Yellowstone Cutthroat Trout Restoration in Sage Creek

Draft Environmental Assessment

April 25, 2008

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Montana Fish, Wildlife & Parks

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List of Abbreviations

BLM	Bureau of Land Management
DEGEE	Diethyl glycol monoethyl ether
DEQ	Montana Department of Environmental Quality
EA	Environmental assessment
EPA	Environmental Protection Agency
FWP	Montana Fish, Wildlife & Parks

$KMnO_4$	Potassium permanganate
MCA	Montana Code Annotated
MOU	Memorandum of understanding
MSDS	Material data safety sheet
NHP	Montana Natural Heritage Program
PEG	Polyethylene glycol
Ppm	Parts per million
USFS	US Forest Service
USFWS	US Fish and Wildlife Service

Executive Summary

Sage Creek is a small stream in the Pryor Mountains that historically supported native Yellowstone cutthroat trout, a species of special concern, and focus of considerable recovery efforts. Montana Fish, Wildlife & Parks, the Crow Tribe, the Bureau of Indian Affairs, the US Fish and Wildlife Service, and the US Forest Service are collaborating on a proposed Yellowstone cutthroat trout reintroduction project that would return Yellowstone cutthroat trout to these waters. Currently, the fishery in Sage Creek consists of non-native rainbow and brook trout, which are incompatible with native cutthroat trout. Therefore, a significant component of the project would involve removing the existing fishery using rotenone, a piscicide or fish toxicant commonly used in these projects.

This document is an environmental assessment (EA) of the potential impacts of the piscicide project on the physical and human environment. EAs are a requirement of the Montana's Environmental Policy Act (MEPA). This act requires state agencies to consider the environmental, social, cultural, and economic impacts of proposed activities.

Evaluation of the impacts of piscicide treatment of Sage Creek found this project would have minor, temporary impacts on the environment, and no effects on social, cultural, or economic considerations. The most significant effect would be elimination of a non-native fishery, and replacement by native Yellowstone cutthroat trout.

MEPA also requires public involvement and opportunity for the public to comment on projects undertaken by state agencies. A 30-day public comment period will extend from April 25, 2008 to May 25, 2008. A public meeting may occur if public interest in the project warrants this additional forum. Interested parties should send comments to:

Ken Frazer
Montana Fish, Wildlife & Parks
2300 Lake Elmo Drive
Billings, MT 59105
(406) 247-2963
kfrazer@mt.gov

1.0 PROPOSED ACTION DESCRIPTION

1.1. Type of Proposed Action

This proposed action is part of native fish restoration efforts aimed at increasing and securing Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) in its historic range in Montana. The Sage Creek trout reintroduction project would chemically remove non-native brook (*Salvelinus fontinalis*) and rainbow trout (*O. mykiss*) in Sage Creek (Figure 1) using the piscicide rotenone. Subsequent to successful removal of non-native fish, pure strain Yellowstone cutthroat trout would be reintroduced into these waters. This proposed action consists of 2-4 phases (depending upon success of removal) to be conducted during the years 2008 to 2012 as a part of an ongoing attempt to protect and ensure the survival of the reintroduced population.

1.2. Agency Authority for Proposed Action

Authority to conduct the proposed actions comes from the Montana Administrative Code, (87-1-702). Specifically, this statue authorizes Montana Fish, Wildlife & Parks "to perform such acts as may be necessary to the establishment and conduct of fish restoration and management projects.

1.3. Name and Location of Project

Sage Creek Native Yellowstone Cutthroat Trout Reintroduction Project. Sage Creek is an isolated drainage near Bridger, Montana in Carbon County. This stream flows from private in holdings within the Custer National Forest, through Crow Reservation and Bureau of Land Management administered lands, private lands and into Wyoming. The proposed treatments would affect the upper 10 miles of stream including its two headwater forks, the North and South forks (Figure 1). The reach proposed for treatment is entirely on private lands surrounded by the Custer National Forest and the Crow Indian Reservation.

1.4. Name and Address of Project Sponsor

Ken Frazer
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2300 Lake Elmo Drive
Billings, MT 59105
(406) 247-2963
kfrazer@mt.gov

1.5. Estimated Commencement Date and Schedule

This project would ensue in several phases (see Figure 1 for spatial extents of various phases). The initial phase would be treatment of the upper 1.1 miles of Sage Creek in late summer to early fall of 2008. The second phase (2009) will involve piscicide treatment of the remaining 7.2 miles of the Sage Creek and its two forks, before the stream enters the Crow Indian Reservation. Reapplication of piscicide would occur in the upper 1.1 miles, if the treatment did not result in complete removal of fish. Biologists will determine the need for additional treatments in 2010 through 2011 by electrofishing. If fish are found, an additional treatment would occur.

1.6. Location Affected by Proposed Action

Sage Creek flows through Big Horn County to the Wyoming border and is a headwater stream in the Shoshone River hydrologic unit (10080014). The project would occur in T7S, R 26 E, sections 19 through 31, and T7S, R27 E, sections 19, 20, 30, and 31.

1.7. Project Size (Acres Affected)

	Acres		Acres
(a) Developed	0	(d) Floodplain	0
Residential	0		
Industrial	0	(e) Productive	0
		Irrigated cropland	0
		Dry cropland	0
(b) Open space/Woodlands/Recreation	0	Forestry	0
		Rangeland	0
(c) Wetlands/Riparian areas	10	Other	0

1.8. Map of Project Area

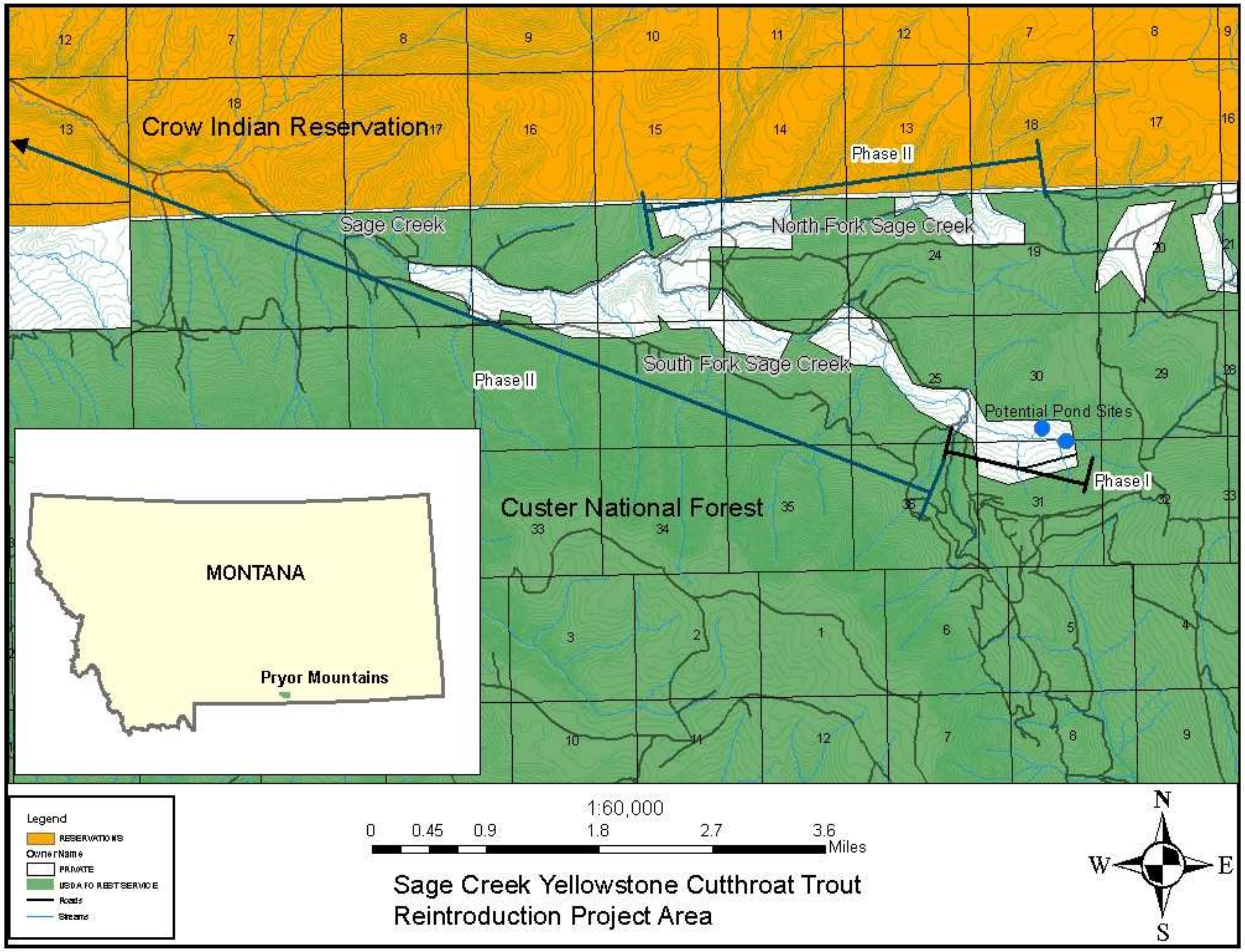

Figure 1: Map of project area

1.9. Listing of Local, State, or Federal Agency That Has Overlapping or Additional Jurisdiction.

(a) Permits:

Agency Name:	Montana Department of Environmental Quality
Permit :	308 Authorization
Date Filed/#:	pending

(b) Funding:

Agency Name:	US Forest Service
Funding Amount:	$5000
Agency Name:	Montana Fish, Wildlife & Parks: Future Fisheries Improvement Program
Funding Amount	$8000

(c) Other Overlapping or Additional Jurisdictional Responsibilities:

Agency Name:	Montana Fish, Wildlife & Parks
Type of Responsibility:	Management of fisheries resources, including recovery of native species

1.10. Narrative Summary of the Proposed Action and Purpose of the Proposed Action.

This action is a native fish restoration project aimed at reestablishing a pure Yellowstone cutthroat trout population in Sage Creek, a headwater stream in the Shoshone River watershed, within the Yellowstone River basin (Figure 1). The Yellowstone cutthroat trout is native to Montana and several neighboring states: Wyoming, Idaho, Utah, and Nevada. In Montana, Yellowstone cutthroat trout historically occupied streams and lakes in the Yellowstone River watershed having suitable habitat, water quality, and thermal regime. Like many native salmonids, Yellowstone cutthroat trout have experienced dramatic declines in abundance and range. Conservation populations of Yellowstone cutthroat trout (> 90% genetically pure) now occupy about 43% of its historic range in Montana (May et al. 2007) with the western portion of the Yellowstone River basin being the stronghold. In the Shoshone River watershed, only 2% of historically occupied habitat currently supports Yellowstone cutthroat trout (May et al. 2007). Reintroduction of Yellowstone cutthroat trout to streams where they have been extirpated, such as Sage Creek, is one component of the overall strategy to restore this native fish (FWP 2000 and 2007).

An understanding of the threats to the persistence of Yellowstone cutthroat trout and its conservation status supports the rationale for this proposed action. Reductions in Yellowstone cutthroat trout populations are the result of several factors. Introduction of non-native fishes is perhaps the greatest threat to this sub-species (Gresswell 1995, Kruse et al. 2000). Brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) have displaced native cutthroat trout, including Yellowstone cutthroat trout, throughout the western US (Behnke 1992). Rainbow trout (*O. mykiss*) hybridize with Yellowstone cutthroat trout, resulting in a loss of genetic integrity.

Often, where these species coexist, hybridization occurs (Allendorf and Leary 1988, Henderson et al. 2000). Hybridization is a leading cause of loss of Yellowstone cutthroat trout populations (Kruse and Hubert 2004). The combined threats of hybridization, competition, and predation provide justification for removal of non-native species to increase the probability of persistence of reintroduced populations of Yellowstone cutthroat trout.

Habitat degradation is another category of disturbance linked to decreases in Yellowstone cutthroat trout populations. Types of habitat degradation include decreased channel and stream bank stability, increased streambed siltation, and reduced health and function of riparian vegetation. These perturbations relate to a host of activities including excessive livestock pressure, streamside logging, and residential development. Fish passage barriers, such as dams, culverts, and irrigation diversions, have also contributed to declines, as some Yellowstone cutthroat trout populations have strong migratory tendencies, and restricting access to spawning, rearing, or overwintering habitats can have a population level effect. Dewatering poses another threat, especially in tributaries used for spawning, and can have far reaching implications for main stem fisheries.

Because reductions in range and abundance of Yellowstone cutthroat trout, state, federal, and tribal entities have assigned special status ratings to Yellowstone cutthroat trout, which guide management activities to promote conservation and restoration of this species. Montana lists Yellowstone cutthroat trout within its borders as an S2 species of special concern. This ranking applies to species "at risk because of very limited and potentially declining numbers, extent and/or habitat making it vulnerable to global extinction or extirpation (NHP and FWP 2006). Likewise, the Bureau of Land Management (BLM) and US Forest Service (USFS) consider Yellowstone cutthroat trout to be a sensitive species. BLM lists a species as sensitive when it is proven to be imperiled in at least part of its range and documented to occur on BLM lands (NHP and FWP 2006). The USFS applies sensitive status to species that the Regional Forester has determined concerns exist for population viability within the state relating to a significant current or predicted downward trend in population or habitat. Similarly, the Crow Tribe lists Yellowstone cutthroat trout as a species of special concern, citing the rarity of pure populations and potential to list Yellowstone cutthroat trout under the Endangered Species Act as rationale.

Conservation of native species on private lands is a vital component of promoting the persistence of these species. This project involves consultation and collaboration between FWP and private landowners on Sage Creek. The landowner at the headwaters of Sage Creek wishes to construct several ponds. Brook trout currently occupy the headwaters springs, but habitat is limited. The construction of these ponds will create improved habitat and brook trout would be likely to increase significantly in abundance. FWP has been working with this landowner to provide outlet structures that would prevent brook trout from entering ponds. The ponds will provide FWP an opportunity to reintroduce Yellowstone cutthroat trout into the headwaters of Sage Creek, to begin the recovery program. Other landowners have been consulted throughout the planning process to garner support for reintroduction of native Yellowstone cutthroat trout.

Concerns over the status of Yellowstone cutthroat trout have prompted advocacy groups to petition the US Fish and Wildlife Service to list this subspecies as a threatened or endangered species. In two separate decisions, the US Fish and Wildlife Service found listing Yellowstone cutthroat trout to be unwarranted, citing the presence of stable, viable, and self-sustaining populations throughout its historic range (USFWS 2001, USFWS 2006). Nonetheless, plaintiffs submitted a notice of intent to sue in 2006, indicating legal challenges are likely.

Sage Creek is particularly well suited for establishing a secure refuge for Yellowstone cutthroat trout. Chronic dewatering downstream of the targeted reach presents a barrier to expansion of competing species from below. Habitat quality is another factor. Sage Creek and its headwater tributaries are Rosgen C-type channels (Rosgen 1996), controlled by bedrock, and beaver dam complexes. Stable riffle/pool habitats and dense riparian vegetation characterize most of the stream. Excellent habitat and water quality support a thriving cold-water fishery comprised of brook trout and rainbow trout.

The same features promoting suitability of Sage Creek for reintroduction of Yellowstone cutthroat trout necessitate removal of the existing fishery with piscicide, rather than mechanical means. Notably, the quality and complexity of the habitat is a constraint to the efficacy of mechanical removal through electrofishing. Habitat complexity increases the refugia available to avoid capture. Moreover, the reproductive capacity of rainbow trout and brook trout in this stream is high, and these species would rebound quickly from the fish that eluded removal. Yellowstone cutthroat trout introduced into the stream would face competition from brook trout, and more importantly, introgression with rainbow trout, which would preclude attainment of a genetically pure population of Yellowstone cutthroat trout.

Habitat complexity also affects efficiency of piscicide. In reaches with simple habitat, only one treatment of piscicide may be required to eliminate the existing fishery. In other cases, two or more treatments would be required. The number of treatments would follow results of fish sampling efforts to minimize piscicide application events, while ensuring complete removal. Even with the need for more than one treatment, piscicide is more cost effective than electrofishing in removing fish.

The proposed piscicide for this action is CFT Legumine™, a relatively new formulation using rotenone as the active ingredient. CFT Legumine™ has several advantages over other formulations of rotenone, including a new emulsifier and solvent that reduce the presence of petroleum hydrocarbon solvents. The hydrocarbons in other rotenone formulations are highly volatile, resulting in a distinct chemical odor during treatment. Fish may be able to detect the hydrocarbons in other formulations, and avoid treated waters, resulting in incomplete fish kills. Because of the lack of hydrocarbons, the new formulation is expected to have fewer of these drawbacks.

Application of piscicide would follow established methodologies, consistent with the product's labeling, as required by federal law. The general approach to piscicide application is as follows. Piscicide is applied to achieve a concentration of 1 ppm of rotenone. A gravity fed, constant head drip station (Figure 2) delivers diluted chemical at a rate calculated from the instructions. Drip stations are allowed to run for at least 8 hours. Application of piscicide to backwater areas or areas not connected to the main creek entails the use of backpack sprayers.

Breakdown of rotenone is related to a number of factors, such as water chemistry (pH, alkalinity), temperature, and turbulence, which affects the required drip station spacing. In general, drip stations would likely be spaced ¼ to 1 mi apart; the required distance would be determined through a bioassay. A bioassay is a trial run, where the chemical is applied to the target water or one of its tributaries and allows determination of the distance the chemical would travel and effectively produce a 100% fish kill (termed travel time). Drip station spacing would follow the results of a bioassay investigation along Sage Creek to ensure adequate application of piscicide along the stream's length.

Figure 2: Example of a drip station used to deliver piscicide to streams.

Travel of rotenone beyond the target reach would be unlikely, as severe dewatering downstream of the project is typical during late summer, the proposed timing for piscicide application. In the event that water is present, or control of the downstream extent of treatment is necessary, detoxification stations stocked with potassium permanganate ($KMnO_4$) would be used. $KMnO_4$, a highly soluble crystalline powder, quickly detoxifies rotenone. $KMnO_4$ is commonly used in water treatment to oxidize metals, kill bacteria and viruses, and remove unpleasant tastes.

Use of a detoxification station at the confluence with the North Fork Sage Creek (Figure 1) would be used in the first phase of piscicide treatment to control the downstream extent of toxic concentrations of rotenone. The intent of this action is to allow continued recreational uses of Sage Creek near the US Forest Service campground during the first year of treatment.

Sentinel or caged fish would indicate the need for application of $KMnO_4$ to Sage Creek. Observers would monitor the behavior of caged fish at the lower end of treatment reaches. If these fish show evidence of toxicity, such as loss of equilibrium or death, $KMnO_4$ would be added to the water to detoxify the remaining rotenone, and limit the downstream effect of piscicide treatment.

Efforts to reintroduce Yellowstone cutthroat trout to Sage Creek would entail several phases involving initial piscicide treatment, and re-treatment of areas where chemical removal was incomplete. Fish removal efforts would begin in the headwaters, and proceed downstream. The proposed spatial scope of this project extends from the headwaters of Sage Creek to the Crow Tribe reservation boundary. Continued, similar conservation efforts to restore Yellowstone cutthroat trout are likely on the Crow Tribe Reservation.

In summary, the primary benefit of this project would be restoration of a genetically pure Yellowstone cutthroat trout population. Major components of the project would include removal non-native brook trout and rainbow trout, which pose significant threats to the persistence of Yellowstone cutthroat trout, and reintroduction of pure Yellowstone cutthroat trout. Ultimately, this project would expand the distribution and safeguard Yellowstone cutthroat trout in south central Montana. In turn, this project would help achieve the goals and objectives listed in the MOU and conservation agreement for Yellowstone cutthroat trout in Montana (FWP 2007) and provide protection consistent with the Montana Administrative Code. Implementation of this and other similar projects would reduce the threats of extinction for Yellowstone cutthroat trout. The social benefit of this effort would be the ability of future generations of Montanans to use and enjoy this important component of Montana’s natural heritage.

1.11. Agencies Consulted during Preparation of the EA

Agency consultation was considerable during preparation of the EA, and included signatories of the cutthroat trout restoration strategy and MOU (FWP 2007). The Montana Department of Environmental Quality (DEQ) was consulted, both as a signatory on the MOU, and the agency responsible for water quality permits. Other agencies were landholders in the basin, including the USFS Custer National Forest and the Crow Tribe, who were also collaborators in the process.

State statute provides clear direction to FWP to implement conservation projects for species with potential to be listed under the Endangered Species Act. Specifically, the Montana Code (MCA 87-1-201 [9ai]) requires FWP to manage fish, wildlife, game, and non-game animals in a manner that prevents the need for listing under state law or the federal Endangered Species Act. Further, FWP has the responsibility to manage species that have potential for listing in a manner that assists in the maintenance or recovery of those species. The Sage Creek Yellowstone cutthroat trout restoration project would return this sensitive, native fish to its historically occupied waters, which is consistent with FWP’s responsibilities under state law.

Conservation of Yellowstone cutthroat trout is a priority for fisheries managers across state, federal, and tribal entities. In 2007, the Montana Cutthroat Trout Steering Committee completed a memorandum of understanding (MOU) and conservation agreement for Yellowstone cutthroat trout and westslope cutthroat trout (FWP 2007), which replaces an expired MOU and conservation strategy for Yellowstone cutthroat trout (FWP 2000). The goals of both documents include the following: 1) ensure the long-term, self-sustaining persistence of each subspecies distributed across their historic ranges, 2) maintain the genetic integrity and diversity of non-introgressed (genetically pure) populations, and 3) protect the ecological, recreational, and economic values of each subspecies. Signatories of this MOU include several of the collaborators on this project: FWP, the Custer National Forest, and Crow Tribe. This project is consistent with the goal of ensuring the long-term persistence of Yellowstone cutthroat trout, and the signatories' commitment to finding collaborative opportunities to restore and expand populations of Yellowstone cutthroat trout within their historic range.

This project is also consistent with USFS management plans for Yellowstone cutthroat trout. The Custer National Forest's management standards for wildlife and fisheries management mandate the following:

> "[M]anage the land to maintain at least viable populations of existing native and desirable non-native vertebrate species, promote the conservation of federally listed threatened and endangered species, and coordinate with appropriate state, federal, and private agencies in the management of habitats for major interest species" (USDA 1986).

Additionally, the Custer Forest Plans standards for management of fisheries resources include the following directives:

1. Fish species and habitats will be managed in cooperation with state and other federal agencies.
2. An inventory will be made of warm and cold water fisheries potential. In suitable areas, activities will be designed to maintain, develop, or create cold and warm water fisheries. Streams and lakes supporting pure strains of fish species will be managed to maintain or expand these populations.

The Crow Tribe also has a stated commitment to conservation of Yellowstone cutthroat trout, both through its inclusion in the MOU, and a joint action resolution aimed at conserving Yellowstone cutthroat trout populations within the reservation (Joint Action Resolution No. JAR0231). The resolution requires protection of Yellowstone cutthroat trout through conservation practices until scientific evidence warrants it no longer needs protection. As Yellowstone cutthroat trout reintroduction activities would extend downstream onto the Crow Indian Reservation, the Crow Tribe is among the collaborators on the Sage Creek Yellowstone cutthroat trout reintroduction efforts.

The Montana Natural Heritage Program (NHP) was another agency consulted in the process of preparing this EA. Queries included requests for information on distribution and natural history of numerous species.

2.0 ENVIRONMENTAL REVIEW

This chapter examines potential risks to human health and the environmental that would occur with implementation of the proposed alternative, application of piscicide to Sage Creek, and the alternative of no action. For more information on selection of alternatives, see 3.0 ALTERNATIVES.

2.1. Physical Environment

2.1.1. Land Resources

Land Resources **Would the proposed action result in:**	**Impact** **Unknown**	**None**	**Minor**	**Potentially Significant**	**Can Impact Be Mitigated**	**Comment Index**
a. Soil instability or changes in geologic substructure?		X				
b. Disruption, displacement, erosion, compaction, moisture loss, or over-covering of soil which would reduce productivity or fertility?		X				
c. Destruction, covering or modification of any unique geologic or physical features?		X				
d. Changes in siltation, deposition or erosion patterns that may modify the channel of a river or stream or the bed or shore of a lake?		X				
e. Exposure of people or property to earthquakes, landslides, ground failure, or other natural hazard?		X				

2.1.2. Air

Air **Would the proposed action result in:**	**Impact** **Unknown**	**None**	**Minor**	**Potentially Significant**	**Can Impact Be Mitigated**	**Comment Index**
a. Emission of air pollutants or deterioration of ambient air quality?		X				
b. Creation of objectionable odors?			X			2b
c. Alteration of air movement, moisture, or temperature patterns or any change in climate, either locally, or regionally?		X				
d. Adverse effects on vegetation, including crops, due to increased emissions of pollutants?		X				
e. Exposure of people or property to earthquakes, landslides, ground failure, or other natural hazard?		X				

Comments on 2b:
Alternative 1: Proposed Action
According to the material safety data sheet (MSDS) for CFT Legumine™ (Appendix A), this compound has a slight solvent odor. Respiratory protection is required when working with undiluted product in a confined space. Likewise, the MSDS for n-methylpyrrolidone, an emulsifying agent in CFT Legumine™ does not require respiratory protection when handling in a well-ventilated area. As CFT Legumine™ will be applied outside, the objectionable solvent odor will likely dissipate rapidly, presenting a minor and temporary creation of objectionable odors. Note that field personnel with experience applying CFT Legumine™ indicate it is far less disagreeable than other formulations of rotenone.

Alternative 2: No Action
This alternative would not result in creation of objectionable odors, and would have no impact.

2.1.3. Water

Water **Would the proposed action result in:**	**Impact** **Unknown**	**None**	**Minor**	**Potentially Significant**	**Can Impact Be Mitigated**	**Comment Index**
a. Discharge into surface water or any alteration of surface water quality including but not limited to temperature, dissolved oxygen or turbidity?			X		YES	3a
b. Changes in drainage patterns or the rate and amount of surface runoff?		X				
c. Alteration of the course or magnitude of flood water or other flows?		X				
d. Changes in the amount of surface water in any water body or creation of a new water body?		X				
e. Exposure of people or property to water related hazards such as flooding?		X				
f. Changes in the quality of groundwater?		X				3f
g. Changes in the quantity of groundwater?		X				
h. Increase in risk of contamination of surface or groundwater?			X		YES	see 3f
i. Effects on any existing water right or reservation?		X				
j. Effects on other water users as a result of any alteration in surface or groundwater quality?			X		YES	3j
k. Effects on other users as a result of any alteration in surface or groundwater quantity?		X				
l. Would the project affect a designated floodplain?			X		YES	3l
m. Would the project result in any discharge that would affect federal or state water quality regulations? (Also see 2a)			X		NO	See 3a

Comments 3a: Discharge into surface waters
Alternative 1: Proposed Action
As this project proposes discharge of a piscicide into Sage Creek, this impact would be unavoidable. Nonetheless, discussion of the nature of the piscicide, physical setting, and mitigative actions provide a framework to predict the severity and spatial extent of the impacts.

Rotenone is an insecticide commonly used in agriculture and home gardening, as well as being an effective piscicide. Compared to other piscicides, rotenone is relatively inexpensive and accessible, and has been routinely used to remove unwanted fish from lakes and streams. Rotenone acts by blocking the ability of tissues to use oxygen, which causes fish to asphyxiate quickly.

CFT Legumine™, is the rotenone formulation proposed for this project. This chemical is registered by the EPA (Reg. No. 75338-2) and approved for use as a piscicide. Information on its chemical composition, persistence in the environment, risks to human health, and ecological risks come from a number of sources including material data safety sheets (MSDS) and manufacturer's instructions. (A MSDS is a form detailing chemical and physical properties of a compound, along with information on safety, exposure limits, protective gear required for safe handling, and procedures to handle spills safely.) In addition, a recent study presented an analysis of major and trace constituents in CFT Legumine™, evaluated the toxicity of each, and examined persistence in the environment (Fisher 2007).

The MSDS for CFT Legumine™ list three categories of ingredients for this formula (Table 1). Rotenone comprises 5% of CFT Legumine™ by weight. Associated resins account for 5%, and the remaining 90% are inert ingredients, of which the solvent n-methylpyrrolidone is a component. Additional information in the MSDS confirms its extreme toxicity to fish. The TVL applies to risks to human health from exposure, which is addressed in 8a.

Table 1: Composition of CFT Legumine™ from material safety data sheets (MSDS)

Chemical Ingredients	Percentage by Weight	CAS No.[1]	TLV[2] (Units)
Rotenone	5.00	83-79-4	5 mg/m^3
Other Associated Resins	5.00		
Inert Ingredients Including N-methylpyrrolidone	90	872-50-4	Not listed

[1]Chemical Abstracts Number
[2]A TLV reflects the level of exposure that the typical worker can experience without an unreasonable risk of disease or injury.

Fisher (2007) analyzed chemical composition of CFT Legumine™, including the inert fraction (Table 2). On average, rotenone comprised 5% of the formula, consistent with MSDS reporting. Other constituents were solvents or emulsifiers added to assist in the dispersion of the relatively insoluble rotenone. DEGEE, or diethyl glycol monoethyl ether, a water soluble solvent, was the largest fraction of the CFT Legumine™ analyzed. Likewise, methylpyrrolidone comprised about 10% of the CFT Legumine™. The emulsifier Fennedofo 99™ is an inert additive comprised of fatty acids and resin acids (by-products of wood pulp and common constituents of soap formulations), and polyethylene glycols (PEGs), which are common additives in consumer products such as soft drinks and suntan lotions. Trace constituents included low concentrations several forms of benzene, xylene, and naphthalene. These organic compounds were considerably lower than measured in Noxfish, another commercially available formulation of rotenone, which uses hydrocarbons to disperse the piscicide.

Table 2: Average percent concentrations and ranges of major constituents in CFT Legumine™ lots to be used in a piscicide project in California (Fisher 2007).

Major CFT Legumine™ Formula Constituent	***Rotenone***	***Rotenolone***	***Methylpyrrolidone***	***DEGEE[1]***	***Fennedefo 99™***
Average %	5.12	0.718	9.8	61.1	17.1
Range	4.64-5.89	0.43-0.98	8.14-10.8	58.2-63.8	15.8-18.1

[1]diethyl glycol monoethyl ether

Toxicity to non-target organisms and persistence in the environment are key considerations in determining the potential risks to human health and the environment. Several factors influence persistence of rotenone and its toxicity to fish. Rotenone has a half-life of 14 hours at 24 °C, and 84 hours at 0 °C (Gilderhus et al. 1986, 1988), meaning that half of the rotenone is degraded and is no longer toxic in that time. As temperature and sunlight increase, so does degradation of rotenone. Higher alkalinity (>170 mg/L) and pH (>9.0) also increase the rate of degradation. Limited alkalinity data exist for Sage Creek; however, two samples collected in the 1970s ranged from 184 to 205 mg/L (STORET database), which would favor rapid breakdown of rotenone. Rotenone tends to bind to and react with organic molecules rendering it ineffective, so higher concentrations are required in streams with increased amounts of organic debris. Trophic status of Sage Creek is unknown; however, available information does not suggest significant retention of organic matter. Without detoxification, rotenone would be reduced to non-toxic levels in one to several days due to its degradation and dilution in the aquatic environment.

Concentration of rotenone in treated waters is another factor relating to potential effects from incidental ingestion by other organisms, including humans. The effective concentration of rotenone is 1 ppm or 1 mg/L, which is well below concentrations harmful to humans from ingestion. The National Academy of Sciences suggested concentrations at 14 ppm would pose no adverse effects to human health from chronic ingestion of water (NAS 1983). Moreover, concentrations associated with acute toxicity to humans are 300-500 mg per kilogram of body weight (Gleason et al. 1969), which means a 160-pound person would have to drink over 23,000 gallons in one sitting to receive a lethal dose (Finlayson et al. 2000). Similarly, risks to wildlife from ingesting treated water are low. For example, ¼ pound bird would have to consume 100 quarts of treated water, or more than 40 pounds of fish and invertebrates within 24 hours for a lethal dose (Finlayson et al. 2000). In summary, this project would have no adverse effect on humans or wildlife associated with ingesting water, dead fish, or dead invertebrates.

Bioaccumulation of rotenone would not result in threats to human health and the environment under this alternative. Rotenone can bioaccumulate in the fat tissues of fish that are not exposed to toxic levels (Gingerich and Rach 1985). As a complete fish-kill is the goal, bioaccumulation would not be a problem.

Potential toxicity and persistence of the other constituents of the CFT Legumine™ formulation are additional considerations. Proposed concentrations of n-methylpyrrolidone (about 2 ppm) would have no adverse effects to humans ingesting treated waters. According to the MSDS, ingestion of 1000 ppm per day for three months does not result in deleterious effects to humans. In addition, n-methylpyrrolidone will not persist in surface waters given its high biodegradability. In fact, this feature, combined with its low toxicity, makes n-methylpyrrolidone an ecologically attractive solvent for use in wastewater treatment plants.

Fisher (2007) examined the toxicity and potential persistence of other major constituents in CFT Legumine™, including DEGEE, fatty acids, PEGs, and trace organic compounds, (benzene, xylene, naphthalene). With proposed application of CFT Legumine™, none of these compounds would violate water quality standards, nor would they reach concentrations shown to be harmful to wildlife or humans. Furthermore, persistence of these chemicals was not a concern. The trace organics would degrade rapidly through photolytic (sunlight) and biological mechanisms.

Likewise, the PEGs would biodegrade in a number of days. The fatty acids are also biodegradable, but would persist longer than the PEGs or benzenes. Nonetheless, these are not toxic compounds, so the relatively longer persistence would not adversely affect water quality. Overall, the low toxicity, low persistence, and lack of bioaccumulation indicate the inert constituents in CFT Legumine™ would have a minor and temporary effect on water quality.

Examination of the risks associated with use of the $KMnO_4$, the oxidizer used in detoxifying treated waters, indicate temporary and minor changes in water quality would occur with the use of this compound. $KMnO_4$ breaks down into potassium, manganese, and water, which are common constituents in surface waters, and have no deleterious effects at the concentrations used (Finlayson et al. 2000).

The physical setting and several mitigative activities would limit the spatial extent of the fish kill to the project reach. Summer low flows and significant dewatering are substantial factors that would limit toxicity to the project reach. Lack of stream flow below the target reach means rotenone would not be transported beyond the project boundary. In addition, chemical detoxification through application of $KMnO_4$, at the downstream end of phase 1 would limit the spatial extent of the fish kill.

To reduce the potential risks associated with the use of CFT Legumine™, the following management practices, mitigation measures, and monitoring efforts would be employed:

1. A pre-treatment bioassay would be conducted to determine the lowest effective concentration and travel time.
2. Piscicides would be diluted in water and dripped into the stream at a constant rate using a device that maintains a constant head pressure.
3. A detoxification station would be set up downstream of the target reach. Potassium permanganate ($KMnO_4$) would be used to neutralize the piscicide at this point.
4. Project personnel would be trained in the use of these chemicals including the actions necessary to deal with spills as prescribed in the MSDS for CFT Legumine™
5. Persons handling the piscicide would wear protective gear consistent exposure control/personal protection gear as prescribed in the MSDS for CFT Legumine™.
6. Only the amount of piscicide and potassium permanganate that is needed for immediate use would be held near the stream.
7. Before the use of piscicides, livestock permittees and local landowners would be notified. At the discretion of the permittee or landowner, project personnel would assist with removing livestock from the stream area temporarily when rotenone is applied.
8. Sentinel (fish in a cage) fish would be located below the detoxification station and within the target reach to determine and monitor the effectiveness of both the rotenone and potassium permanganate. Yellowstone cutthroat trout obtained from a state hatchery would be the species used in monitoring toxicity.

Alternative 2: No Action
This alternative would have not result in discharge into surface water and would have no impact.

Comment 2f: Changes in groundwater quality

Alternative 1: Proposed Action

The risk that rotenone would enter and be mobile in groundwater is minimal because it has a strong tendency to bind to organic soil particles (Dawson et al. 1991), and has a low solubility in water. Once bound to organic molecules, rotenone becomes inert and breaks down quickly in the environment without detoxification. Moreover, rotenone would be detoxified with $KMnO_4$ at the downstream boundary of the project. Even if groundwater contamination did occur, no consequences for human health would occur because the surface water concentrations to be used in this project have already been shown to have no toxic effect on humans or other mammals (see 2a). Furthermore, the chance for exposure to rotenone is minimal given the location of domestic water sources. The following factors suggest very little, if any, rotenone would reach any wells:

1. Virtually all piscicide that reaches these points would have already been broken down by natural conditions or been oxidized by KMnO4;
2. Any remaining piscicide would likely be bound up by sediments before entering groundwater; and
3. Any piscicide that enters groundwater would be diluted by water already present in the aquifer.

Alternative 2: No Action

This alternative would have no impact of groundwater.

Comment 2j: Effects on other water users

Alternative 1: Proposed Action

Application of rotenone would have a minor, temporary effect on other users. According to the CFT Legumine™ label, water treated with rotenone cannot be used to irrigate crops. This would result in a temporary restriction on this use, given the rapid breakdown of rotenone and the short duration of piscicide application in Sage Creek. Contact recreation, or swimming, in rotenone treated water is not allowable until all the piscicide has been thoroughly mixed into the water according to labeling instructions.

Field personnel would ensure compliance with these minor and temporary requirements. The area would be posted with signs designating the water temporarily off-limits to swimming. Irrigators would be apprised of the temporary unsuitability of treated waters for irrigation, and informed when the piscicide application was complete and no long effecting Sage Creek. Timing application to late summer or early fall limits the effect on irrigators, as many will likely have shut down operations by that time.

Effects on recreational uses associated with a public campground would be limited to later phases with use of the detoxification station. Detoxifying treated water at the confluence of the North Fork of Sage Creek would result in no restrictions in contact recreation or fishing during the first phase of treatment.

Alternative 2: No action.

This alternative would have no effect on other users.

2.1.4. Vegetation

Vegetation **Would the proposed action result in:**	**Impact** **Unknown**	**None**	**Minor**	**Potentially Significant**	**Can Impact Be Mitigated**	**Comment Index**
a. Changes in the diversity, productivity or abundance of plant species (including trees, shrubs, grass, crops, and aquatic plants)?			X			4a
b. Alteration of a plant community?		X				
c. Adverse effects on any unique, rare, threatened, or endangered species?		X				4c
d. Reduction in acreage or productivity of any agricultural land?		X				
e. Establishment or spread of noxious weeds?			X		YES	4e
f. Would the project affect wetlands, or prime and unique farmland?		X				

COMMENT 4a: Changes in diversity, productivity, or abundance of plants.
Alternative 1: Proposed Action
Field personnel would contribute to minor trampling of vegetation along the stream corridor and campsites. These effects would be short term and minor.

Alternative 2: No action.
This alternative would have no effect on vegetation.

COMMENT 4c: Effects on any unique, rare, threatened, or endangered species.
The NHP maintains a database detailing presence and status of species of special concern, including unique, rare, threatened, or endangered species. Included in this information is ranking information that details state and range-wide status of plants and animals (Table 3). Potential threats to plants of concern would be surface disturbance associated with trampling by fish crews.

Table 3: NHP's ranking system (G = global or range wide, S = state or within Montana

Code	*Description*
G1 S1	At high risk because of extremely limited and/or rapidly declining numbers, range, and/or habitat, making it highly vulnerable to global extinction or extirpation in the state.
G2 S2	At risk because of very limited and/or declining numbers, range, and/or habitat, making it vulnerable to global extinction or extirpation in the state.
G3 S3	Potentially at risk because of limited and/or declining numbers, range, and/or habitat, even though it may be abundant in some areas.
G4 S4	Uncommon but not rare (although it may be rare in parts of its range), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern.
G5 S5	Common, widespread, and abundant (although it may be rare in parts of its range). Not vulnerable in most of its range.
B	Breeding population in Montana
T	Infraspecific Taxon (trinomial) —The status of infraspecific taxa (subspecies or varieties) are indicated by a "T-rank" following the species' global rank.

Three plants of special concern are known to occur within or adjacent to the Sage Creek watershed (Table 4). Both the beartooth large-flowered goldenweed and the Cary's beardtongue are endemic to the Pryor Mountains. Their restricted native distribution provides the rationale for inclusion as species of special concern. Both species are typical of uplands, and would be unlikely to be encountered by fish crews operating near the stream. The goldenweed is likely tolerant of mechanical disturbance as it benefits from livestock grazing.

Jove's buttercup has been observed in the adjacent Crooked Creek watershed, which suggests its occurrence in the Sage Creek watershed is possible. Nonetheless, suitable habitat for this species includes sagebrush grasslands and open forest slopes, so field crews working streamside would be unlikely to encounter this plant. In addition, this plant completes its sensitive reproductive stages (flowering and fruiting) by early June.

Overall, potential impacts to sensitive plant species would be negligible. All three species tend to occur in uplands; whereas, the bulk of the activity would occur immediately adjacent to the stream. Nevertheless, field personnel would be provided field guide information on these special plants to avoid inadvertent impacts during application of piscicide.

Table 4: Plant species of special concern known to occur in or adjacent to the Sage Creek watershed.

Common Name	***Scientific Name***	***Natural Heritage Ranks***	***Known Distribution***
Beartooth large-flowered goldenweed	*Haplopappus carthamoides* var. *subsquarrosus*	State: S1S2 Global:G4G5T2T3	Occurs in Sage Creek drainage (T7S, R26E, Section 30)
Cary's beardtongue	*Penstemon caryi*	State:S3 Global: G3	Occurs adjacent to Sage Creek drainage (T7S, R27E, Section 31)
Jove's buttercup	*Ranunculus jovis*	State: S2 Global: S4	Occurs adjacent to Sage Creek drainage (T7S, R27E, Section 32)

Alternative 2: No action.
This alternative would have no effect on rare or sensitive plant species.

COMMENT 4e: Establishment or spread of noxious weeds
Alternative 1: Proposed Action
Trucks and four wheelers transporting gear and personnel have potential to spread noxious weeds from seeds transported in the undercarriage. To mitigate and reduce the risk of invasion or spread of noxious weeds, all vehicles would be cleaned before arrival on site, including an undercarriage wash. If access is allowed through private lands by 4-wheeled vehicles, a power washer would be set up to wash the vehicles before entering the area.

Alternative 2: No action.
This alternative would have no effect on spread on establishment or spread of noxious weeds.

2.1.5. Fish and Wildlife

Fish and Wildlife **Would the proposed action result in:**	**Unknown**	**Impact** **None**	**Minor**	**Potentially Significant**	**Can Impact Be Mitigated**	**Comment Index**
a. Deterioration of critical fish or wildlife habitat?		X				
b. Changes in the diversity or abundance of game animals or bird species?			X		YES	5b
c. Changes in the diversity or abundance of non-game species?			X		NO	5c
d. Introduction of new species into an area?		X				
e. Creation of a barrier to the migration or movement of animals?		X				
f. Adverse effects on any unique, rare, threatened, or endangered species?		X				5f
g. Increase in conditions that stress wildlife populations or limit abundance (including harassment, legal or illegal harvest or other human activity)?		X				
h. Would the project be performed in any area in which T&E species are present, and would the project affect any T&E species or their habitat? (Also see 5f)		X				
i. Would the project introduce or export any species not presently or historically occurring in the receiving location? (Also see 5d)		X				

Comment 5b: Changes in the diversity or abundance of game animals or bird species?
Alternative 1: Preferred Action
This proposed action would alter fish community composition in Sage Creek. Currently, this portion of Sage Creek supports non-native brook trout and rainbow trout. This project would remove these species; however, reintroduction of native Yellowstone cutthroat trout will mitigate loss of non-native salmonids.

As discussed in 2.1.3 Water, exposure to rotenone through ingestion of treated water or dead fish presents no threat to wildlife due to low toxicity. Nonetheless, reductions in aquatic prey species, both fish and sensitive macroinvertebrates, may have a negative effect on species relying on prey of aquatic origin. Evaluations of potential effects to game and bird species include examination of their seasonal occurrence within the project area, food habits, and availability of alternative food sources.

Mink (*Mustela vison*) are semi-aquatic predators, and the Sage Creek watershed is within their range in Montana. (Northern river otter [*Lontra canadensis*], another semi-aquatic predator, has an inferred range that encompasses the upper Sage Creek watershed; however, as a small stream, habitat suitability for otters is marginal at best.) As opportunistic predators, mink prey on a variety of terrestrial and aquatic species, including small mammals, birds, reptile, and amphibians, allowing flexibility in response to temporary reductions in fish abundance. Furthermore, the phased approach to piscicide application would result in the presence of fish-bearing reaches in Sage Creek for the first year. Overall, this project would have minor, temporary effects on mink.

Invertivorous birds would also have potential to be affected by reductions in macroinvertebrate populations. The American dipper (*Cinclus mexicanus*) is the species typically considered in effects analysis relating to rotenone treatment, as this species consumes benthic macroinvertebrates as its primary food source. The NHP does not extend the breeding range of the American dipper into the Pryor Mountains, although another source provides incidental evidence of dippers breeding in the general area (Bergeron et al. 1992). If present in the Sage Creek watershed, impacts on dippers would be minor and temporary. First, not all invertebrates would succumb to piscicide treatment, resulting in a remaining forage base in treated waters. In addition, the phased approach would result in presence of neighboring reaches with intact benthic communities. Finally, macroinvertebrate populations recover biomass rapidly following this type of disturbance, making the decrease in forage availability a short-term alteration.

A number of other wildlife species consume winged adult invertebrates of aquatic origin, including songbirds. Timing piscicide application towards late summer or early fall would reduce potential impacts on invertivorous birds for several reasons. Notably, by this time, most neotropical migrants will have begun their migrations south. Field guide information on common birds associated with streams indicate migration begins around August 20 and extends through early September (http://fieldguide.mt.gov/default.aspx) meaning few birds would still be in the area during piscicide treatment. In addition, as aquatic macroinvertebrates emerge throughout the spring and summer, the season's supply of winged adults would be largely depleted. The phased approach and select toxicity of rotenone are other features that will limit impacts on insectivorous birds. Combined, life history considerations of invertebrates and birds, along with the phased implementation, indicate this project would have a minor, temporary on songbirds that rely on aquatic invertebrates.

Birds consuming fish are another group with potential to be affected by this project. These include bald eagles (*Haliaetus leucocephalus*), osprey (*Pandion haliaetus*), and belted kingfishers (*Megaceryle alcyon*). Effects of the proposed project on these species would be an initial glut of available fish due to the fish kill, followed by reduced availability of fish until restocking occurs. Effects on bald eagles and osprey would likely be minor given their tendency to forage on larger streams. Elimination of fish in 10 miles of Sage Creek would have a more pronounced effect on belted kingfishers, which would find this stream unsuitable during the second and subsequent phases of piscicide treatment. However, neighboring drainages would still support fish, and belted kingfishers could recolonize from these areas following reintroduction of Yellowstone cutthroat trout. Overall, the effect of piscicide treatment on fish-eating birds would be minor and temporary.

Alternative 2: No Action
This alternative would have no impact on game or bird species.

Comment 5c: Changes in the diversity or abundance of non-game species?
Alternative 1: Proposed Action
In addition to the non-native game species targeted for removal, Sage Creek likely supports numerous vertebrates, primarily reptiles and amphibians, and associated aquatic life such as benthic macroinvertebrates. Rotenone is toxic to organisms that respire through gills, which

include fish, larval amphibians, and some macroinvertebrates such as mayflies, caddisflies, and stoneflies.

Detailed surveys of amphibian distribution are lacking for this part of Montana; however, several sources allow inference on the potential for species to occur in upper Sage Creek. First, range maps provided by the NHP's field guide provide a coarse indication of species potentially present. Next, examination of the database of observations maintained by the NHP allows identification of observations with the Sage Creek or neighboring drainages. Finally, habitat preference information allowed evaluation of the suitability for aquatic habitat in the project area to support adult or larval forms.

Amphibians with potential to occur in the project area include toads, frogs, and a salamander (Table 5). Plains spadefoot, boreal chorus frogs, and tiger salamanders have been observed in or near a reservoir on an unnamed tributary of Sage Creek, about 14 miles downstream of the project area. Although the reservoir may contribute to clustering of three species there, as some of the only public land in the lower drainage, this also represents an opportunity for state biologists to sample without needing permission, which contributes to clustering of observations. Northern leopard frogs have been observed in the Pryor Creek drainage, at an elevation similar to the project area. Woodhouse's toads have been frequently seen along the Clark's Fork of the Yellowstone, to the west of the Sage Creek drainage. Overall, amphibians likely to occur within Sage Creek probably make incidental use of the stream, as most prefer standing waters for breeding or foraging. Amphibians with the greatest potential for exposure to rotenone will be those using the seeps in the stream's headwaters, which may provide habitat for both adult and juvenile amphibians.

Table 5: Amphibians likely to occur in the Sage Creek watershed, timing for metamorphosis, and nearest observation to the Sage Creek Yellowstone cutthroat trout reintroduction project (information from NHP field guide.

Common Name	***Scientific Name***	***Metamorphosis Timing***	***Nearest Observation***
Plains spadefoot	*Spea bombifrons*	Variable	Sage Creek drainage
Woodhouse's toad	*Bufo woodhousii*	Tadpoles present to early September	Clark's Fork of the Yellowstone drainage
Boreal chorus frog	*Pseudacris maculatua*	8 weeks	Sage Creek drainage,
Northern leopard frog	*Rana pipiens*	July to September	Pryor Creek watershed
Tiger salamander	*Ambystoma tigrinum*	2 to 3 years at higher elevation	Sage Creek drainage

The influence of piscicides on amphibians varies with reproductive strategy, life history stage, and, in the case of tiger salamanders, life form. (Under conditions of a secure water source, usually a lake or reservoir, tiger salamanders may retain gills as adults. This life form is unlikely to occur in Sage Creek.) Larval amphibians possessing gills are likely to be as vulnerable to both piscicides as fish (Maxell and Hokit 1999). Timing application of piscicide in late summer to fall would be protective of most amphibians, as they would be past their vulnerable, gilled stage of development. Moreover, frogs and salamander prefer standing waters for reproduction and rearing, so their presence in Sage Creek would be unlikely or incidental, with seeps in the stream's headwaters being the only likely locations for larval frogs and salamanders. The Plains spadefoot relies on ephemeral waters following large storm events for reproduction, making presence of larvae highly unlikely in the marshy, seeps area.

Tiger salamanders have a considerably longer period as gill-retaining larvae, which may extend to three years. Nonetheless, consideration of key life history strategies suggest that affects tiger salamander populations that may be present in the marshy seeps in upper Sage Creek, will be minor and temporary. Notably, tiger salamanders are resilient to loss of a year class (Bryce Maxell, NHP, personal communication). Frequently, the older year class of tiger salamander larvae will cannibalize the newer generation. This strategy ensures the success of the older year class, resulting in staggered year class success.

Toxicity of rotenone to adult amphibians is comparatively low and relates to the species aquatic respiration, and their probability of entering or occurring in treated waters (Maxell and Hokit 1999). Effects on adult Woodhouse's toads would be negligible given their impermeable skin and terrestrial affinities. Northern leopard frogs can respire through their skin; however, they are not wholly dependent on the aquatic environment and can leave, making them less likely to suffer mortality (Maxell and Hokit 1999). Although this species has declined in the western portion of Montana, it is relatively secure in the eastern portions of the state, which suggests this project would have minor, if any effect, on northern leopard frogs.

No observational data or other records were available documenting painted turtles in Sage Creek and only one observation was available for the Montana portion of the Shoshone hydrologic unit (Maxell et al. 2003). Nonetheless, the NHP includes the Sage Creek watershed within its range. According to Maxell and Hokit (1999), piscicides can be toxic to turtles, especially those capable of aqueous respiration such as snapping turtles (*Chelydra serpentina*) and spiny softshell (*Trionyx spiniferus*), species not present in Sage Creek. Most probably, painted turtles are less vulnerable than snapping turtles and spiny softshells, as they were not included among turtles capable of aquatic respiration, and are more likely to transverse terrestrial environments. Because of its secure status throughout its range, its presumed rarity in Sage Creek, and its ability to leave contaminated waters, impacts on painted turtles would likely be minimal.

Three species of snake with affinity for water have ranges that encompass the Sage Creek watershed. All are gartersnakes, and consume a variety of prey items, including amphibians. As timing of piscicide application will not coincide with sensitive, early life history stages of their amphibian prey, and risks to exposure from ingestion are low, this project will not adversely affect the three gartersnake species with potential to occur along Sage Creek.

Table 6: Vertebrates present or potentially present in Sage Creek (MFISH database, Maxell et al. 2003, Montana Natural Heritage field guide [http://fieldguide.mt.gov/])

Class	***Species***	***Scientific Name***	***Use of Sage Creek***	***Abundance***
Osteichthyes (bony fishes)	Rainbow trout	*O. mykiss*	Year round resident	Abundant
	Brook trout	*S. fontinalis*	Year round resident	Abundant
Amphibia (amphibians)	Tiger salamander	*Ambystoma tigrinum*	Potentially present, prefer lentic waters. Two observations are available for a reservoir on a tributary of Sage Creek (T8NR24Esection24)	Unknown
	Woodhouse's toad	*Bufo woodhousii*	Potentially present, adults partly terrestrial but found near water	Unknown
	Northern leopard frog	*Rana pipiens*	Potentially present, prefer densely vegetated sedge-meadows or cattail marshes	Unknown
Reptilia (reptiles)	Painted turtle	*Chrysemys picta*	Potentially present, prefer environments with soft, mud bottoms, and little to no current	Unknown
	Common gartersnake	*Thamnophis sirtalis*	Potential present around streams	Unknown
	Plains gartersnake	*T. radix*	Potential present around streams	Unknown
	Terrestrial gartersnake	*T. elegans*	Potential present around streams	Unknown

Rotenone is lethal to benthic invertebrates with gills such as mayflies, stoneflies, and caddisflies. The predicted effect would be a temporary decrease in some invertebrate taxa. These populations rebound quickly from many types of disturbance through two primary mechanisms. Invertebrates drift as a normal component of their life history strategies, so untreated, fishless headwaters would provide a source of invertebrates. Likewise, aerial adults would supplement drift by laying eggs in Sage Creek allowing for recovery of sensitive invertebrates within one year. Additionally, applying piscicide in late summer or early fall would coincide with relatively low numbers of gilled invertebrates, as most would have emerged to complete their life cycle. A large proportion of taxa will be present in the stream as eggs, which are tolerant of rotenone.

Information specific to macroinvertebrate community composition in upper Sage Creek is lacking; however, investigations in nearby streams allow inference on potential for Sage Creek to support rare or unique invertebrates. Neighboring streams tend to have similar water quality, geology, and thermal regime, which result in a tendency to support similar macroinvertebrate communities. Moreover, as most of the sensitive, gill-bearing invertebrates disperse as winged adults, nearby streams will share the same species.

Dry Head Creek lies to the east of the divide between the Shoshone and Big Horn River hydrologic units (Figure 3). In 1999, US Forest Service personnel collected macroinvertebrate samples from Dry Head Creek within the Custer National Forest. This site was within two miles of the headwaters of Sage Creek. Species composition was typical of healthy mountain streams in Montana. No unknown or unique invertebrates were present in the three kick samples collected (McGuire 2000).

Punch Bowl Creek is adjacent to Sage Creek, and is a tributary of Dry Head Creek (Figure 3). Macroinvertebrate data collected for this stream in 2004 (FWP, unpublished data) showed an assemblage consistent with a healthy, mountain Montana stream. Similar to Dry Head Creek, no rare or unique invertebrates were present in the sample.

In summer of 2007, NHP personnel sampled the upper reach of Pryor Creek (Figure 3). This stream is also a close neighbor of Sage Creek, and likely to share many of its invertebrate taxa. Similar to Dry Head Creek, invertebrates present in Pryor Creek were typical of healthy mountain streams (NHP unpublished data). Moreover, no rare or unique taxa were present in samples. Combined, the Dry Head Creek, Punch Bowl Creek, and Pryor Creek macroinvertebrate data suggest piscicide treatment of Sage Creek would not affect rare macroinvertebrate taxa in Sage. Furthermore, these neighboring streams provide a source for recolonization from winged adults.

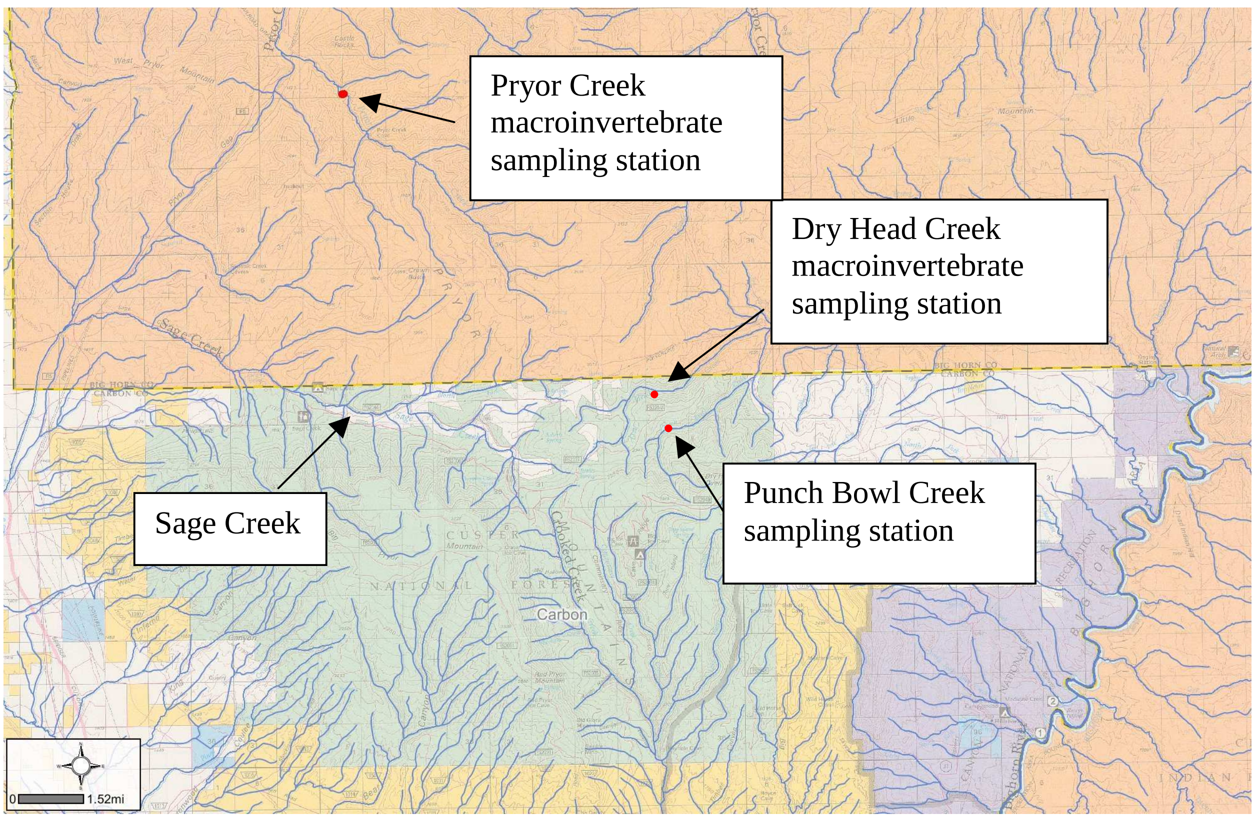

Figure 3: Map of Sage Creek, Pryor Creek, and Dry Head Creek showing proximity of macroinvertebrate sampling stations to Sage Creek.

Comment 5f: Adverse effects on any unique, rare, threatened, or endangered species
The NHP database lists several vertebrate species of special concern as occurring in or near the Sage Creek watershed (Table 2-7). Field guide information provided by the NHP website allows inference on potential impacts to these species. Evaluation of their habitat needs, forage base,

presumed distribution, and migration timing suggests impacts to these species would be nonexistent or negligible.

Bald eagles have wide distribution in Montana, and are likely to make at least incidental use of Sage Creek. As discussed in Comment 5b, effects of the project on bald eagles would be minor and temporary given their preference for larger streams.

Three species of bat listed as species of special concern have inferred distributions that encroach close to, but do not enter the Sage Creek watershed. As bats feed on aerial insects, a temporary reduction in invertebrates produced in Sage Creek has potential to affect bats. Habitat observations and diet information provided by the NHP suggest that these species do not rely on invertebrates with an aquatic life history stage. Spotted bats (*Euderma maculatum*) forage over mesic to arid environments and specialize on moths. Likewise, Townsend's big-eared bats (*Corynorhinus townsendii*) consume mostly moths, although other taxa listed in their diet preferences include terrestrial invertebrates such as wasps and beetles. Although some moths have an aquatic early life history stage, most are of terrestrial origin. The pallid bat (*Antrozous pallidus*) also tends to forage over arid to mesic shrublands or forests. Its diet is varied, with terrestrial invertebrates comprising the bulk of the listed taxa. Given the arid to mesic habitat affinities of these three species of bats, combined with the apparent lack of reliance on invertebrates with an aquatic life history stage, the preferred option would likely have a negligible affect on these species. Moreover, the other species of bat occurring in this area would suffer minor if any impact owing to a lack of reliance on invertebrates of aquatic origin.

Bird species of special concern occurring near the project area include the sage thrasher and bobolink. The preferred alternative would unlikely to have an impact on either species for a host of reasons. Timing piscicide application to late summer or early fall would avoid sensitive nesting and breeding periods. Moreover, both species begin their fall migration in mid-August, so few if any birds would remain during treatment. Habitat suitability is another issue. As the name suggests, sage thrashers prefer mesic sagebrush and grasslands, making their presence near Sage Creek incidental. Likewise, bobolinks are a grassland bird, preferring open meadows. The combination of project timing and narrow extent of human activity (within the riparian corridor) makes adverse affects on either species highly unlikely.

The plains spadefoot is a species of special concern documented to be present in the Sage Creek watershed. As noted in Comment 5c, the plains spadefoot would be highly unlikely to experience adverse effects from piscicide treatment. This species of toad has impermeable skin and is not capable of aquatic respiration. Moreover, its reproductive strategy involves use of ephemeral standing waters formed by large storm events. Therefore, no larval spadefoot would likely be present in Sage Creek, including its marshy headwaters.

The western hognose snake is a species of special concern with limited potential to occur in the Sage Creek watershed. The NHP considers its range to encompass most of the eastern two-thirds of Montana; however, relatively few records are available for the state (Maxell et al. 2003). None are in or near the Sage Creek watershed. Little is known about its preferred habitat or habits in Montana, although this species typically consumes toads as its primary prey. If western hognose snake does occur in the upper Sage Creek watershed, negative effects on this species would likely be negligible. Piscicide treatment would have little effect on its forage base, as application would occur after the sensitive larval stage of toads and frogs.

Table 2-7: Vertebrate species of special concern known to occur in or near the Sage Creek watershed.

Common Name	***Scientific Name***	***Natural Heritage Ranks***	***Known/Inferred Distribution***
Bald eagles	*Halieatus leucocephalus*	G5S3	Nearest known nest is about 14 miles away.
Spotted bat	*Euderma maculatum*	G4S2	Higher elevations in Sage Creek watershed (T8S R26E Sections 1-5)
Pallid bat	*Antrozus pallidus*	G5S2	Adjacent to Sage Creek watershed (T7S, R27E, Section 32)
Townsend’s big-eared bat	*Corynorhinus townsendii*	G4S2	Higher elevations in Sage Creek watershed (T7S, R27E Sections 29, 31, and 32)
Bobolink	*Dolichonyx oryzivorus*	G5S2B	Uplands to the northwest of project area.
Sage thrasher	*Oreoscoptes montanus*	G5S3B	Uplands to the southwest of the project area.
Plains spadefoot	*Spea bombifrons*	G5S3	Documented in the Sage Creek watershed
Western hognose snake	*Heterodon nasicus*	G5S2	Known from several sightings in the neighboring, Big Horn River basin

2.2. Human Environment

2.2.1. Noise and Electric Effects

			Impact			
Would the proposed action result in:	**Unknown**	**None**	**Minor**	**Potentially Significant**	**Can Impact Be Mitigated**	**Comment Index**
a. Increases in existing noise levels?		X				
b. Exposure of people to serve or nuisance noise levels?		X				
c. Creation of electrostatic or electromagnetic effects that could be detrimental to human health or property?		X				
d. Interference with radio or television reception and operation?		X				

2.2.2. Land Use

Would the proposed action result in:	Unknown	Impact None	Minor	Potentially Significant	Can Impact Be Mitigated	Comment Index
a. Alteration of or interference with the productivity or profitability of the existing land use of an area?		X				7a
b. Conflicted with a designated natural area or area of unusual scientific or educational importance?		X				
c. Conflict with any existing land use whose presence would constrain or potentially prohibit the proposed action?		X				
d. Adverse effects on or relocation of residences?		X				

Comment 7a: The high quality of the habitat in Sage Creek relates in part to voluntary changes in grazing management implemented by the landowner in recent years. No future changes in grazing are anticipated related to this project, even if Yellowstone cutthroat trout are listed as threatened or endangered under the Endangered Species Act.

2.2.3. Risks/Health Hazards

Would the proposed action result in:	Unknown	Impact None	Minor	Potentially Significant	Can Impact Be Mitigated	Comment Index
a. Risk of an explosion or release of hazardous substances (including, but not limited to oil, pesticides, chemicals, or radiation) in the event of an accident or other forms of disruption?			X		YES	8a
b. Affect an existing emergency response or emergency evacuation plan or create a need for a new plan?		X				
c. Creation of any human health hazard or potential hazard?			X		YES	see 8c
d. Would any chemical piscicides be used?			X		YES	see 8a and 3a

Comment 8a: Risk of explosion or release of hazardous substances
Alternative 1: Proposed Action
Rotenone would be used in phase 1 of this project, which constitutes release of a substance hazardous to fish and gill-respiring organisms. See comments 3a on risks to the environment and human health, and mitigative actions to minimize adverse effects.

MSDSs for CFT Legumine™ and $KMnO_4$, describe risks of explosion for these compounds (Appendix A). With a flashpoint of 192 °F (89 °C), CFT Legumine™ has a low risk of combustion or explosion. Special caution is required for transporting and using materials with a flashpoint of less than 140 °F (60 °C). Nevertheless, foam or CO_2 fire extinguishers would be available during transport and handling or undiluted product. $KMnO_4$ is non- flammable, but has an explosion hazard when in contact with organic or readily oxidizable compounds. Such materials would not be at the project site, which eliminates the risk of explosion from $KMnO_4$ reacting with other chemicals.

Alternative 2: No Action
This alternative presents no risk of explosion or release of hazardous substances.

Comment 8b: Creation of a human health hazard or potential hazard.
Alternative 1: Proposed Action
Hazards to human health relate to handling non-dilute CFT Legumine™ and $KMnO_4$. (As described in 2.1.3 Water, application of CFT Legumine™ or $KMnO_4$ to surface waters according manufacturer's instructions does not present a risk to human health from exposure to treated water.) To prevent health risks associated with skin contact and inhalation, workers handling full strength CFT Legumine™ would follow exposure controls/personal protection requirements detailed in the MSDS. Workers with potential to be exposed to non-dilute CFT Legumine™ would wear chemical resistant gloves, boots, and protective eyewear. Respiratory protection is required only when working in a non-ventilated area, which would not occur under field application of CFT Legumine™.

$KMnO_4$ presents a potential human health hazard with skin contact, inhalation, or ingestion. Personnel working with the non-dilute product would follow safety practices detailed in the MSDS for KMnO4. This includes gloves and eye protection.

Accidental spills present another potential avenue for threats to human health from either CFT Legumine™ or KMnO4. In the event of a spill, workers would follow accidental release measures detailed in the MSDSs for each compound, which involve containment and disposal Protective eyewear and gloves are required to handle spills.

Alternative 2: No Action
This alternative would not create a human health hazard or potential hazard.

2.2.4. Community Impact

Would the proposed action result in:	Impact Unknown	None	Minor	Potentially Significant	Can Impact Be Mitigated	Comment Index
a. Alteration of the location, distribution, density, or growth rate of the human population of an area?		X				
b. Alteration of the social structure of a community?		X				
c. Alteration of the level or distribution of employment or community or personal income?		X				
d. Changes in industrial or commercial activity?		X				
e. Increased traffic hazards or effects on existing transportation facilities or patterns of movement of people and goods?		X				

2.2.5. Public Services/Taxes/Utilities

Would the proposed action result in:	Impact Unknown	None	Minor	Potentially Significant	Can Impact Be Mitigated	Comment Index
a. Would the proposed action have an effect upon or result in a need for new or altered governmental services in any of the following areas: fire or police protection, schools, parks/recreational facilities, roads or other public maintenance, water supply, sewer or septic systems, solid waste disposal, health, or other governmental services? If any, specify: _______________		X				
b. Would the proposed action have an effect upon the local or state tax base and revenues?		X				
c. Would the proposed action result in a need for new facilities or substantial alterations of any of the following utilities: electric power, natural gas, other fuel supply or distribution systems, or communications?		X				
d. Would the proposed action result in increased used of any energy source?		X				
e. Define projected revenue sources			X		YES	10e
f. Define projected maintenance costs		X				

Comment 10e: This proposed project would be accomplished cooperatively using funds and labor contributed by the Custer National Forest, FWP, the Crow Tribe, and a grant funded through the Future Fisheries Improvement Program. Implementation of this project would be accomplished through a commitment of 109-111 person-days from agency biologists and volunteers from 2008 through 2009 (Table 1). Similar effort would be required if additional piscicide treatments were necessary.

Table 8: Labor required to accomplish preferred alternative.

Activity	*Number of People*	*Number of Days*	*Person –days*
Make and break camp	3	2	6
Electrofish	12	3	36
Bioassays	2	2-3	4-6
Treatment #1	12	1	12
Treatment #2	6	2	12
Stock Yellowstone cutthroat trout	3	1	12
2-year assessment	12	2	3
		14-15 Days	109-111

2.2.6. Aesthetics/Recreation

Aesthetics/Recreation Would the proposed action result in:	Unknown	Impact None	Minor	Potentially Significant	Can Impact Be Mitigated	Comment Index
a. Alteration of any scenic vista or creation of an aesthetically offensive site or effect that is open to public view?		X				
b. Alteration of the aesthetic character of a community or neighborhood?		X				
c. Alteration of the quality or quantity of recreational/tourism opportunities and settings? (Attach Tourism Report)			X			11c
d. Would any designated or proposed wild or scenic rivers, trails or wilderness areas be impacted? (Also see 11a, 11c)		X				

Comment 11c: Alteration of the quality or quantity of recreational/tourism opportunities and settings?

Alternative 1: Proposed Action
As Yellowstone cutthroat trout have been nearly extirpated from south central Montana, restoration of Yellowstone cutthroat trout Sage Creek would provide a rare opportunity to fish for native fish in this beautiful setting. Nonetheless, fishing pressure would likely be low. Private landowners control much of the access, except at a public campground. Those willing to make the drive to visit the Pryor Mountains would benefit, but the distance and the availability of abundant resources throughout the adjacent Absaroka-Beartooth Wilderness would limit numbers.

Alternative 2: No Action
This alternative would not alter the quality or quantity of existing recreational/tourism opportunities.

2.2.7. Cultural/Historical Resources

Cultural/Historical Resources Would the proposed action result in:	Unknown	Impact None	Minor	Potentially Significant	Can Impact Be Mitigated	Comment Index
a. Destruction or alteration of any site, structure or object of prehistoric historic, or paleontological importance?		X				
b. Physical change that would affect unique cultural values?		X				
c. Effects on existing religious or sacred uses of a site or area?		X				
d. Would the project affect historic or cultural resources?		X				

2.2.8. Summary Evaluation of Significance

Would the proposed action, considered as a whole:	Impact: Unknown	None	Minor	Potentially Significant	Can Impact Be Mitigated	Comment Index
a. Have impacts that are individually limited, but cumulatively considerable? (A project or program may result in impacts on two or more separate resources which create a significant effect when considered together or in total.)		X				
b. Involve potential risks or adverse effects which are uncertain but extremely hazardous if they were to occur?		X				
c. Potentially conflict with the substantive requirements of any local, state, or federal law, regulation, standard or formal plan?		X				
d. Establish a precedent or likelihood that future actions with significant environmental impacts would be proposed?		X				
e. Generate substantial debate or controversy about the nature of the impacts that would be created?			X		YES	13e
f. Is the project expected to have organized opposition or generate substantial public controversy? (Also see 13e)			X		YES	see 13e
g. List any federal or state permits required.						13g

Comment 13e: Potential for debate or controversy

Alternative 1: Proposed Action

Public response to fish restoration projects entailing piscicide has varied. A westslope cutthroat trout restoration project begun in the 1990s (Cherry Creek, Gallatin National Forest) generated substantial controversy over the use of fish piscicides to remove non-native trout. In contrast, in Montana, several piscicide projects proceed each year, with no opposition and considerable public support. For example, in 2007, public response to a piscicide project to protect pure Yellowstone cutthroat trout in the Goose Creek watershed was overwhelmingly positive.

Alternative 2: No Action

Given the status of Yellowstone cutthroat trout, not proceeding with this project may also generate controversy or debate. Considerable support exists for restoring Yellowstone cutthroat trout to its historic habitat. Failure to proceed with proposed projects where environmental assessments find environmental, social, economic, cultural impacts to be minor and temporary may spur controversy or debate from native fish advocates.

Comment 13g: List and federal or state permits required.

Discharge of piscicide would require acquisition of 308 Authorization from the Montana Department of Environment Quality, which is otherwise known as the “application for short-term exemption from surface water quality standards for emergency remediation/pesticide application - 75-5-308, MCA”.

3.0 ALTERNATIVES

Four alternatives received consideration during preparation of the environmental assessment. The proposed alternative (alternative 1) and no action (alternative 2) were evaluated in detail. Two additional alternatives were eliminated from full consideration, as they were more expensive, less feasible, and would have a low probability of meeting project objectives, namely establishment of a genetically pure population of Yellowstone cutthroat trout.

3.1. Alternatives Given Detailed Study

3.1.1. Alternative 1: Non-native fish eradication followed by native fish introduction

The proposed action includes removal of brook and rainbow trout in a 10-mile reach of Sage Creek using piscicide. Removal of non-native fishes would reduce the threats associated with predation, competition, and hybridization. The anticipated outcome would be complete removal of brook and rainbow trout from the project area, because piscicides have been demonstrated to be 100% effective with use of proper techniques. The predicted consequence of alternative 1 is establishment of a genetically pure, self-sustaining population of Yellowstone cutthroat trout.

Mitigative measures associated listed under the comments in the environmental review would minimize the amount of piscicide used and reduce the risk of exposure to humans and livestock. Consequently, this alternative would have a minor effect on state waters while being economically, environmentally, and technologically feasible. Compared to electrofishing or angling (alternative 3), the use of piscicide takes less time and money in removing non-native fish, which gives this option the greatest economic feasibility. Likewise, the combination of low persistence of these chemicals in the environment, and the mitigative steps to reduce environmental impacts, makes this an environmentally feasible alternative. As piscicides can be 100% effective in removal, this alternative is also technically feasible.

3.1.2. Alternative 2: No action.

The predicted consequence of the "No Action" alternative is that a Yellowstone cutthroat trout population in Sage Creek would not be restored, and brook and rainbow trout would flourish.

3.2. Alternatives Considered but Not Given Detailed Study

3.2.1. Alternative 3: Introduction of Yellowstone cutthroat trout without removal of existing fish populations.

This alternative would not allow attainment of the purpose of the project, namely establishment of a genetically pure population of Yellowstone cutthroat trout. Rainbow trout are well established in this portion of Sage Creek, and would likely hybridize with re-introduced Yellowstone cutthroat trout. To a lesser extent, the abundance of brook trout is also likely to limit the success of this project, given the high reproductive potential of brook trout in Sage Creek, and the tendency of brook trout to displace Yellowstone cutthroat trout in small streams. Because the continued presence of brook trout and rainbow trout is incompatible with establishment of a sustainable, pure population of Yellowstone cutthroat trout, this alternative was not evaluated in detail. These factors render this alternative technically and economically infeasible.

3.2.2. Alternative 4: Introduction of Yellowstone cutthroat trout with mechanical removal of existing fish populations.

This alternative is the same as the proposed action, except no piscicides would be used. Removal of fish would be by mechanical means only, including both electrofishing and angling. Angling is the least effective of these methods, and an estimated 20% of fish can be removed this way on an annual basis. Reproduction from year-to-year would nullify much of this effect. Angling is also a particularly inefficient method for removing small fish. Electrofishing is also inefficient at removing small fish, and effectiveness on Sage Creek would likely to be 5-80% depending upon the staff and the amount of cover in the stream. Habitat complexity in Sage Creek would provide refugia from the electrical current and netting, which would prevent full removal of brook trout and rainbow trout. The remaining rainbow trout would spawn with Yellowstone cutthroat trout resulting in hybridization. Similarly, competition with the remaining brook trout would jeopardize persistence of Yellowstone cutthroat trout.

This alternative is economically and technologically infeasible because of the uncertainties associated with the success, and the number of years that would be required before efforts even close to 100% success could be guaranteed. This would need to be conducted continually on a one or two year basis. Costs would be $6,000 to $12,000 per year and provisions would have to be made to staff this project on an annual or biannual basis. These time delays would not only cost more money, but would also slow the process of Yellowstone cutthroat trout recovery.

4.0 ENVIRONMENTAL ASSESSMENT CONCLUSION SECTION

4.1.1. Evaluation of Significance Criteria and Identification of the Need for an EIS

Evaluation of potential impacts on the physical and human environment in 2.0 ENVIRONMENTAL REVIEW provides the basis for determining the need for an environmental impact statement (EIS), which is a more rigorous evaluation of potential impacts to human health and the environment from the proposed action. If evaluation of these significance criteria suggests the proposed action would result in significant impacts, an EIS would be required.

This environmental review demonstrates that the impacts of this proposed project are not significant. The proposed action would benefit Yellowstone cutthroat trout in Sage Creek with minimal impact on the physical, biological, or the human environment.

4.1.2. Level of Public Involvement

Several factors influence the appropriate level of public involvement for a given proposed action. Risks to human health, the environment, local economics, as well as the seriousness of the environmental issues are key considerations. This project will include a 30-day public comment period. The public will be informed of the potential project through press releases in local newspapers and through a notice on FWP’s website (http://fwp.mt.gov/news/default.aspx). If public interest is considerable, FWP will host a public meeting.

4.1.3. Public Comments

The public comment period will extend from April 25, 2008 through May 25, 2008.

Send comments to:

Ken Frazer
Montana Fish, Wildlife & Parks
2300 Lake Elmo Drive
Billings, MT 59105
(406) 247-2963
kfrazer@mt.gov

4.1.4. Parties Responsible for Preparation of the EA

Carol Endicott
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Montana Fish, Wildlife, and Parks
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Livingston, MT 59047
(406) 222-3710
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Appendix A : Material Data Safety Sheets and Manufacturer's Labels

Material Safety Data Sheet

SECTION 1: CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT/CHEMICAL NAME: CFT Legumine™

Emergency Contact: 1-800-858-7378 (National Pesticide Information Center)

Transportation Emergency Contact: 1-800-858-7378 (National Pesticide Information Center

Manufactured for: CWE Properties Ltd., LLC
1140 38th Avenue, Suite 2
Greeley, CO 80634

SECTION 2: HAZARDS IDENTIFICATION SUMMARY

KEEP OUT OF REACH OF CHILDREN – DANGER – POISONOUS – Fatal if inhaled. May be fatal if swallowed. Causes substantial, but temporary, eye injury. Causes skin irritation. Do not breathe spray mist. Do not get in eyes, on skin, or on clothing. Wear goggles or safety glasses. This product is an orange, viscous liquid with slight petroleum odor.

SECTION 3: COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Ingredients:	Percentage By Weight	CAS No.	TLV (Units)
Rotenone	5.00	83-79-4	5 mg/m^3
Other Associated Resins	5.00		
Inert Ingredients,	90.00		
Including N-Methylpyrrolidone		872-50-4	not listed

SECTION 4: FIRST AID MEASURES

IF SWALLOWED: Call a physician, Poison Control Center, or the National Pesticide Information Center at 1-900-858-7378 immediately for treatment advice. Do not induce vomiting unless told to do so by the Poison Control Center or physician. Do not give any liquid to the person. Do not give anything by mouth to an unconscious or convulsing person.

IF INHALED: Remove victim to fresh air. If not breathing, give artificial respiration, preferably by mouth-to-mouth. Call a physician, Poison Control Center, or the National Pesticide Information

Center at 1-800-858-7378 immediately for treatment advice.

IF IN EYES: Hold eyelids open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. Call a physician, Poison Control Center, or the National Pesticide Information Center at 1-800-858-7378 immediately for treatment advice.

IF ON SKIN OR CLOTHING: Take off contaminated clothing. Rinse skin with plenty of water for 15-20 minutes. Call a physician, Poison Control Center, or the National Pesticide Information Center at 1-800-858-7378 immediately for treatment advice.

Note: Have the product container or label with you when obtaining treatment advice.

SECTION 5: FIRE FIGHTING MEASURES

Flash Point (Method Used): 192ºF (89°C) (Closed Cup)

Flammable Limits: LFL: Not established
UFL: Not established

Extinguishing Media: CO_2, foam, dry chemical water spray.

Special Fire Fighting Procedures: Use self-contained breathing apparatus and full protective equipment. Fight fire from upwind from a safe distance and keep non-essential personnel out of area.

SECTION 6: ACCIDENTAL RELEASE MEASURES

SPILL/LEAK PROCEDURES: Wear protective clothing as described in Section 8 (Exposure Controls / Personal Protection) of this MSDS. Absorb liquid with material such as clay, sand, sawdust, or dirt. Sweep up and place in a suitable container for disposal and label the contents. Area can be washed down with a suitable solution of bleach or soda ash and an appropriate alcohol (methanol, ethanol, or isopropanol). Follow this by washing with a strong soap and water solution. Absorb any excess liquid as indicated above, and add to the disposal container. This product is extremely toxic to fish. Fish kills are expected at recommended use rates. Keep spills and cleaning runoff out of municipal sewers and open bodies of water.

SECTION 7: HANDLING AND STORAGE

HANDLING: Avoid inhalation of vapors. Harmful if swallowed, inhaled or absorbed through skin. Avoid contact with skin. Wear clean protective clothing. Wash hands before eating, drinking, chewing gum, using tobacco or using the toilet. Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing. Remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.

STORAGE: Store in original containers only. Store in a dry place away from children and domestic animals. Do not store at temperatures below $40^{O}F/4.4^{O}C$. This product is stable for a minimum of 1 year when stored in sealed drums at $70^{O}F/21.1^{O}C$. Do not contaminate water, food or feed by storage or disposal.

SECTION 8: EXPOSURE CONTROLS / PERSONAL PROTECTION

ENGINEERING CONTROLS: Provide general or local exhaust ventilation systems to maintain airborne concentrations below OSHS PELs (see section 3).
RESPIRATORY PROTECTION: When working with undiluted product, wear either a respirator with an organic vapor cartridge with pesticide pre-filter (MSHA/NIOSH approval number TC-23C), or a canister approved for pesticides (MSHA/NIOSH approval number 14G), or a NIOSH approved respirator with an organic vapor (OV) cartridge or canister with any R, P, or HE prefilter. For emergency or non-routine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. ***Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres***. If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas.
PROTECTIVE CLOTHING/EQUIPMENT: Wear chemical-resistant gloves, boots, and aprons to prevent prolonged or repeated skin contact. Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133).

SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES

Physical State: Viscous liquid
Appearance and Odor: Orange liquid with slight solvent odor.
Specific Gravity: 1.019 g/ml
Bulk Density: 8.506 lbs./gal.

SECTION 10: STABILITY AND REACTIVITY

Stability: Stable at room temperature in closed containers under normal storage and handling conditions.
Conditions to Avoid: None known.
Incompatibility: Strong acids and strong oxidizers,
Hazardous Decomposition Products: Oxides of carbon.
Hazardous Polymerization: Will not occur.

SECTION 11: TOXICOLOGICAL INFORMATION

Acute Oral LD_{50} (rat): 55.3 – 264 mg/kg
Acute Dermal LD_{50} (rabbit): >2020 mg/kg
Inhalation LC_{50} (rat): 0.048 mg/L (4 HR)
Eye Irritation (rabbit): Moderately irritating
Skin Irritation (rabbit): Moderately irritating
Skin Sensitization (guinea pig): Not a sensitizer
Carcinogenic Potential: Not listed by IARC, NTP, or OSHA. ACGIH lists Rotenone as TLV A4: Not classifiable as to human carcinogenicity.

SECTION 12: ECOLOGICAL INFORMATION

This product is extremely toxic to fish. Fish kills are expected at recommended usage rates. Consult local Fish and Game agencies before applying this product to public waters to determine if a permit is needed for such an application.

SECTION 13: DISPOSAL CONSIDERATIONS

Do not reuse empty containers. **Plastic:** Triple rinse (or equivalent), then offer for recycling, or puncture and dispose of in a sanitary landfill, or incineration, or, if allowed by state and local authorities, by burning. If burned, stay out of smoke. **Metal:** Triple rinse (or equivalent), then offer for recycling or reconditioning, or puncture and dispose of in a sanitary landfill or by other procedures approved by state and local authorities. Pesticide wastes are acutely hazardous. Improper disposal of excess pesticide, spray mixture or rinsate is a violation of Federal law and may contaminate groundwater. Do not contaminate water, food or feed by storage or disposal.

SECTION 14: TRANSPORT INFORMATION

U.S DOT Shipping Description: Pesticide, Liquid, Toxic, N.O.S. (Rotenone), 6.1, UN2902, III, Marine Pollutant, ERG Guide 151

SECTION 15: REGULATORY INFORMATION

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) HAZARD RATINGS:

Category	Rating	
Health	4	0: Least
Flammability	2	1: Slight
Instability	0	2: Moderate
		3: High
		4: Severe

SARA Hazard Notification/Reporting:
SARA Title III Hazard Category:
Immediate: Yes – Fire: No – Delayed: No – Reactive: No
Reportable Quantity (RQ) U.S. CERCLA: Not listed
SARA Title III, Section 313: N-methylpyrrolidone (CAS: 872-50-4) 10.0%
RCRA Waste Code: Not listed
California Proposition 65: WARNING: This product contains chemicals known to the State of California to cause cancer or birth defects or other reproductive harm.

SECTION 16: OTHER INFORMATION

Prepared by: ERR
Issue Date: September 26, 2005
Revision Notes: September 26, 2005 (changed EPA Registration number)
NOTE: *CFT Legumine is a Restricted Use Pesticide due to Aquatic and Acute Inhalation Toxicity*

NOTICE: The information herein is presented in good faith and believed to be accurate as of the effective date shown above. However, no warranty, expressed or implied, is given. Regulatory requirements are subject to change and may differ from one location to another; it is the buyer's responsibility to ensure that its activities comply with federal, state, and local laws and regulations.

Burdick & Jackson

Material Safety Data Sheet

N-Methylpyrrolidone

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: N-Methylpyrrolidone

OTHER/GENERIC NAMES: NMP.
1-Methyl-2-pyrrolidone.

PRODUCT USE: Solvent

MANUFACTURER: Honeywell, Burdick & Jackson
1953 South Harvey Street
Muskegon, MI 49442

FOR MORE INFORMATION CALL:
(Monday-Friday, 8:00am-5:00pm)
1-800-368-0050

IN CASE OF EMERGENCY CALL:
(24 Hours/Day, 7 Days/Week)
1-800-707-4555 (Honeywell)
For Transportation Emergencies:
1-800-424-9300 (CHEMTREC - Domestic)
703-527-3887 (CHEMTREC - International)

2. COMPOSITION/INFORMATION ON INGREDIENTS

INGREDIENT NAME	CAS NUMBER	WEIGHT %
N-Methylpyrrolidone	872-50-4	100%

Trace impurities and additional material names not listed above may also appear in Section 15 toward the end of the MSDS. These materials may be listed for local "Right-To-Know" compliance and for other reasons.

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW: Combustible liquid and vapor. Causes skin, eye and respiratory tract irritation. Harmful if swallowed, inhaled or absorbed through the skin.

POTENTIAL HEALTH HAZARDS

SKIN: Can cause itching, redness, scaling and hives. Quickly absorbed through the skin and is capable of transporting other dissolved toxins into the body.

EYES: Can cause irritation and corneal burns.

INHALATION: Can cause respiratory tract irritation, headache, nausea, dizziness and drowsiness.

INGESTION: Can cause dizziness, drowsiness, nausea, vomiting, cramps, and chills.

DELAYED EFFECTS: Liver and Kidney damage can occur.

Ingredients found on one of the OSHA designated carcinogen lists are listed below.

INGREDIENT NAME	NTP STATUS	IARC STATUS	OSHA LIST
No ingredients listed in this section.			

4. FIRST AID MEASURES

SKIN: Flush affected area with large amounts of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical attention for irritation or any other symptom.

EYES: Immediately flush eyes with large quantities of water for at least 15 minutes. Get immediate medical attention.

INHALATION: Remove victim to fresh air. If breathing has stopped, apply artificial respiration. If breathing is difficult, give oxygen provided a qualified operator is available. Get immediate medical attention.

INGESTION: If person is conscious, rinse mouth with water. Patient may drink water or milk to dilute stomach contents. Do not induce vomiting unless directed to do so by medical personnel. Get immediate medical attention.

ADVICE TO PHYSICIAN: No specific advice. Treat according to symptoms present.

5. FIRE FIGHTING MEASURES

FLAMMABLE PROPERTIES

FLASH POINT: 187?F (88?C)
FLASH POINT METHOD: Closed Cup
AUTOIGNITION TEMPERATURE: 346?C
UPPER FLAME LIMIT (volume % in air): 9.5%
LOWER FLAME LIMIT (volume % in air): 1.3%
FLAME PROPAGATION RATE (solids): Not Applicable
OSHA FLAMMABILITY CLASS: Combustible Liquid

EXTINGUISHING MEDIA:
Carbon Dioxide, Dry Chemical, or Foam.

UNUSUAL FIRE AND EXPLOSION HAZARDS:
Heat will build pressure within containers and may cause containers to rupture. May form explosive mixtures with air when heated above the flash point.

SPECIAL FIRE FIGHTING PRECAUTIONS/INSTRUCTIONS:
Wear full protective clothing and NIOSH approved self-contained breathing apparatus with full facepiece.

6. ACCIDENTAL RELEASE MEASURES

IN CASE OF SPILL OR OTHER RELEASE: (Always wear recommended personal protective equipment.)
Eliminate sources of ignition. Isolate the spill area. Contain and recover liquid when possible. Absorb with inert absorbent and place in an approved chemical waste container. For large spills, dike up with inert material and transfer into same container. Do not allow to enter into sewers or waterways.

Spills and releases may have to be reported to Federal and/or local authorities. See Section 15 regarding reporting requirements.

7. HANDLING AND STORAGE

NORMAL HANDLING: (Always wear recommended personal protective equipment.)
Keep away from heat and open flame. Use with adequate ventilation. Avoid contact with skin, eyes and clothing. Do not eat, drink or smoke in the work area. Wash thoroughly after handling.

STORAGE RECOMMENDATIONS:
Store in a cool, dry, well ventilated area away from heat and sources of ignition and incompatible materials. Keep containers upright and tightly closed. Protect containers from physical damage. Do not reuse containers. Empty containers may contain product residue and/or vapors. Label warnings apply to empty containers that have not been cleaned.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

ENGINEERING CONTROLS:
Ensure adequate mechanical ventilation. Use local ventilation at product handling or transfer points.

PERSONAL PROTECTIVE EQUIPMENT

SKIN PROTECTION:
Wear impervious protective clothing, including boots, gloves, lab coat, apron or coveralls as appropriate to prevent skin contact.

EYE PROTECTION:
Wear safety glasses with non-perforated sideshields for normal handling. Goggles or a full-face shield may be necessary depending on quantity of material and conditions of use.

RESPIRATORY PROTECTION:
Not required for properly ventilated areas. If there is potential for inhalation of vapor or mist, use an appropriate NIOSH approved respirator. Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.

The respirator must be selected based on contamination levels and use conditions found in the workplace, must not exceed the working limits of the respirator and be approved by the National Institute for Occupational Safety and Health (NIOSH) and used in accordance with Occupational Safety and Health Administration (OSHA) 29 CFR 1910.134.

ADDITIONAL RECOMMENDATIONS:
Provide eyewash station and safety showers convenient to work areas.

EXPOSURE GUIDELINES

INGREDIENT NAME	ACGIH TLV	OSHA PEL	OTHER LIMIT
N-Methylpyrrolidone	None Established	None Established	10 ppm 8 hr TWA ** Skin contact can invalidate limit values.

* = Limit established by Honeywell International, Inc.
** = Workplace Environmental Exposure Level (AIHA).
*** = Biological Exposure Index (ACGIH).

OTHER EXPOSURE LIMITS FOR POTENTIAL DECOMPOSITION PRODUCTS:
None.

9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE:	Clear
PHYSICAL STATE:	Liquid
MOLECULAR WEIGHT:	99.15
CHEMICAL FORMULA:	C_5H_9NO
ODOR:	Amine like odor
SPECIFIC GRAVITY (water = 1.0):	1.03

SOLUBILITY IN WATER (weight %):	100%		
pH:	Not Applicable		
BOILING POINT:	396?F (202?C)		
MELTING POINT:	-11?F (-24?C)		
VAPOR PRESSURE:	<1 mm Hg @ 68?F (20?C)		
VAPOR DENSITY (air = 1.0):	3.4		
EVAPORATION RATE:	>1	**COMPARED TO:**	Butyl Acetate = 1
% VOLATILES:	~100		
FLASH POINT:	187?F (88?C)		

(Flash point method and additional flammability data are found in Section 5.)

10. STABILITY AND REACTIVITY

NORMALLY STABLE? (CONDITIONS TO AVOID):
Stable under normal conditions of use and storage. Avoid heat, flames, ignition sources and incompatible material.

INCOMPATIBILITIES:
Oxidizers, and strong acids.

HAZARDOUS DECOMPOSITION PRODUCTS:
Thermal decomposition may produce carbon monoxide, carbon dioxide, and nitrogen oxides.

HAZARDOUS POLYMERIZATION:
Not expected to occur.

11. TOXICOLOGICAL INFORMATION

IMMEDIATE (ACUTE) EFFECTS:
Oral-Rat LD_{50}: 3914 mg/kg.
Oral-Mouse LD_{50}: 5130 mg/kg.
Dermal Approximate LD_{50} (rabbit): 4000-8000 mg/kg (intact skin) and 2000-4000 mg/kg(abraded skin).
Dermal Irritation (rabbit): slight irritation, Primary Dermal Irritation Index of 0.5/8.0.
Eye (rabbit): severe irritation.

DELAYED (SUBCHRONIC AND CHRONIC) EFFECTS:

Subchronic:
In a repeated dose study in which mice were fed dietary concentrations of 0, 1,000, 2,500, or 7500 ppm over a 3-month period, concentrations of 2500 and 7500 produced toxic effects of the liver. The study concluded that 1000 ppm was a NOAEL level.

Chronic:

Rats were exposed to vapor concentrations of 0, 40 (10 ppm), or 400 mg/m^3 (100 ppm) 6 hr/d, 5 d/wk for 2 years. No life-shortening toxic or carcinogenic effect was observed at any level. The body weight of males exposed to 400 mg/m^3 was reduced slightly, while a NOEL was determined to be 40 mg/m^3.

OTHER DATA:

Reproductive/Developmental Toxicity:

Three inhalation developmental/reproductive studies in rats showed toxicological effects in the offspring, with a fourth study giving indications of behavioral problems, making that the endpoint of concern. Data from these studies indicate an inhalation NOEL of approximately 100 ppm (400 mg/m^3) for reproductive/developmental effects in rats.

For rats exposed dermally, the fetal and maternal NOAEL is reported to be 237 mg/kg/day. Developmental effects were observed at the maternally toxic level of 750 mg/kg/day.

Mutagenicity:

Ames Test: Negative
Mouse Micronucleous Test: Negative, after single oral doses up to 3800 mg/kg.
Chinese Hamster Bone Marrow Test: Negative, after single oral doses up to 3800 mg/kg.

12. ECOLOGICAL INFORMATION

No data reported.

13. DISPOSAL CONSIDERATIONS

RCRA

Is the unused product a RCRA hazardous waste if discarded? Not listed.
If yes, the RCRA ID number is: Not Applicable.

OTHER DISPOSAL CONSIDERATIONS:

Whatever cannot be saved for recovery or recycling should be managed in an approved waste disposal facility. Dispose of container and unused contents in accordance with federal, state and local requirements.

The information offered here is for the product as shipped. Use and/or alterations to the product such as mixing with other materials may significantly change the characteristics of the material and alter the RCRA classification and the proper disposal method.

14. TRANSPORT INFORMATION

Proper DOT Shipping Description:

Domestic non-bulk shipment (119 gal or less): Not Regulated
Domestic bulk shipment (> 119 gal): Combustible Liquid, N.O.S. (N-Methylpyrrolidone), NA 1993, III.

Label(s) or Placards Required:

Domestic non-bulk shipment (119 gal or less): None Required.
Domestic bulk shipment (> 119 gal): Combustible Placard.

NA Emergency Response Guidebook: Guide No. 128.

For additional information on shipping regulations affecting this material, contact the information number found in Section 1.

15. REGULATORY INFORMATION

TOXIC SUBSTANCES CONTROL ACT (TSCA)

TSCA INVENTORY STATUS: On the TSCA Inventory.

OTHER TSCA ISSUES: TSCA Section 4(a) Final Testing Consent Orders.
TSCA Section 8(a) Inventory Update Rule.
TSCA Section 12(b) One-Time Export Notification. Notice required only for first export or intended export to a particular country.

SARA TITLE III/CERCLA

"Reportable Quantities" (RQs) and/or "Threshold Planning Quantities" (TPQs) exist for the following ingredients.

INGREDIENT NAME	SARA/CERCLA RQ (lb)	SARA EHS TPQ (lb)
No ingredients listed in this section.		

Spills or releases resulting in the loss of any ingredient at or above its RQ requires immediate notification to the National Response Center [(800) 424-8802] and to your Local Emergency Planning Committee.

SECTION 311 HAZARD CLASS: Immediate. Delayed. Fire.

SARA 313 TOXIC CHEMICALS:
The following ingredients are SARA 313 "Toxic Chemicals". CAS numbers and weight percents are found in Section 2.

INGREDIENT NAME	COMMENT
N-Methylpyrrolidone [872-50-4]	De Minimis concentration is 1.0%.

STATE RIGHT-TO-KNOW

In addition to the ingredients found in Section 2, the following are listed for state right-to-know purposes.

INGREDIENT NAME	WEIGHT %	COMMENT
No ingredients listed in this section.		

ADDITIONAL REGULATORY INFORMATION:
N-Methylpyrrolidone is on the California Proposition 65 List of chemicals known to the State to cause reproductive toxicity.

WHMIS CLASSIFICATION (CANADA):
Class B, Division 3.
This product has been classified in accordance with hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by the Controlled Products Regulations.

FOREIGN INVENTORY STATUS:
N-Methylpyrrolidone is on the following inventories:
- Australian.
- Canadian DSL.
- Chinese.
- EINECS.
- Japanese (ENCS).
- Korean.
- Philippine (PICCS).

16. OTHER INFORMATION

CURRENT ISSUE DATE: August 31, 2001.
PREVIOUS ISSUE DATE: June, 2000

CHANGES TO MSDS FROM PREVIOUS ISSUE DATE ARE DUE TO THE FOLLOWING:

Amended Hazards Identification, Section 3.
Amended First Aid Measures, Section 4.
Amended Personal Protective Equipment, Section 8.
Amended Exposure Guidelines, Section 8.
Amended Toxicological Information (Other Data), Section 11.
Amended Transport Information, Section 14.
Amended Other TSCA Issues, Section 15.
Amended Additional Regulatory Information, Section 15.
Amended Foreign Inventory Status, Section 15.

OTHER INFORMATION: **NFPA Rating:**
Health: 2
Flammability: 1
Reactivity: 0

5. POTASSIUM PERMANGANATE

Potassium permanganate ($KMnO_4$) is used primarily to control taste and odors, remove color, control biological growth in treatment plants, and remove iron and manganese. In a secondary role, potassium permanganate may be useful in controlling the formation of THMs and other DBPs by oxidizing precursors and reducing the demand for other disinfectants (Hazen and Sawyer, 1992). The mechanism of reduced DBPs may be as simple as moving the point of chlorine application further downstream in the treatment train using potassium permanganate to control taste and odors, color, algae, etc. instead of chlorine. Although potassium permanganate has many potential uses as an oxidant, it is a poor disinfectant.

5.1 Potassium Permanganate Chemistry

5.1.1 Oxidation Potential

Potassium permanganate is highly reactive under conditions found in the water industry. It will oxidize a wide variety of inorganic and organic substances. Potassium permanganate (Mn 7+) is reduced to manganese dioxide (MnO_2) (Mn 4+) which precipitates out of solution (Hazen and Sawyer, 1992). All reactions are exothermic. Under acidic conditions the oxidation half-reactions are (CRC, 1990):

$$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O \qquad E^o = 1.68V$$

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O \qquad E^o = 1.51V$$

Under alkaline conditions, the half-reaction is (CRC, 1990):

$$MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^- \qquad E^o = 0.60V$$

Reaction rates for the oxidation of constituents found in natural waters are relatively fast and depend on temperature, pH, and dosage.

5.1.2 Ability To Form a Residual

It is not desirable to maintain a residual of $KMnO_4$ because of its tendency to give water a pink color.

5.2 Generation

Potassium permanganate is only supplied in dry form. A concentrated $KMnO_4$ solution (typically 1 to 4 percent) is generated on-site for water treatment applications; the solution is pink or purple in color. $KMnO_4$ has a bulk density of approximately 100 lb/ft^3 and its solubility in water is 6.4 g/mL at 20ºC.

Depending on the amount of permanganate required, these solutions can be made up in batch modes, using dissolver/storage tanks with mixers and a metering pump for small feed systems. Larger systems will include a dry chemical feeder, storage hopper and dust collector configured to automatically supply permanganate to the solution dissolver/storage tank.

$KMnO_4$ solution is made up of dry crystalline permanganate solids added to make-up water and then stirred to obtain the desired permanganate concentration. The cost of $KMnO_4$ ranges from $1.50 to $2.00 per pound (1997 costs), depending on the quantity ordered. Shipment containers are typically buckets or drums. Potassium permanganate is supplied in various grades. Pure $KMnO_4$ is non-hygroscopic but technical grades will absorb some moisture and will have a tendency to cake together. For systems using dry chemical feeders, a free-flowing grade is available that contains anti-caking additives (Hazen and Sawyer, 1992).

Potassium permanganate is a strong oxidizer and should be carefully handled when preparing the feed solution. No byproducts are generated from making the solution. However, this dark purple/black crystalline solid can cause serious eye injury, is a skin and inhalation irritant, and can be fatal if swallowed. As such, special handling procedures include the use of safety goggles and a face shield, an MSA™/NIOSH approved dust mask, and wearing impervious gloves, coveralls, and boots to minimize skin contact.

5.3 Primary Uses and Points of Application

Although potassium permanganate can inactivate various bacteria and viruses, it is not used as a primary or secondary disinfectant when applied at commonly used treatment levels. Potassium permanganate levels that may be required to obtain primary or secondary disinfection could be cost prohibitive. However, potassium permanganate is used in drinking water treatment to achieve a variety of other purposes including:

- Oxidation of iron and manganese;
- Oxidation of taste and odor compound;
- Control of nuisance organisms; and
- Control of DBP formation.

5.3.1 Primary Uses

5.3.1.1 Iron and Manganese Oxidation

A primary use of permanganate is iron and manganese removal. Permanganate will oxidize iron and manganese to convert ferrous (2+) iron into the ferric (3+) state and 2+ manganese to the 4+ state. The oxidized forms will precipitate as ferric hydroxide and manganese hydroxide (AWWA, 1991). The precise chemical composition of the precipitate will depend on the nature of the water, temperature, and pH.

The classic reactions for the oxidation of iron and manganese are:

$$3Fe^{2+} + KMnO_4 + 7H_2O \rightarrow 3Fe(OH)_{3(s)} + MnO_{2(s)} + K^+ + 5H^+$$

$$3Mn^{2+} + 2KMnO_4 + 2H_2O \rightarrow 5MnO_{2(s)} + 2K^+ + 4H^+$$

These reactions show that alkalinity is consumed through acid production at the rate of 1.49 mg/L as $CaCO_3$ per mg/L of Fe^{+2} and 1.21 mg/L as $CaCO_3$ per mg/L of Mn^{+2} oxidized. This consumption of alkalinity should be considered when permanganate treatment is used along with alum coagulation, which also requires alkalinity to form precipitates.

The potassium permanganate dose required for oxidation is 0.94 mg/mg iron and 1.92 mg/mg manganese (Culp/Wesner/Culp, 1986). In practice, the actual amount of potassium permanganate used has been found to be less than that indicated by stoichiometry. It is thought that this is because of the catalytic influence of MnO_2 on the reactions (O'Connell, 1978). The oxidation time ranges from 5 to 10 minutes, provided that the pH is over 7.0 (Kawamura, 1991).

5.3.1.2 Oxidation of Taste and Odor Compounds

Potassium permanganate is used to remove taste and odor causing compounds. Lalezary et al. (1986) used permanganate to treat earthy-musty smelling compounds in drinking water. Doses of potassium permanganate used to treat taste and odor causing compounds range from 0.25 to 20 mg/L.

5.3.1.3 Control of Nuisance Organisms

Asiatic Clams

Cameron et al. (1989) investigated the effectiveness of potassium permanganate to control the Asiatic clam in both the juvenile and adult phases. The adult Asiatic clam was found to be much more resistant to permanganate than the juvenile form. Potassium permanganate doses used to control the juvenile Asiatic clam range from 1.1 to 4.8 mg/L.

Zebra Mussels

Klerks and Fraleigh (1991) evaluated the effectiveness of permanganate against adult zebra mussels. Continuous potassium permanganate dosing of 0.5 to 2.5 mg/L proved to be the most effective.

5.3.1.4 DBP Control

It is anticipated that potassium permanganate may play a role in disinfection and DBP control strategies in water treatment. Potassium permanganate could be used to oxidize organic precursors at the head of the treatment plant minimizing the formation of byproducts at the downstream disinfection stage of the plant (Hazen and Sawyer, 1992). Test results from a study conducted at two water treatment plants in North Carolina (Section 5.5.1) showed that pretreatment with permanganate reduced chloroform formation; however, the reduction was small at doses typically used at water treatment plants. The study also indicated that pre-oxidation with permanganate had no net effect on the chlorine demand of the water (Singer et al., 1980).

5.3.2 Points of Application

In conventional treatment plants, potassium permanganate solution is added to the raw water intake, at the rapid mix tank in conjunction with coagulants, or at clarifiers upstream of filters. In direct filtration plants, this oxidant is typically added at the raw water intake to increase the contact time upstream of the filter units (Montgomery, 1985). In all cases, potassium permanganate is added prior to filtration.

Potassium permanganate solution is typically pumped from the concentrated solution tank to the injection point. If the injection point is a pipeline, a standard injection nozzle protruding midway into the pipe section is used. Injection nozzles can also be used to supply the solution to mixing chambers and clarifiers. Permanganate is a reactive, fast-acting oxidizer and does not require special mixing equipment at the point of injection to be effective.

5.3.2.1 Impact on Other Treatment Processes

The use of potassium permanganate has little impact on other treatment processes at the water treatment facility. See Section 5.7 for permanganate operational considerations.

5.4 Pathogen Inactivation and Disinfection Efficacy

Potassium permanganate is an oxidizing agent widely used throughout the water industry. While it is not considered a primary disinfectant, potassium permanganate has an effect on the development of a disinfection strategy by serving as an alternative to pre-chlorination or other oxidants at locations in a treatment plant where chemical oxidation is desired for control of color, taste and odor, and algae.

5.4.1 Inactivation Mechanisms

The primary mode of pathogen inactivation by potassium permanganate is direct oxidation of cell material or specific enzyme destruction (Webber and Posselt, 1972). In the same fashion, the permanganate ion (MnO_4^-) attacks a wide range of microorganisms such as bacteria, fungi, viruses, and algae.

Application of potassium permanganate results in the precipitation of manganese dioxide. This mechanism represents an additional method for the removal of microorganisms from potable water (Cleasby et al., 1964). In colloidal form, the manganese dioxide precipitant has an outer layer of exposed OH groups. These groups are capable of adsorbing charged species and particles in addition to neutral molecules (Posselt et al., 1967). As the precipitant is formed, microorganisms can be adsorbed into the colloids and settled.

5.4.2 Environmental Effects

Inactivation efficiency depends upon the permanganate concentration, contact time, temperature, pH, and presence of other oxidizable material. Several of the key parameters are discussed below.

5.4.2.1 pH

Alkaline conditions enhance the capability of potassium permanganate to oxidize organic matter; however, the opposite is true for its disinfecting power. Typically, potassium permanganate is a better biocide under acidic conditions than under alkaline conditions (Cleasby et al., 1964 and Wagner, 1951). Results from a study conducted in 1964 indicated that permanganate generally was a more effective biocide for E. coli at lower pHs, exhibiting more than a 2-log removal at a pH of 5.9 and a water temperature of both 0 and 20°C (Cleasby et al., 1964). In fact, Cleasby found that pH is the major factor affecting disinfection effectiveness with potassium permanganate. As such, natural waters with pH values of 5.9 or less would be conducive to potassium permanganate disinfection, particularly as a substitute for prechlorination. Moreover a study conducted at the University of Arizona found that potassium permanganate will inactivate *Legionella pneumophila* more rapidly at pH 6.0 than at pH 8.0 (Yahya et al., 1990a).

These results are consistent with earlier results concerning the effects of pH on commercial antiseptic performance (Hazen and Sawyer, 1992). In general, based on the limited results from these studies, disinfection effectiveness of potassium permanganate increases with decreasing pH.

5.4.2.2 Temperature

Higher temperatures slightly enhance bactericidal action of potassium permanganate. The results from a study conducted on polio virus showed that oxidation deactivation is enhanced by higher temperatures (Lund, 1963). These results are consistent with results obtained for *E. coli.* inactivation (Cleasby et al., 1964).

5.4.2.3 Dissolved Organics and Inorganics

The presence of oxidizable organics or inorganics in the water reduces the disinfection effectiveness of this disinfectant because some of the applied potassium permanganate will be consumed in the oxidation of organics and inorganics. Permanganate oxidizes a wide variety of inorganic and organic substances in the pH range of 4 to 9. Under typical water conditions, iron and manganese are oxidized and precipitated and most contaminants that cause odors and tastes, such as phenols and algae, are readily degraded by permanganate (Hazen and Sawyer, 1992).

5.4.3 Use as a Disinfectant

A number of investigations have been performed to determine the relative capability of potassium permanganate as a disinfectant. The following sections contain a description of the disinfection efficiency of potassium permanganate in regards to bacteria, virus, and protozoa inactivation.

5.4.3.1 Bacteria Inactivation

High dosage rates were required to accomplish complete inactivation of bacteria in three studies. Early research showed that a dose of 2.5 mg/L was required for complete inactivation of coliform bacteria (Le Strat, 1944). In this study, water from the Marne River was dosed with potassium permanganate at concentrations of 0 to 2.5 mg/L. Following mixing, the samples were placed in a darkened room for 2 hours at a constant temperature of 19.8°C.

Banerjea (1950) investigated the disinfectant ability of potassium permanganate on several waterborne pathogenic microorganisms. The investigation studied *Vibrio cholerae*, *Salm. typhi*, and *Bact. flexner*. The results indicated that doses of 20 mg/L and contact times of 24 hours were necessary to deactivate these pathogens; however, even under these conditions the complete absence of *Salm. typhi* or *Bact. flexner* was not assured, even at a potassium permanganate concentration that turned the water an objectionable pink color.

Results from a study conducted in 1976 at the Las Vegas Valley Water District/Southern Nevada System of Lake Mead water showed that complete removal of coliform bacteria were accomplished at doses of 1, 2, 3, 4, 5, and 6 mg/L (Hazen and Sawyer, 1992). Contact times of 30 minutes were provided with doses of 1 and 2 mg/L, and 10 minutes contact times were provided for higher dosages in this study.

5.4.3.2 Virus Inactivation

Potassium permanganate has been proven effective against certain viruses. A dose of 50 mg/L of potassium permanganate and a contact time of 2 hours was required for inactivation of poliovirus (strain MVA) (Hazen and Sawyer, 1992). A "potassium" permanganate dose of 5.0 mg/L and a contact time of 33 minutes was needed for 1-log inactivation of type 1 poliovirus (Yahya et al., 1990b). Tests showed a significantly higher inactivation rate at 23°C than at 7°C; however, there was no significant difference in activation rates at pH 6.0 and pH 8.0.

Potassium permanganate doses from 0.5 to 5 mg/L were capable of obtaining at least a 2 log inactivation of the surrogate virus, MS-2 bacteriophage with *E. coli* as the host bacterium (Yahya et al., 1989). Results showed that at pH 6.0 and 8.0, a 2-log inactivation occurred after a contact time of at least 52 minutes and a residual of 0.5 mg/L. At a residual of 5.0 mg/L, approximately 7 and 13 minutes were required for 2-log inactivation at pHs of 8.0 and 6.0, respectively. These results contradict the previously cited studies that potassium permanganate becomes more effective as the pH decreases.

5.4.3.3 Protozoa Inactivation

No information pertaining to protozoa inactivation by potassium permanganate is available in the literature. However, based on the other disinfectants discussed in this report, protozoa are significantly more resistant than viruses; therefore, it is likely that the dosages and contact times required for protozoa inactivation would be impractical.

5.4.3.4 CT Curves

Table 5-1 shows CT values for the inactivation of bacteriophage MS-2. These data have been provided as an indication of the potential of potassium permanganate. These values are somewhat inconsistent and do not include a safety factor and should not be used to establish CT requirements.

Table 5-1. Potassium Permanganate CT Values for 2-log Inactivation of MS-2 Bacteriophage

Residual (mg/L)	pH 6.0[1] (mg min / L)	pH 8.0[1] (mg min / L)
0.5	27.4 (a)	26.1 (a)
1.5	32.0 (a)	50.9 (b)
2	-	53.5 (c)
5	63.8 (a)	35.5 (c)

Source: USEPA, 1990.
Note: [1] Letters indicate different experimental conditions.

A 1990 study investigated CT values for *Legionella pneumophila* inactivation. CT values for 99 percent (2-log) inactivation of *Legionella pneumophila* at pH 6.0 were determined to be 42.7 mg min/L at a dose of 1.0 mg/L (contact time 42.7 minutes) and 41.0 mg min/L at a dose of 5.0 mg/L (contact time 8.2 minutes) (Yahya et al., 1990a).

5.5 Disinfection Byproduct Formation

No literature is available that specifically addressed DBPs when using potassium permanganate. However, several studies have been conducted with water treatment plants that have replaced the pre-chlorination process with potassium permanganate and relocated the point of chlorine addition for post-treatment disinfection. Pretreatment with permanganate in combination with post-treatment chlorination will typically result in lower DBP concentrations than would otherwise occur from traditional pre-chlorination (Ficek and Boll, 1980; and Singer et al., 1980). Under this approach, potassium permanganate serves as a substitute for chlorine to achieve oxidation and may also reduce the concentration of natural organic matter (NOM). However, systems should evaluate the impact on CT values before moving the point of chlorination. The following subsections summarize the outcomes of two studies.

5.5.1 Chapel-Hill and Durham, North Carolina Water Treatment Plants

An investigation was conducted at the Chapel-Hill and Durham Water Treatment Plants to evaluate the effects of potassium permanganate pretreatment on trihalomethane formation (Singer et al., 1980). The Chapel-Hill Water Treatment Plant uses pre-chlorination prior to the rapid mix tank. At the Durham Water Treatment Plant, chlorine is not added until after the sedimentation basin prior to the filtration. Both are surface water treatment plants, treating water with low concentrations of alkalinity. Both sources of water are known to have high trihalomethane formation potentials (Young and Singer, 1979).

Raw water samples taken from Chapel-Hill were found to contain relatively high turbidities, ranging from 46 to 110 NTU and total organic carbon (TOC) concentrations ranging from 5.6 to 8.9 mg/L. The Durham samples were coagulated then allowed to settle, which resulted in better water quality than the Chapel-Hill samples. Following settling, this sample had a turbidity of 6.4 NTU and a TOC of 2.9 mg/L. Sulfuric acid and sodium hydroxide were used to adjust the sample pH to either 6.5 or 10.3. These pH values were selected because they encompass the pH range typically found in surface water coagulation-filtration and lime-softening treatment plants.

Potassium permanganate doses of 2 and 5 mg/L were found to be totally consumed within 1 and 4 hours, respectively, by the Chapel-Hill samples. At doses of 2 and 5 mg/L, the potassium permanganate demand of the Durham samples after 4 hours were approximately 1.3 and 1.8 mg/L, respectively.

This difference in permanganate demands between the Chapel-Hill and Durham samples may be attributed to the water quality of the samples, in particular the TOC concentrations. TOC measurements before and after the application of permanganate were approximately equal; however, it is likely that the TOC after disinfection was at a higher oxidation state. Results of this study also showed that permanganate is more reactive as an oxidant at higher pH values.

Despite the high degree of permanganate consumption, the reaction of permanganate appears to have relatively little effect on chlorine demands. For example, consumption of 6 mg/L of permanganate resulted in a chlorine demand reduction of approximately 1 mg/L. This observation suggests that permanganate reacts with water impurities in a different manner, or at different sites, than chlorine. One other possible explanation is that permanganate oxidizes certain organic substances, thereby eliminating their chlorine demand and only partially oxidizing other organic substances making them more reactive to chlorine.

Both the Chapel-Hill and Durham samples were tested for their chloroform formation potential. This measurement is based on the amount of chloroform produced after seven days. The potential of the Durham sample was reduced by 30 and 40 percent at pH 6.5 and 10.3, respectively, as a result of the application of 10 mg/L of potassium permanganate for a period of 2 hours. Similar results were obtained for the Chapel-Hill samples; however, the results at pH 6.5 did not show a reduction in chloroform formation potential at low doses.

Two experiments were conducted on Chapel-Hill raw water to further explore the effects of low doses of permanganate. The results indicated that permanganate has no effect on chloroform production at doses up to 1 mg/L. At higher doses, chloroform formation potentials were reduced.

In summary, the key results obtained from the studies conducted at the Chapel-Hill and Durham Water treatment plants were:

- The reactivity of permanganate is a function of pH, permanganate dose, and raw water quality.
- Permanganate reduces chloroform formation potentials. The reduction in the chloroform formation potential is proportional to the amount of permanganate available after the initial demand is overcome. Doses up to 1 mg/L were found to have no effect on chloroform formation potentials.
- At pretreatment doses typically employed at water treatment plants, the effect of permanganate on the overall chloroform production is relatively small. If permanganate is to be used specifically to reduce trihalomethane formation, larger doses will be required. However, one advantage for using permanganate for pretreatment is that the point of application of chlorine can be shifted downstream of the sedimentation basins. This is likely to result in fewer trihalomethane compounds.

5.5.2 American Water Works Association Research Foundation TTHM Study

Another investigation examined the impacts of potassium permanganate addition on byproduct formation at four water treatment plants (Ficek and Boll, 1980). All were conventional plants using pre-chlorination in the treatment process. Plant design capacities ranged from 4.5 to 15 mgd. Process modifications were made at each plant to replace the pre-chlorination facilities with oxidation facilities for potassium permanganate addition. After the modifications were complete, an AWWARF research team conducted a study to determine the impact of potassium permanganate addition on total trihalomethane (TTHM) concentrations (George et al., 1990).

Prior to switching from pre-chlorination to pre-oxidation with potassium permanganate, average daily TTHM concentrations at all four plants were between 79 and 99 µg/L. The average TTHM concentration for all four plants was 92 µg/L. Following the conversion to potassium permanganate, three of the four plants experienced greater than 30 percent reduction in TTHM concentrations. In addition to TTHM reduction, potassium permanganate was found to oxidize taste and odor causing compounds, iron and manganese, organic and inorganic matter, and reduce algal growth. Results from the study also showed that the simultaneous application of potassium permanganate and chlorine can increase THM formation.

5.6 Status of Analytical Methods

The atomic adsorption spectrophotometry method for the measurement of manganese is the preferred method for measuring permanganate concentrations. Two colorimetric methods, persulfate and periodate are also available (Standard Methods, 1995).

5.7 Operational Considerations

In utilizing potassium permanganate in water treatment, caution should be taken to prevent overdosing, in which case, excess manganese will pass through the treatment plant. Proper dosing should be maintained to ensure that all of the permanganate is reduced (i.e., forming MnO_2 solids) and removed from the plant upstream of, or within, the filters. If residual manganese is reduced downstream of the filters, the resulting solids can turn the finished water a brown/black color and precipitate in the homes of consumers on heat exchange surfaces such as hot water heaters and dishwashers.

Use of potassium permanganate can also be a source of manganese in the finished water, which is regulated in drinking water with a secondary maximum contaminant level of 0.05 mg/L. Under reducing conditions, the MnO_2 solids accumulated in filter backwash water and settling basins can be reduced to soluble Mn^{2+} and pass through the filters thereby remaining in the finished water.

Also, under these conditions, soluble Mn^{2+} in return water from settling basin dewatering facilities and filter backwash water recycled to the head of the plant are potential sources of manganese that will have to be treated and/or controlled to minimize finished water manganese levels (Singer, 1991).

Overdosing of permanganate in conventional plants is generally corrected by settling the excess MnO_2 solids in the settling basin. Removal of the excess permanganate can be monitored qualitatively by observing the disappearance of the pink color characteristic of permanganate. In plants that do not utilize flocculation and sedimentation processes permanganate dosing should be closely monitored (Montgomery, 1985).

In general, potassium permanganate does not interfere with other treatment processes or plant conditions. Permanganate can be added downstream of, or concurrently with, coagulant and filter polymer aids. Powdered activated carbon (PAC) and permanganate should not be added concurrently. PAC should be added downstream of permanganate because it may consume permanganate, rendering it unavailable for the oxidation of target organics. (Montgomery, 1985).

The space requirements for permanganate feed equipment vary depending on the type and size of feed system. Dry feed systems require about half the floor area of batch systems because batch systems typically have two dissolving tanks for redundancy. However, the head space requirements are greater for dry feed systems where the storage hopper and dust collector are stacked on top of the dry feeder (Kawamura, 1991). On-site storage of potassium permanganate also warrants some consideration. Per OSHA requirements, oxidants such as permanganate should be stored separate from organic chemicals such as polymers and activated carbon.

5.8 Summary

5.8.1 Advantages and Disadvantages of Potassium Permanganate Use

The following list highlights selected advantages and disadvantages of using potassium permanganate as a disinfection method for drinking water. Because of the wide variation of system size, water quality, and dosages applied, some of these advantages and disadvantages may not apply to a particular system.

Advantages

- Potassium permanganate oxidizes iron and manganese.
- Potassium permanganate oxidizes odor and taste-causing compounds.
- Potassium permanganate is easy to transport, store, and apply.
- Potassium permanganate is useful in controlling the formation of THMs and other DBPs.
- Potassium permanganate controls nuisance organisms.
- The use of potassium permanganate has little impact on other treatment processes at the water treatment facility.
- Potassium permanganate has been proven effective against certain viruses.

Disadvantages

- Long contact time is required.
- Potassium permanganate has a tendency to give water a pink color.
- Potassium permanganate is toxic and irritating to skin and mucous membranes.
- No byproducts are generated when preparing the feed solution, however this dark purple/black crystalline solid can cause serious eye injury, is a skin and inhalation irritant, and can be fatal if swallowed. Over-dosing is dangerous and may cause health problems such as chemical jaundice and drop in blood pressure.

5.8.2 Summary Table

More research is needed regarding the disinfection properties and oxidation byproducts of permanganate in water treatment. Also, a CT credit needs to be assigned to permanganate if it is to be utilized as a disinfectant. However, given that alternative oxidants, such as ozone and chlorine dioxide, demonstrate much greater efficacy in microbial control, permanganate is not likely to be utilized as a primary oxidant for precursor control. Table 5-2 summarizes the information presented in this chapter regarding the use of potassium permanganate in the drinking water treatment process.

Table 5-2. Summary of Potassium Permanganate Use

Consideration	Description
Generation	Product supplied in dry form in buckets, drums, and bulk. On-site generation of solution is required using chemical mixing and feed equipment.
Primary uses	Control of odor and taste, remove color, control biological growth, and remove iron and manganese.
Inactivation efficiency	Not a good disinfectant. Can serve better as an alternative to chlorine or other disinfectants where chemical oxidation is desired.
Byproduct formation	No literature was found that specifically addressed DBP formation from potassium permanganate oxidation. Pretreatment with permanganate in combination with post-treatment chlorination will typically result in lower DBP concentrations than would otherwise occur from traditional pre-chlorination.
Limitations	Not a good disinfectant; primarily used for pretreatment to minimize chlorine usage and byproduct formation.
Points of application	Conventional Treatment: raw water addition, rapid mix tank in conjunction with coagulants, clarifiers upstream of filters. Direct Filtration: raw water intake. In all cases permanganate should be added upstream of filters.
Special considerations	Caution should be taken to prevent overdosing. More research is needed to determine disinfection properties and oxidation byproducts.

5.9 References

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