities by more closely mimicking natural flows. The Bull Trout Restoration Scientific Team recommends this management strategy

(BTRT, 1996.). Although IRCs were adopted by the Northwest Power Planning Council in 1994, they have not been implemented.

GOAL: Restore instream flow patterns throughout the basin to support healthy and thriving native fisheries. Dams should be managed to emulate as closely as possible the natural hydrograph.

RECOMMENDED ACTIONS: Restore flows in the Upper Clark Fork during low-flow years to at least the levels established in the Montana Department of Fish Wildlife and Park instream flow reservation application (MTDFWP 1986). The MTDFWP should determine desired instream flows for other streams throughout the Clark Fork River Basin that suffer from dewatering. These flows should be based on temperature requirements as well as food production for streams which currently support or historically supported bull trout or westslope cutthroat.

***Incorporate Integrated Rule Curves in reservoir management where appropriate.**

***Watershed councils should develop drought management plans for any subbasin which suffers chronic dewatering. Appoint a water commissioner**

to each subbasin whose responsibility is to monitor stream flows, communicate this information to water users, and coordinate conservation efforts.

***Continue the legislative basin closure of the upper Clark Fork and Bitterroot, and add groundwater that will affect surface water flows.**

***Include instream flows as a beneficial use of equal value to all other beneficial uses. Focus on improving irrigation efficiency and acquiring some or all of the conserved water for instream flows.**

***Do not allocate any additional water rights within the basin which could cause significant degradation (degradation is insignificant if the cumulative change in mean monthly flows since 1993 is less than 15%, or the 7 day -10 year flow is changed less than 10%).**

TEMPERATURE

Montana is renowned for its blue ribbon trout streams. Trout, especially native bull trout, are dependent on cold stream temperatures. The two most critical elements for maintaining instream temperatures are vegetative cover and instream flows. If riparian vegetation is removed, or the stream channel widened, the percentage of stream surface

area exposed to sunlight increases, and the water temperature increases. Under these conditions, temperature changes can be large and abrupt and severely impact aquatic life.

Water temperature influences the metabolism, development and activity of stream organisms. For example, water temperatures above 66 degrees F, cause a trout to use more energy in foraging than is contained in the food it consumes (MTDFWP 1986). As a result, rainbow and brown trout do not grow at temperatures above 66 degrees F. Furthermore, species preferences for temperature affect the ability of an organism to successfully compete for resources, influencing community composition and abundance.

Water temperature is critical to native bull trout, a sensitive species in the state of Montana. Bull trout are bottom dwellers that generally select deep pools of cold-water rivers, lakes and reservoirs (Moyle 1976). According to Shepard (1989), bull trout migrate from Flathead Lake to the mainstem Flathead River, generally beginning in April. In late June or July, the spawners move slowly upriver and arrive at the North and Middle Forks. Finally, in late July through September, they enter the tributary streams. This is a critical time. During the last months of the summer, tributaries are most vulnerable to dewatering and increased water temperatures.

Pratt (1984) indicated that the distribution of bull trout in a basin is associated with water temperatures. She found the highest densities of bull trout in the Pend Oreille basin in streams with groundwater influence and a closed forest canopy (Pratt 1985). Higher bull trout densities were observed in the Flathead Basin where water temperatures were 12 degrees C or less (Shepard 1983). Juvenile bull trout were rarely found in streams when summer maximum temperatures exceeded 15 degrees C (Fraley and Shepard, 1989).

Goetz (1989) found adult bull trout selected water temperatures between 8.9 and 12.8 degrees C. Rieman and McIntyre (1993) conclude that "temperatures in excess of 15 degrees C are thought to limit bull trout distributions...and the optimum temperatures for rearing are about 7-8 degrees C.

Recent research by Swanburg (1995, unpub.) showed that adult and subadult bull trout that don't spawn, concentrate in thermal refuges (cooler water pockets) and confluence areas. He also recorded bull trout leaving the mainstem to hide in the confluence of tributaries up to two months before spawning time. Movement corresponded with an increase in mainstem temperatures in the Blackfoot (from 12 to 18 degrees C) and a decrease in discharge.

GOAL: Restore stream temperature regimes to levels that support a sustainable and productive population of native fish.

RECOMMENDED ACTIONS: In streams that currently or historically supported bull trout, temperatures should be restored or maintained at 6-8 degrees C for spawning and 10-12 degrees C for rearing habitat, and 12 degrees C in migratory stream corridors. Focus restoration efforts on restoring riparian vegetation and instream flows. Protect flows in streams that provide critical thermal refuges.

SUBSTRATE (Streambed Material)

The material (or substrate) that forms the streambed is usually made up of a diversity of patches of different particle sizes. This pattern is a key factor influencing the diversity of aquatic life which may inhabit the stream. However, certain land-use practices may significantly change this natural pattern by increasing the percentage of fine sediments (particles less than 6.35 mm in diameter); habitat diversity may be lowered as a result.

Fine sediment may cover gravel bottoms that many organisms need for feeding and reproduction, and fill the deep pools and cover the rocks and woody debris where game fish live and feed (Rosebloom et al, 1983). High levels of fine sediments in spawning gravels can prevent oxygenated water from reaching embryos, trap metabolic wastes within the spaces surrounding the embryos, and form a physical barrier preventing fry emergence.

Macroinvertebrates also rely on intra-gravel spaces as a refuge from predators and strong currents and as a feeding area for early life stages. These spaces also functions as a site for nutrient transformation (Stanford and Ward, 1988). All of these functions are altered when fine sediments fill the tiny spaces in the streambed.

Salmonid survival at early life stages has been directly linked to the amount of fines in the substrate (Rich et al. 1992). Bull trout embryos and fry are particularly vulnerable to increases in fine sediments because they remain within the streambed for more than 200 days (Fraley and Shepard 1989). Researchers have demonstrated an inverse relationship between the proportion of fine sediment and emergence success in bull trout eggs (Weaver and Fraley 1991, Shepard 1984).

Table 6. Relationship between the proportion of fine sediment and emergence success in bull trout eggs. Source (Weaver and Fraley 1991)

Spawning Gravels % fines (<6.35 mm)	Percent embryo survival
50	0
40	1
30	21
20	38
10	48

Chapman and Macleod's 1987 report, *Development of Criteria for Fine Sediment in the Northern Rockies Ecoregion*, identifies a threshold of sediment impact starting at 10-20% fine sediment in spawning gravels. Mortality rates increased greatly above this level.

Westslope cutthroat trout are also vulnerable to increases in fine sediment. In laboratory studies, embryo survival to hatching for westslope cutthroat trout was generally less than 50 percent when the percentage of fine sediment (material less than 6.35 mm) within the redd (fish nest) exceeded 20 percent (Idaho Cooperative Fisheries Research Unit, University of Idaho, Moscow).

GOAL: In general, fine sediment should comprise less than 20% of the streambed spawning gravels.

RECOMMENDED ACTIONS: Adopt sediment criteria for streams which currently support or historically supported native bull or westslope cutthroat trout:

Stage 1: When fine sediments in the spawning gravels reach 15%, managers should be concerned about possible negative effects on fish reproduction and survival. Studies should identify sediment sources, and mitigating measures to prevent further increases should begin.

Stage 2: When fine sediments reach 20%, effects on salmonids may be serious. Immediate steps must be taken to halt or drastically modify new sediment producing activities and decrease sediment loading to streams. No new sediment producing project may be permitted.

Stage 3: When fine sediments in the spawning gravels reach 30% fine sediment deposition, the situation for salmonid reproduction and survival is critical. All sediment producing activities must be halted until measures are begun to lower sediment loads to acceptable levels. Restoration of riparian areas should receive priority.

Sediment Toxicity

Certain toxic substances tend to attach to sediments. This is a particular concern in the Upper Clark Fork River where an estimated 100 million tons of mining waste have been transported downstream and deposited along banks and floodplains from the mining and smelting operations in Butte and Anaconda (Moore and Luoma, 1990; Nimick, 1990).

Bank and floodplain mine waste continuously recontaminate bed sediments through bank erosion, runoff, and leaching of soluble substances into surface water and groundwater (Nimick, 1990). As a result, the Clark Fork River is continuously exposed to hazardous substances from the contaminated floodplain soils (ENSR, 1992; Lambing, 1991). The Montana Natural Resource Damage Program (MTNRDP 1993) compared the bed sediments of Silver Bow Creek, the Warm Springs Ponds and the upper Clark Fork River to reference streams which have not been contaminated from historic mining operations. They concluded that bed sediments in Silver Bow Creek, the Warm Spring Ponds and the Upper Clark Fork River exceed baseline conditions for arsenic, cadmium, copper, lead and zinc.

Many aquatic insects live in and on bed sediments and are exposed directly to hazardous substances contained in the sediments. Because these macroinvertebrates are a primary food source for many fish species, fish have also been exposed to, and injured by, these hazardous substances. (Woodward, 1994 & 1995)

Conditions in Silver Bow Creek, one of the headwater tributaries to the Clark Fork River, are so severe that no fish exist in this stream. In addition, fish populations in the rest of the Upper Clark Fork mainstem are less than 1/6 of the stream potential. Contaminated sediments in the Warm Springs ponds are also a concern because they can be washed downstream by a flood event and serve as an ongoing source of hazardous substances to surface water and groundwater. According to MTNRDP (1993), without this active restoration, the natural recovery time of these resources is predicted to be hundreds if not thousands of years.

Blackfoot River

Contaminated sediments are also present in the Blackfoot River due to past mining activity. Elevated metal concentrations occur in Mike Horse Creek and Beartrap Creek - two headwater streams of the Blackfoot River - as well as the mainstem Blackfoot (McCulley et al 1994). When assessed by Moore et al. (1991), concentrations of arsenic, cadmium, copper, manganese, nickel, lead and zinc were 10 to 1000 times higher in the bed sediments of the upper few kilometers of the Blackfoot River compared with uncontaminated tributaries or sediment downstream. Some contaminants extend at least 25 km downstream from the main sources (Moore et al. 1991).

GOAL: Bed sediments should support a healthy benthic and fish community. Contaminated sediments should be actively reclaimed to a level where toxicity bioassays reveal no chronic or acute affects.

RECOMMENDED ACTIONS: Contaminated bed sediments and the underlying contaminated alluvial material in Silver Bow Creek should be excavated, contaminated fine sediments removed and coarse material replaced. However, where the stream is perched above the groundwater, the streambed should not be disturbed.

***Bed sediments in the upper Clark Fork should be allowed to recover naturally once the upstream sources of contamination have been removed**

(streamside tailings and contaminated bed sediments in Silver Bow Creek).

***Contaminated sediments behind Milltown Dam should be removed because natural recovery will not occur with Milltown Dam in place.**

***Prevent further contamination of bed sediments in the Blackfoot River by removing streamside mine wastes.**

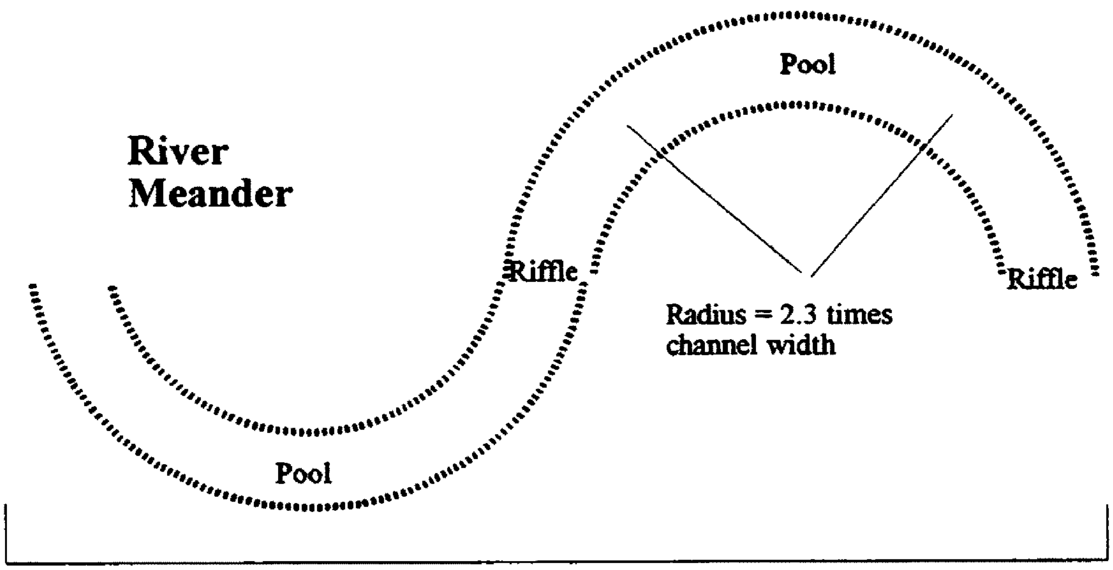
CHANNEL STRUCTURE

The physical structure of the stream channel constantly changes in response to flows, sediment levels, streamside vegetation and other factors. However, many land use practices alter the natural tendencies of the stream channel.

Stream Sinuosity

Rivers in unconfined valleys all tend to flow in S-shaped, meandering patterns. Stream meanders are important for channel stability because they provide a source of friction that controls stream velocity and distributes stress evenly throughout the river's course. The S-shaped pattern creates a more diverse habitat that increases the probability of meeting the needs of different life stages of fish, including spawning, rearing, hatching and food supply. While these meanders vary in size, they follow a fairly predictable set of proportions. One complete S curve of the stream is generally 10 to 14 times the stream channel width. The radius of the S curvature is 2.3 times the river width.

Figure 20. Stream channel geomorphology.

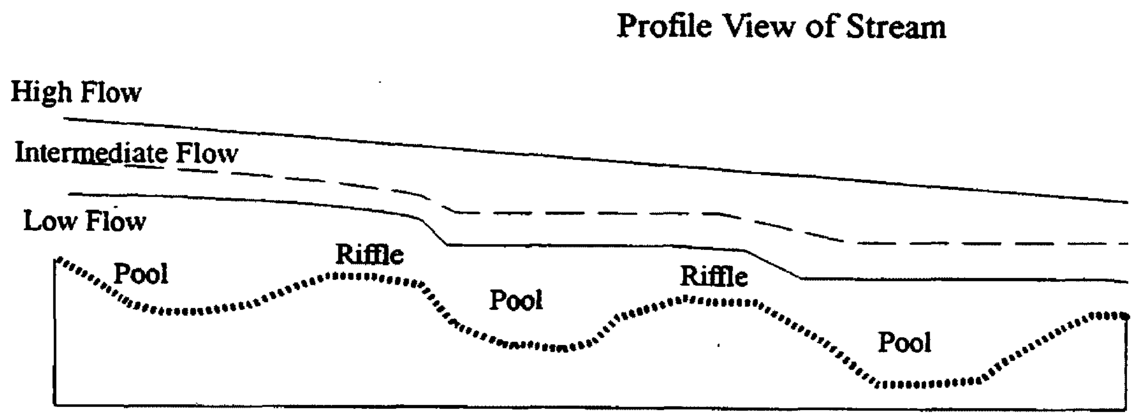


Structures such as roads, railways, berms and riprap which channelize or straighten the river channel may trigger many downstream effects. They may increase stream velocity, erosion, bed scour, suspended sediment and water temperature (Crandall et al. 1984). Land use activities, such as timber harvesting and grazing, which remove upland vegetation and increase runoff and sediment yield may have a similar effect.

Pool/Riffle Ratio

Riverbeds undulate in elevation in a regular repeating pattern. Shallow parts, called riffles, alternate with deeps or pools. Alternating pools and riffles are a fundamental characteristic of nearly all natural channels of a certain size and gradient are important to biological diversity.

Figure 21. Pool/riffle sequence.



Pool-riffle ratios are considered to be important measures of trout habitat quality (Platts et al. 1983; 1987). Pools are important as refuges (especially at low flows) and riffles are important for fish food production. Leopold (1960) concluded that streams (order 3 or larger) are characterized by a 1:1 pool-riffle ratio and pool-riffle spacing six times the channel width. Small headwater streams in steep areas generally form step/pool patterns (pools separated by small cascades) rather than pool/riffle patterns. Natural step pool channels generally have pools spaced roughly one to four channel widths apart (Grant et al. 1990).

Activities such as timber harvesting increase water and sediment yields and may reduce pool frequency and pool volume. In ten Oregon streams, Hicks (1990) found that the number of scour pools associated with large woody debris decreased in proportion to the percentage of the drainage basin that had been logged. Thomas et al (1993) reports an overall reduction of 58% in the number of large deep pools in national forest streams in western and eastern Washington over the last 50 years and a decrease of 80 percent in

streams on private lands in coastal Oregon. The primary reason for the loss of pools was filling by sediments, loss of pool-forming structures and loss of channel sinuosity by channelization.

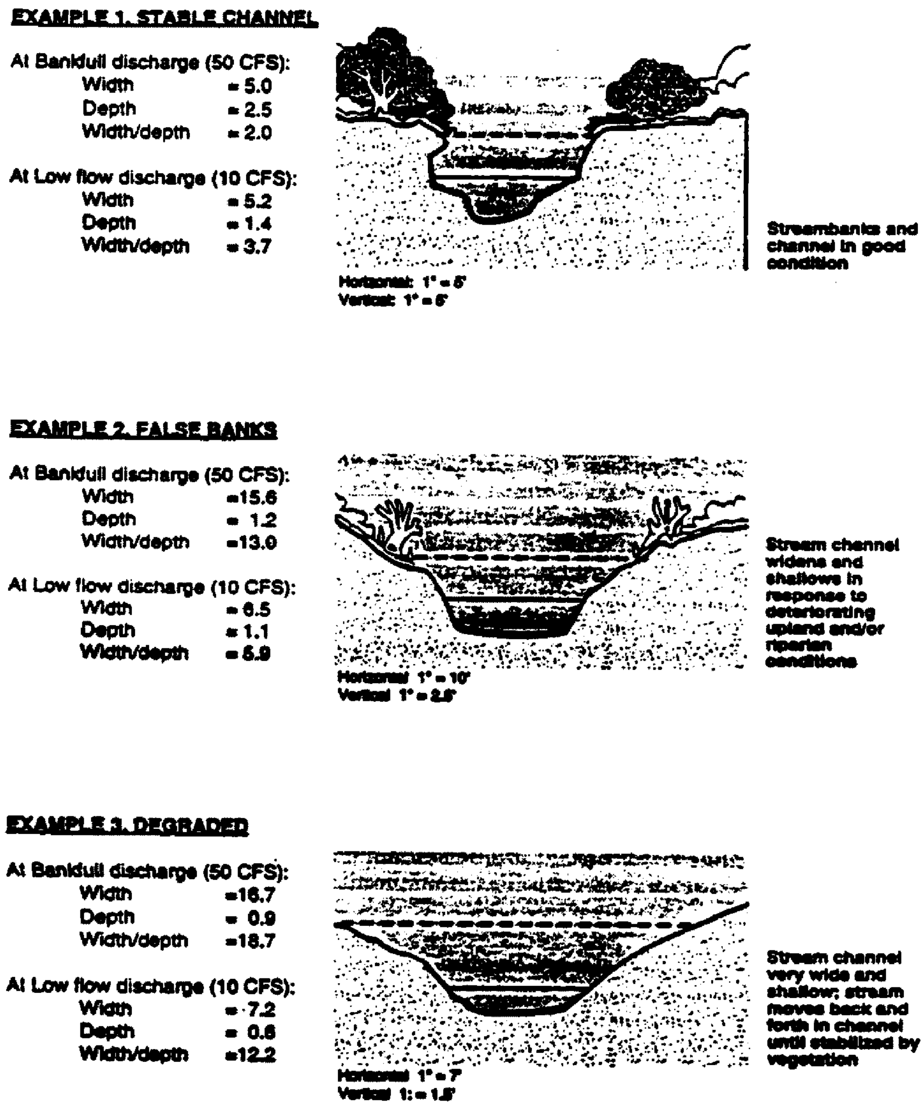
Instream structures such as log weirs have often been used by fisheries managers in the past to create pools in streams. Evaluation of these projects reveals some serious unanticipated problems (Doppelt 1993). The structures often caused harmful side effects including severe bank erosion and blockages to juvenile fish migration. The highest failure rates occurred in severely damaged watershed and stream reaches with continued disturbance. Likewise, boulders placed in streams to form pools, may also increase water temperatures (C. Frissell, pers. comm. 1995).

Width to Depth Ratio

The ratio of bankfull channel width to mean bankfull water depth is a good indicator of channel cross section shape and determines, to a large degree, the amount of rearing space and quality of cover for fish (Binns, 1979). Streams which are narrow and deep are more efficient channels for streamflow. These channels usually have greater pool volume and provide a larger amount of living space at low streamflows.

When riparian vegetation is removed, the streambank loses its anchoring root mass and may begin to erode. The end result is generally a much wider and shallower stream channel with fewer overhanging banks. In general, the width/depth ratio increases with channel degradation. While channels naturally meander, rapid widening and/or downcutting are usually indicative of human-caused degradation.

Figure 22. Comparison of three channel cross sections: stable banks, false banks and degraded condition. Source: Bauer & Burton (1993).



Many government agencies classify streams by their morphology using a stream classification system developed by Rosgen (1994). Rosgen's system is based on the idea that certain physical characteristics are usually observed together in similar streams.

Rosgen classifies natural streams into seven basic types (A through G). In general, an "A" stream has a steep, entrenched, cascading step/pool channel; a "B" stream has a moderately entrenched, riffle dominated channel; a "C" stream has a low gradient,

meandering riffle/pool channel; a "D" stream has multiple channels; an "E" stream has a low gradient, meandering channel with a low width to depth ratio; an "F" stream has an entrenched meandering riffle/pool channel; and a "G" stream has an entrenched gully-like step/pool channel with a low width to depth ratio. These 6 classifications are further subdivided relative to stream slope and dominant bed material.

The information obtained from this classification system is important in restoring "disturbed" rivers to their natural channel pattern. For example, many streams in Montana are severely impacted by historic and current placer-mining operations. In the process of dredging streambed material in search of ore, stream channels are disrupted, often to the point where natural recovery would take hundreds of years. In order for reclamation or restoration efforts to be successful, the stream's natural channel structure must be determined and reconstructed. Although stream reclamation is required according to Montana Placer Mining Best Management Practices (MBMC 1993), bonding requirements have generally been set too low to ensure compliance.

GOAL: Natural stream morphology should not be substantially altered as a result of human activity - such alteration constitutes degradation.

RECOMMENDED ACTIONS: Streams should be restored to their natural channel geomorphology. In general, stream restoration should be accomplished by ending the practice(s) that caused the morphological alteration and allowing natural recovery processes to heal the stream.

Projects proposing to alter stream morphology should be viewed critically and pursued only as a last resort. Streambank stabilization should use soft methods (revegetation and fencing) rather than riprap, concrete etc.

***intensive management such as stream reconstruction should not be pursued unless stream recovery would be unacceptably slow - putting biological populations at risk or preventing beneficial uses, and until there is some assurance that the land uses responsible for stream impairment will change and reconstruction efforts will be maintained.**

***Remove or move stream channelizing structures such as berms, riprap, roads and railroad beds wherever possible.**

***Placer mining permits must require that streams be restored to their natural morphology, and a bond sufficient to accomplish this must be required before the permit is issued. No more than 500 feet of stream should be disturbed at any one time.**

***In many reaches of the Upper Clark Fork River, streamside mine tailings would erode into the stream as it meanders across its floodplain. Restoring the river channel to its natural meandering pattern would cause**

further contamination to occur. This should be delayed until streamside tailings have been removed.

B. The Riparian Zone

Riparian zones are the land areas immediately adjacent to streams, rivers, lake, ponds and wetlands. They are the most productive and diverse part of all western lands. Although riparian environments make up only 3% of the land area, they support about 50% of all vertebrate species found in Montana (Genter 1990). Approximately 59% of the land birds in western Montana breed in riparian habitats with 35% breeding exclusively there (Greater Yellowstone Coalition, 1994). Raptors such as eagles, hawks and owls are highly dependent on riparian zones for roosting cover, nest sites, and prey.

Abundance of small mammals are often greatest within 300 feet of a stream (Gomez, 1992), and most amphibian populations are generally found less than 900 feet from water sources (Nussbaum et al. 1983).

Not only do riparian areas provide critical habitat for terrestrial wildlife, they are essential to stream integrity. Riparian areas provide numerous functions such as stabilizing banks, providing shade, filtering runoff, absorbing flood energy and supplying food for aquatic organisms (Hansen, 1995). Restoration and management of the riparian area is generally more cost effective in improving water quality and fish habitat than practices applied farther upland (National Resource Council, 1992).

BANK STABILITY & COVER

Healthy riparian vegetation stabilizes streambanks, making them less likely to erode during high flows and heavy runoff. The root mass of riparian plants, such as willow and sedge, traps sediment that would otherwise degrade fish habitat and water quality, to build banks and increase plant production (Hansen et al. 1995). Trees provide shade and streambank stability because of their large size and massive root systems. Shrubs protect the streambanks from erosion, and their overhanging branches add cover for fish. Grasses provide the vegetative mats that trap sediment and help rebuild damaged stream banks (Bauer and Burton 1993).

Riparian vegetation also plays an important role in moderating water temperatures by providing shade and insulation. In a stream where riparian vegetation was clearcut, Moring (1975) demonstrated a direct relationship between reduced salmonid populations and elevated summer water temperatures. Riparian vegetation is also instrumental in providing insulative cover to prevent freezing of intragravel eggs during cold "open" winters with little snow cover insulation (Chapman and Bjornn 1969).

Since streams are naturally dynamic and continually move across their flood plain, some unstable streambanks are natural. However, poor land use practices such as over-grazing and inappropriate urban development often degrade or destroy the riparian vegetation, resulting in accelerated streambank degradation. In most cases, rapidly eroding streambanks provide little or no cover for fish.

Bank Stability in the Clark Fork Basin

Tralles (1992) evaluated overall stream conditions and support of uses in 99 streams in the Clark Fork Basin. Of the 99 streams surveyed, 65 percent were given an overall rating of "impaired" (partial or non-support of the stream's designated uses). Geographically, the largest share of impaired streams occurred in the upper Clark Fork and Blackfoot River basins. More than two-thirds of the assessed streams in this area were rated as impaired. Forty-five percent of the Clark Fork River drainage below Missoula, and 33% of the Bitterroot Valley stream miles were also rated as impaired.

Land use activities in impaired drainages were dominated by grazing (75% of all reaches) followed by road construction (44%) and mining, logging and irrigation (20%). The problems which contributed to impaired ratings were sedimentation (affecting 85% of the reaches), streambank instability (58%), and damage to streamside vegetation (30%).

Grazing

Livestock are attracted to riparian areas for shade, water and succulent vegetation. Typically riparian areas receive 20 to 30% greater use than adjacent uplands (Platts 1991). As a result, riparian areas are highly vulnerable to degradation. Livestock trampling may cause streambanks to collapse and erode directly into the stream. Excessive grazing reduces their capacity to protect streambanks and trap sediments.

Improvements in water quality and stream channel stability can be achieved with improved grazing practices. Strategies for protecting or restoring riparian areas may include 1) fencing or herding livestock out of riparian areas, 2) controlling the timing of

grazing to protect streambanks or to coincide with the needs of the target plant species, 3) adding more rest to the grazing cycle, 4) limiting grazing intensity, 5) changing the kind of livestock, 6) moving livestock from the allotment once target use levels for vegetation are reached, 7) permanently excluding livestock from riparian areas at risk while grazing adjacent uplands (Chaney et al. 1991).

The State of Montana has recently released grazing BMPs. Compliance is voluntary on private land, although technical assistance is available through the Natural Resource Conservation Service. The U.S. Forest Service and private individuals who lease grazing allotments on federal land are required to meet or exceed state BMPs. The Bureau of Land Management is also developing standards and guidelines for grazing on riparian and upland areas on federal land as part of a range reform program (Sandy Brooks, pers. comm.). They anticipate that these will be completed in February of 1997. In the meantime, they must also meet state BMPs.

GOAL: Riparian areas should be restored and maintained to provide a healthy and diverse community with a deep binding root mass and woody and herbaceous species of different age classes. Guidelines for determining vegetative potential are described in the "Classification and Management of Montana's Riparian and Wetland Sites" by Hansen et al. (1995).

RECOMMENDED ACTIONS: Riparian BMPs should be developed to protect beneficial uses where water bodies are impaired. BMPs should be mandatory and audits should occur every two years to ensure compliance. A monitoring system should be established to determine whether BMPs are effectively protecting beneficial uses.

***Focus bank stabilization efforts on removing impacts to riparian vegetation rather than through man-made structures such as rip-rap or concrete. Prohibit riparian clearing for new urban and residential development or other purposes.**

***The Montana Dept. of Natural Resources and U.S.F.S should manage grazing intensity on state and federal lands: 1) to prevent a seasonal change greater than 10 to 15% in the amount of stable or covered streambank and, 2) so that no shrubs are in the heavily hedged form class, and less than 25% of the shrubs are in the moderately hedged form class as recommended in (MTDSL, 1995).**

***Avoid early spring grazing use when soils and streambanks are wet and susceptible to compaction and physical damage. No grazing unit should be grazed for more than half the growing season of key plant species.**

***Good stewardship incentives such as tax benefits, technical assistance and low interest loans should be provided to private landowners that comply with BMPs.**

LARGE WOODY DEBRIS & LEAF LITTER

Riparian zones play a critical role in the physical structure of streams by providing large woody debris (LWD) (Bisson et al. 1987, Harmon et al 1986). In fact, greater than 90% of the wood lying in streams originates within 200 feet of the channel (McDade et al. 1990 and Van Sickle and Gregory 1990).

In steep headwater streams, LWD creates a stair-stepped effect. This pattern reduces the stream's energy and results in less erosion, more sediment storage in the channel, slower downstream movement of organic material, and greater habitat diversity than in straight, even-gradient channels (Bisson et al 1987). Bilby and Ward (1989) discovered that LWD makes up about 40% of the obstructions that trap sediment in forested streams.

In larger streams with lower gradients, fallen trees or branches create a number of pool types that serve as different habitats for juvenile trout and provide areas that serve as refugia for juveniles at high flows (Murphy et al 1985; Bisson et al. 1982). Scattered LWD may be critical to maintaining spawning beds relatively low in fine sediments. LWD reduces the rate of sediment movement downstream by routing sediment through the stream ecosystem slowly. LWD in rivers can influence meandering, provide cover, and increase invertebrate production for juvenile salmonids (Ward et al 1982). LWD also

traps vital nutrients within the stream system. Filter feeding invertebrates, algae and diatoms attach in large numbers to LWD and influence nutrient cycling and consequently, downstream water quality.

Sedell et al (1990) found that LWD was associated with important thermal refugia. Cold pockets of water are used extensively by juvenile salmonids during the warmest hours of the day, allowing thermally sensitive species to persist in some warmer segments of the river.

In small headwater streams, much of the organic matter (leaf litter etc.) that the aquatic community feeds on originates from riparian trees overhanging the banks (Naiman and Sedell 1979, Cummins et al. 1982). In forested ecosystems, up to 99 percent of the stream energy input may come from bordering riparian vegetation with only 1 percent coming from instream photosynthesis by algae and mosses (Cummins 1974). Invertebrate communities are often dominated by species that break down wood fragments, needles, leaves, and other debris particles. Riparian areas that have a diversity of herbaceous, shrub and tree communities produce more diverse inputs to the stream than those dominated by a single vegetation type. For example, herbaceous components of riparian vegetation typically drop leaves earlier in the season, contain higher nutritional content, and are more readily processed by the aquatic community than inputs from deciduous trees and shrubs. Deciduous trees and shrubs, in turn, are of higher quality and are more readily processed than needles and litter from coniferous trees (Melilillo et al. 1983, Conners and Naiman 1984). This translates into more diverse, productive and resilient ecosystems.

GOAL: Riparian vegetation should be restored to a level that provides the amount and distribution of large woody debris characteristic of least impacted riparian ecosystems in the region.

RECOMMENDED ACTIONS: The U.S. Forest Service, Bureau of Land Management and Montana Dept. of Natural Resources and Conservation Forestry Division should determine the amount and distribution of LWD characteristic of least impaired riparian ecosystems in the region and adopt BMPs designed to maintain these levels.

STREAMBANK AND RIPARIAN PROTECTION LAWS

Montana Natural Streambed and Land Preservation Act

The Montana Natural Streambed and Land Preservation Act of 1975 states that it is Montana policy that natural rivers and streams and the lands and property immediately adjacent to them are to be protected and preserved in their natural state (MCA 75-7-101). This law regulates modification of the streambed and bank up to the high water mark by private entities. Any modification requires a "310 permit" from the local water and land conservation district board. Unfortunately, riparian vegetation is not protected. Once it is removed, the natural streambank erodes away and land owners often choose to put in

bulkheads or otherwise modify streambanks. They prefer to pay the fine rather than risk more erosion. To protect the streambank, the law needs to protect riparian vegetation.

The Streamside Management Act

In 1991, Montana passed the Streamside Management Act (MCA 77-5-301) which prohibits certain forestry and road construction activities within a streamside management zone (SMZ). This law applies to waterbodies (streams, rivers, lakes etc.) on federal, state and private lands.

Under this Act, certain forestry and road construction activities are prohibited within 50 feet of each side of the waterbody. This minimum SMZ may be extended to 100 feet to include wetlands and areas with steep slopes or erosive soils. Tree harvest is limited based on stream class. Class 1 streams are those that support fish, contribute water to other streams or lakes that support fish, or have continuous flow during most of the year. Class 2 streams are those that do not carry surface flow to a Class 1 stream, lake or other body of water during most years. On Class 1 streams, no more than 50% of the trees 8 inches or larger can be removed in the SMZ (leaving at least 10 trees per 100 feet of SMZ). On Class 2 streams, a minimum of 10 trees of any size must be left per 100 feet of stream.

In 1992, a conservation strategy for protecting fish habitat in national forests was developed by a scientific team appointed by the Forest Service Chief (Thomas et al. 1993). Although the strategy was originally intended to address habitat for anadromous fish

within the range of the northern spotted owl, it was expanded to include national forests which support bull trout.

Thomas et al (1993) recommends that streamside management zones be expanded to 300 feet for fish bearing streams to account for "edge effect". The stream side of a riparian zone is subject to floods, changes in stream channel, wind exposure and variations in temperature depending on the width of the stream. The upland edge, if harvested, may suffer increased mortality from blowdown and increased stress resulting from variable air temperatures and altered rates of evapotranspiration. This may result in greater susceptibility to disease and insects (Caruso 1973, Ranney 1977, Wagner 1980).

As a result, the scientific team recommends the following riparian protection zones. The first 200 feet of the SMZ recognizes the land adjacent to the stream as a source of shade, large wood and detritus. The last 100 feet maintain microclimate, protect the first 200 feet from fire and wind damage, and help ensure that the integrity of the functional SMZ survives over the long-term to benefit fish and riparian dependent species.

Streamside Management Zone Audits

Implementation of Montana's Streamside Management Act was evaluated by the Dept. of State Lands from 1992 - 1994 (MTDSL, 1994). Departures from the streamside management zone laws occurred on approximately 85% of the applicable federal sites; 36% of the industrial sites; 42% of the non-industrial private sites; and 40% of the state sites. Equipment operation within the SMZ occurred on 27% of the sites and was the most common violation

GOALS: Streamside management zones should be sufficiently wide to sustain diverse, vigorous riparian vegetation in the face of natural disturbance.

RECOMMENDED ACTIONS: Amend the Montana Natural Streambed and Land Preservation Act to prohibit clearing of riparian vegetation within 100 feet of the streambanks and provide greater enforcement capabilities to the Natural Resource Conservation Service.

***The Dept. of Natural Resource and Conservation Forestry Division should continue to audit SMZ compliance for all private, state, and federal entities. Educational and enforcement efforts should be increased for those areas of the Act where departures occur most frequently. All entities should reduce SMZ violations to less than 10%.**

***Change the Streamside Management Zone Act to adopt the following SMZ's from Thomas et al. (1993):**

> **Perennial Streams: The SMZ should consist of the stream and the area on either side of the stream extending from the edges of the**

active stream channel out to the greatest of these distances: 1) to the top of the inner gorge, 2) to the outer edges of the 100-year floodplain, 3) to the outer edges of the riparian vegetation, or 4) for fish bearing streams a distance equal to the height of two site-potential trees, or 300 feet horizontal distance or 5) for non fish bearing streams a distance equal to the height of one site-potential tree, or 150 feet horizontal distance.

***Lakes, Ponds, Reservoirs and Wetlands Greater Than One Acre: The SMZ should consist of the body of water or wetland and the greatest of these areas: 1) to the outer edges of the riparian vegetation, 2) to the extent of seasonally saturated soil, 3) to the extent of moderately and highly unstable areas, 4) to a distance equal to the height of one site-potential tree, or 5) 150 feet horizontal distance (except lakes SMZ which go to height of 2 site potential trees or 300 feet horizontal distance).**

***Seasonally Flowing or Intermittent Streams, Wetlands Less Than One Acre, Landslides and Landslide Prone Areas: This category applies to riparian ecosystems with high variability in size and site-specific characteristics. The SMZ should consist of the stream**

channel or wetland and the area from the edges of the stream channel or wetland to the top of the inner gorge, or to a distance equal to the height of one site-potential tree, or 100 feet horizontal distance, whichever is greatest.

Floodplain and Subdivision Regulations

Private landowner development is a major impact to the floodplain and riparian areas along the Bitterroot River and the Clark Fork near Missoula. The U.S. Bureau of the Census reports that from 1990-1994, Missoula County's population increased 8.9% and Ravalli County's population increased 22.8% (U.S. Bureau of Census 1995). Based on current growth rates, it is estimated that Missoula will see an influx of up to 50,000 people in the next 20 years and Ravalli county's population is expected to more than double by 2012. (O'Herren et al 1995).

The State of Montana has a minimum set of floodplain regulations, and the counties are required to meet or exceed them (MCA Title 76-5-101). Various uses are permitted in the floodway and the floodplain. The floodway consists of the river channel and those portions of the floodplain adjacent to the channel which carry and discharge floodwater during high flow. Uses that are permitted within this area include, 1) agricultural uses, 2) industrial commercial uses such as parking areas, 3) private and public recreational uses such as golf courses, tennis courts and parks and, 4) residential uses such as lawns and gardens.

The floodplain is defined as the area covered by a 100-year flood. That is, a flood that has a 1% chance of occurring in any given year, but which is expected to recur once every 100 years on the average. New construction is prohibited in the 100 year floodplain without a permit (MCA 76-6-401). However, construction is routinely allowed if ground floor levels are 2 feet above 100 year flood levels, and waste systems are either connected to county sewer or septic tank drainfields are located a minimum of 100 feet outside of the floodplain. These provisions provide some protection for the landowner, but no protection for the floodplain.

The Missoula Office of Rural Planning reports that riparian areas are the lands in most demand for development. About 91% of Missoula County is currently subdivided, much of it in parcels as small as 1 acre (Dowdall 1995), and 99% of the riparian area in the county is roaded or has a road within 1/2 mile of it (O'Herren et al. 1995).

Missoula County Subdivision Regulations include special guidelines for "Areas of Riparian Resource." These are intended to "ensure that no subdivision shall be approved which is ...unsuitable by reason of flooding, erosion, inadequate drainage, or impact on areas of riparian resources..." However, the county planning board retains the right to grant a variance. Management plans for subdivisions which include riparian areas must be submitted with the subdivision plans to the county planning office. These plans are required to include mitigation measures, limiting of access through riparian zones, restoration and site specific buffer zones.

Ravalli County subdivision regulations include a "no build alteration zone" along streams or rivers which prohibit building or altering vegetation within 100 feet of the edge

of the Bitterroot River and within 50 feet from the centerline of small streams.

A GIS database has been completed for Missoula County which maps species of concern, development, floodplain and watershed characteristics, and riparian zones, among other things. These databases can be used to guide future development plans and identify undesirable development proposals.

GOALS: Urban and rural development should be managed to protect riparian and floodplain functions.

RECOMMENDED ACTIONS: Work for passage of federal, state or local laws that prohibit any new development in the 100 year floodplain. This includes rebuilding any structure which was destroyed by flooding. State and federal aid should only be provided to those who agree to rebuild outside of the floodplain.

***County subdivision laws should prohibit clearing of riparian vegetation and any new structures within 100 feet of a stream or 300 feet of a lake. Encourage natural parks and greenways in areas where future urban growth is anticipated. Seek federal Land and Water Conservation Funds to supplement local public and private funds for acquisition of riparian lands (or conservation easements) at risk for development.**

C. Cumulative Impacts At the Watershed Scale

Stream health is intimately connected to the health of its drainage basin - the watershed. Although individual management actions may appear to have minimal effects, the cumulative effects of many individual land use activities may result in unacceptable habitat degradation and long-term declines in aquatic populations.

The cumulative result of many impacts often results in ecosystem simplification. As ecosystem complexity is reduced, the system's ability to repair itself after disturbance erodes (Doppelt 1993). For example, grazing, timber harvest, dam and road building led to a decrease in the diversity of anadromous salmonids in the Pacific Northwest (Bisson and Sedell 1984; Li et al 1987; Hicks 1990).

WATER YIELD THRESHOLDS

Removal of upland vegetation decreases the infiltration capacity of an area and increases the amount and intensity of runoff. In the Lolo National Forest, it is assumed that most 3rd through 5th order drainage channels can sustain a 10% increase in average annual runoff as a result of timber harvesting or other vegetation manipulation, and that removal of up to 15% of the crown cover has little or no effect on increasing water yields (Pfankuch 1973). Watershed modeling efforts suggest that once 25-35% of the forest canopy is removed, aquatic ecosystems can be seriously affected by increased water yields. Furthermore, changes in snow interception patterns, evapotranspiration rates and snow accumulation patterns associated with vegetation removal also vary water yields, especially their seasonal pattern.

GOALS: The cumulative effects of all land use practices within a watershed should not increase water yield enough to alter the physical character of the stream channel. Cumulative vegetation removal should not cause more than a 10% change in water yield. Unless demonstrated otherwise, this is assumed to occur once 25%of the forest canopy is removed.

RECOMMENDED ACTIONS: Coordinate State and Federal activities with private operations to ensure that cumulative impacts do not exceed water yield threshold levels. Once the threshold is reached, no additional removal (from logging or other factors) should proceed on public lands until these areas have recovered.

***Monitor conditions during and after disturbance to determine if state water quality standards are being violated or water yield thresholds exceeded.**

***All forest practices, including salvage logging, must comply with the National Environmental Policy Act, National Forest Management Act, Sustainable Yield Multiple Use Cut, and riparian protection rules. Salvage logging and burned areas should be included in watershed calculations for maximum allowable water and sediment yield increases.**

BEST MANAGEMENT PRACTICES

Best Management Practices (BMPs) are practices designed to reduce or eliminate nonpoint source pollution. Section 319 of the Clean Water Act requires that agencies develop state management plans which incorporate BMPs for waterbodies which do not meet water quality objectives due to significant nonpoint sources.

Forestry BMPs

Except for Streamside Management Zone Act regulations which are mandatory, compliance with forestry BMPs on private lands are voluntary in Montana. However, landowners are required to notify the state of plans to harvest timber with the exception of, 1) operations of nurseries or Christmas tree farms, 2) harvesting Christmas trees, 3) harvesting for firewood or other personal use by owner (MCA 76-13-131). Although BMPs are state regulated, the U.S. Forest Service agreed to meet or exceed the minimum state standards.

Implementation of forestry BMPs was evaluated in 1990, 92, and 94 (MTDSL, 1994). Overall, the application and effectiveness of BMPs by federal, state and private entities has shown improvement; however, water quality impacts still occurred on a majority of the sites audited. Sixty-seven percent of the sites audited produced at least minor/temporary impacts, while 28% of all sites produced major/temporary impacts. Overall, the greatest impacts were associated with road drainage.

The lowest degree of effectiveness was found on federal and non-industrial private lands. Federal and non-industrial private landowners provided adequate protection on

only 76% and 75% of audited sites, respectively, whereas state and industrial landowners were rated as providing adequate protection on 93% of evaluated sites. Federal lands were reported as having minor/temporary impacts on 93%, and major/temporary, minor/prolonged impacts on 43% of audited sites. Whereas state lands were reported as having minor/temporary impacts on 60%, and major/temporary, minor prolonged on 0% of audited sites.

The audit team also questioned whether cumulative watershed effects had been addressed. Federal and state agencies claimed that cumulative effects had been taken into account on all sites that they managed, whereas, industrial and non-industrial private lands claimed that cumulative effects were considered on only about 50% of the sites they managed.

Mining BMPs

Montana has adopted some mining BMPs for reclamation, settling pond design, stormwater runoff and has adopted a set of voluntary placer mining BMPs (MBMC, 1993). As part of the mining permit, the Montana Department of Environmental Quality may require site-specific BMPs to control non-point pollution.

GOAL: Best Management Practices should protect all beneficial uses and provide for the environmental conditions necessary for native fish recovery.

RECOMMENDED ACTIONS: Where beneficial uses are impaired or water quality standards are being violated, mandatory Best Management Practices and audit processes should be adopted for all land use activities including forestry, mining, subdivision development, livestock grazing and agriculture.

***For those private landowners who comply with BMPs, good stewardship incentives should be provided such as tax benefits, technical assistance and low interest loans. Increase education and enforcement efforts in areas where violation of BMPs occur most frequently. Reduce BMP violations on all private, state and federal entities to less than 10%.**

MINING LAW REFORM

Widescale degradation has occurred in the Clark Fork Basin as a result of past and present mining activities. Existing laws which govern hard rock mining simply do not provide sufficient protection for human health or the environment. Adequate protection for the Clark Fork Basin will not occur until these harmful antiquated laws are changed.

The initial purpose of the 1872 mining law was to encourage settlement of the west by opening public land to private individuals. Although the initial intent is a thing of the past, the 1872 mining law is still the governing force for the extraction of hard rock minerals from public lands (30 U.S.C. Section 22). Mining is set above all other uses of public land including grazing, wildlife habitat, watershed protection, recreation or logging

because there are no provisions for weighing mineral values against other important resource values.

Under the 1872 law, a person who discovers a suspected valuable mineral deposit on federal land can have exclusive rights to mine it by posting the land and legally filing a claim. To maintain the right, the miner must show evidence of at least $100 worth of work at the claim site each year (Mineral Policy Center, 1995).

The government receives no royalties from minerals removed from public lands. Furthermore, the 1872 law allows miners with a valid claim to gain private ownership of the federal land overlying valuable deposits by obtaining a patent from the BLM. To receive a patent, an operator must demonstrate that at least $500 has been spent in labor or money working a claim. Once these requirements have been met and filed, a patent to the land may be purchased for the same fee as in 1872: 5$ an acre for lode claims and mill sites and $2.50 an acre for placer claims. The law provides no reclamation standards or other environmental protections (Mineral Policy Center, 1995).

GOAL: Provide long-term protection for the Clark Fork Basin by reforming the 1872 Mining Law in the following manner (Mineral Policy Center, 1995):

RECOMMENDED ACTIONS: Replace the patent system with a term lease agreement which retains public ownership of federal land. Establish a royalty return on the gross value of the extracted ore and commit a portion of these funds towards historical mine reclamation.

*Before exploration and mining phases, submit reclamation plans and sufficient bonds to fully cover costs in the event of accident, abandonment or default. No permit must be given for mining activities which require perpetual maintenance. Provide sufficient funds for state or federal monitoring efforts.

*Consider past track records as an important element in the permitting process. No new permits to any company with repeated or flagrant violations, or at least more complete bonding.

*Submit a water and watershed protection plan before any mining activity commences with at least 2 years of baseline data on potential impacts.

*The full costs of protecting, restoring and replacing water resources affected by mining must be outlined explicitly.

The overriding mission of the Clean Water Act is "to restore chemical, physical and biological integrity to the nation's waters"
-Congress 1972

Section III. BIOLOGICAL GOALS

The main objective of chemical and physical goals is to protect and restore the biological integrity of aquatic ecosystems. Biological integrity is defined as "the capability of the environment to support and maintain a biota (structural and functional performance) comparable to the natural habitats of the region" (Karr 1993). Throughout the country, water quality protection efforts have fallen far short of achieving this objective.

The severity of the situation is clearly illustrated by the collapse of salmon populations in the Pacific Northwest. Over 90 salmon stocks (genetically distinct populations native to a particular drainage system) are currently at a high risk of extinction. The greatest number of these occur in the Columbia River Basin (Nehlson et al. 1991). In the Clark Fork Basin, westslope cutthroat and bull trout populations have plummeted.

Fish are not the only aquatic species in trouble. About 50% of the freshwater mussel species in the U.S. are either listed or have been proposed for the federal endangered or threatened list, and 50% of crayfish in the U.S. and Canada are in need of conservation recognition (Doppelt 1993; Taylor et al. 1996).

Like the miner's canary, aquatic communities are important indicators of environmental quality. Therefore, long term success in protecting water resources requires biological monitoring and criteria as a complement to traditional chemical

parameters. In Ohio, for example, conventional chemical criteria failed to detect 50% of the impairment of surface waters when compared to the assessment provided by biological criteria (Yoder 1991). Recognizing this, the EPA in 1990 developed regulations requiring states to adopt narrative biological criteria by 1993 and numerical criteria by 1996.

Whereas chemical monitoring provides information on the chemical characteristics of the water column at a specific place and point in time, biological monitoring integrates cumulative impacts from point and non-point sources, flow alteration and other diverse impacts and integrates all these over time (Karr, 1993). Thus, it may reflect physical degradation as well as chemical contaminants. Furthermore, biological monitoring may reveal synergistic interactions, or the effects of substances for which chemical criteria have not yet been issued. Chemical criteria exist for only 109 toxins, a fraction of the chemicals used and discharged into surface waters (Adler et al. 1993).

Biological monitoring is a particularly important aspect of conservation, preservation, and restoration efforts because it can assess resource trends in space and time, indicating whether specific goals are being met. An integrated approach to water resource assessment which combines chemical, physical and biological criteria provides a higher degree of accuracy and, as a result, greater protection (Karr, 1993).

A. Macroinvertebrates

In the west, diverse macroinvertebrate communities are good indicators of water quality conditions because certain species are very sensitive to environmental degradation (Plafkin et al. 1989). Many species of Ephemeroptera, for example, are extremely

sensitive to metals pollution, whereas many species of Diptera are quite tolerant of these conditions (Rosenberg and Resh, 1993). Thus, the composition of the community reflects the environmental conditions in that stream. Even after a disturbance has ceased, the impact may be apparent for some time. Due to their fairly sessile mode of life, macroinvertebrate communities are an important tool for assessing localized impacts. Montana's Dept. of Environmental Quality has been monitoring macroinvertebrate populations in the Clark Fork River mainstem since 1986 (McGuire, 1998).

AQUATIC COMMUNITY METRICS

Metrics summarize measures of community structure. Taxa Richness and Shannon Diversity provide general summaries of a community's integrity. Biotic Index and Percent Relative Abundance of Filter Feeders indicate degree of organic pollution, and EPT Richness and Metals Tolerance Index indicate degree of metals pollution. A brief description of these metrics as provided by McGuire (1998) are as follows:

1. Taxa Richness

Taxa richness is the number of different taxa present. Taxa are different categories of living things such as species. It is probably the best single indicator of high quality water and habitat because the loss of the most sensitive taxa to any stress will reduce taxa richness .

2. Shannon Diversity

Shannon Diversity is a measure of organic pollution as well as other forms of environmental stress. It is influenced by taxa richness and evenness (the distribution of individual organisms among taxa). Values above 3.3 are indicative of good water quality while values less than two indicate communities typical of pollution or other stress. (Weber 1973).

3. Biotic Index

The Hilsenhoff Biotic Index is used to detect organic pollution. It is based on the indicator organism approach to water quality assessment. Each species is assigned a value based on its sensitivity to organic pollution. The index uses a scale of 0 to 10 with higher values indicating communities typical of greater impact (Hisenhoff 1987).

4. Percent Relative Abundance of Filter Feeders

The relative abundance of feeding groups (filterers, scrapers, shredders, etc) can provide an indication of energy source, organic loading and toxic conditions. The importance of each functional feeding group varies with the season. During the summer, filterers are a major component (20 to 50%) of the benthic fauna in most large rivers. Relative abundances greater than about 50 percent are usually associated with organic/nutrient enrichment or lake outflows. Large changes in this metric suggest changes in energy source over time.

5. Metals Tolerance Index

This metric quantifies changes in community composition associated with metal tolerance. Tolerance values are assigned to each taxon based on sensitivity to heavy metals rather than organics. Tolerance values range from 0 to 10 with high values reflecting increased community tolerance to metals pollution.

6. EPT Richness

Ephemeroptera, Plecoptera and Trichoptera (mayflies, stoneflies and caddisflies) are three classes of aquatic insects which, in general, are highly intolerant of pollutants. With a few exceptions, species in these groups are among the first to be eliminated by metals toxicity, low oxygen, warm water and fine sediments (Weiderholm 1985, Clements 1991). The wide scoring range used for this metric maximized sensitivity to toxic pollutants while minimizing the influences of other pollutants (McGuire 1993).

7. Macroinvertebrate Density

This metric can be an important feature of community structure if interpreted carefully. Unusually high or low macroinvertebrate densities may be considered indicative of environmental stress. Organic or nutrient enrichment tends to cause an increase in macroinvertebrate densities. At the same time, macroinvertebrate density tends to decrease in response to toxic substances or severe habitat degradation. Lower macroinvertebrate densities were used as an index of metals pollution in the upper Clark Fork.

8. Percent Baetidae of Ephemeroptera

Members of the Baetidae family (Mayflies) are fairly tolerant of pollution. When baetids comprise most of the mayfly fauna, slight to moderate environmental stress is indicated. This metric ranges from 0 to 1 with values >0.85 indicating biological impairment.

9. Percent Hydropsychinae of Trichoptera

The subfamily Hydropsychinae is generally more tolerant of pollution than most other caddisflies. Metric values range from o to 1 with values higher than 0.85 indicating biological impairment.

10. EPT to Chironomidae Ratio (EPT/EPTC)

Most Ephemeroptera, Plecoptera and Trichoptera are considered sensitive to environmental stresses while Chironomidae, are generally more tolerant. This metric is determined by calculating (E+P+T)/(E+P+T+C). An even distribution of individuals among the four groups indicates good biotic conditions. A disproportionate number of chironomids reflects environmental stress. Values greater than 0.55 indicate biological impairment.

The Dept. of Environmental Quality has incorporated these 10 metrics into a single index of biological integrity. Each metric is assigned a score (0 to 6) based on its comparability to reference values established by McGuire (1993). The scores for all 10

metrics are summed, expressed as a percentage of the maximum possible score and used as an estimator of biological integrity. In addition, selected subsets of metrics were used to illustrate the relative severity of metals and organic/nutrient pollution. Biological integrity can be categorized as nonimpaired (90-100%) of the reference value, slightly impaired (70-90%), moderately impaired (50-70%) or severely impaired (<50%).

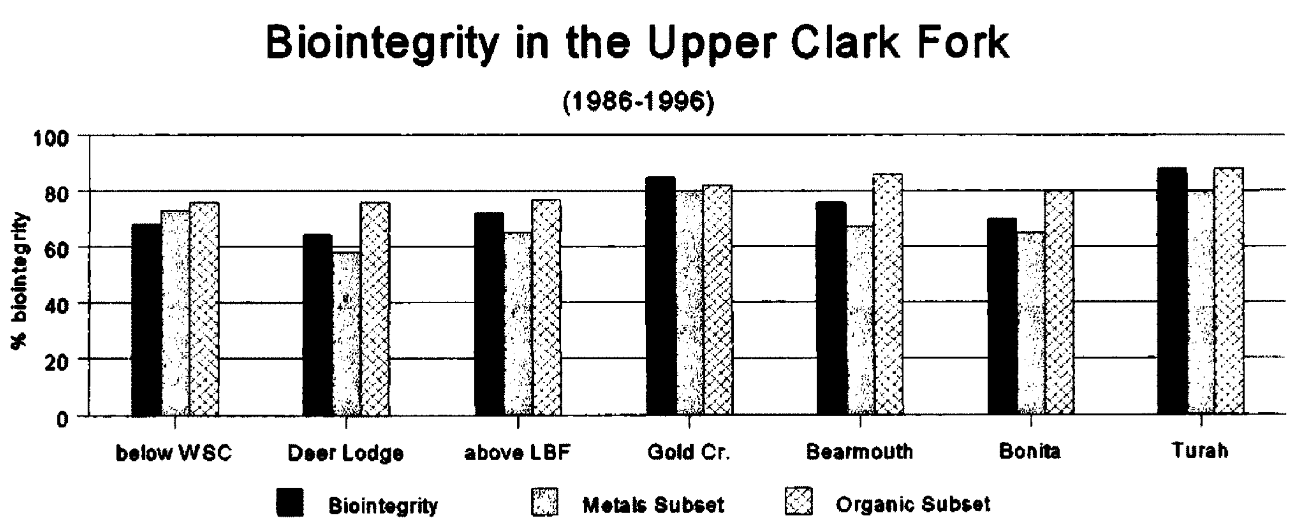
Metal and organic pollution subsets were estimated by summing the scores of the metrics in each subset, expressed as a percentage of the maximum possible score. Metrics comprising the organic subset were community density, biotic index, and the percent relative abundance of filter feeders. The subset for metals pollution consists of community density, EPT richness and the metals tolerance index. A specific type of pollution is indicated when the score of one subset is substantially lower than the other. Impacts attributable to these pollutants are categorized as slight (60-80%) moderate (40-60%) or severe (<40%). This classification scheme reflects the limitations of assessment based on only three metrics. Except for borderline values, scores in different categories are considered significantly different.

METRIC RESULTS FOR SILVER BOW CREEK AND THE UPPER CLARK FORK

Biological impairment remains severe and biointegrity consistently lowest at the two upstream stations in Silver Bow Creek. Biological integrity generally increased with distance downstream from these sites in lower Silver Bow Creek and the upper Clark Fork.

Temporal trends analysis indicated that biological integrity generally increased from 1986 to 1996 at seven monitoring stations in the upper Clark Fork (three stations in Silver Bow Creek, Warm Springs Creek, the lower Blackfoot River and in the Clark Fork below Warm Springs Creek, and at two stations by Turah) (McGuire 1998). Improved biointegrity at these stations was primarily attributable to a slight, but widespread reduction in metals pollution. Biointegrity (based on 11-year means) was lowest in the upper Clark Fork River mainstem from the confluence of Warm Springs Creek to Deer Lodge. Trends indicating reduced nutrient/organic pollution were detected in the Clark Fork River below Warm Spring Creek and at Turah (McGuire 1998).

Figure 23. Biointegrity at mainstem stations in the Upper Clark Fork River - 11 year range. Source: McGuire (1998).



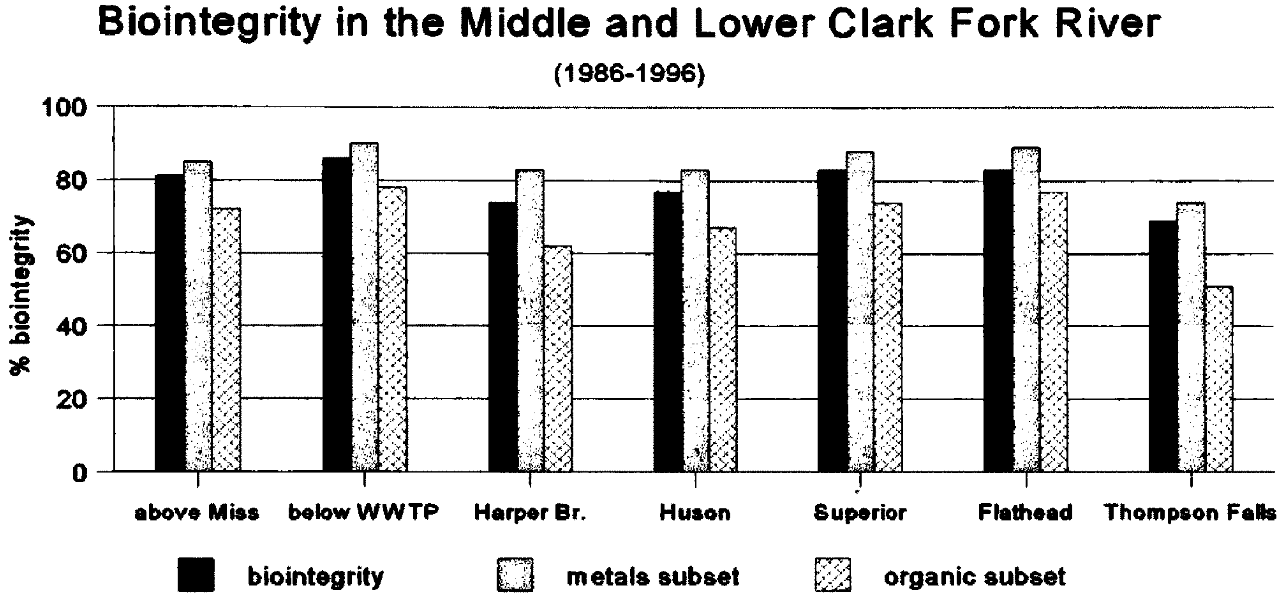
METRIC RESULTS FOR THE MIDDLE CLARK FORK

Metric values continue to indicate slight to moderate nutrient/organic pollution at a number of middle Clark Fork sites. Impacts appear to result from nutrient loading from the Missoula WWTP and the Bitterroot River. Biointegrity scores at the Superior station in 1996 were the lowest recorded since monitoring began in 1986. This may be related to very high flows in the lower Clark Fork during the spring and summer of 1996 or it may reflect environmental stress from a major chlorine spill which occurred approximately 35 river miles upstream during the spring of 1996.

METRIC RESULTS FOR THE LOWER CLARK FORK

The station above Thompson Falls Reservoir is the only station located in the lower Clark Fork River. Samples were not obtainable during the 1996 monitoring season due to high flows. However, biointegrity scores for the previous nine years averaged 69% - indicating moderate impairment.

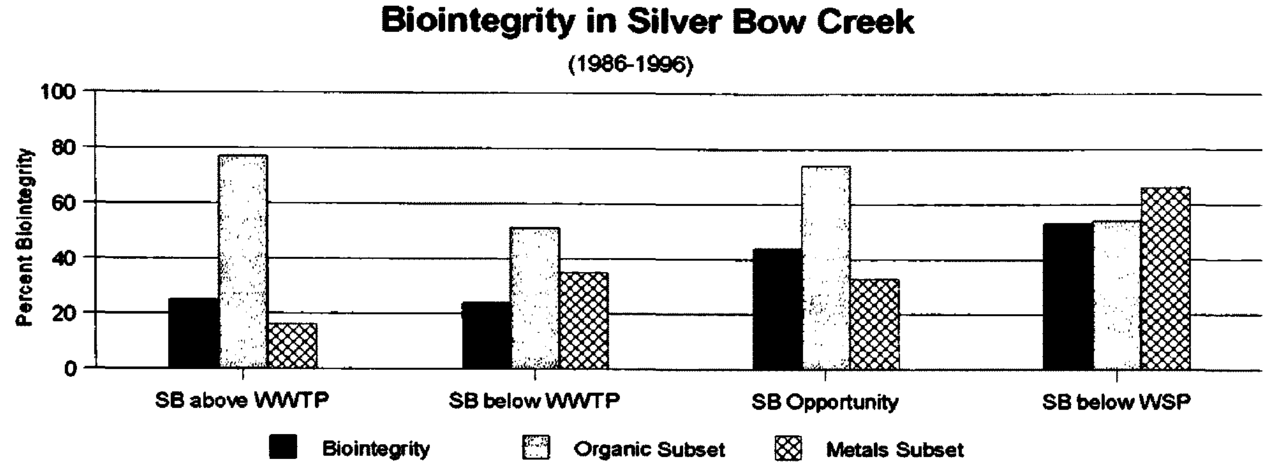
Figure 24. Biointegrity at mainstem stations in the middle and lower Clark Fork River - 11 year mean. McGuire (1998).

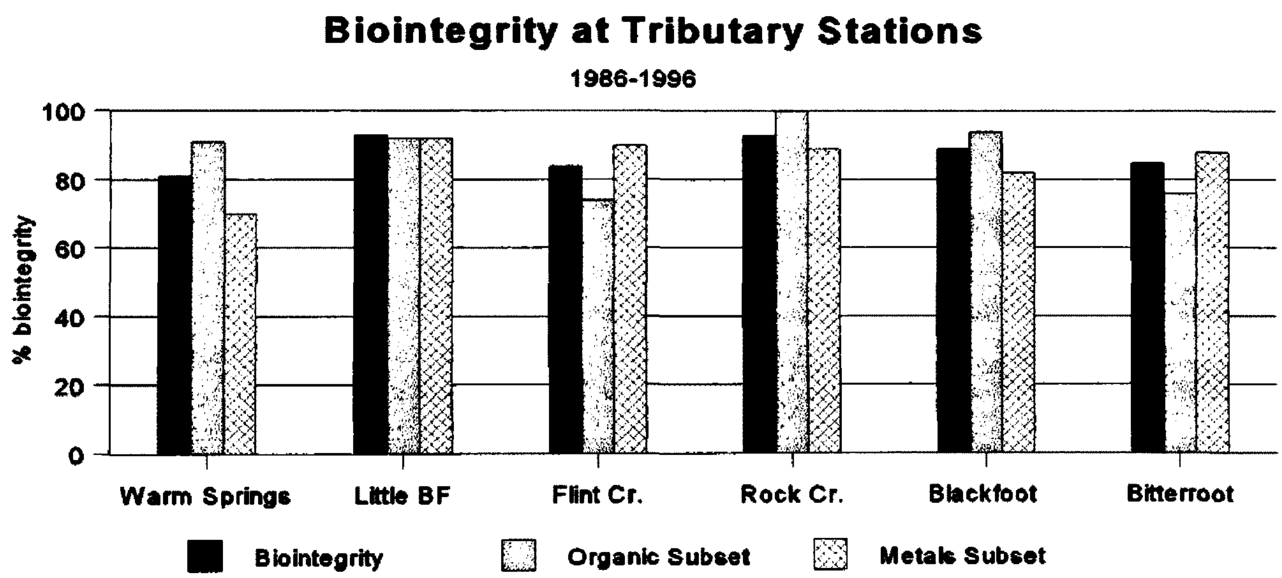


METRIC RESULTS FOR TRIBUTARIES TO THE CLARK FORK

Biointegrity values varied considerably among the Clark Fork River's tributary stations. Biointegrity in the Little Blackfoot River, Rock Creek near Clinton, and the Blackfoot River have been consistently high, indicating excellent water quality. Flint Creek and the Bitterroot have generally received ratings of slight impairment due to nutrient and sediment pollution.

Figures 25 and 26. Long term mean benthic community biointegrity in selected Clark Fork River tributaries (Silver Bow Creek, Warm Springs Creek, Blackfoot River, and Bitterroot River: 1986-1996; all others 1993-1996). Source: McGuire (1998).





GOALS: Macroinvertebrate communities throughout the Clark Fork River Basin should consistently receive ratings of unimpaired or slightly impaired for mean biointegrity according to the Dept. of Environmental Quality's bioassessment methods.

*Macroinvertebrate communities should also consistently receive ratings of unimpaired or slightly impaired for each metric subset (metals, organic etc.) because high scores for some metrics may obscure low scores for other metrics. Mean biointegrity scores may not reveal these subtleties.

RECOMMENDED ACTIONS: Where macroinvertebrate communities frequently receive ratings of moderate to severe impairment, emphasis should be placed on restoring the physical and chemical factors that support a healthy biotic community as described in the Chemical and Physical Sections.

*Sampling sites should be increased in the lower Clark Fork River to provide a more complete representation of this reach. Reference streams should be provided with stringent protection because they represent typical least altered areas and serve as benchmarks for comparison with altered areas.

B. Algae

A four-year study initiated by Montana's State Governor in 1988 identified nutrient levels and excessive algae growth as one of the highest priority issues affecting the Clark Fork River Basin (Johnson and Schmidt 1988). Nuisance algae has been reported in the Clark Fork River in 1973, 1986, 1987, 1988, 1990 and 1995 (Braico 1973, Watson, 1988, 1989, 1990 & 1995).

Algae are a natural and important part of most aquatic environments. However, under certain conditions algae may grow to levels which harm water quality. These conditions include: 1) High nutrient levels from sources such as wastewater treatment plants, agricultural and urban runoff, 2) Low flows which concentrate nutrient loads and reduce the amount of abrasive sediment which seasonally scours algae free from the channel bottom or, 3) Disturbances which reduce the numbers of aquatic organisms that graze on algae.

RIVERINE ATTACHED ALGAE CONCENTRATIONS & COMMUNITY COMPOSITION

Before 1998, Montana has no specific criteria for algal levels. Instead, algae growth was considered excessive if it contributed to violations of numeric state water quality standards (lowers dissolved oxygen below standard) or interfered with beneficial uses such as irrigation, recreation or support of aquatic life. The level of algae growth that interferes with healthy fisheries varies with flow, temperature and other factors,

however, one of the most severe impacts to fish and aquatic insects is the depletion of dissolved oxygen levels.

The river bottom (or benthic) community uses oxygen 24 hours a day; however, during the day, algal photosynthesis produces oxygen to offset this oxygen demand. At night, in the absence of photosynthesis, respiration of the river bottom community, may lower the concentration of dissolved oxygen to a level harmful to fish and other aquatic organisms. Benthic respiration contributed to violations of the state water quality standards for dissolved oxygen in the Clark Fork River in the summers of 1973, 1986, 1987 and 1988 (Braico 1973 and Watson 1989 a&b).

Benthic respiration may also be responsible for fluctuations in pH levels. This is critical in the Clark Fork River because pH levels affect the availability and toxicity of instream metals. Research in 1994 revealed daily pH fluctuations of 8.2 to 8.7 in the upper Clark Fork due to biotic respiration/photosynthesis (Brick and Moore, 1995).

Algae may also reduce intergravel oxygen levels by trapping fine sediment, reducing intergravel flow and contributing decomposing organic matter. When algae break off and wash downstream, foaming may increase and water clarity decrease.

The level of algal growth that interferes with recreation depends primarily on the expectations and tastes of each individual. Complaints from basin citizens concerning reduced water clarity, odors and foam, and interference with irrigation and angling were responsible for initiating research efforts on excess algal levels in the Clark Fork in the mid 1980's. The majority of citizens informally surveyed in 1995 found pictures of algal levels which exceeded 50 mg/m^2 Chlorophyll a aesthetically unacceptable, but would accept

levels up to 100 if convinced they were a normal part of a healthy ecosystem (Watson, pers. comm., 1995).

Guidelines For Nuisance Algae Levels

Numerous studies have been conducted to determine what algal levels are considered a nuisance. Carmichael (1983) described levels of 24-32 mg/m^2 Chlorophyll a as heavy. Gough (1975) considered algae levels of 94 mg/m^2 Chlorophyll a to be unacceptably high in a recreation stream. Nordin (1985) reported citizen complaints and reduced angling enjoyment at levels in excess of 100 mg/m^2 Chlorophyll a in the Thompson River in British Columbia. Welch et al. (1987) and Jacoby et al. (1983) considered levels above 100-150 mg/m^2 Chlorophyll a to be nuisance levels.

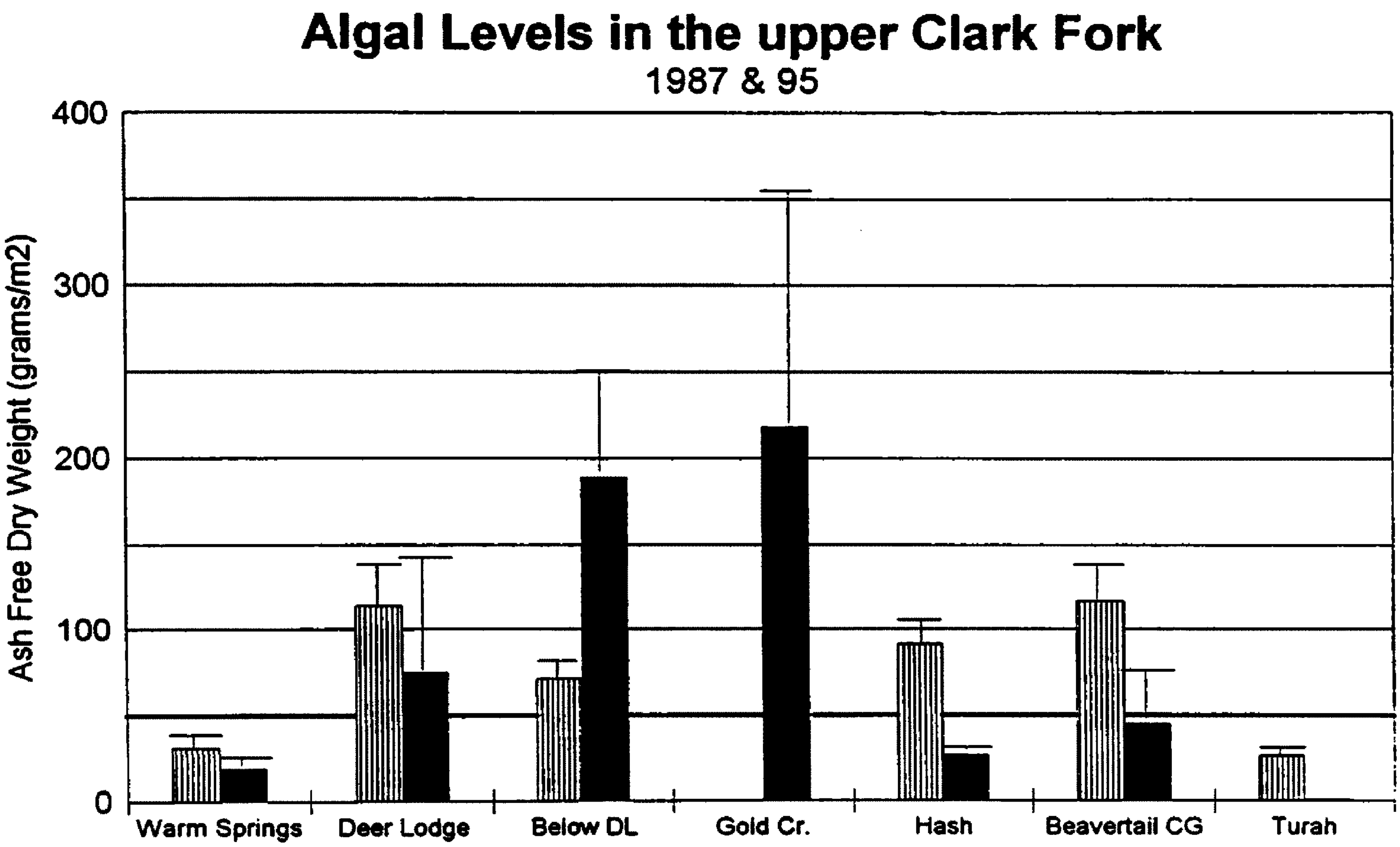
The British Columbia Ministry of the Environment has set management guidelines for algal concentrations at <50 mg/m^2 chlorophyll a to protect uses related to recreation and aesthetics and <100 mg/m^2 to protect against undesirable changes in the aquatic community (Nordin 1985). These guidelines were originally established for small streams with relatively shallow channels, however, Watson & Gestring (1996) argued for using these criteria in the Clark Fork in the shallow areas along the river's banks. The Clark Fork VNRP nutrient committee decided to use the British Columbia chlorophyll criteria in the Clark Fork and adopted the algal sampling scheme proposed by Watson and Gestring (1996).

Watson and Gestring (1996) also proposed converting the chlorophyll a guidelines into an ash free dry weight guideline (100 mg/m^2 chlorophyll a to 50 grams $AFDW/m^2$

using a model that correlated chlorophyll a and ash free dry weight in the Clark Fork. AFDW provides a much less variable and less time consuming measurement for sites dominated by Cladophora (Watson & Gestring, 1996). Chlorophyll a guidelines, however, are still used for sites dominated by diatoms because non-algal biomass (macroinvertebrates) sometimes comprises a high percentage of the sample at these sites, so chlorophyll is the best measure of algal biomass at these sites.

Algal levels in the Clark Fork River have been measured several times in past years. The upper Clark Fork River is dominated primarily by Cladophora glomerata, a filamentous green alga. Strands of Cladophora may grow up to 2-3 meters in length and fill the entire river channel. In 1987, a low flow year, algal levels within the 30-40 cm depth range exceeded aquatic community impairment guidelines at all sites but two -- Warm Springs and Turah (Watson, 1989). Although 1995 was an average flow year with cool temperatures, mean algal levels within the 30-40 cm depth range once again exceeded criteria at many sites in the upper river. The nuisance level proposed by Watson & Gestring (>50 grams/m^2 AFDW) was exceeded by mean algal levels at three sample sites-- Deer Lodge, Below Deer Lodge and Gold Creek.

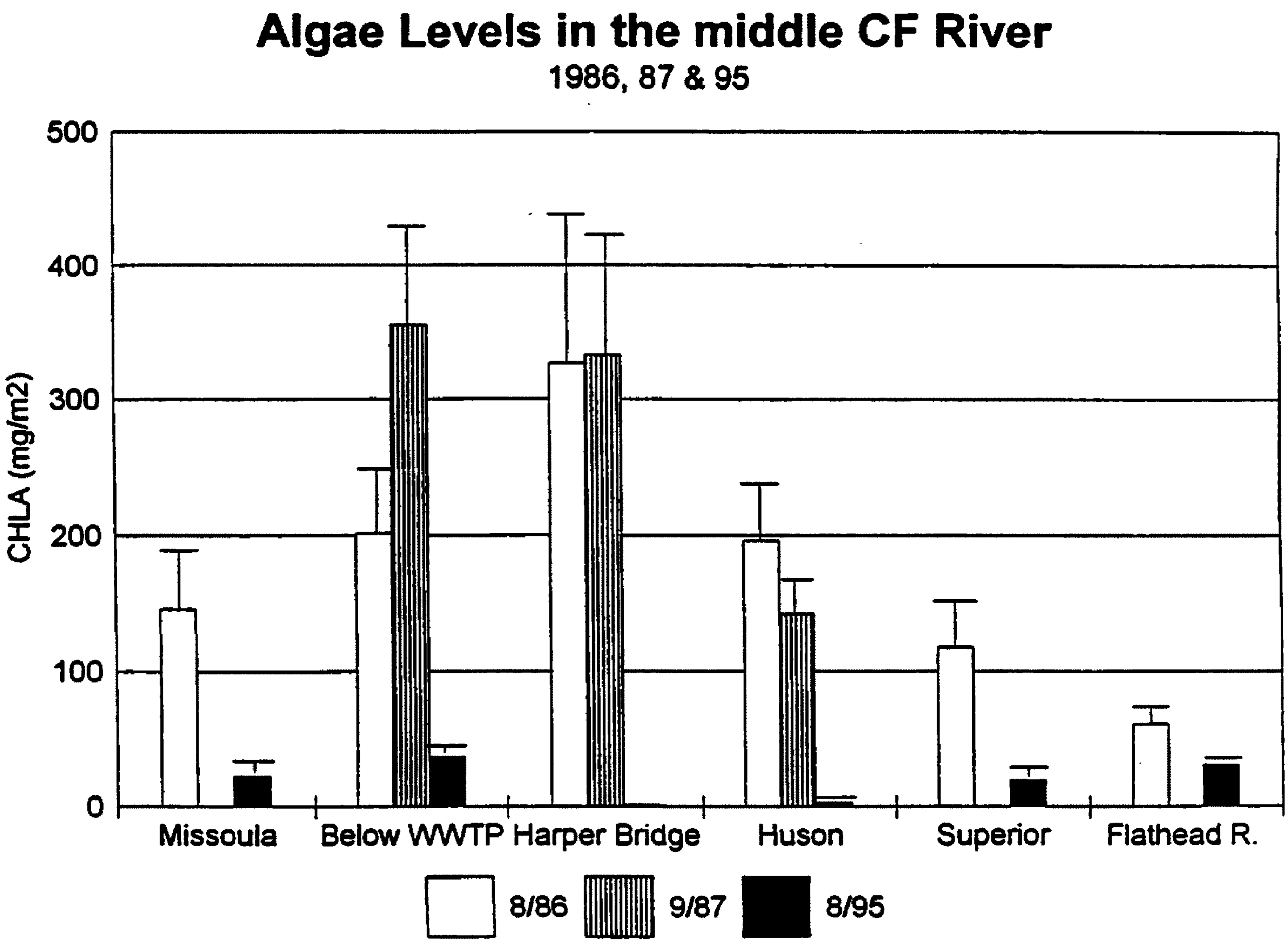
Figure 27. Attached algae levels in the upper Clark Fork River. Source: (Watson and Gestring, 1996)



Algal communities in the middle river are dominated, for the most part by a diverse group of diatom species. Mean algal levels in 1986 (Weber, 1986) and 1987 (Watson, 1989) exceeded the VNRP chlorophyll guidelines within the 30-40 cm depth range at all sites but one: below the Flathead River. In 1995, heavy growths of Cladophora were present in bands along the river channel at two sites: Missoula (above the Van Buren Bridge) and Alberton. In these swaths, algal levels exceeded the chlorophyll guidelines. Compared to conditions in the upper Clark Fork, however, these bands covered only a

small proportion of the stream channel. Outside of these bands and at all other middle river sites, mean algal concentrations in 1995 were well below guidelines.

Figure 28. Attached algae levels in the middle Clark Fork River. Source: (Watson and Gestring, 1996)



Factors Controlling Levels of Attached River Algae

A literature review by Dodds (1991) summarized many of the factors associated with <u>Cladophora</u> dominance of benthic algal communities including high levels of light, pH

above 7.0, high dissolved calcium levels, and high nutrient levels, but low N:P ratios. All these factors are prevalent in the upper Clark Fork River.

One of the most important factors influencing Cladophora growth is nutrient concentrations. Nitrogen and phosphorus, two nutrients necessary for algal growth, are elevated in the Clark Fork River due to effluent discharge from the Missoula, Butte, and Deer Lodge sewage treatment plants, as well as agricultural and urban runoff and some geological sources of phosphorus in the upper river. Not only are elevated nutrient levels a key factor in algal growth, they are probably the factor most controllable by humans. Nutrient goals to reduce algal growth are outlined in detail in the chemical section.

GOALS: Algal levels and community composition should resemble those of relatively undisturbed streams in this ecoregion that do not receive high additions of nutrients from human sources. Some reaches of the river itself can also be used as a relatively low nutrient reference community including the upper Clark Fork River between Turah and Missoula and the lower Clark Fork River downstream of the confluence with the Flathead River.

RECOMMENDED ACTIONS: Adopt algal criteria recommended by Watson & Gestring (1996) until low nutrient reference communities are characterized: summertime mean (<100 mg Chlorophyll a /m^2); summertime peak (<150 mg Chlorophyll a/m^2)

***Use Ash Free Dry Weight to monitor algal levels rather than Chlorophyll a wherever Cladophora occurs at nuisance levels.**

***Maintain natural stream flow patterns to provide scour of algae during peak spring flows and dilution of nutrients during low summer flows. Continue the moratorium of new water permits and develop drought management plans to avoid severely low summer flows. Question any off-stream storage proposals that would reduce scouring peak flows, for these could increase algae problems.**

ALGAE COMMUNITY COMPOSITION

Algal community composition is a good indicator of ecological integrity for many reasons. Algae have short life cycles and high reproductive rates so they are good indicators of short term impacts. High levels of algae growth can be indicative of poor water quality and are easily noticeable by the public. In addition, algal communities are sensitive to some pollutants which may not visibly affect other aquatic organisms, or may only affect other organisms at higher concentrations (e.g., herbicides and inorganic nutrients).

The Montana Department of Environmental Quality has been surveying benthic algal communities at numerous sites along the mainstem Clark Fork River and several tributaries from 1986 to 1996 (Bahls 1987 and 1989; Weber 1991, 1993, 1995, 1996, and

1998) . These sites have been compared with a composite of least-impaired reference streams to evaluate biological integrity (Weber 1998).

Several metrics were used to measure the composition and structure of diatom and non-diatom communities in the Clark Fork River. Diatom algae metrics included: Shannon Diversity Index, Pollution Index, Siltation Index, and Species Richness. Shannon Diversity (Weaver, 1973) measures species richness as well as the evenness of distribution of individuals among the taxa present. High diversity values are found in communities where no taxa are strongly dominant in numbers. This is generally the case in unimpaired streams. The Pollution Index measures the extent to which pollution tolerant species dominate the community. The Siltation Index is defined as the total percent relative abundance of species of Navicula, Nitzschia and Surirella diatoms present (Bahls 1993). These genera are highly motile diatoms well adapted to existence on unstable substrates. Values range from 0 to 10. Species Richness is a basic indicator of community health. Generally, unpolluted waters in Montana have more than 25 diatom species (Bahls 1979). Non-diatom algae metrics included: the number of dominant non-diatom genera, the domininant non-diatom phylum and indicator taxa.

The scores from these indexes were combined and compared to scores from least-impaired reference streams (Bahls, 1993) to determine biological integrity and overall impairment of the aquatic community at each sampling site. Tables 7, 8, 9 and 10 are adapted from Weber (1998) to illustrate the results.

Based on these algal metrics, the upper Clark Fork River shows moderate-to-severe impairment of water quality and biological integrity. Upper Silver Bow Creek has

consistently received poor ratings. However, water quality conditions in Silver Bow Creek below the Warm Springs Ponds, however, have improved. Efforts to improve the ponds' treatment efficiency and eliminate frequent bypasses of highly toxic water to the Clark Fork occurred recently. This may account for the improved rating.

The upper Clark Fork stations from Warm Springs Ponds to the confluence with the Little Blackfoot rated only fair for biological integrity in 1995 and 1996. Ratings of these three stations over the eight year period have been fairly variable - rating fair for most years with one poor year and one good year. Elevated siltation index values are responsible for the low 1996 ratings.

Metric values indicate very constant, relatively unimpaired water quality in the upper Clark Fork from Gold Creek Bridge to the Turah Bridge. However, values for all four stations in this reach may exhibit a very slight downward trend over the entire period (Weber 1998).

The Clark Fork River from above Missoula to the confluence with the Flathead River was rated as having good biological integrity with minor aquatic life impairment for most of the eight year period. Downstream from the confluence with the Flathead River, the Clark Fork consistently receives high biological integrity ratings.

Figure 29. Biological integrity at Clark Fork tributary stations during August of the eight years 1989-1996, as determined by low scores under bioassessment Protocol 1 (1 = poor; 2=fair, 3=good; 4=excellent). Blank dates not sampled. Source: Weber (1998).

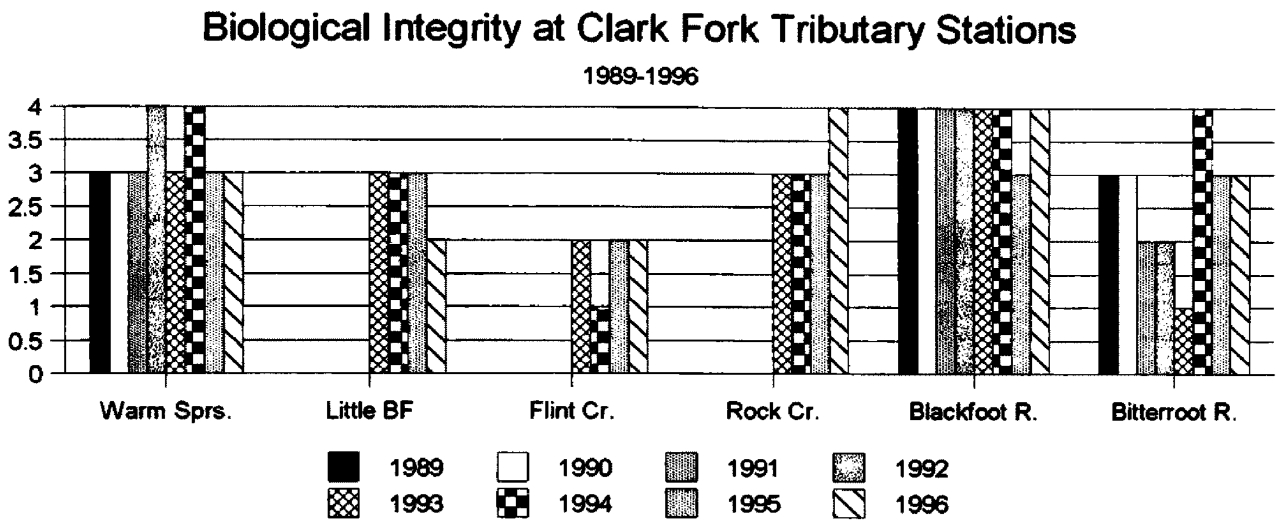


Figure 30. Biological integrity at Silver Bow Creek and upper Clark Fork stations during August of the eight years 1989-1996 as determined by low scores under bioassessment Protocol 1. Source: McGuire (1998).

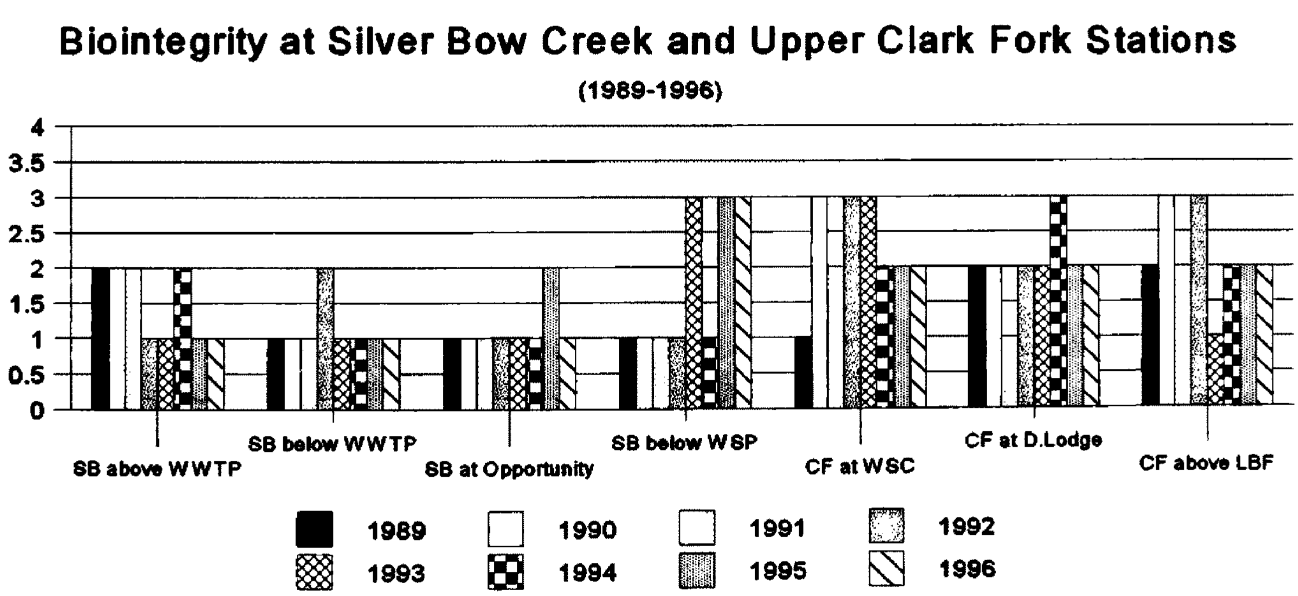
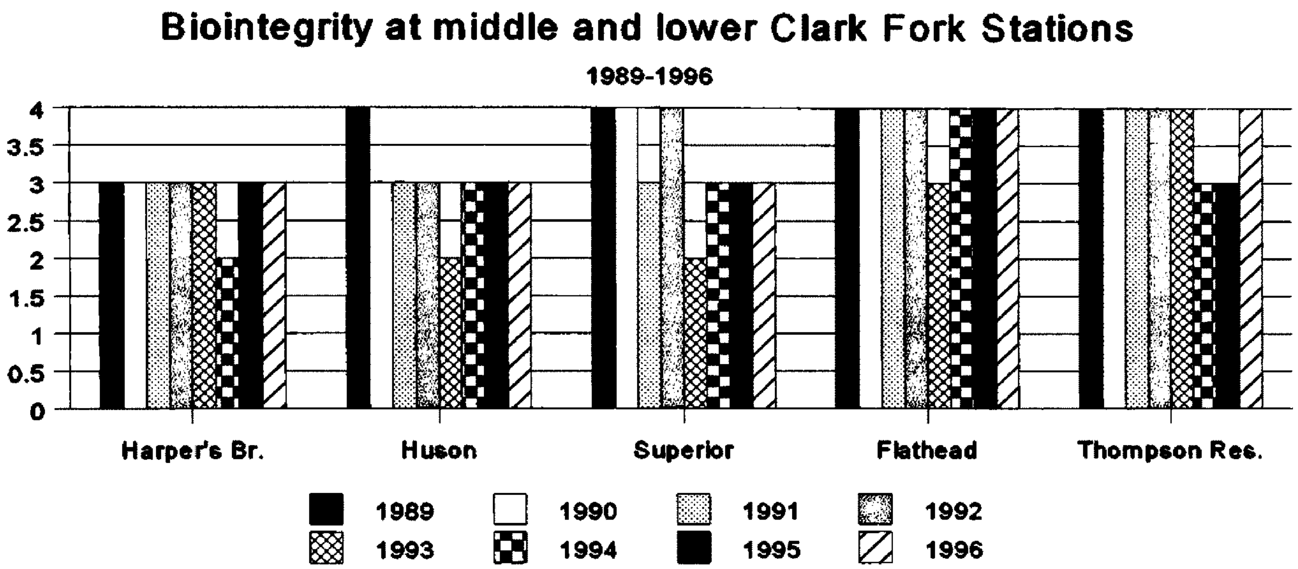


Figure 31. Biological integrity at middle Clark Fork stations during August of the eight years 1989-1996, as determined by low scores under bioassessment Protocol 1. Source: McGuire (1998)



GOALS: Restore stream reaches until the algal community structure scores good to excellent for biological integrity and overall impairment is rated as none to minor on a consistent basis according to criteria established by Bahls (1993).

***Restoration efforts should focus on managing nutrients according to Tri-State Implementation Council's recommendations, restoring instream flows, reducing metal levels and restoring riparian areas to reduce siltation.**

C. FISH

Overall, one third of all North American fish are endangered, threatened or of special concern, a significant increase during the past decade (Williams et al. 1989). Even in western Montana, widely recognized throughout the country for its blue ribbon trout streams, fisheries have suffered severe declines. Native westslope cutthroat occur in only 14% of their native range in Montana (MTDFWP, 1998) and bull trout occur in only 42% of their native range (Thomas, 1992).

Fish populations are a critical element of biological communities and an important part of Montana's economy. Because fish are long-lived, mobile and at the top of the aquatic food chain, they indicate long term effects, broad habitat conditions and are important for assessing contamination (Plafkin et al, 1989).

Migratory bull trout, for example, are particularly good indicators of the fragmentation or cumulative loss of habitat because they require many kinds of habitat at different life stages. Migratory bull trout spawn in small tributary streams. When the young bull trout are 2-3 years old, they migrate, often long distances, to large rivers or lakes. There, they mature, eventually returning once again to the small headwater streams to spawn. Impaired habitat conditions anywhere along the journey reduce their chance of survival.

Because of their life history pattern and sensitivity to environmental impacts resulting from many land use activities, bull trout and westslope cutthroat are good indicators of overall river system integrity. For these reasons, their status and conservation are emphasized in this section.

SPECIES OF SPECIAL CONCERN

Bull trout and Westslope cutthroat have three life history patterns - resident, fluvial and adfluvial. Fluvial and adfluvial trout are migratory forms which use small tributary streams to spawn and move to lakes (adfluvial) or rivers (fluvial) to mature. Resident trout live their entire life in their natal stream, or a nearby stream.

Before the construction of the dams along the Clark Fork River in the 1950's, large populations of native westslope cutthroat and bull trout migrated from Lake Pend Oreille all the way to the headwaters to spawn. Once this migratory path was cut-off and exotic species introduced into the area, the Clark Fork mainstem became dominated primarily by nonnative brown and rainbow trout. Westslope cutthroat and bull trout were restricted mostly to the tributaries. To date, twelve native and 14 non-native fish species occur in the Clark Fork Basin.

Tables 7 & 8. Native and Non-native Fish of the Clark Fork Basin. Adapted from Howard et al. (1988).

NATIVE FISH IN THE CLARK FORK RIVER BASIN		
SPECIES	**LOCATION**	**HABITAT**
Bull Trout	Mostly small tributaries	Cold water lakes and streams
Westslope Cutthroat Trout	Small tributaries and small lakes	Cold streams and lakes
Mountain Whitefish	Throughout drainage	Large clear cold rivers
Pygmy Whitefish	Uncommon	Deep Cold Lakes
Northern Squawfish	Throughout drainage	Slow rivers, lakes
Redside Shiner	Throughout drainage	Lakes, ponds, mod. fast streams
Longnose Dace	Throughout drainage	Riffle areas
Longnose Sucker	Throughout drainage	Cold clear lakes and streams
Coarsescale Sucker	Throughout drainage	Lakes and rivers

Slimy Sculpin	Throughout drainage	Rocky riffles
Shorthead Sculpin	Upper Flathead and tributaries to upper Clark Fork	Riffles of small, clear cold stream
Peamouth	Throughout drainage	Lakes, streams, weedy areas

NON-NATIVE FISH IN THE CLARK FORK BASIN		
SPECIES	**LOCATION**	**HABITAT**
Rainbow Trout	Throughout drainage	Cool streams, lakes
Brown Trout	Throughout drainage	Valley streams, rivers, lakes with spawning tributaries
Brook Trout	Tributaries	Well oxygenated streams and lakes
Kokanee Salmon	Georgetown Lake	Cold lakes and reservoirs
Lake Whitefish	Flathead L., Noxon Rapids, Cabinet Gorge	Deep, cold lakes
Northern Pike	Lower drainage	Bays of lakes and reservoirs, margin areas of rivers
Yellow Perch	Middle and lower Clark Fork	Warm to cool lakes, slow weedy streams
Largemouth Bass	Throughout drainage	Warm silty lakes and backwaters
Small mouth Bass	Mid. and Lower Clark Fork	Rocky lakes and streams
Black Bullhead	Lower Clark Fork	Turbid lakes and reservoirs
Pumpkinseed	Throughout drainage	Margins of lakes and streams; areas with aquatic veg.
Black Crappie	Cabinet Gorge Reservoir	Sandy or silty large lakes, reservoirs and slow rivers.
Burbot	Noxon Reservoir	Large rivers, cold deep lakes and reservoirs
Arctic Grayling	Heart Lake, Fuse Lake	Small cold clear lakes, tributaries.

As a result of population declines, bull trout and westslope cutthroat are both listed as "Class A" species of special concern by the American Fisheries Society. A "Class A" designation means that the species has limited numbers and/or limited habitats both in Montana and elsewhere in North America; elimination from Montana would be a significant loss to the gene pool of the species or subspecies (Hunter 1994). In 1998, the U.S. Fish and Wildlife Service listed bull trout as a threatened species under the Endangered Species Act.

In 1994, public concern convinced the Governor of Montana to establish a Bull Trout Restoration Team to develop a restoration or conservation plan for bull trout recovery in Montana. The Restoration Team in turn, created a Scientific Group to provide guidance on the technical aspects of bull trout recovery. This team prepared separate reports (Ginger Thomas, 1995) for each of twelve major Recovery/Conservation Areas (RCAs). The Clark Fork Basin includes 8 RCAs: the upper, middle and lower Clark Fork, the Blackfoot, Bitterroot, Swan, Flathead and the S. Fork of the Flathead.

Although the recovery plan specifically addresses bull trout, restoration measures will also benefit other native fish such as westslope cutthroat (D. Peters, MTDFWP, pers. comm). Westslope cutthroat and bull trout ranges overlap considerably within the Clark Fork Basin, and recovery efforts could be integrated to some degree.

Rieman and McIntyre (1993), fisheries biologists with the Intermountain Research Station, Forestry Sciences Laboratory in Boise, Idaho, have also outlined recommendations for bull trout conservation in their report, "Demographic and Habitat Requirements for Conservation of Bull Trout". The following discussion draws largely on these sources.

IMPACTS TO NATIVE FISH AND THEIR HABITAT

There is no single factor which can be blamed for the decline of native fish in the Clark Fork Basin. A combination of human impacts has resulted in the degradation of stream ecosystems, riparian habitat and water quality and quantity. Here is a brief description of some of the most widespread impacts.

Introduced Species

The introduction of non-native species to the Clark Fork River Basin has had profound and far-reaching effects. Approximately 97% of the remaining native westslope cutthroat populations (Liknes 1984) and 51% of the state's bull trout populations are threatened by genetic contamination, predation or competition with introduced species (Thomas, 1992). Pure West Slope Cutthroat are presently found in only 2.9% of their historic distribution (MTDFWP, 1998). Forty-five percent of those remaining populations are considered viable.

Hybridization is one of the most significant impacts of non-native fish. When brook trout pair with bull trout, the hybrids are likely to be sterile and experience developmental problems. Not only do male bull trout pair directly with female brook trout as demonstrated by mitochondria DNA analysis of Bitterroot drainage trout (Leary et al 1993), but brook trout males have also been observed sneaking in and releasing sperm during bull trout pair spawning in the Flathead (Kitano et al 1994). Both species spawn at about the same time and have similar optimum temperature requirements. Furthermore, brook trout may have a reproductive advantage over resident bull trout because they mature earlier (Leary et al 1991). Hybridization also occurs between Westslope cutthroat and rainbow trout. The hybrid fish are not sterile, but they may have reduced reproduction and survival rates (Allendorf and Leary 1988).

Lake trout may compete with bull trout for food and space and prey on young bull trout entering Flathead Lake (Fraley, 1989). The Bull Trout Scientific Team reports that

juvenile bull trout and westslope cutthroat trout have been found in the stomachs of lake trout in the Flathead River and Flathead Lake (Thomas, 1995c).

Although the interrelationship between non-native brown trout and bull trout is still uncertain, there is some indication that the introduction of brown trout may cause declines in bull trout populations (Bond 1992, Mullan et al 1992). Brown trout compete directly with westslope cutthroat trout, and are more aggressive in defending territories and less susceptible to angling pressure (Gresswell and Varley, 1988; Wang and White, 1994).

In some areas, native fish have been eliminated entirely due to introduced species; in others, they have been restricted to remote or isolated headwater streams. Maintaining genetic diversity under these conditions is difficult because native fish can no longer intermix with other populations. The risk of extinction increases with the loss or isolation of local populations (Rieman &McIntyre 1993).

The most common means of non-native species introduction into bull trout range are State and Federal stocking programs, introduction through private pond permits and illegal introduction (Thomas, 1995b). The present policy of Montana's Fish Wildlife and Parks discourages stocking in streams that support wild or native trout; however, stocking of non-native species does occur in some areas. Rainbow trout are stocked in the upper Clark Fork River. Largemouth bass are stocked in Placid Lake and Seeley Lake, with unknown implications for bull trout populations.

Illegal introductions are particularly harmful because they usually involve the introduction of non-native species, and they add the risk of introducing fish pathogens

such as whirling disease. Illegal introductions are a tremendous concern in the Flathead Basin, where the Dept. of Fish, Wildlife and Parks has documented at least 50 illegal introductions in the state in the last five years despite increased educational efforts (Thomas, 1995c). Generally, these introductions have involved warmwater species such as bass, perch, pike and walleye or non game species such as minnows, suckers, carp and bullheads.

Non-native fish may also enter the system through private ponds. Although stocking of non-native fish into private ponds must be licensed by MTDFWP, many people are either unaware of the requirement or ignore it entirely (Thomas 1995a-e). Due to the increase in rural residential development in many areas of the basin, the number of private ponds is increasing. The Bull Trout Scientific Team indicates that the existing permit system is inadequate to control the expansion of non-native fish (Thomas, 1995a).

Although introduced species have been identified as a major impact on native fish populations, removal or suppression of introduced fish species is not feasible on a large scale (Clancy et al. 1995). However, it may be considered as part of the bull trout recovery program in a few situations: 1) where a recent invasion has occurred or a localized population of introduced species exists, 2) where a unique bull trout population is immediately threatened with extinction, 3) where core and nodal areas (see pages 108-109) can be maintained and, 4) where preservation of native species is a priority (e.g. national parks, tribal lands, wilderness areas etc).

GOALS: Native and non-native fish fisheries should be maintained as self-

sustaining populations through restoration and protection of water quality and habitat and fishery regulations - not through stocking. Where non-native species pose a threat to native species, removal or suppression of non-native species may be considered as part of a restoration plan. However, habitat degradation should first be eliminated as the cause for native species declines, and risks to non-target species carefully considered.

RECOMMENDED ACTIONS: Prohibit the introduction of non-native species throughout the Basin. Upgrade the current permit system for licensing private ponds and increase public awareness regarding the potential hazards to native fish from private pond stocking. Review past permits, and revoke or modify if negative interactions are likely.

Physical Habitat

Habitat loss, fragmentation and simplification are key factors in the decline of native fish populations. While each individual habitat disturbance impacts only a small portion of the species' historic distribution, thousands of habitat changes distributed over their entire range have severely reduced native fish ranges to their current level. In Montana, 80.5% of the area within core bull trout area watersheds is federally administered, 3% are state-owned and 12.6% are private (MTBRT, 1998). Federal lands

are estimated to support over 75% of the remaining Westslope Cutthroat in Montana (MTDFWP 1998).

The Montana Bull Trout Scientific Group has identified several land use activities as having major impacts on bull trout habitat including dams, mining, forestry practices, agriculture, rural residential development and grazing (Thomas, 1995a-e). Forestry practices was identified as the greatest risk towards restoration of bull trout. (MTBRT 1998). The effects of various land use activities on habitat and water quality, and specific goals are discussed in the physical and chemical sections of this report.

GOAL: Land use activities must provide for the protection of all beneficial uses. The chemical and physical integrity of aquatic ecosystems throughout the Basin must be maintained at a level that supports a thriving native fisheries.

Stream Barriers and Diversions

Irrigation diversions may trap or block trout as they migrate between the tributaries and mainstem river. Irrigation diversions are considered a high risk to bull trout recovery in many areas of the Basin (Thomas, 1995 a,b,d). Problem areas in the Upper Clark Fork basin include the Little Blackfoot River, Flint Creek and uppermost reaches of the mainstem. In the Blackfoot drainage, problem areas include Poorman and Nevada Creeks and the North Fork of the Blackfoot River. The majority of the large tributary streams north of Darby in the Bitterroot drainage are heavily diverted.

In some areas, culverts prevent migration of natives, and in others, they prevent introduced fish from entering a drainage area. Although culverts are not considered a significant problem to bull trout recovery, there are a few areas where improvements might benefit native fisheries if it is determined that introduced species are not an issue.

GOAL: Native migratory fish populations must be able to fulfill spawning, rearing and over-wintering requirements.

RECOMMENDED ACTIONS: Restore connections between waterbodies by removing migration barriers in tributaries except where these protect native gene pools. Screen irrigation diversions to protect fish from becoming trapped in irrigation channels.

Fishing

Bull trout are particularly susceptible to overharvest for several reasons. Bull trout spawn in small streams, so they are easily observed and targeted. They are easily caught by anglers because of their tremendous appetites, and because they tend to congregate at the mouth of key tributaries or in favored spawning areas. Estimates based on interviews with nine poachers in northwest Montana, indicate that 22 bull trout were killed per week per poacher during July to September (Long, 1994). In many areas, the slow maturation rate of bull trout and westslope cutthroat subjects them to substantial angling mortality

before they have a chance to spawn. A voluntary, state-wide catch-and-release program exists for westslope cutthroat. A mandatory program exists for bull trout.

GOAL: Sport fishing must not impede native fish recovery efforts.

RECOMMENDED ACTIONS: Increase public concern for the plight of bull trout and westslope cutthroat and public awareness of fishing regulations. Provide substantial fines and increase enforcement efforts for poaching during critical spawning periods. Adopt mandatory, catch-and-release program for westslope cutthroat where appropriate.

Disease

Whirling disease is caused by a parasite (Myxobolus cerebralis) which invades young trout and eats the cartilage in and around the brain (MTDFWP, 1995). Damage to the neural system causes many fish to swim in circles. Although the parasite may not directly kill a trout, infected fish often cannot feed or escape predators because of their inability to swim. When infected fish die and decompose, or are consumed and excreted by predators or scavengers, the whirling disease spore is released. The parasite can survive within live or dead fish, in water or in wet or dry river mud. To date, there is no known way to prevent the disease or the spread of the disease once it is in a river.

Rainbow trout are considered to be the most susceptible to infection, followed by sockeye salmon, golden trout, cutthroat trout, brook trout, steelhead, chinook salmon,

Atlantic salmon, brown trout and coho salmon (MTDFWP, 1995). It is possible that lake trout may be immune to the disease. Westslope cutthroat appear to be only slightly less susceptible than rainbow trout (McDowell et al. 1997). However, it has been suggested that the life history trait of spawning high up in tributaries that are poor habitat for the parasite's tubifex worm host, may be limiting the impact of whirling disease on westslope cutthroat (MTDFWP, 1998).

Whirling disease has been found in the following creeks throughout the Clark Fork Basin: Racetrack, Warm Springs, the North Fork of Flint, Stuart Mill, Flint below Georgetown Lake and the Clark Fork River directly below Milltown Dam. Thus far sampling has revealed no whirling disease in Rock Creek, the Blackfoot River and the Bitterroot River (Don Peters, MTDFWP, 1996, pers. comm.).

GOALS: Limit spread of whirling disease within the Clark Fork River Basin, particularly into important bull trout and westslope cutthroat spawning and juvenile rearing habitats.

RECOMMENDED ACTIONS: Continue to monitor the spread of whirling disease in the Clark Fork Basin. Consider maintaining or establishing barriers that prevent the passage of infected fish into drainages that support critical spawning habitat.

***Increase public awareness concerning the harm of whirling disease and the following guidelines designed to prevent the spread of whirling disease (MTDFWP, 1995):**

***Do not transport any live fish or aquatic plants from one place to another. Remove all aquatic plants and mud from your vehicle, boat, anchor, trailer and axles, waders, boots, and fishing gear before departing from the site.**

***Do not dispose of fish entrails, skeletal parts, or other by-products in any waterbody. Dry your boat and equipment, including coolers, buckets and live wells between trips.**

CURRENT CONDITIONS BY SUBBASIN

Upper Clark Fork

The primary impact to fish populations in the upper Clark Fork River is heavy metal contamination from past mining activities. The Montana Natural Resource Damage Program, a state agency which has assessed the damages to natural resources from mining impacts in the Upper Clark Fork Superfund complex, concluded that fish are exposed to toxic metals in the water column and through the food chain (MTNRDP, 1995). Exposure to these hazardous substances has resulted in the total elimination of fish from Silver Bow

Creek (a headwater tributary), substantial reductions in the number of trout present in the Clark Fork River, and reductions in the diversity of trout species.

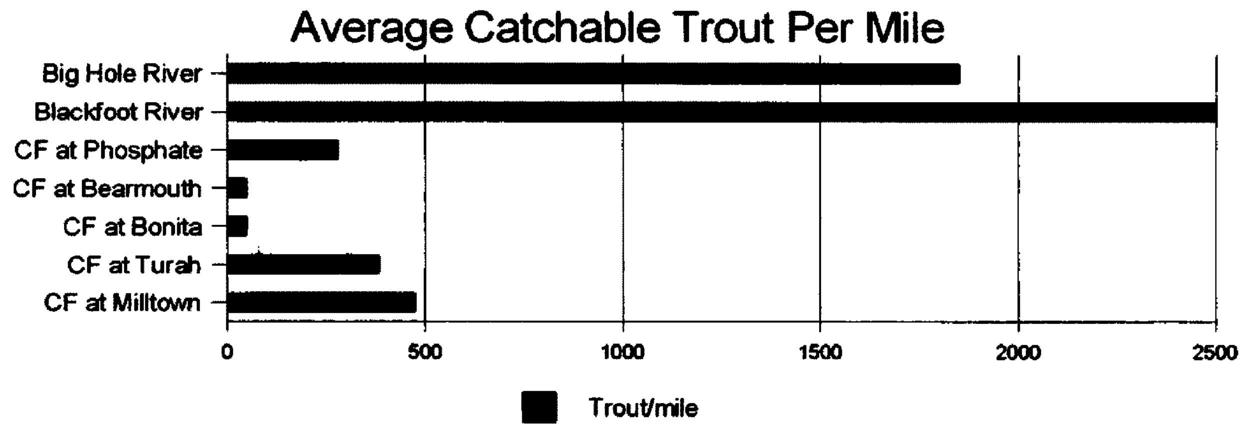
Dewatering is another significant problem in the upper Clark Fork. The Montana Dept. of Fish Wildlife and Parks has listed 388.7 stream miles as chronically dewatered, meaning that dewatering is a significant problem in virtually all years (MTDFWP, 1994). The Little Blackfoot River drainage accounts for 75.2 miles, the Flint Creek drainage accounts for 66.8 miles, the Rock Creek drainage has 21.9 miles, and the rest of the upper Clark Fork and tributaries account for 224.8 miles.

Except for Rock Creek, which supports the only migratory bull trout population in the upper basin, bull trout populations consist of resident fish inhabiting tributary streams (Thomas, 1995a). In place of bull trout, non-native brown trout dominate the upper river mainstem from Butte to Rock Creek, and non-native rainbow trout dominate the river downstream of Rock Creek. Research indicates that rainbow trout are more sensitive to acute pulse toxicity than brown trout (MTNRDP, 1993).

The average population of all sections of the Clark Fork above Missoula (excluding the reach just downstream of Warm Springs Ponds) is roughly 300 trout/mile (Knudson, 1988 & MTDFWP, 1988). However, a considerable length of the river, the segment from Bearmouth to Bonita, supports less than 50 trout per mile. Fish population estimates are based on the number of catchable trout (greater than 7") per mile. Fish kills linked to elevated metal concentrations occurred in the upper Clark Fork in 1983, '84, '87, '88, '89, '90 and '91 (MTNRDP, 1995). MTNRDP (1994) compared the upper Clark Fork

River to various reference streams and concluded that trout populations in the upper Clark Fork are at approximately 17% of baseline.

Figure 32. Fish populations in the upper Clark Fork River compared to reference streams. (Knudsen, 1988 and MTDFWP, 1988).



GOALS: Water quality and streamside mine wastes must no longer limit the production of fish in the upper Clark Fork River. Trout densities should be restored to those of applicable reference streams (MTNRDP 1993).

RECOMMENDED ACTIONS: Restore a self-sustaining migratory population of westslope cutthroat in the Upper Clark Fork that spawns in tributary streams.

***Adopt the following Bull Trout Scientific Team Goals: Restore a self-sustaining migratory population of bull trout in the Upper Clark Fork drainage that spawns in tributary streams. This population should include**

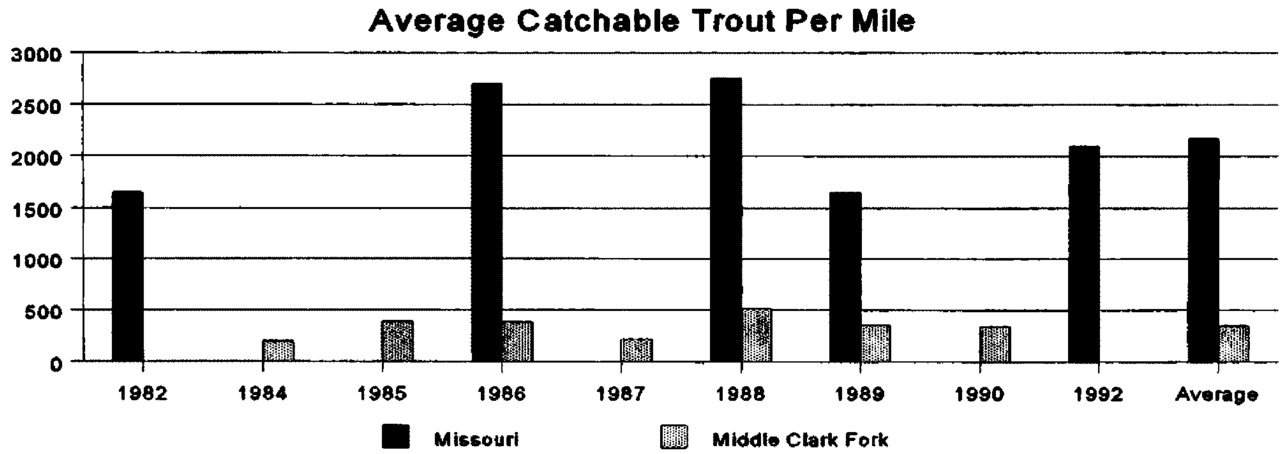
at least 100 redds or 2000 total individuals in the migratory population within 15 years. If this goal is reached, an increasing trend and a higher more stable number of fish is the ultimate goal. Preserve the bull trout population's genetic structure throughout the drainage basin.

Middle Clark Fork

Trout populations in the middle Clark Fork River have been estimated from fall population estimates at six study sections: below Milltown Dam, Missoula, Huson, Superior, St. Regis and Quinn Hot Springs (Berg, 1992). Although not every site was sampled each year, the data indicates that the middle Clark Fork supports about 350 catchable trout per mile.

A rough comparison can be made between fish populations in the middle Clark Fork and the Missouri River between Hardy and Cascade. These two reaches are similar in size, and elevation and are located, for the most part, within the same ecoregion. Trout population estimates from three sample sites indicate that the Missouri supports an average of 2,177 catchable trout per mile. If this represents the Clark Fork's potential, on average the middle Clark Fork supports only about 2,177/350 = 6% of its potential on average.

Figure 33. Fish populations in the middle Clark Fork River and upper Missouri River. All years were not sampled at all sites (Berg, 1992 and MTDFWP,).



GOALS: Trout densities in the middle Clark Fork River should be restored to those of appropriate reference streams.

RECOMMENDED ACTIONS: Restore upper river conditions to prevent toxic pulses from passing over Milltown Dam. Adopt recommendations of the Bull Trout Scientific Group when they become available.

***Re-establish a migratory corridor to the Upper Clark Fork River through Milltown Dam which allows for the passage of native fish, but prevents the passage of introduced species and any fish infected with whirling disease.**

Lower Clark Fork

The lower Clark Fork fishery is dramatically different from the upper and middle Clark Fork. Two-thirds of the river is impounded by the Cabinet Gorge, Noxon Rapids and Thompson Falls reservoirs. Warm water temperatures resulting from the operation of Kerr dam on the Flathead River as well as rapid turnover rates in the reservoirs have tremendous influence on the species of fish which can survive in the lower Clark Fork. Currently, the reservoirs are being managed as a warm water fishery, and there is some stocking of largemouth and smallmouth bass.

The Noxon Rapids and Cabinet Gorge reservoirs, owned and operated by Washington Water Power, are currently undergoing the 5 year relicensing process. As part of the initial "information gathering" stage, the Dept. of Fish, Wildlife and Parks requested research in several areas including: 1) the biological and technological feasibility of providing passage for bull trout and other salmonids over the dams while preventing passage of non-natives, 2) the availability of spawning and rearing habitat if fish passage becomes available, and 3) the feasibility of selective withdrawal on Noxon Rapids reservoir to allow thermal regulation of Cabinet Gorge Reservoir (J. Vashro, pers. comm. 1996).

Bull trout status in the lower Clark Fork River and Lake Pend Oreille was evaluated by Pratt and Huston (1993). Small population sizes and limited nursery areas imply that the bull trout population is fragile. Most of the individual nursery streams which contribute to the total population appear to have unstable populations.

Pratt and Huston (1993) found that sixteen nursery areas support the Lake Pend Oreille population, however, only two of those tributaries support stable stocks. In Noxon Rapids Reservoir, eight streams supported bull trout nursery areas historically, whereas only four streams support nursery areas today. In the Cabinet Gorge area, the distribution of bull trout nursery areas declined from five tributaries to only two. The small number of nursery streams in the Cabinet Gorge area increase the likelihood that populations will not be able to recover from a catastrophic event. Furthermore, the high annual variation of a spawning population suggests a high risk of local extinction. Currently there are probably 1,100 to 2,000 bull trout available to spawn annually in tributaries to Lake Pend Oreille (Pratt & Huston, 1993).

Tributaries appear to be a limiting factor in the lower Clark Fork (Vashro, pers. comm. 1996). Many tributaries no longer maintain perennial flows, resulting in a loss of habitat and connectivity. Extensive logging occurs along many tributaries such as the Bull and Vermillion Rivers and the Snake, Beaver, White Pine and Marten Creeks. Furthermore, the lack of land use controls in Sanders County is allowing subdivision development to proceed unchecked.

GOALS: Reservoirs should be managed to support a self-sustaining warm water fishery. Dams should not prevent native migratory fish populations in Lake Pend Oreille from expressing their natural life history patterns.

RECOMMENDED ACTIONS: Reestablish genetic connections between Lake Pend Oreille and the mainstem Clark Fork River by providing for passage for natives but preventing passage for non-natives through the Cabinet Gorge, Noxon Rapids and Thompson Falls dams.

***Determine distribution and status of westslope cutthroat in Lake Pend Oreille and the lower Clark Fork River Basin. Develop westslope cutthroat recovery plan.**

***Adopt the following recommendations of the Bull Trout Scientific Group: Protect existing bull trout populations in Lake Pend Oreille and the population genetic structure of the watershed. Restore migratory populations in the lake, with spawning distributed among all core tributaries.**

Blackfoot River

The Blackfoot River originates near the Continental Divide and flows 132 miles to its confluence with the Clark Fork River at Bonner near Missoula, Montana. Brown trout dominate the Blackfoot from Lincoln to Monture Creek, rainbow trout dominate the Blackfoot River below Monture Creek, and native westslope cutthroat dominate most of the headwater reaches. Upstream of Lincoln the river disappears underground almost

annually during the driest part of the summer. According to the Montana Dept. of Fish Wildlife and Parks, 82.4 miles of stream are chronically dewatered in the Blackfoot (MTDFWP 1994).

Introduced species, primarily brook trout, are considered to be the greatest threat to bull trout in the Blackfoot drainage (Thomas, 1995b). Thus far, Belmont Creek, the Landers Fork and Copper Creek are the only bull trout watersheds where brook trout have not been found.

Bull trout are in extremely low densities throughout the drainage. In 1989, only 3 of 19 sampled major tributaries to the Blackfoot River carried significant densities of young-of-the-year bull trout: the North Fork, Copper Creek and Monture Creek. In Monture Creek, one of the 3 tributaries with significant numbers of young-of-the-year, redd counts revealed a 59% decline from 1985 to 1988 & 1989. Researchers also noted declining numbers and sizes of adult bull trout during spring population sampling. Despite the decline of bull trout in the drainage, the Blackfoot population is considered one of the last relatively large fluvial populations in western Montana.

Pure westslope cutthroat are generally restricted to the headwater areas of tributaries except in the mainstem of the upper Blackfoot where westslope cutthroat trout are present in significant numbers. Peters (1990) reported that westslope cutthroat appear to be spatially isolated from non-native species by natural, environmentally controlled mechanisms. This isolation may reduce hybridization in these areas, but it also reduces the genetic exchange between pure populations, thus, threatening the long term viability of cutthroat populations. Westslope Cutthroat were present in good densities in only 3 of

the 19 tributary streams sampled: Chamberlain, Gold and Poorman Creeks. Densities in the mainstem are considered low based on historical records, however the upper Blackfoot River represents the largest unfragmented population in the entire mainstem river.

Peters (1990) also evaluated seventeen tributaries for habitat quality for spawning fish. Several factors limiting spawning were common: 1) barriers to migrating fish, 2) bank instability due to livestock trampling, 3) dewatering, 4) timber harvesting and 5) poor road/stream side management. In most cases, tributaries that did not originate in the wilderness had intensive timber harvest in the upper portion of the tributary and problems with unstable streambanks in the lower portion of the tributary. Nevada Creek and Union Creek were two of the major contributors of excessive turbidity in the Blackfoot drainage (Peters 1990).

Most of the decline of habitat occurred on private lands associated with agricultural practices, primarily livestock grazing. An analysis of 6 tributaries to the Blackfoot by Pierce (1991) found significant degradation due to uncontrolled grazing on agricultural lands and poor logging practices in mountain riparian areas.

The Bull Trout Scientific Group identifies historic and future mining activities as another major threat to the Blackfoot River. In 1975, the Mike Horse mine tailings impoundment was breached and released its toxic contents. Research conducted by Moore et al. (1991), determined that contamination extended downstream 25 km from the source, and cadmium and zinc remain bioavailable over long stretches of the river. Significant cadmium contamination was observed in stoneflies and large brown trout more

than 75 km downstream from the input of acid mine drainage. In 1988, the abundance of age 1 and older cutthroat trout was less than 25% of that in 1973 (Moore et al. 1991).

The proposed McDonald Mine, located near the confluence of the Blackfoot River and Landers Fork, has the potential to complete the destruction of these fish populations. The Copper Creek/Landers Fork watershed is an important stronghold for the recovery of fluvial cutthroat and bull trout in the Blackfoot River Basin. Copper Creek, a major tributary to Landers Fork, supports the second best bull trout population in the drainage, and is not at risk of hybridization with brook trout.

In addition, the westslope cutthroat population which dominates the headwaters represents the largest unfragmented population remaining in the mainstem. Any water quality or water quantity impacts to this area could harm recovery chances of these native trout throughout the basin.

An evaluation of the proposed mine project by OEA (1995) identified the following potential impacts to fisheries in the Blackfoot River Basin: 1) sedimentation, 2) acid mine drainage 3) nitrogen enrichment of the river leading to unnatural or nuisance accumulations of benthic algae, 4) acute or chronic ammonia and/or cyanide toxicity problems for aquatic organisms and 5) the depletion of instream flows in the Landers Fork, stranding migrating fish, causing losses to native trout habitat, reducing the dilution and buffering of heavy metal toxicity originating in the river's headwaters.

GOALS: Historic and future mining activities must not impair native fish recovery efforts in the Blackfoot River. Land use activities such as

agriculture and timber harvesting must provide for the protection of all beneficial uses and support native fish recovery efforts.

RECOMMENDED ACTIONS: Increase the connectivity between the Blackfoot River and it's tributaries, and restore the connectivity between the Blackfoot drainage and the Clark Fork River.

***Develop westslope cutthroat recovery plan. In the meantime, preserve existing westslope cutthroat populations.**

***Adopt the following Bull Trout Scientific Group Goals: Preserve the population genetic structure throughout the watershed. Preserve the migratory bull trout population that currently exists in the Blackfoot River, with spawning distributed among all core drainages. Establish a baseline of redd counts for all drainages that currently support spawning migratory fish. Restore bull trout levels to at least 100 redds or 2000 individuals throughout the watershed. If the total baseline counts exceed these levels, then an increasing trend is the goal.**

Bitterroot River

The Bitterroot River originates high in the Bitterroot and Sapphire Mountains. The East and West Forks join near the town of Conner and flow north through the

Bitterroot Valley about 85 miles to join the Clark Fork near Missoula. Bitterroot National Forest manages about 64% of the Bitterroot drainage area; the rest is private land.

Fish populations in the Bitterroot river are severely below potential due to chronic dewatering. Many tributaries are diverted for irrigation before they reach the river. The Montana Dept. of Fish Wildlife and Parks has listed 64.5 miles of streams in the Bitterroot as chronically dewatered (MTDFWP 1994).

Introduced species are the other highest risk factors for native fish populations. Approximately 75% of the bull trout streams also contain brook trout within the drainage. Brown trout are common in the Bitterroot River and the lower end of most tributary streams. Westslope cutthroat populations are more numerous in the upper river than the lower river, but their numbers are too low to allow populations estimates to be made.

Migratory bull trout have been virtually eliminated in the mainstem from the mouth of the Bitterroot river to Blodgett Creek (Thomas, 1995d). From Blodgett Creek to the East Fork of the Bitterroot, migratory bull trout are rare. In the upper reaches of the East and West Forks, there are some migratory fish but only in small numbers. Resident bull trout exist in many of the tributary systems--primarily those in the Bitterroot National Forest. However, they are isolated from other bull trout streams by habitat degradation, dewatering and other barriers.

GOALS: De-watering must no longer limit fishery production in the Bitterroot River. Trout populations should be restored to historic levels.

RECOMMENDED ACTIONS: Determine distribution and status of westslope cutthroat populations and develop recovery plan for basin. In the meantime, preserve the existing westslope cutthroat populations.

***Adopt the following goals as recommended by the Bull Trout Scientific Group: Restore a self-sustaining migratory population in the Bitterroot River which spawns in tributary streams and has at least 100 redds or 2000 total individuals in the migratory population within 15 years (Thomas, 1995). Once this goal has been reached, increase goal to a more stable population density. Preserve the current self-sustaining bull trout populations and the population genetic structure through the watershed.**

***Prevent de-watering of tributaries.**

Flathead

Several dams fragment fish populations and disrupt historic migration patterns in the Flathead River Basin. Big Fork Dam blocks migration from Flathead Lake into the Swan River drainage. Hungry Horse Dam blocks off the South Fork of the Flathead River, and Kerr Dam blocks fish migrating from the lower Flathead River into Flathead Lake.

Currently, Flathead Lake supports a population of large migratory bull trout which spawn primarily in the North and Middle Fork drainages. Bull trout populations in the

North and Middle Forks of the Flathead Basin appear to have plummeted in the last few years. The average redd count for the two tributaries over the past 16 years of monitoring was 313 redds. In 1992, 1993 1994 and 1995 the total redd counts equaled 123, 122, 115 and 161(MTDFWP, 1995). Bull trout redds in the Swan River drainage appears to have increased in recent years. The 1994 & 1995 redd counts of 493 and 501 are record highs (MTDFWP, 1995). However, these figures represent the average of the four least-impacted watersheds in the Swan River drainage. It appears that bull trout populations in the other watersheds are decreasing (Frissel pers. comm. 1996).

Adfluvial westslope cutthroat occur primarily in the North Fork of the Flathead downstream from Polebridge and the Middle Fork of the Flathead downstream from the wilderness boundary. Fluvial cutthroat occur primarily in the Middle Fork upstream of the wilderness boundary, and possibly, the North Fork from Polebridge to the Canadian border.

The Montana Bull Trout Scientific Group identified the primary threat to bull trout populations as changes in the Flathead lake ecosystem resulting from the introduction of Mysis relicta (opossum shrimp). Alterations of the food web have resulted in the decline of Kokanee salmon and the increase of lake trout populations (Spencer et al. 1991). Lake trout compete with and prey upon bull trout.

Timber harvesting and associated road building have increased sediment levels, water yield and erosion. The Bull Trout Scientific Group indicates that there is significant potential for further impacts from these activities (Thomas, 1995c).

Additional threats include 1) the high incidental catch of bull trout in the other popular lake and river fisheries (cutthroat and lake trout etc.), 2) management emphasis on introduced species such as lake trout, Kokanee and lake whitefish, and 3) illegal harvest.

The South Fork of the Flathead, cut off by Hungry Horse dam, supports the single most intact native fish ecosystem in western Montana (Thomas, 1995c). Bull trout spawn in the tributaries and mature in the reservoir. Gillnet catch rates of bull trout are similar to historic records which date back to 1958. The South Fork above Hungry Horse Dam is also the last remaining stronghold of westslope cutthroat in Montana.

The lower Flathead river mainstem, below Kerr dam, is not used for irrigation, however, sections of these streams are often severely dewatered. Tributaries on the southeastern side of the river originate in the Mission Mountain Wilderness. There is some impact to these tributaries by livestock grazing. The tributaries on the northwestern side of the river are much more impacted due to irrigation dewatering, livestock damage and timber harvest in the upper headwater areas.

RECOMMENDED ACTIONS: Prevent drawdown of the Hungry Horse Dam beyond the recommended 85 feet, and incorporate the Integrated Rule Curves (IRC) Concept in reservoir management.

***Determine the distribution and status of westslope cutthroat throughout the Flathead Basin. Develop a westslope cutthroat recovery plan. In the**

meantime, preserve the existing westslope cutthroat populations in the South Fork of the Flathead and throughout the rest of the Basin.

***Adopt the following goals recommended by the Bull Trout Scientific Team: Preserve the current bull trout populations in the South Fork of the Flathead River, and the bull trout population genetic structure throughout the drainage.**

***In the North and Middle Forks of the Flathead River, restore bull trout spawners at least to the average redd count level of the 1980's, and maintain this level for 15 years. Average redd counts of index streams in the North Fork and Middle Fork during the 1980's were 240 and 151, respectively.**

***Restore and protect self-sustaining migratory populations in the core areas of the Flathead River drainage and protect the population genetic structure. Develop goals for the "disjunct" populations in headwater lakes in the Flathead Basin.**

HATCHERIES AND FISH TRANSPLANTS

The Bull Trout Scientific group has identified two kinds of risks associated with the use of hatcheries in the bull trout recovery program: social and biological (Clancy et al. 1995). Social risks include a false sense of security, diversion of funds from other restoration efforts, management by activity rather than objective, and political abuse due to public pressures. Biological risks include loss of genetic diversity within and among populations, interbreeding between hatchery and native fish, competition with or predation by hatchery fish, effects on non-target species, disease, introduction and depletion of wild populations by hatchery stock.

The Bull Trout Scientific Group emphasizes a cautious approach in the use of hatcheries and fish transplants, but identifies two situations in which they may be a potential tool in bull trout recovery (Clancy et al. 1995).

A genetic reserve is a population of fish maintained under wild or hatchery conditions to preserve the genetic diversity of a declining population. Genetic reserves are considered a viable restoration strategy when trend data indicate a declining population and extinction of a regionally important stock appears imminent (i.e. extinction is likely to occur before there is time for remedial actions to produce sufficient recovery and/or the causes of decline are unknown).

Restoration Stocking is the re-establishment of a self-sustaining bull trout population in habitat where bull trout were driven out. This involves stocking appropriate habitat with fertilized eggs or fish from donor populations. This strategy should only be

used once the cause of population decline has been eliminated and time has been allowed for re-colonization.

Three strategies associated with hatchery use or fish transplants have been rejected by the Bull Trout Scientific Group (Clancy et al. 1995). Supplementation is the use of artificial propagation to maintain or increase an existing bull trout population. The negative effects of stocking hatchery-reared fish into habitat currently occupied by wild populations include: a) intra-specific competition for food and space, b) predation on one another, c) transmission of diseases or parasites, d) reducing spawning and migratory success due to interbreeding with hatchery fish producing offspring that are not adapted to local conditions.

Introductions to expand the range or distribution of bull trout was rejected as a potential strategy because of the possibility of altering other ecosystems (impact on amphibians, invertebrates etc. of introducing a major predator.), and the potential diversion of funds, resources, and attention away from restoration of their historical habitat.

"Put, grow and take" involves stocking hatchery fish (generally in reservoirs and lakes) solely for the use of anglers. This was rejected as a restoration strategy by the Bull Trout Scientific Team as it provides no biological benefits to the recovery of bull trout.

GOALS: Genetic reserves should only be used where trend data indicate a declining population, and extinction of a regionally important stock

appears imminent. Restoration stocking should only be used if the actual cause of the decline is identified and corrected first.

***Avoid the use of artificial propagation to maintain or increase existing native fish populations, the use of stocking to expand populations outside of their native range, and the use of "Put, Grow and Take" as a strategy for recovery.**

A WATERSHED APPROACH TO FISHERY RECOVERY

The Pacific Rivers Council has developed a watershed recovery program that calls for the protection, expansion and reconnection of the remaining least disturbed aquatic habitats (Doppelt et al. 1993). The few remaining least disturbed areas are critical because they provide physical refuges for native species and a source of colonists to adjacent areas. Colonists are critical to the recovery of degraded systems (Yount and Niemi 1990 and Niemi et al 1990). Biological recovery was delayed or entirely precluded in stream systems where disturbance was widespread and no accessible refugia remained. Least disturbed areas also serve as references against which degraded areas be compared to determine restoration goals.

These ideas have been incorporated into a bull trout conservation strategy outlined by Rieman and McIntyre (1993). They recommend that “core areas” for bull trout conservation be selected from the best available habitat or from habitat with the best opportunity to be restored to high quality.

The Montana Bull Trout Restoration Team identified core areas within each of the Recovery/Conservation Areas (Upper Clark Fork, Middle Clark Fork, Lower Clark Fork, Blackfoot, Bitterroot, Swan and Flathead Rivers) in the Clark Fork Basin. Core areas are watersheds, including tributary drainages and adjoining uplands, used by migratory bull trout for spawning and early rearing, and by resident bull trout for all life history requirements. These areas generally represent relatively undisturbed habitat and typically support the strongest remaining populations of spawning and early rearing bull trout in an RCA. These core areas must be provided with the most stringent protection (Thomas et al, 1995a-e).

Table 9. Bull Trout Core Areas. Adapted from Thomas (1995a-e).

BULL TROUT CORE AREAS	
Basin	**Core Areas (by drainage)**
Upper Clark Fork	**Rock Creek and its tributaries, Boulder Creek, Warm Springs Creek, Harvey Creek, Racetrack Creek, Little Blackfoot River.**
Blackfoot River	**North Fork of the Blackfoot River, Monture Creek, Copper Creek, Gold Creek, Cottonwood Creek, Clearwater River drainage above Rainy Lake, Deer Creek, Placid Creek, Belmont Creek, Landers Fork, East Fork Clearwater River, West Fork Clearwater River and Morrell Creek.**
Bitterroot River	**Upper East Fork Bitterroot River, Warm Springs Creek, Sleeping Child Creek, Skalkaho Creek, Fred Burr Creek, West Fork Bitterroot River above Painted Rocks Reservoir, and upper Burnt Fork Creek.**
Middle Clark Fork	**Fish Creek, St. Regis River, Trout Creek, Cedar Creek, Petty Creek, Rattlesnake Creek, W. ForkThompson River/Fishtrap Creek, Jocko River, Mission Creek above Mission Dam, Post Creek above McDonald Dam.**
Lower Clark Fork	**Prospect Creek, Rock Creek, Vermillion River, Bull River.**
Flathead River	**In the North Fork - Big, Coal, Whale, Trail, Red Meadow, Howell and Cabin Creeks. In the Middle Fork - Nyack, Park, Ole, Bear, Long, Granite, Morrison, Schafer, Clack, Strawberry and Bowl Creeks.**

South Fork of the Flathead	**The entire drainages of tributaries flowing directly into Hungry Horse Reservoir (Wounded Buck, Wheeler, and Sullivan Creeks) as well as tributaries to the South Fork upstream from the Reservoir (Spotted Bear River, Bunker Creek, Little Salmon Creek, White River, Gordon Creek, Youngs Creek and Danaher Creek) and the south Fork itself upstream from Gordon Creek.**
Swan River	**Elk Creek, Goat Creek, Lion Creek, Piper Creek, Jim Creek, Lost Creek, Woodward Creek, Cold Creek, Lindbergh Lake, Holland Lake.**

Isolated core areas alone cannot restore and sustain a healthy fishery. There must be a wide-ranging, connected network of these areas. Rieman and McIntyre (1993) recommended that core areas for bull trout recovery must be distributed throughout the historic range of the species to maintain genetic diversity through adaptation to local conditions. Most of the genetic variation for bull trout is contained among different populations, rather than within any single population (Leary et al 1991). A particular life-history strategy may dominate under stable conditions, but another life-history strategy may be favored with a changing environment (Gross 1991; Northcote 1992). Thus, diversity is essential for stable populations in highly variable environments.

Based on modelling efforts using bull trout population data from the Flathead, Salmon, Pend Oreille and Swan rivers, Rieman and McIntyre (1993) concluded that migratory populations which include fewer than 50-100 redds or resident populations which include fewer than 1,000 to 2,000 bull trout that are yearlings or older, may have a considerably higher risk of extinction.

Migration corridors are also important to the persistence and interaction of resident populations because they connect safe wintering areas to summer or foraging areas and provide support for weaker populations or allow recolonization of depopulated streams (Rieman and McIntyre, 1993). The Bull Trout Scientific Group has identified

"nodal habitats" throughout the basin which include migratory corridors, overwintering areas, and critical rearing habitat.

Table 10. Bull Trout Nodal Areas. Adapted from Thomas (1995a-e).

BULL TROUT NODAL AREAS	
Basin	**Nodal Area (by drainage)**
Upper Clark Fork	**Clark Fork River from Warm Springs Creek to Milltown Dam.**
Blackfoot	**Blackfoot River, Clearwater River, and the Clearwater chain of lakes (Salmon, Seeley, Placid, Inez, Alva, Rainy and Clearwater).**
Bitterroot	**East Fork of the Bitterroot River, the West Fork Bitterroot River, Painted Rocks Reservoir, and the entire Bitterroot mainstem.**
Middle Clark Fork	**Not yet available.**
Lower Clark Fork	**Not yet available.**
North and Middle Forks of the Flathead River	**North Fork, Middle Fork, upper mainstem Flathead River and Flathead Lake.**
South Fork of the Flathead	**South Fork of the Flathead River downstream from Gordon Creek including Hungry Horse Reservoir.**
Swan River	**Not yet available.**

The Flathead Basin also includes many glacial headwater lakes containing "disjunct" migratory populations of bull trout. The streams draining these lakes generally do not contain bull trout, because they tend to have warmer summer and fall water temperatures that possibly restrict upstream colonization by bull trout under current climatological conditions. Therefore, these lakes are considered functionally isolated. Disjunct lakes are classified as nodal habitat and their associated spawning streams as core areas. The following table lists the nodal lakes and core areas (including the entire interconnected watershed upstream). All are upstream of the lake except where otherwise noted.

Table 11. Disjunct Core Areas in the Flathead Basin. Adapted from Thomas (1995 c & e).

DISJUNCT CORE AREAS IN THE FLATHEAD BASIN	
Watershed	**Core areas with their nodal lakes in parenthesis**
North Fork	**Kintla Creek (Kintla L.), Kintla Creek - downstream (Upper Kintla L.), Rainbow, Quartz Creeks - downstream (Cerulean L.), Rainbow, Quartz Creeks (Upper Quartz L.), Quartz Creek - (Middle and Lower Quart Lakes), Akokala Creek (Akoklala L.), Logging Creek (Logging L.), Bowman Creek (Bowman L.), Camas Creek (Arrow L. & Trout L.), Cyclone Creek - downstream (Cyclone L.), Unnamed inlet stream in B.C. (Frozen L.).**
Middle Fork	**Park Creek (Lower Isabel L.), Park Creek downstream (Upper Isabel L.), Harrison Creek (Harrison L.), McDonald Creek (L. McDonald), Lincoln Creek - downstream (Lincoln L.).**
Stillwater	**Swift & W.Fk. Swift Creek (Whitefish L.), E. Fk. Swift Creek (Upper Whitefish L.), Logan Creek (Tally L.), Fitzsimmons Creek and upper portion of Stillwater R. (Upper and Lower Stillwater L., and Still water River nodal).**
South Fork	**Big Salmon Creek (Big Salmon L.), Doctor Creek (Doctor L.).**

In general, restoration must begin in the headwaters and proceed downstream. This ensures that degraded conditions upstream do not destroy restoration efforts downstream. Primary emphasis should be placed on removing the impacts to the watershed responsible for degradation and allowing the watershed to recover on its own.

Lastly, restoration resources should not be allocated for severely degraded areas, unless a heavily degraded area is a threat to human health or located at the headwaters of a drainage and is serving as a continuous source of degradation downstream. Sites that are not good bets or buys for fishery restoration should be remediated to meet water quality standards with water quality funds. This approach emphasizes the prevention of degradation rather than attempting to repair damage once it has occurred--a more effective and cost efficient method.

GOALS: Wild, self-sustaining native bull trout and westslope cutthroat fisheries will be restored throughout their native range. Fisheries recovery will occur through a watershed restoration plan that protects, expands and reconnects the remaining least disturbed habitats within the watershed. Restoration efforts will focus on removing impacts and allowing natural stream processes to work (i.e. riparian and floodplain restoration). Wherever possible, restoration efforts will begin at the headwaters and proceed downstream.

RECOMMENDED ACTIONS: Aggressively develop and pursue restoration plans for westslope cutthroat and bull trout. Westslope cutthroat and bull trout recovery efforts should be integrated wherever possible.

*State and Federal agencies must instigate changes in land management practices which provide for the restoration of bull trout and westslope cutthroat. These land management practices must be monitored for effectiveness, and altered as needed.

*Core and nodal bull trout areas must be provided with the most stringent protection. These areas must be managed to meet the life history requirements of bull and westslope cutthroat trout.

***While voluntary watershed groups may play an important role in native fish recovery efforts, they are limited in what they can accomplish on a landscape level. Restoration plans for bull trout and westslope cutthroat must be adequately funded and staffed.**

***Restoration plans must contain a time-line and mileposts for determining if recovery is on track. Land managers must be accountable for plan implementation.**

Section IV. MONITORING

In order to protect human health, a physician measures elements of the human system such as heart rate and blood pressure. Once a problem has been diagnosed (e.g. high blood pressure), recovery depends on identifying the source or cause of the problem (i.e. stress, poor diet, etc.) and prescribing a solution (i.e. better diet, less stress). Return checkups provide an opportunity to evaluate patient recovery or to prescribe an alternative if the anticipated recovery does not occur.

The same elements are critical to any watershed protection program. To achieve watershed CPR a monitoring plan must be able to: 1) quantify the physical, chemical and biological structure and behavior of the stream, lake and riparian ecosystems in the basin; 2) compare the condition of these systems to the goals set for them; 3) detect changes in structure or behavior before major degradation occurs. 4) delineate and quantify sources of loads (point source discharges) or other causes of degradation (such as dewatering or riparian degradation) and; 5) detect positive changes resulting from restoration efforts.

Numerous agencies are responsible for monitoring efforts in the Clark Fork-Pend Oreille Basin. As a result, efforts have often been fragmented and uncoordinated. To implement CPR on a watershed scale, an independent umbrella organization is needed whose main mission is to assess the 'big picture', prioritize and coordinate monitoring efforts.

The Tri-State Implementation Council, established by the 1987 reauthorization of the Clean Water Act to study water quality issues in the Clark Fork-Pend Oreille Basin, has been responsible for large-scale monitoring efforts over the last few years, and is the

logical entity to perform this role. Information derived from status reports, trend analysis, and GIS mapping should be provided to the council by the appropriate agency and used to define or refine watershed goals and recommend appropriate management changes.

WATERSHED STATUS & TRENDS

A critical element in the monitoring process is long-term, consistent data. Rivers and streams are variable systems. Changes in flow, for example, may vary considerably from one year to the next based solely on climatic conditions. In order to detect water quality degradation resulting from human impacts or fishery recovery resulting from restoration efforts, long term, consistent data is needed.

Land and Water Consulting Inc., a Missoula based consulting firm contracted by the State of Montana on behalf of the Tri-State Implementation Council, is currently evaluating the Clark Fork - Pend Oreille's existing monitoring network to determine its adequacy for detecting trends, to provide recommendations for improving sampling design, and to recommend a statistical approach for trend analysis (Anderson, 1995). They have indicated that in general, 5-10 year records are necessary to detect trends (on the order of one standard deviation) based on monthly sampling. Therefore, comparison of annual results can be performed to check for evidence of emerging trends, but statistically meaningful results are likely to be limited to periods of record exceeding five years.

Listed below are important elements that should be monitored on a consistent, long term basis (summarized in tables 14 & 15).

Physical Integrity

1) Instream Flows, Suspended Sediment & Temperature. Temperature, suspended sediment and continuous flow monitoring at historic USGS stations on mainstem and tributary stations should be continued. Historic records can be used by the USGS to determine 10 year moving averages of peak, low and average flows. Significant changes can be determined by comparing historic flow patterns to existing flows. Historic records can also be used to identify significant temperature and suspended sediment changes. In order to evaluate restoration efforts in the upper Clark Fork, suspended sediment, temperature and flows should be monitored at Silver Bow Creek, Mill-Willow Creek, Warm Springs Creek, and the upper Clark Fork to below Milltown.

2) Bank Stability. The U.S. Forest Service, Bureau of Land Management and the Dept. of Health and Environmental Sciences should use the Geographic Information Systems (GIS) to assist with mapping and monitoring the condition of riparian areas. However, considerable fieldwork is needed here.

Chemical Integrity

1) Nutrient Concentrations and Loads. The existing DHES sampling stations should be continued unless statistical analysis indicates that some can be eliminated as reliably predictable from other stations. The highest priority stations for nutrient levels and loads include: the Clark Fork river at Deer Lodge, Turah, above and below Missoula, above and below Stone Container, Superior, above the confluence of the Flathead River, above

and below the reservoirs and above and below Lake Pend Oreille and one or two sites in the Pend Oreille River. Tributaries should include: mouths of the Blackfoot, Bitterroot and Flathead.

2) Metals and pH. Metals and pH should be monitored (flow-weighted) at stations in Silver Bow Creek, Mill-Willow Creek, Warm Springs Creek, and the upper Clark Fork River to below Milltown Dam to evaluate restoration efforts.

3) Dissolved Oxygen. Predawn sampling should be conducted by dischargers at the most sensitive river reaches in July and August. The highest priority sites include: all upper river sites (especially Deer Lodge, Bonita, and Turah), above and below Missoula, above and below Stone Container, Bitterroot River, Alberton and Superior. pH and metal samples should be taken in conjunction with DO diurnal surveys in the upper river because there is evidence that metal levels rise at night as DO and pH levels drop (Brick and Moore, 1995).

Biological Integrity

1) Aquatic Macroinvertebrates. The Dept. of Health and Environmental Sciences should continue annual sampling at existing DHES sites if possible, including reference streams.

2) Periphyton (attached algae). The Dept. of Health and Env. Sciences is developing a bioassessment method for periphyton community composition as a measure of biotic integrity. Over the long term, this will provide additional information on water quality trends in the Clark Fork Basin. Algal standing crop (biomass) is the most direct measure of use impairment. A few select sites along the mainstem should be analyzed for algal biomass and algal coverage.

3) Macrophytes. Macrophyte density in the Pend Oreille River could be assessed using low altitude remote sensing or quantitative boat surveys. Surveys could assess macrophytic density and depth to sediment along transects and provide information concerning the effectiveness of strategies such as harvesting, dredging, sediment flushing, or introduction of grazers.

4)Lake Pend Oreille Biomonitoring. Midlake clarity, nearshore algal accumulation, nutrient concentrations, dissolved oxygen, temperature, chlorophyll, phytoplankton, and zooplankton should be monitored. Trained citizen monitors could be responsible for secchi disk, water and periphyton sampling. Water sample analysis for chlorophyll, nutrients, phytoplankton and zooplankton should be conducted by the State Water Quality Division.

5) Fish The Montana Dept. of Fish, Wildlife and Parks and U.S. Fish and Wildlife Service should continue to monitor fish populations. Results should be integrated with watershed monitoring network.

Although state and federal agencies are responsible for most watershed monitoring activities, budget constraints preclude monitoring all streams, lakes and rivers in the basin. Therefore, citizens should be encouraged to participate in watershed monitoring efforts. Programs such as Adopt-A-Stream train citizens to perform standard stream monitoring techniques, and play an important role in watershed protection efforts by alerting agencies to changes in stream quality in areas where state or federal monitoring does not occur. Local watershed councils should also be encouraged to form and work in collaboration with local conservation districts to instigate specific restoration and protection efforts within their own small watershed.

SOURCES AND CAUSES

All point source dischargers should be required to report discharge volumes, concentrations and loads of constituents of concern. Larger dischargers (Butte, Anaconda, ARCO, Deer Lodge, Missoula, Stone Container, Kalispell, Polson, Sandpoint) should also be required to monitor receiving waters above their discharge and below their mixing zone as appropriate. Nonpoint sources (mines, timber harvests, roads, subdivision etc.) should be included in the Clark Fork GIS system to facilitate the interpretation of general watershed monitoring results.

Changing land cover and uses should also be evaluated through the GIS mapping system. The Upper Columbia River Basin EIS, developed by the U.S. Forest Service, will shape future management of the Clark Fork-Pend Oreille watershed. For this purpose, the Wildlife Spatial Analysis Lab at the University of Montana is developing a a GIS land cover data base for the region with 5 acre mapping units useful for tracking large land cover changes, as well as smaller mapping units that allow delineation of finer features. This information can be used to identify and prioritize conservation, preservation and restoration efforts and to influence land use decisions.

PUBLIC INVOLVEMENT

Each agency should be responsible for putting their data into a centralized data storage system (i.e. EPA STORET) and providing information to the Tri-State Implementation Council. Basin reports should be prepared by each state every even year. A tri-state, basin-wide report should be prepared by the EPA and/or the Tristate Implementation Council on the entire basin every odd year.

Public involvement and support is essential to Watershed CPR - especially as the basin's population increases and places greater demands on limited resources. Ninety percent of the impaired waterbodies in Montana are caused by non point source pollution. Therefore, watershed CPR depends on the participation and cooperation of citizens basin-wide. To provide a forum for public involvement, annual public meetings could be conducted to present state reports one year and basin reports the next.

Table 12. Watershed Monitoring Plan.

WATERSHED MONITORING PLAN				
Monitor Watershed Status & Trends	**Parameters**	**Responsible Entity**	**Location**	**Timing**
Physical Integrity	flow	USGS	USGS flow stations	Continuous
	suspended sediment	USGS	USGS flow stations	Flow weighted
	riparian condition public land private land	 USFS, BLM DHES, citizens	 degraded areas degraded areas	 semi-annual semi-annual
	temperature, turbidity, guage height	citizens	many	daily/weekly
Chemical Integrity	ph, metals, hardness, TP, SRP, TN, SIN	USGS, DHES, 3 state WQ agencies	upper river 525 sites	monthly monthly
Biological Integrity	Dissolved Oxygen predawn diurnal	 dischargers citizens	 upper & mid river 525 sites	 July/August once/summer
	RBP metrics	DHES	525 sites	annual
	periphyton biomass	citizens	river & lake	over summer
	macrophyte density	citizens & remote sensing	management areas	annual
	lake clarity & chlorophyll,	citizen sample	mid lake	monthly in spring &summer
	fish populations	State fish/game	throughout basin	semi-annual

Table 13. Monitoring Plan

Identify Sources/ Causes	**Parameters**	**Responsible Entity**	**Location**	**Timing**
Point Sources	discharge volume, concentrations of nutrients, metals, other as appropriate	discharges	end of pipe	flow weighted or depends on variability
Nonpoint Sources	sediment/turbidity, nitrates, other	state WQ agencies USFS, BLM	select based on WQ problems, riparian or watershed assessment	flow weighted intermittent
Hydrologic Change	flow, other	USGS, USFS	"	time-integrate
Watershed Change	land cover (GIS)	USFS, BLM	entire basin	annual
Evaluate Management	Note significant changes in above; change/sustain action?	state WQ agencies EPA, Council	by state entire basin	even years odd years

Develop/Refine Goals	Estimate loads for TMDL, modeling etc. Change/sustain goals? Seek funding!	state WQ agencies EPA council	by state entire basin	even years odd years
Analyze & Report To Decision Makers & Public	Health of river/lake/river Health of basin	state WQ agencies EPA, Council	by state entire basin	even years odd year

CONCLUSION

The health and biological integrity of the Clark Fork River Basin depends upon the citizens it supports. An informed and committed community is essential to Watershed conservation, preservation and restoration. We must all recognize the influence we have on our surrounding environment and the role we play in defining its future.

Direct actions must be taken now and in the future to restore and protect the watershed. We must work together to strengthen the laws and regulations governing watersheds and moderate our own behavior to fit within its limits as well.

An integrated program of chemical, physical and biological goals and criteria are critical to long-term, watershed protection efforts. The most critical actions involve protecting and restoring riparian areas and floodplains, ensuring adequate instream flows and reducing sediment yields to natural levels.

The health of our native fisheries is the best guide for monitoring progress. They provide the litmus paper by which our efforts may be tested.

This paper does not pretend to have all the answers and many other actions will be needed to fully recover watersheds than those proposed here. Nevertheless, these goals and action steps are achievable and can provide a basis for future efforts.

REFERENCES

Adler R.W., Landman, J.C., and Cameron, D.M. 1993. The Clean Water Act: Twenty Years Later. Natural Resources Defense Counsil. Island Press.

Allendorf, F. & Leary, R. 1988. Conservation and Distribution of Genetic Variation in a Polytypic Species. The Cutthroat Trout. Conservation Biology. 3: 170-194.

Anderson, B. 1995. Proposal for Water Quality Status and Trends Monitoring System for the Clark Fork - Pend Oreille Watershed RFP #59501. Land and Water Consulting Inc. Missoula, Montana. Prepared for Montana Dept. of Health and Env. Sciences, Helena, Mt.

Andrews, E.D. 1987. Longitudinal dispersion of trace metals in the Clark Fork River, Montana. In R.C. Everett and D.M. McKnight, eds., Chemical Quality of Water in the Hydologic Cycle. Chelsea, MI: Lewis Publishers.

ASARCO. 1994. Plan of operations. Rock Creek Mine.

Bahls, L. 1995. Personal Communication. Mt. Dept. of Health and Env. Sciences. December 6, 1995.

Bahls, L. 1992, revised 1993. Periphyton Bioassessment methods for montana streams. Dept. of Health and Env. Sciences, Helena, MT.

Bahls, L., Bukantis, R., and Tralles, S. 1992. Benchmark biology of Montana Reference Streams, Department of Health and Environmental Science, Helena, MT.

Bauer S.B. and T.A. Burton. 1993. Monitoring Protocols to Evaluate Water Quality Effects of Grazing Management on Western Rangeland Streams. Idaho Water Resources Research Institute. University of Idaho. Moscow Idaho. Submitted to USEPA.

Berg, Rod. 1992. Clark Fork Blackfoot River Fishery Investigation. Project No. F-46-R-5, Montana Dept. of Fish, Wildlife and Parks. Missoula, MT.

Bilby R.E. and Ward, J.W. 1989. Changes in characteristics and function of woody debris with increasing size of of streams in western Washington. Transactions of the American Fisheries Society. 118: 358-378.

Binns, N.A. 1979. A habitat quality index for Wyoming trout streams. Monogr. Ser., Fish. Res. Rep.2. Cheyenne, WY: Wyoming Game and Fish Dept.

Bisson, P.A., J.L. Nielsen, R.A. Palmason, and L.E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Pages 62-73. in N.B. Armantrout, editor. Acquisiton and utilization of aquatic habitat inventory information. Western Division American Fisheries Society, Portland, Oregon, The Hague Publishing, Billings, Montana.

Bisson, P.A. and J.R. Sedell. 1984. Salmonid populations in streams in clearcut vs. old-growth forests of western Washington. Pages 121-129. in W.R. Meehan Tj.R. Merrell, Jr., and T.A. Hanley, editors. Fish and wildlife relationships in old-growth forests. American Institute of Fishery Research Biologists, Juneau Alaska.

Bisson, P.A.; Bilby, R.E.; Bryant, M.D., et al. 1987. Large woody debris in forested streams in the Pacific Northwest; past, present, and future. Pages 143-190 in: Salo, E.O.; Cundy, T.W., eds. Streamside management: forestry and fishery interations. Contribution No. 57. Seattle, WA: University of Washington, Institute of Forest Resources.

Bond C.E., and J.J. Long. Unique fish survey, Fremont National Forest. Final report. Cooperative agreement No. 237. USDA Forest Service Pacific Northwest Range Experiemental Station, Corvallis, OR.

Bothwell, M.L. 1988. Growth rate responses of lotic periphytic diatoms to experimental phosphorus enrichment - the influence of temperature and liglht. Can.J. Fish. Aquat. Sci. 45: 261-70.

Bothwell, M.L. 1989. Phosphorus-limited growth dynamis of lotic periphytic diatom communities: areal biomass and cellular growth rate responses. Can. J. Fish. Aquat. Sci. 46: 1293-1301.

Braico, R.D. 1973. Dissolved oxygen and temperature diurnal variations in the Clark Fork River between Deer Lodge and Superior, MT. for the period August 2-3, 1973. 34 pp. Report to Water Quality Bureau, Mt. Dept. of Health and Env. Science.

Brick C.M.and Moore, J.N. 1995. Diel Variation of Trace Metals in the Upper Clark Fork River, Montana. unpublished. University of Montana. Missoula, MT 59812.

Bronmark, C., Rundle, S.D. & Erlandsson, A. 1991. Interactions between freshwater snails and tadpoles: competitions and facilitation. Oecologia 87: 8-18.

Brooks, S. 1996. Bureau of Land Management. Billings, MT. Personal communication. January. 1996.

Brown, P. 1985. Dolly Varden culture in British Columbia. Pages 62-67 in: D.D. MacDonald, editor. Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange.

Burns, J.W. 1971. The carrying capacity for juvenile salmonids in some northern California streams. Calif. Fish and Game 57:44-57.

Carl, L. 1985. Management plan for bull trout in Alberta. Pages 71-80 in: D.D. MacDonald, ed. Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of the Environment, Cranbroook, B.C.

Carlson, Jim. Washington Water Power Biologist. Nov. 16, 1995. Personal Communication.

Carmichael, N.B. 1983. Biological sampling on Galen Creek, Dupont's Baker Mine. File report in file 50-6110 dated July 11, 1983. Waste Management Branch, Prince George. (cited in Nordin 1985).

Caruso, J.R. 1973. Regeneration within a middle-elevation Douglas-fir clearcut. Seattle, WA: University of Washington. Ph.D. dissertation.

Chapman, D.W. and T.C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. Pages 153-176 in T.G. Northcote, editor. Symposium on Salmon and Trout in Streams. H.R. MacMillan Lectures in Fisheries, Institute of Fisheries, University of British Columbia. Van Couver, Canada.

Chapman, D.W. and McLeod K.P. 1987. Development of Criteria for Fine Sediment in the Northern Rockies Ecoregion. United States Environmental Protection Agency. Water Division, Report 910/9-87-162, Seattle, Washington.

Clancy, C., Frissell, C., Weaver, T. 1995a. The Role of Removal or Suppression of Introduced Fish in Bull Trout Recovery. Prepared for the Montana Bull Trout Restoration Team by the Montana Bull Trout Scientific Group. May 1995.

Clancy, C., Decker, G., Evarts, L., Fredenberg, W., Frissell, C., Leary, R., Sanborn, B., Watson, G., Weaver, T. 1995b. The Role of Hatcheries and Fish Transplants in Bull Trout Recovery. Prepared for the Bull Trout Restoration Team by the Montana Bull Trout Scientific Group. August 1995.

Clements, W.H. 1991. Community responses of stream organisms to heavy metals: A review of observational and experimental approaches. In: Newman M. and A. McIntosh (eds). Metal Ecotoxicology: Concepts and Applications. Lewis Publishers.

Cline, S.P., and C.A. Phillips. 1983. Coarse woody debris and debris-dependent wildlife in logged and natural riparian zone forests: a western Oregon example. Pages 33-39 in J.W.

Davis, G.A. Goodwin, and R.A. Ockenfels, technical coordinators. Snag Habitat Management: Proceedings of the symposium. Flagstaff, AZ. USFS General Technical Report RM-GTR99.

Cliver, D.O. 1981. Wastewater and emergent environmental and health issues. Pub. 6.10. Small Scale Waste Management Project, University of Wisconsin and Madison, WI.

Conners, E.M. and R.J. Naiman. 1984. Particulate allochthonous inputs: relationships with stream size in an undisturbed watershed. Canadian Journal of Fisheries and Aquatic Sciences 41: 1473-1484.

Creed, R.R. Jr. 1994. Direct and indirect effects of crayfish grazing in a stream community. Ecology 75(7): 2091-2103.

Cummins, K.W., J.R. Sedell, F.J. Swanson, G.W. Minshall, S.G. Fisher, C.E. Cushing R.C. Petersen and R.L. Vannote. 1982. Organic matter budgets for stream ecosystems problems in their evaluation. Pages 299-353 in G.W. Minshall and J.R. Barnes, (eds.) Stream ecology: application and testing of general ecological theory Plenum, NY, NY.

Davis, G.A. Goodwin, and R.A. Ockenfels, technical coordinators, Snag Habitat Managment: Proceedings of the Symposium, Flagstaff, Arizona, USA. United States Forest Service General Technical Report RM-GTR99.

Davis. 1975. Review of Oxygen Requirements of Aquatic Life. J. Fish. Res. Board Can. 32(12).

Dodds, W.K. 1991 Factors associated with Dominance of the Filamentous Green Algal Cladophora Glomerata. Water Research 25(11): 1325-1332.

Dodds W.K. and Gudder, D.A. 1992. The Ecology of Cladophora. Journal of Phycology. Vol. 28: 415-427.

Doppelt B., Scurlock M., Frissell C., and Karr J. 1993. Entering the Watershed : A New Approach to Save America's River Ecosystems. The Pacific River Council.

ENSR. 1992. Continued Releases Work Plan - Task X, Estimate Continuous Releases of Sediments and Metals/Arsenic from Milltown Reservoir. Milltown Reservoir Sediments Site. Prepared by ENSR Consulting and Engineering for ARCO, Anaconda, MT.

Erickson, L., Olson, D.R. and Block, A. 1990. Reclaiming the Wealth: A Citizen's Guide to Hard Rock Mining in Montana. Northern Plains Resource Council.

Essig, D.A. and Moore, J.N. 1992. Clark Fork Damage Assessment: Bed Sediment Sampling and Chemical Analysis Report. Prepared for the State of Montana, National Resource Damage Program.

Everest, L.I. 1993. Habitat attributes of the St. Joe River drainage . Abstract of presentation to the Idaho Chapter of the American Fisheries Society, February 25-27, 1993. McCall Idaho.

Falter, C.M., D. Olson, and J.Carlson. 1992. *The Nearshore Trophic Status of Pend Oreille Lake*, Idaho, Dept. Fish and Wildlife, Univ. of Idaho, Moscow.

Fraley J., and B.B. Shepard. 1989. Life history, ecology and population status of migratory bull trout (Salvelinus confluentus) in the Flathead Lake and River system, Montana. Northwest Sciences. 63: 133-143.

Fraley J. Weaver T., and Vashro J. 1989. Cumulative Effects of Human Activities on Bull Trout (Salvelinus confluentus) in the Upper Flathead Drainage, Montana. Pages 111-119 in W.W. Woessner and D.F. Potts, editors. Proceedings on the Symposium of Headwaters Hydrology, American Water Resources Association. Techinical Publication TPS-89-1, Bethesda, Maryland.

Freeman, M.C. 1986. The role of nitrogen and phosphorus in the development of Cladophora glomerata (L.) Kuzing in the Mazawatu River, New Zealand. Hydrobiologia 131:23-30.

Frenzel, S.A. 1991b *Nutrient Budgets, Pend Oreille Lake, Idaho*, 1989-90. U.S. Geological Survey. Boise, Idaho.

Frissell, C. 1996. Fisheries Biologist. Flathead Biological Station. University of Montana. personal communication. January 1996.

Frissell, C. 1993. "A New Strategy For Watershed Restoration and Recovery of Pacific Salmon in the Pacific Northwest." A report prepared for the Pacific Rivers Council, Eugene, OR.

Genter, Dave. Forestry Practices and Its Effect on Threatened and Endangered Species from 4th Annual Montana Riparian Association Workshop 1990.

Gerba, C.P. 1983. Virus survival and transport in groundwater. Dev. Ind. Microbiol. 24: 247-251.

Goetz, F. 1989. Biology of the bull trout., "Salvelinus confluentus," a literature review. Dept. of Agriculture, Forest Service. Wilamette National Forest. Eugene, Oregon, 53 pp.

Gomez, D.M. 1992. Small mammal and herpetofauna abundance in riparian and upslope areas of five forest conditions. Corvallis, OR: Oregon State University. 118 p. M.S. thesis.

Gough, G. 1975. Unpub. report and data on Sakwi Creek-Weaver Creek spawning channel. Waste Management Branch, B.C. Ministry of Environment. Surrey, B.C. (cited in Nordin 1985).

Gould, W. R. 1987. Features in the early development of bull trout (Salvelinus confluentus). Northwest Science. 61:264-268.

Graham, J.M., Auer, M.T., Canale, R.P. & Hoffmann, J.P. 1982. Ecological studies and mathematical modeling of Cladophora in Lake Huron: 4. Photosynthesis and respiration as functions of light and temperature. J. Great Lakes Res. 8: 100-11.

Grant, G.E., F.J. Swanson, and M.G. Wolman. 1990 Pattern and origin of stepped-bed morphology in high-gradient streams, western Cascades, Oregon. Geological Society of America Bulletin 102: 340-352.

Greater Yellowstone Coalition. 1994. Sustaining A Greater Yellowstone, A Blueprint for the Future. Bozeman, MT.

Gresswell, R.E. and J.D. Varley. 1988. Effects of a Century of Human Influence on the Cutthorat Trout of Yellowstone Lake. Pages in R.E. Gresswell, editor. Status and Management of Interior Stocks of Cutthroat Trout. American Fisheries Symposium. Bethesda Maryland.

Hansen P. 1995. Clark Fork Riparian Zone Report: Prepared for ARCO by the Riparian and Wetland Research Program, Feb. 1995.

Hansen, P., Pfister, R.D., Boggs K., Cook B.J., Joy J., and Hinckley D.K. 1995. Classification and Managment of Montana's Riparian and Wetland Sites. Montana Forest and Conservation Experiment Station. School of Forestry, University of Montana. Missoula, MT.

Harmon, M.E.; Franklin, J.F.; Swanson, F.J., et al. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research. New York, NY: Academic Press; 15: 133-302.

Hart, D.D. 1992. Community organization in streams: The importance of species interactions, physical factors and chance. Oecologia. 91 (2): 220-228.

Hauer, F.R., and C. Blum. 1991. The effect of timber management on stream water quality. Flathead Basin Forest Practices, Water Quality and Fisheries Study. Open quality. Flathead Basin Forest Practices, Water Quality and Fisheries Study. Open File Report 121-91. Flathead Lake Biological Station, University of Montana, Polson, Montana.

Heede, Burchard H., April 1980. USDA, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-72. "Stream Dynamics: An Overview for Land Managers.

Hicks, B.J. 1990. The influence of geology and timber harvest on channel morphology and salmonid populations in Oregon Coast Range streams. Dissertation. Oregon State University. Corvallis, Oregon. As cited in Naiman R.J., 1992. Watershed Management: Balancing Sustainability and Environmental Change. Springer Verlag.

Hilsenhoff W.L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. J. N. Am. Benthol. Soc. 7(1):65-68.

Hilsenhoff, W.L. 1987 An improved biotic index of organic stream pollution. Great Lakes Entomologist. 20:31-39.

Horner, R.R., E.B. Welch and R.B. Veenstra. 1983. Development of nuisance periphytic algae in laboratory streams in relation to enrichment and velocity. pp. 121-134. In R.G. Wetzel ed. Periphyton of the Freshwater Ecosystems. Junk.

Horpestead, A. Water Quality Division, Dept. of Health and Environmental Sciences. Helena, MT. personal communication, Feb. 1996.

Hunter C. 1994. Fishes of special concern list updates. Montana Outdoors. Sept./Oct. 1994 issue.

Hunter, C. 1996. Fisheries Biologist, MTDFWP. Personal Communication. February, 1996.

Ingman G.L., Kerr M.A., and D.L. McGuire. 1990. Water Quality Investigations in the Blackfoot River Drainage, Montana: A Report to the Big Blackfoot River and Oakbrook, Illinois Chapters of Trout Unlimited. Dept. of Health and Env. Sciences. Water Quality Bureau, Helena, MT.

Ingman, G.L. 1992. Assessment of Phosphorus and Nitrogen Sources in the Clark Fork River Basin 1988-1991. Final Report. Section 525 of the 1987 Clean Water Act Amendments. Dept. of Health and Environmental Sciences, Water Quality Bureau, Helena, MT.

Ingman, G.L. 1992. A Rationale and Alternatives for Controlling Nutrients and Eutrophication Problems in the Clark Fork River Basin. Section 525 of the 1987 Clean Water Act Amendments. Dept. of Health and Env. Sciences. Helena, MT.

Ingman, G.L. 1995. Water Quality Success Stories In the Making: Water Quality Trends in the Clark Fork River 1984-1995. Presented at the Clark Fork River Symposium April 28, 1995. Missoula, MT.

Jakober, M. 1992. Influence of stream size and morphology on the seasonal distribution and habitat use of resident bull trout and westslope cutthroat trout in western Montana. Unpublished progress report on file at: U.S. Dept. of Agriculture, Forest Service, Intermountain Research Station, Boise, ID. 7 p.

Jacoby, J.M., E.B. Welch and R.R. Horner. 1983. Factors affecting periphytic algal biomass in six Swedish streams. Abstract for Amer. Soc. Limnol. Oceanogr. Annual Conf. June 1983. St. Johns, Newfoundland.

Johnson, H.E. and C.L Schmidt 1988. Clark Fork Basin Project: Status Report and Action Plan. Prepared for the Office of the Governor, Helena, Montana.

Karr J.R. 1995. Using Biological Criteria to Protect Ecological Health. pp, 137-152 in D.J. Rapport, C. Gaudet and P. Calow (eds). Evaluation and Monitoring the Health of Large Scale Ecosystems. Springer-Verlag Berlin Heidelberg.

Karr J.R. 1993. Measuring Biological Integrity: Lessons from Streams. pp. 83-105 in Woodley,S., J.Kay, G. Francis (eds.). Ecological Integrity and the Management of Ecosystems. St. Lucie Press.

Kerr, M.A. 1987a Dissolved oxygen in the Clark Fork River near the Missoula Wastewater Treatment Plant and Stone Container Corporations, July, 1986. Montana Dept. of Health and Env. Sciences. Helena, MT.

Kerr, M.A. 1987b. Unpublished results of diel dissolved oxygen surveys for nine locations in the upper Clark Fork River during July 1987. Mont. Dept. of Health and Env. Sciences. Helena, MT.

Keswick, B.H., C.P. Gerba. 1980. Viruses in Groundwater. Environ. Sci. and Tech. 14(11) 1290-1297.

Kitano, S., Maekawa K., Nakano S., and Fausch K. 1994 Spawning Behavior of Bull Trout in the Upper Flathead Drainage, Montana, with Special Reference to Hybridization with Brook Trout. Transactions of the American Fisheries Society 123: 988-992.

Knudson K. 1984. A Preliminary Assessment of Impacts to the Trout Fishery: Upper Clark Fork River Montana. Ken Knudson, consulting biologist.

Knudson, K. 1992. Potential Effects of Nutrient Control Measures in the Clark Fork Basin on Resident Fisheries. Prepared for the Mont. Dept. of Health and Env. Sciences. Ecological Resource Consulting. Helena, MT.

LaLonde, R.T., Morris, C.D., Wong C.F., Gardner, L.C., Eckert, D.J. King, D.R. & Zimmerman R.H. 1979. Response of Aedes triseriatus larvae to fatty acids of Cladophora. J. Chem. Ecol. 5: 371-381.

Lambing, J.H. 1995. Water Quality and Transport of Suspended Sediment and Trace Elements in the Upper Clark Fork Basin of Western Montana and Plans for Long-Term Monitoring. Presented at the Clark Fork River Symposium. April 28, 1995. Missoula, MT.

Lambing, J.H. 1991. Water-quality and Transport Characteristics of Suspended Sediment and Trace Elements in Streamflow of the Upper Clark Fork Basin from Galen to Missoula, Montana, 1985-90. Prepared by U.S. Geological Survey, Water Resources Investigations Report 91-4139. Helena, Montana in cooperation with U.S. EPA, Nov. 1991.

Lauerman, B. 1995. An Argument for Numerical Simulation of the Physical-Hydrogeologic System at the Proposed McDonald Pit near Lincoln, Montana. Prepared for Environmental Studies Clinic, University of Montana.

Leary, R.F.; Allendorf, F.W.; Knudson, K.L. 1983. Consistently high meristic counts in natural hybrids between brook trout and bull trout. Systematic Zoology. 32: 369-376.

Leary R.F; Allendorf, F.W.; Forbes, S.H. 1991. Conservation genetics of bull trout in the Columbia and Klamath river drainages. Wild Trout and Salmon Genetics Lab. Rep. Missoula, MT: University of Montana.

Leary, R.F., F.W. Allendorf and S.H. Forbes. 1993. Conservation genetics of bull trout in the Columbia and Klamath River drainages. Conservation Biology 7: 856-865.

Leathe, S.A. and P.J. Graham. 1984. Cumulative effects of micro-hydro development of the fisheries of the Swan River Drainage, Montana, Fisheries Research and Special Projects Bureau, Montana Dept. of Fish, Wildlife and Parks, Kalispell, Montana.

Leathe, S.A. and F.A. Nelson. 1986. A Literature Evaluation of Montana's Wetted Perimeter Inflection Point Method for Deriving Instream Flow Recommendations. Montana Dept. of Fish Wildlife and Parks. Helena, MT.

Leopold, L.B. and Wolman, M.G. 1960 River meanders. Bull. Geol. Soc. AM., 71: 769-794.

Li, H.W., C.B. Schreck, C.E. Bond and E. Rexstad. 1987. Factors influencing changes in fish assemblages of Pacific Northwest streams. Pages 193-202 in W.J. Mathews and D.C. Heins, editors. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman, Oklahoma.

Liknes, G. 1984. The Present Status and Distribution of the Westslope Cutthroat Trout (Salmo clarki lewisi) East and West of the Continental Divide in Montana. Prepared for the Montana Dept. of Fish Wildlife and Parks.

Lloyd, D.S. 1987. Turbidity as a Water Quality Standard for Salmonid Habitats in Alaska. North American Journal of Fisheries Management. 7:34-45.

LLoyd. R. 1961. Effect of dissolved oxygen concentrations on the toxicity of several poisons to Rainbow Trout. J. Exp. Bio. 38: 447-455.

Long, M.H. 1994. Sociological implications of bull trout management in northwest Montana. Illegal harvest and game warden efforts to deter poaching. Presented: Friends of the Bull Trout Conference, Calgary, Alberta, Canada, May 1994. As reported in Thomas (1995c).

Master, L. 1990. "The imperiled status of North American aquatic animals." Biodiversity Network News (The Nature Conservancy) 3(3): 1-2, 7-8.

McCulley, Frick and Gilman Inc. 1994. Upper Blackfoot Mining Complex: Anaconda and Mike Horse Mine Waste Materials; Identification of Remedial Actions and Work Plan for Implementation of Remedial Action. Prepared for ASARCO and ARCO corporations.

McDade, M.H. Swanson, F.J.; McKee, W.A., et al. 1990. Source distances for coarse woody debris entering small streams in western Oregon and Washington. Canadian Journal of Forest Research. 20: 326-330.

McGuire D.L. 1993. Clark Fork River Macroinvertebrate Community Biointegrity: 1986 - 1992. Technical report prepared for the Montana Dept. of Health and Env. Sciences. Water Quality Bureau, Helena MT.

McGuire D.L. 1995. Clark Fork River Macroinvertebrate Community Biointegrity: 1986-1993. Technical report prepared for the Montana Dept. of Health and Env. Sciences. Water Quality Bureau, Helena, MT.

McGuire D.L. 1998. Clark Fork River Macroinvertebrate Community Biointegrity: 1996 Assessment. Prepared for Montana Department of Environmental Quality Planning, Prevention and Assistance Division. Helena, MT. June 1998.

McPhail J.D. and C. Murray. 1979. The early life history and ecology of Dolly Varden (Salvelinus malma) in the upper Arrow Lakes. Report to the British Columbia Hydro and Power Authority and Kootenay Dept. of Fish and Wild.

Meehan, W.R., F.J. Swanson and J.R. Sedell. 1977. Influences of riparian on aquatic ecosystem with particular reference to salmonid fishes and their food supply. In: Importance, Preservation and Management of Riparian Habitat. USDA Forest Service General Technical Report RM-43:137-143. Rocky Mountain Forest and Range Experiment Station Fort Collins, CO.

Melilo, J.M., R.J. Naiman, J.D. Aber, and K.N. Eshleman. 1983. The influence of substrate quality and stream size on wood decomposition dynamics. Oecologia 58: 281-285.

Mineral Policy Center. 1995. 1872 Mining Law Packet. Mineral Policy Center, Washington DC.

Montana Legislative Audit Bureau (MLAB). 1994. Enforcement of the Water Quality and Public Water Supply Act: Performance Audit Report. Office of the Legislative Auditor. Sept. 1994. Report # 94P-36.

Montana Natural Heritage Program (MNHP). 1987. Plant and animal element occurences: Clark Fork reservation project. Montana State Library, Helena, MT.

Moore J., Luoma S., and Peters. 1991. Downstream Effects of Mine Effluent on an Intermontane Riparian System. Can. J. Fish. Aquat. Sci. 48:222-232.

Moring, J.r. and R.L. Lantz. 1975. The Alsea Watershed Study: effects of logging on the aquatic resouof three headwater streams of the Alsea River, Oregon. Part 1 - Biological studies. Oregon Dept. Fish Wildlife Fish. Res. Rep.

MTBRT. 1998. Draft Restoration Plan for Bull Trout in the Clark Fork River Basin and Kootenai River Basin Montana. Montana Bull Trout Restoration Team. September 1998. Helena. Mt.

MTDFWP. 1984. Inventory and Survey of the Waters of the Big Hole and Ruby River Drainages. Project No. F-9-R-31/F-9-R-32.

MTDFWP. 1985-1986. Inventory and Survey of the Waters of the Big Hole, Beaverhead and Ruby River Drainages. Project No. F-9-R-34.

MTDFWP, 1986, Application for Reservations of Water in the Upper Clark fork River Basin. Montana Dept. of Fish Wildlife and Parks. Missoula, MT.

MTDFWP. 1991. Bitterroot River Fisheries Management Plan: For the Period September 1991 to September 1996.

MTDFWP. 1994. Dewatered Streams List. Revised Master Copy 1/5/94. Montana Dept. of Fish, Wildlife and Parks.

MTDFWP. 1995. Whirling Disease & Montana's Wild Trout. (brochure) Montana Fish Wildlife and Parks, Helena, MT.

MTDFWP. 1998. Conservation Agreement and Management Plan for Westslope Cutthroat Trout (Oncorhynchus clarki lewisi) in Montana. Draft. June 1, 1998. Montana Fish Wildlife and Parks, Helena. Montana.

MTDHES. 1994. Administrative Rules of Montana. Surface Water Quality Standards. Revised July 1994. Montana Dept. of Health and Env. Sciences, Water Quality Division, Helena, MT.

MTDHES. 1994. Montana Water Quality: The Montana 305b Report. Water Quality Division, MT Dept. of Health and Environmental Sciences. Helena, MT

MTDHES. 1994, Administrative Rules of Montana, Nondegradation of Water Quality. Revised July, 1994. Montana Dept. of Health and Env. Sciences. Water Quality Division, Helena, MT.

MTDSL. 1994. Forestry Best Management Practices Implementation Monitoring: The 1994 Forestry BMP Audits Final Report.

MTNRDP. 1995. State of Montana Natural Resource Damage Program: Butte Groundwater Injury Assessment Report: Upper Clark Fork River NPL Sites.

MTNRDP. 1995. Restoration Determination Plan: Upper Clark Fork River Basin. Helena. MT.

MTNRDP. 1995. State of Montana Natural Resource Damage Program: Milltown Groundwater Injury Assessment Report.

MTNRDP. 1995. State of Montana Natural Resource Damage Program: Anaconda Groundwater Injury Assessment Report: Deer Lodge Valley, Montana.

MTNRDP. 1993. State of Montana Natural Resource Damage Program: Groundwater Resources Injury Assessment Reports: Upper Clark Fork River Basin.

MTNRDP. 1993. State of Montana Natural Resource Damage Program: Aquatic Resources Injury Assessment Report. Upper Clark Fork Basin.

Murphy, M.L., K.V. Koski, J. Heifetz, S.W. Johnson, D. Kirchofer and J.F. Thedinga 1985. Role of large organic debris as winter habitat for juvenile salmonids in Alaska Streams. Proceedings, Western Association of Fish and Wildlife Agencies 1984: 251-262.

Naiman, R.J., and J.R. Sedell. 1979. Benthic organic matter as a function of stream order in Oregon. Canadian Journal of Fisheries and Aquatic Sciences 37: 834-847.

Naiman, R.J.; Beechie, T.J.; Benda, L.E., et al. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest coastal ecoregion. Pages 127-188. in: Naiman, R.J., ed. Watershed management: balancing sustainability and environmental change. New York, NY. Springer-Verlag.

National Resource Council. 1992. Restoration of Aquatic Ecosystems; Science, Technology and Public Policy.

Nehlsen W., J.E. Williams and J.A. Lichatowich, 1991. "Pacific salmon at the crossroads: stocks at risk from California, oregon, Idaho and Washington" Fisheries 16(2): 4-20.

Newcombe C.P. and D.D MacDonald. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management. 11(1): 72-82.

Niemi, G.J., et al. 1990. Overview of case studies on recovery of aquatic systems from disturbance. Environmental Management. 14: 571-587.

Nimick, D.A. 1990. Stratigraphy and Chemistry of Metal-Contaminated Floodplain Sediments, Upper Clark Fork River Valley, Montana. M.S. Thesis Univesity of Montana, Missoula, Montana.

Nordin, R. N. 1985. Water quality criteria for nutrients and algae (technical appendix). Water quality Unit. Resource Quality Section, Water Management Branch, B.C. Ministry of Environment, Victoria 104 pp.

Northern Plains Resource Council. 1978. Hard Rock Minerals Policy: Recommendations for Replacing the General Mining Law of 1872. Billings MT.

Nussbaum, R.A.; Brodie, E.D., Jr.; Storm, R.m. 1983. Amphibians and reptiles of the Pacific Northwest. Moscow, ID: University Press of Idaho. 332 p.

OEA. 1995. Potential Impacts of Open Pit Gold Mining on the Trout Fishery of the Blackfoot River. Prepared for the Clark Fork Coalition. Missoula, MT.

O'Herren, Pat et al. Cumulative Effects and Carrying Capacity Project from GIS data base. Missoula Office of Community Development.

Pacific Rivers Council. 1994. Restoration: A Blueprint for Saving Wild Fish and Watersheds in the Northwest.

Pacific Rivers Council. 1995. Northern Rockies Forests and Endangered Native Fish: THe Urgent Need for Watershed and Native Fish Protection and Resotration in Idaho, Montana, and Northwest Wyoming. Briefing Book.

Patrick , R., Rhyne, C.F., Richardson, R.W., III, Larson, R.A., Bott, T.T. & Rogenmuser, K. 1983. The potential for biological controls of Cladophora glomerata. USEPA. 600/3-83-065.

Peters D. 1990. Inventory of Fishery Resources in the Blackfoot River and Major Tributaries. MTDFWP. Missoula, MT.

Peters D. 1996. Fisheries biologist. Montana Dept. of Fish Wildlife and Parks. Personal Communication. February 10, 1996.

Pfankuch, 1973. Vegetation Manipulation Guidelines. Lolo National Forest.

Pfeifer R.F. & McDiffett, W.F. 1975. Some factors affecting primary productivity of stream riffle communities. Arch. Hydrobiol. 75: 306-17.

Pierce, R. 1991. A Stream Habitat and Fisheries Analysis for Six Tributaries to the Big Blackfoot River. MTDFWP. Missoula, MT.

Plafkin J.L. Barbour, M.T., Porter, K.D., Gross, S.K., and R.M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. U.S.EPA. Wash. D.C.

Platts W.S., Hill, Hillman, and Miller, 1993. Preliminary Status Report on Bull Trout in California, Idaho, Montana, Nevada Oregon and Washington. Prepared for Intermountain Forest Industry Association.

Platts W.S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification. U.S. Forest Service, SEAM publication, Billings, MT.

Pratt, K.L. 1984. Habitat use and species interactions of juvenile cutthroat (Salmo clarki lewisi) and bull trout (Salvelinus confluentus) is the upper Flathead River Basin. Masters thesis. University of Idaho, Moscow Idaho.

Pratt, K.L. 1985. Habitat preferences of juvenile bull trout in the Flathead River Basin. In D.D. McDonald, ed. Proceedings of the Flathead Basin bull trout biology and population dynamics modeling exchange. Fisheries Branch, British Colubmbia Ministry of Environment, Cranbrook, British Columbia.

Pratt K.L., and J.E. Huston. 1993. Status of Bull Trout in Lake Pend Oreille and the Lower Clark Fork River: Draft. Prepared for Washington Water Power Company. Spokane, WA.

Rand G.M. and Petrocelli, S.R. 1985. Fundamentals of Aquatic Toxicology: methods and applications. Washington: Hemisphere Pub. Corp.

Ranney, J.W. 1977. Forest island edges - their structure, development, and importance to regional forest ecosystem dynamics. Environmental Sciences Division Publication No. 1069. Oak Ridge, TN: Oak Ridge National Laboratory.

Redfield, A.C. 1958. The Biological control of Chemical Factors in the Environment. Am. Sci. 46:20521. 1958.

Reese, J. 1995. State Superfund. Personal Communication. Nov. 1995.

Rieman B.E., and McIntyre J.D. 1993. Demographic and Habitat Requirements for Conservation of Bull Trout. USDA Forest Service, Intermountain Research Station. Ogden, Utah.

Rieman B.E. and McIntyre J.D. 1995. Occurrence of Bull Trout in Naturally Fragmented Habitat Patches of Varied Size. Transactions of the American Fisheries Society. Vol. 124:

Rosenberg, D.M. and V.H. Resh. 1993. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, New York, New York.

Rosgen, David L., 1994, A Classification of Natural Rivers. Catena vol. 22 p. 169-199.

Samuels and Hallock. 1994. TMDL Technical Assistant Team and Mini-Grant Program: Development of Clark Fork River Nutrient Wasteload Allocations.

Sedell, J.R. Reeves, G.H.; Hauer, F.R., et al. 1990. Role of refugia in recovery from disturbance: modern fragmented and disconnected river systems. Environmental Management 14: 711-724.

Sedell, J.R.; Beschta, R.L. 1991. Bringing back the bio in bioengineering. Pages160-175 in: Fisheries bioengineering: Proceedings of a symposium; Bethesda, MD. American Fisheries Society Publication 10.

Seven Up Pete Joint Venture. 1994. Plan of Operations. McDonald Gold Mine.

Shepard, B.B. and P. Graham. 1982. Monitoring spawning bed material used by bull trout on the Gacier View district Flathead National Forest. Montana Dept. of Fish, Wildlife and Parks, Kalispell, Montana.

Shepard, B.B. 1984. *Life Histories of Westslope Cutthroat and Bull Trout in the Upper Flathed River Basin, Montana*. EPA, Denver, Colorado.

Shepard, B.B., S.A. Leathe, T.M. Weaver, and M.D. Enk. 1984. Monitoring levels of fine sediment within tributaries to Flathead Lake and impacts of fine sediment on bull trout recruitment. Paper presented at the Wild Trout III Symposium. Yellowstone National Park, WY. September 1984.

Shepard, B.B. 1985. Habitat variables related to bull trout spawning site selection and thermal preference exhibited in a thermal gradient. Page 18 in: D.D. McDonald, ed. Proceedings of the Flathead River Basin bulltrout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of the Environment, Cranbrook, B.C.

Shepard, B.B. 1993. Managing for native fish species - an idea whose time has come. In: Montana chapter AFS Bull Trout Panel, February 24-25, 1993, Great Falls, Montana.

Sierra Club Legal Defense Fund. 1989. The Poisoned Well: New STrategies for Groundwater Protection. Island Press, Wash. D.C.

Spencer, C., R. McClelland, and J. Stanford. 1991. Shrimp introduction, salmon collapse and bald eagle displacement: cascading interactions in the food web of a large aquatic ecosystem. Bioscience 41(1): 14-21.

Stanford , J.A. and Ward, J.V. 1988. The hyporheic habitat of river ecosystems. Nature 335: 64-66.

Stevenson, R.J. & Stoermer. E.F. 1982. Luxury consumption of phosphorus by five Cladophora epiphytes in Lake Huron. Trans. Am. Microsc. Soc. 101: 151-61.

Swanberg, T. 1995. Progress Report 1994: Adult fluvial bull trout movement in upper Clark Fork River drainages. Biological Sciences Program, University of Montana, Missoula.

Swanson R. 1992. Personal communication of unpublished data. June 16. Washington, D.C. U.S. Dept. of the Interior, Bureau of Land Management. As reported in Rieman and McIntyre (1993).

Taylor C.A., Warren M.L., Fitzpatrick J.F., Hobbs H.H., Jezerinac R.F., Pflieger W.L., and H.W. Robison. 1996. Conservation Status of Crayfishes of the U.S. and Canada. Fisheries 21(4) 25-38.

Tennant, D.L. 1976. Instream Flow Needs, Volume II. American Fisheries Society. Bethesda, Maryland.

Thomas, G. 1995a. Upper Clark Fork River Basin: Bull Trout Status Report. Prepared for: The Montana Bull Trout Restoration Team by: the Montana Bull Trout Scientific Group. June, 1995.

Thomas, G. 1995b. Blackfoot River Drainage: Bull Trout Status Report. Prepared for: The Montana Bull Trout Restoration Team. by: The Montana Bull Trout Scientific Group. June 1995.

Thomas, G. 1995c. Flathead River Drainage: Bull Trout Status Report, Prepared for: The Montana Bull Trout Restoration Team. By: The Montana Bull Trout Scientific Group. August 1995.

Thomas, G. 1995d. Bitterroot River Drainage: Bull Trout Status Review. Prepared for The Montana Bull Trout Restoration Team. By: The Montana Bull Trout Scientific Group. May, 1995.

Thomas, G. 1995e. South Fork Flathead River Drainage: Bull Trout Status Report. Prepared for The Montana Bull Trout Restoration Team. By: The Montana Bull Trout Scientific Group. October 1995.

Thomas G. 1993. Viability Assessment and Management Considerations for species associated with late successional and old growth forests of Pacific Northwest: the report of the scientific Analysis Team.

Thomas, G. 1992. Status Report: Bull Trout in Montana. Montana Dept. of Fish, Wildlife and Parks. Helena Mt.

Thurston, R.V., G.R. Philips, R.C. Russo and S.M. Hinkins. 1981. Increased toxicity of ammonia to rainbow trout (Salmo gairneri) resulting from reduced concentrations of dissolved oxygen. Canadian Jounral of Fish and Aquatic Science 38: 983-988.

Tralles, S. 1992. Results of Nonpoint Source Stream Reach Assessments for Clark Fork River Basin Tributary Watersheds. Unpublished report. Montana Dept. of Health and Env. Sci. Helena, MT.

Tristate Implementation Council. 1998. Clark Fork River Voluntary Nutrient Reduction Program. Sandpoint, Idaho. August 1998.

Tyler, J. 1985. Occurrence in water of viruses of public health significance. J. Appl. Bacteriol. Symp. Suppl. 59(14) 375-465.

Upper Clark Fork River Basin Steering Committee. 1994. Upper Clark Fork River Basin: Water Management Plan.

US Bureau of Census. 1994. State population studies. Washington D.C.

USEPA. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers; Benthic Macroinvertebrates and Fish.

USEPA. 1991. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska.

USEPA. 1991. Guidelines for the Preparation of the 1992 State Water Quality Assessments (305(B) Reports). Assessment and Watershed Protection Division (WH-553). Office of Wetlands, Oceans and Watersheds. Office of Water. U.S. EPA. Washington, D.C.

USEPA. 1992. Record of Decision: Warm Springs Ponds Inactive Area Operable Unit (OU12), Silver Bow Creek Butte Area NPL Site (original portion) Clark Fork River Basin, Montana. Prepared by U.S. EPA Region VIII.

USEPA. 1993. Clark Fork Pend Oreille Basin Water Quality Study: A Summary of Findings and a Management Plan; Conducted Under Section 525 of the Clean Water Act of 1987.

USFWS and University of Wyoming. 1992. Second draft of the final report for the USEPA Milltown Endangerment Assessment Project: Effect of Metal contaminated sediment, water, and diet on Aquatic Organisms. Prepared by C.G. Ingersoll, W.G. Brumbaugh, A.M. Farag, T.W. LaPoint and D.F. Woodward for U.S. Dept. of the Interior, Fish and Wildlife Service, Columbia, MO.

USGS. 1994. Water-Quality, Bed Sediment, and biological Data (October 1992 through September 1993) and Statistical Summaries of Water-Quality Data (March 1985 through September 1993) For Streams in the Upper Clark Fork Basin, Montana. Open File Report 94-375. U.S.G.S., Helena, MT.

Van Sickle, J.; Gregory, S.V. 1990. Modeling inputs of large woody debris to streams from falling trees. Canadian Journal of Forest Research. 20: 1593-1601.

Vashro, J. 1996. Fisheries Biologist, Montana Dept. of Fish Wildlife and Parks, Kalispell, MT. Personal Communication.

Ver Hey, M.E. 1987. Contributions to Potable Water Contamination from Septic System Effluent in Unswered Areas Underlain by Coarse Sand and Grave Substrate. Masters Thesis, University of Montana. Missoula, MT.

Wagner, R.G. 1980. Natural regeneration at the edges of Abies amabilis zone clearcut on the west slope of the central Washington Cascades. Seattle, WA: University of Washington. M.S. thesis.

Wang, L. and R.J. White. 1994. Competition between wild brown trout and hatchery greenback cutthroat trout of largely wild parentage. North American Journal of Fisheries Management. 14: 475-487.

Watkins. R. 1995. Program Director, Tri-State Implementation Council. Personal communication. Dec. 1995.

Watson, G. 1991. Analysis of fine sediment and dissolved oxygen in spawning gravels of the upper Yakima River Basin. Final Report, Washington Dept. of Fisheries and Washington Dept. Ecology.

Watson, V.J. 1989. Maximum Levels of Attached Algae in the Clark Fork River. Proceedings of the Montana Academy of Sciences.

Watson, V.J. 1989a. Dissolved oxygen in the upper Clark Fork River, Summer 1987. Rept. of Montana Dept. Fish, Wildlife, and Parks. Submitted to Proc. Montana Acad. of Sci. 49:146-162.

Watson, V.J. 1989b. Dissolved oxygen in the middle Clark Fork River, Summer 1987. Rept. to the city of Missoula. Submitted to Proc. Montana Acad. Sci. pp.287-97.

Watson V.J., Berlind, and Bahls. 1990. Control of Algal Standing Crop By P and N In the Clark Fork River. Proceedings of the Clark Fork River Symposium. April 20, 1990. University of Montana. Missoula, MT.

Watson, V.J. 1995. Professor of Environmental Studies. University of Montana. Personal Communication. Nov. 1995.

Watson, V.J. and B. Gestring, 1996. Monitoring algae levels in the Clark Fork River. Intermountain J. Sci. 2(2):17-26.

Weaver, T. M., Fraley, J. 1991. Fisheries habitat and fish populations. Flathead basin forest practices, water quality and fisheries copperative program. Kalispell, MT: Flathead Basin Commission.

Weaver, T. 1985. Effects of sediment introduction on the eggs and aliveness of bulltrout under field and laboratory conditions. In: D.D. MacDonald, editor. Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

Weber, C.I. 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. Report. No. EPQ-670/4-73-001. USEPA, Cincinnatti.

Weber, E.E. 1986. Algal concentrations in the Clark Fork River. unpublished. Montana Dept. of Health and Environmental Sciences. Helena, MT.

Weber, E.E. 1995. An Assessment of Biological Integrity and Impairment of Aquatic Life in the Clark Fork River and its Major Tributaries Based On the Structure and Composition of Algae Associations in the periphyton Community During August 1993. Phycologic. East Helena, Montana.

Weber, E.E. 1998. Clark Fork Basin Periphyton Monitoring: An assessment of Biological Integrity and Impairment Based on Algae Associations During August 1996. Prepared for the State of Montana Department of Environmental Quality Planning, Prevention and Assistance Division. Phycologic. East Helena, Montana.

Welch, E.B., J.M. Jacoby, R.R. Horner and M.R. Seeley. 1987. Nuisance biomass levels of periphytic algae in streams. Hydrobiologia. 157:161-8.

Williams, J.E., J.E. Johnson, D.A. Hendrickson, S. Contreras Balderas, J.D. Williams, M. Navarro-Mendoza, D.E. McAllister, and J.E. Deacon. 1989. Fishes of North America: endangered, threatened or of special concern, Fisheries (Bethesda) 14(6): 2-20.

Woessner et al. 1995. Executive Summary: Phase II Cumulative effects of domestic sewage disposal on groundwater of Missoula county: An analysis of carrying capacity. Dept. of Geology, Univ. of MT, Missoula MT.

Woods, P .F. 1991b. *Nutrient Load/Lake Response Model, Pend Oreille Lake, Idaho. 1989-90* U.S. Geological Survey, Boise, Idaho.

Woodley et al. 1993. Ecological Integrity and the management of ecosystems. Measuring Biological Integrity: Lessons from Streams. St. Lucie Press.

Woodward, D. F., W.G. Brumbaugh, A.J. DeLonay, E.E. Little, C.E. Smith, F.T. Barrows. 1995. Metals-contaminated benthic invertebrates in the Clark Fork River, Montana. Trans. Amer. Fisheries Society 123:51-62.

Woodward, D.F., A.M. Farag, H.L. Bergman, A.J. DeLonay, E. E. Little, C.E. Smith, F.T. Barrows. 1995. Metals-contaminated benthic invertebrates in the Clark Fork River Montana: effects on age-0 brown trout and rainbow trout. Can. J. Fish. Aquat. Sci. 52: 1994-2004.

Yates, M.V., C.P. Gerba and L.M. Kelley. 1985. Virus persistence in groundwater. Appl. Envir. Microbiol. 49(4): 778-781.

Yoder, C.O. 1990. Some questions and concerns about biological criteria based on experiences in Ohio. Ohio EPA, Colubus, OH. As reported in Karr 1993.

Yount J.D. & Niemi, G.J. 1990. Recovery of lotic communities from disturbance - a narrative review of case studies. Environmental Management. 14: 547-569.