ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF ENFORCEMENT

REPORT ON

POLLUTION AFFECTING WATER QUALITY OF THE CHEYENNE RIVER SYSTEM WESTERN SOUTH DAKOTA

DIVISION OF FIELD INVESTIGATIONS - DENVER CENTER

DENVER, COLORADO

AND

REGION VII

KANSAS CITY, MO.

REGION VIII

DENVER, COLO.

CLEAN WATER

SEPTEMBER 1971

ADDENDUM TO REPORT ON POLLUTION AFFECTING WATER QUALITY OF THE CHEYENNE RIVER SYSTEM, WESTERN SOUTH DAKOTA

On page 2, end of last paragraph, add -- The cooperation and support of various Federal, State and private agencies is gratefully acknowledged.

Page 3, 5th line from bottom, change 2.5 to 2.35.

Page 4, 5th line after "Whitewood Creek" insert -- The suspended solids discharge is approximately 375 times greater [illegible] under the applicable water quality criteria, at a streamflow of 30 cfs.

Page 15, line 7 after "mercury" insert -- with concentrations as high as 124 micrograms per liter.

Page 15, line 11 after "agreed" add -- and discontinued use of mercury amalgamation in December 1970.

Page 15, 3d line from bottom after "fish samples" add -- or 3.9 percent of the analyses.

Page 15, 2d line from bottom after "fish samples" add -- or 15.2 percent of the analyses.

Page 19, 2d line from the bottom, change to read -- known to inhabit the study area but may not be harmful to insect larvae.

Page 21, at top, add -- Elk Creek heads in the Black Hills just south of the Lead-Deadwood area. It flows east, passing into the plains just north of Rapid City. From this point to the mouth, Elk Creek flows over deposits of marine shales. A water sample collected during June contained 2.0 μg/l of mercury, or a load of 1.2 lbs/day. This was the highest concentration of mercury observed in any stream not influenced by Homestake discharges, and resulted from leaching of mercury adhering to suspended sediment particles. Subsequent water samples collected during July did not contain detectable mercury. The benthos community of Elk Creek reflected the influence of domestic waste or agricultural drainage and intermitten flows; however, the flesh of fish collected from this stream contained only 0.05 ppm of mercury.

Page 22, 2d line from bottom, change "1.5 micrograms per liter" to "1.4 micrograms per liter."

Page 25, 2d paragraph, 6th line after "arsenopyrite" insert sentences -- The suspended solids concentrations in Whitewood Creek, according to applicable stream standards, should be less than 90 mg/l. This indicates that the maximum allowable load of suspended solids in Whitewood Creek from all natural and artificial inputs can be no greater than 7.3 tons per day at a flow of 30 cubic feet per second. Therefore, the discharge of Homestake Mining Company effluent is approximately 375 times greater than the maximum permitted solids load in Whitewood Creek at 30 cfs. To meet existing standards, there must be a reduction of at least 99.7 percent of the present solids discharge from the Homestake Mining Company.

Page 29, 4th line, delete "during this study" and substitute "in the Cheyenne River system outside of Oahe Reservoir."

Page 30, after second paragraph, insert new paragraph -- A mineral of the amphibole group was common at all [illegible] [illegible] the Homestake discharge, but was not found at those stations upstream of the Homestake discharges. It was common in the deposits of buried tailings. The amphibole was also observed in sediment from the Cheyenne River arm of Oahe Reservoir. Optical mineralogy techniques were utilized to determine that the amphibole was the mineral cummingtonite, which is reported to be a major constituent of the Homestake ore.

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF ENFORCEMENT

Report on POLLUTION AFFECTING WATER QUALITY OF THE CHEYENNE RIVER SYSTEM WESTERN SOUTH DAKOTA

Division of Field Investigations - Denver Center
Denver, Colorado

Region VII
Kansas City, Missouri

Region VIII
Denver, Colorado

September 1971

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I. INTRODUCTION

During the summer of 1970, the U. S. Food and Drug Administration (FDA) analyzed fish from the Cheyenne River Arm of Oahe Reservoir, and other areas throughout western South Dakota. They found that mercury in the flesh of many fish in the Cheyenne Arm exceeded the FDA guideline of 0.5 parts per million (ppm). Fish from other areas, notably Angostura and Belle Fourche Reservoirs, contained some mercury, but generally at levels less than the FDA guideline.

Since the latter part of the nineteenth century, mercury had been used for gold recovery at the Homestake Mining Company Lead-Deadwood mill. Examination of published and unpublished information also led to the belief that other mining activities in the Black Hills previously had discharged mercury. Various State and Federal authorities have speculated that natural deposits of mercury minerals in the Black Hills and in marine shales throughout western South Dakota may cause mercury pollution.

Sampling in 1970 by the Environmental Protection Agency (EPA) revealed that Homestake Mining Company was discharging from twelve to forty pounds per day of mercury in their tailings slurry releases to Whitewood Creek, a tributary of the Cheyenne River system. The company discontinued the use of mercury in December 1970. Subsequent sampling revealed that the company was discharging cyanide, arsenic, and other toxic materials, together with vast quantities of suspended solids.

The Governor of South Dakota, by letter of April 23, 1971 (Appendix A) under Section 10(d)(1) of the Federal Water Pollution Control Act, requested that the Administrator of the U. S. Environmental Protection Agency call a conference of State and Federal agencies, to consider the occurrence, distribution, and significance of cyanide, mercury, and other metals pollution in western South Dakota.

This report presents the results of technical studies conducted in the Cheyenne River system by the Division of Field Investigations - Denver Center (DFI-DC), Office of Enforcement, EPA.

Objectives of these studies were:

1. To investigate the effects of natural mercury deposits throughout the Cheyenne River system in western South Dakota.
2. To determine the location and extent of reservoirs of mercury and other toxic materials due to previous mining activity, and measure the effect of the toxic substances on surface water, ground water, and biota.
3. To document and characterize the discharge of tailings solids and various dissolved toxic pollutants from the Homestake Mining Company Deadwood-Lead mill.
4. To ascertain the movement and fate of these pollutants in the hydrologic environment, and the effect of these pollutants on the biota.

To meet these objectives, data gathered by State and Federal agencies, universities, and companies were utilized. Special studies of biota, surface streams, ground water and sediment were also conducted.

II. SUMMARY AND CONCLUSIONS

1. Streams draining areas of placer mining and mineral deposits in the Black Hills do not contain significant concentrations of mercury or arsenic during normal runoff. Certain of the streams examined contained high concentrations of mercury during infrequent periods of high runoff. Fish in these streams contain mercury at concentrations less than the FDA guideline of 0.5 ppm. Streams draining areas of marine shale contain detectable quantities of mercury during infrequent periods of high runoff, but do not contain detectable mercury during normal stream flow. Fish in these streams contain mercury at levels generally less than the FDA guideline of 0.5 ppm.
2. The benthos communities of Spearfish Creek, Redwater River, Belle Fourche River at Fruitdale, Cheyenne River at Wasta and French, Battle, Rapid and Elk Creeks were not damaged by siltation or toxic materials. The flesh of fish collected from all of these stream reaches, with the exception of Redwater River, contained mercury at concentrations less than the FDA guideline. Redwater River carp contained mercury in excess of FDA standards.
3. Although Homestake Mining Company discontinued the use of mercury in their milling process in December, 1970, the plant effluents still contain approximately 2.5 pounds per day of mercury. This results from the leaching of mercury contained in the ore fed to the Homestake mill. A major portion of the discharged mercury is adsorbed by sediment in Whitewood Creek. From 0.1 to 0.5 pounds per day of mercury is transported into the Belle Fourche River during periods of low flow.

Larger amounts are transported during high stream flows.

4. Analyses of effluents discharged during June, 1971, showed the Homestake Mining Company to be adding daily loads of 312 pounds of cyanide, 240 pounds of zinc, 72 pounds of copper, and 2735 tons of suspended solids to Whitewood Creek. The tailings solids include a load of 9.5 tons per day of arsenic in the form of arsenopyrite, an arsenic-iron sulfide. The arsenopyrite is oxidized, resulting in arsenic concentrations in the Cheyenne River which are four times greater than the U. S. Public Health Service water-supply criterion.

5. Whitewood and Deadwood Creeks, upstream from the Homestake discharges, contain high levels of mercury during runoff periods, but lower levels at other times. Flesh of fish from these streams does not contain detectable mercury concentrations. Deadwood and City Creeks, as well as Whitewood Creek upstream from Gold Run, were inhabited by diverse communities of aquatic organisms, including a predominance of forms sensitive to pollution. Whitewood Creek from Gold Run downstream to the mouth was severely damaged by discharges from Homestake Mining Company. No aquatic organisms were found in this stream reach. Concentrations of cyanide, arsenic, mercury, and suspended solids were each sufficiently high, independently or in concert, to damage the biota of Whitewood Creek. Damage extended into the Belle Fourche River downstream from the mouth of Whitewood Creek. Siltation and high arsenic concentrations in the Belle Fourche reduced the numbers and variety of benthos. Fish from this reach of the river contained high mercury concentrations.

6. Previously-discharged Homestake tailings solids have been deposited

along Whitewood Creek and the Belle Fourche and Cheyenne Rivers. These solids are eroded and leached during high stream flows. Buried deposits of tailings solids occur in abandoned river meanders, chiefly along the Belle Fourche River. Leaching of mercury from such deposits contaminates ground water, as well as surface streams. The ground water is used as a supply for domestic wells. Large quantities of mercury are contained in the buried tailings, and may be leached by ground water. After cessation of the discharge of solids from Homestake, the deposits will be eroded by surface streams as the streams adjust to a new hydrologic regime. Research is currently underway to develop methods of recovering mercury from sediments. The buried tailings also contain large quantities of arsenopyrite which may be leached to surface streams or ground water.

7. Deposits of Homestake Mining Company tailings occur in the Cheyenne River Arm of Oahe Reservoir. Mercury from these deposits contaminates the flesh of fish in the Cheyenne River Arm of Oahe Reservoir at levels often exceeding the FDA guideline.

8. Plans are underway for construction by the Lead-Deadwood Sanitary District of a tailings pond-sewage lagoon which will treat raw sewage from Lead and Deadwood as well as the Homestake Mining Company effluents. The facility is scheduled for completion in November 1973.

9. Interim tailings-pond sites are available which would result in a reduction of about 80 percent of the pollution carried by Whitewood Creek, pending completion of the Sanitary District facilities.

III. RECOMMENDATIONS

It is recommended that:

1. The Lead-Deadwood Sanitary District proposed treatment facility at Centennial Valley, for domestic sewage and Homestake tailings, be constructed and in operation by November 1973. Progress schedules as specified by the Refuse Act Permit Application are to be met.
2. Pending completion of the Sanitary District facility, Homestake Mining Company construct and operate an interim tailings pond, to control the continuing mercury pollution from Homestake, and substantially reduce the cyanide, arsenic, and tailings solids in Whitewood Creek. If the interim facility is not completed and operating by July 1, 1972, Homestake be cited under the provisions of the Rivers and Harbors Act of 1899, for discharging toxic materials and solids to the Cheyenne River system.
3. The location and composition of buried tailings materials along Whitewood Creek, the Belle Fourche River, and the Cheyenne River be carefully ascertained and fully documented. Toxic materials be recovered as the technology becomes available. Pending the development of recovery techniques, the deposits be contained to prevent their re-entry into the hydrologic system.
4. Arsenic concentrations in wells drawing water from alluvium downstream of the Homestake discharges be determined, to ascertain whether these sources are acceptable for domestic or agricultural water supply uses.
5. The South Dakota Department of Game, Fish, and Parks assure that the excessive concentrations of mercury in fish of the Cheyenne River

system are known to the public, such notification to include recommendations of non-consumption of fish. Commercial fishing in the Cheyenne Arm of Oahe Reservoir should be prohibited.

6. A complete inventory of the location and composition of abandoned tailings piles in the area north and west of Lead be conducted by the State of South Dakota. The State take appropriate measures to assure that adverse effects on water quality and aquatic life resulting from residual toxic materials contained in these tailings shall not occur. The State assure that the tailings are controlled in accordance with the best available technology.

7. Water quality standards be established for Whitewood Creek and Deadwood Creek, including an implementation plan for abatement of existing pollution.

IV. DESCRIPTION OF AREA

A. PHYSICAL DESCRIPTION

The Black Hills are the dominant physical feature of western South Dakota, extending for approximately 50 miles in the north-south direction and approximately 30 miles in the east-west direction. The mountain crests have an average elevation of approximately 6,000 feet, with isolated peaks exceeding 7,000 feet. Headwaters of most major western South Dakota streams rise in the Black Hills.

B. CLIMATE

Precipitation throughout western South Dakota is closely related to elevation. The high areas of the Black Hills receive an annual precipitation of more than 20 inches per year while the plains areas receive less than 15 inches per year. Precipitation occurs both in the form of winter snows and early summer thunder storms. Lake evaporation is approximately 40 inches per year.

C. GEOLOGY

The Black Hills uplift is the dominant geologic feature of western South Dakota. The elliptical dome has influenced the outcrop and dip of strata in an area approximately 125 by 60 miles. Crystalline rocks of pre-Cambrian age are exposed in the central portion of the Black Hills. These rocks are more resistant to erosion than surrounding rocks. This results in higher elevations, and hence greater rainfall and runoff than from surrounding plains areas. The pre-Cambrian rocks have been extensively fractured and mineralized by subsequent intrusions. The mineralization includes arsenopyrite, an iron-arsenic sulfide: and cinnabar, mercuric sulfide.

Younger sedimentary strata dip radially away from the uplift, with formation outcrops in the form of concentric bands around the Black Hills, and are progressively younger with increasing distance from the dome. The sediments consist of limestones, sandstones, and shales. Some of the limestones and sandstones are regionally important aquifers. Several of the limestones contain solution cavities, which permit uninhibited movement of water.

Outside the Black Hills region, western South Dakota is underlain by Cretaceous and Tertiary shales, largely flat-lying. These were deposited under marine and lacustrine conditions, and contain numerous soluble salts. Such shales were suspected by South Dakota officials as sources of natural mercury pollution.

D. HYDROLOGY

Most of western South Dakota is drained by the Cheyenne River and its tributaries, the chief of which is the Belle Fourche River. Both of these streams head in northeastern Wyoming, in an area of Tertiary shales and sandstones. They then flow around the Black Hills uplift, with the Cheyenne River passing to the south and the Belle Fourche River skirting the north end. Several streams drain from the Black Hills to join the rivers on the uplift margin. The drainage pattern of western South Dakota, shown in Figure 1 at the back of this report, is thus greatly modified by the more-resistant rocks exposed in the Black Hills.

Spring, French, Rapid, and Battle Creeks drain the southern Black Hills, in the vicinity of Custer, Hill City, and Silver City. Much of the early mining took place in this region, with resultant disruption of the stream beds. Available information indicates that mercury was not widely used in this early mining.

Whitewood and Deadwood Creeks join in Deadwood at a point approximately 30 miles upstream of the confluence with the Belle Fourche River. The natural flow in both streams is minor except during runoff periods. The flow is augmented by the waste discharge from the Homestake sand dams and slime plant, and by the raw sewage discharge from Lead and Deadwood.

Ground water is available in western South Dakota from two sources: alluvium in bedrock valleys cut by surface streams, and consolidated aquifers which dip radially away from the Black Hills. The alluvial valleys are locally important as a source of supply for ranches along the streams, and are recharged by surface stream flow. The consolidated aquifers, sandstones and limestones, are regionally important as sources of supply, although the water is highly mineralized at points remote from outcrops of the various aquifers.

V. WASTE SOURCES

Mining of placer and lode gold deposits has occurred over much of the Black Hills region. In his letter requesting the western South Dakota pollution conference, Governor Kneip voiced concern over pollution resulting from past mining activities. Such pollution could include particulates eroded from old tailings piles, acids and metals from sulfide oxidation, and mercury from placer dredging and hard-rock milling.

Several inactive mill tailings piles, located west of Lead, were observed to be eroding during surface runoff events. Such runoff carries mineral-laden sediment into the water courses, for subsequent leaching, and could be a source of water-quality degradation.

Prior to the end of 1970, all gold recovery from lode mines in the Lead-Deadwood area involved use of mercury for gold amalgamation. First milling was by use of an arrastra, followed by the advent of stamp mills. The Homestake Mining Company batch process was developed around the turn of the century. In it, amalgamation plates were used to recover large gold particles. The ground rock was then separated into sand and slime fractions, for subsequent cyanide leaching to recover fine gold particles. After the gold was leached from the ore, the spent rock was sluiced from the plant. Formerly, all the solids were discharged into Whitewood Creek. In recent years, Homestake Mining Company has returned approximately 80 percent of the sand fraction to the mine, to prevent subsidence. Due to the bulking effect which results during grinding of the ore, all the ground rock cannot be replaced in the mined spaces. Therefore, the remaining 20 percent of the sand fraction, and all the slime fraction, is sluiced directly into Whitewood Creek. Under present production levels, this results in a 2,735 ton per day discharge of suspended solids to Whitewood Creek. This material consists of finely-ground particles containing arsenopyrite, an arsenic-iron sulfide, and other sulfide minerals. The water solution used in sluicing the solids from the plant contains residual cyanide used in ore leaching. The liquid and solid material contained mercury lost from the amalgamation plates.

After mercury was recognized as a serious pollutant, officials of Homestake Mining Company agreed to discontinue use of amalgamation as a gold-recovery method, and to rely on the use of cyanide leaching for all gold recovery. This change was achieved early in 1971. Currently, the sand and slime fractions are treated in a series of cyanide washes and rinses, with gold recovery achieved by zinc-dust precipitation. Barren rock and cyanide are still sluiced directly into Whitewood Creek, and affect water quality in the Belle Fourche and Cheyenne Rivers.

Deposits of previously-discharged tailings solids buried in active streams and abandoned meanders constitute a continuing source of toxic materials to surface streams of western South Dakota, and may pollute nearby ground water.

The towns of Lead and Deadwood have only rudimentary sewage-treatment facilities. Collection systems are old, and carry storm runoff, infiltration, and sanitary sewage. Most of the sewage from Lead and Deadwood is discharged directly to Whitewood Creek, with no treatment.

VI. WATER QUALITY AND RELATED FACTORS

A. APPLICABLE STANDARDS

Water quality standards for surface waters of South Dakota were adopted by the South Dakota Committee on Water Pollution, February 16, 1967, and were subsequently approved by the Secretary of the Interior.

The standards, under general requirements, specify that no sewage or industrial waste shall be discharged which produces, among other effects, material discoloration, sludge deposits, or other offensive effects. The general provisions also prohibit the discharge of toxic materials which harm aquatic life.

The standards specify that the Belle Fourche and Cheyenne Rivers are for warm water semi-permanent fishery, limited contact recreation, wildlife propagation and stock watering, and irrigation. Numerical limits for several important constituents which apply for such uses are:

Cyanide, less than 0.02 mg/l

Iron, less than 0.2 mg/l

pH, 6.3 to 9.0

Suspended solids, less than 90 mg/l

Turbidity, less than 100 Jackson Turbidity Units

No numerical standards have been established for Whitewood Creek. Portions of the applicable stream standards are reproduced in Appendix B.

B. PREVIOUS STUDIES

The first known cognizance of pollution from the Homestake operation is contained in "South Dakota, A Guide to the State",[1/] a WPA authors project book. In this publication, it is stated that "Whitewood Creek, once a crystal-clear tumbling mountain stream, now a dirty leaden color, literally a flow of liquid mud, caused by the tailings from the Homestake Mine at Lead, flows through the center of Deadwood. Livestock will drink the water along the lower reaches; but no animal life is possible in it."

An early study of the waste loads discharged by Homestake, and their effects on receiving streams, was carried out in June and July 1959, by the South Dakota Department of Health, with assistance from the U.S. Public Health Service. In two reports[2,3/], published in 1960, the State Department of Health reported a discharge of 2400 tons per day of tailings solids and 133 pounds per day of cyanide to Whitewood Creek. One of these disclosed that the waste destroyed all life in Whitewood Creek and the first several miles of the Belle Fourche River downstream from the mouth of Whitewood Creek. Tables of stream data generated by the 1959 survey are reproduced from the 1960 reports in Appendix C. The data show that concentrations of cyanide in Whitewood Creek below the Homestake discharges ranged to over 2.10 mg/l. Cyanide was detectable in the Belle Fourche and Cheyenne Rivers, below the Whitewood Creek inflow.

A settling-tank study conducted in conjunction with the 1959 survey indicated that significant water quality improvement could be achieved by installation of a tailings pond. Accordingly, in the "Report on Gold Recovery Wastes," the State recommended that "Programming be initiated to exclude solids from the receiving stream."

By August 1970, no progress had been made in the Homestake waste-treatment practices and the tailings solids were still being discharged to Whitewood Creek. The discharges were found to contain significant quantities of mercury. Table 1 contains mercury data collected during the various stream sampling periods in 1970.

Following the discovery of high mercury levels in the streams, Homestake Mining Company was requested to discontinue use of mercury in its amalgamators. Homestake officials agreed, and removed all mercury from the milling cycle by January 1971. Samples were collected downstream of the Homestake Mill shortly after amalgamation was discontinued. High levels of mercury in the effluent indicated the presence of residual mercury in the milling equipment. The data contained in Table 2 show the continued presence of mercury in Whitewood Creek downstream of the Homestake discharges. Cyanide concentrations in Whitewood Creek were at levels considered harmful to fish[4/].

Flesh of fish from the Cheyenne River Arm of Oahe Reservoir was found to contain mercury at levels greater than the FDA guideline of 0.5 parts per million. Results of fish sampling throughout South Dakota during 1970 are summarized by South Dakota agencies (Appendix D). Only two fish samples from the areas not influenced by Homestake discharges exceed the FDA guideline of 0.5 ppm. Seven fish samples from the area influenced by Homestake discharges exceeded the FDA guideline.

TABLE 1

Mercury Concentrations in South Dakota Water Samples
Collected During 1970

Location	1970 Date		Mercury Concentration (µg/l)
Whitewood Creek above Gold Run	7/14		<1.0
	8/13		<1.0
	11/14		<1.0
Deadwood Creek above its mouth	8/13		<1.0
Whitewood Creek at Deadwood	8/13-14	Comp.	100
	8/14-15	Comp.	Interference
	11/3-4	Comp.	68
	11/4	Comp.	80
Whitewood Creek one mile above its mouth	8/12		96
	11/4		124
Belle Fourche River above Whitewood Creek	7/16		<1.0
	8/12		<1.0
Belle Fourche River at Route 79 Bridge	8/12		16.5
Belle Fourche River at Route 34 Bridge	8/12		3.0
Belle Fourche River southeast of Hereford	8/12		3.0
Belle Fourche River at Elm Springs	8/12		2.6
Cheyenne River at Route 34 Bridge	8/12		1.8
Cheyenne River at Route 63 Bridge	8/12		1.1

TABLE 2

Mercury and Cyanide Concentrations in
Stream Samples from Lead-Deadwood, S. D.
January, 1971

Location	Mercury µg/l	Free CN mg/l	Total CN mg/l
Combined Discharges - Whitewood Creek at Rodeo Campground - Deadwood, South Dakota (Flow 13.2 cfs)			
Composite January 21, 1971 (1230 to 2300 hours)	12.	*	*
Composite January 22, 1971 (0001 to 1100 hours)	29.±7	2.6	3.65
South Dakota on Crook Mountain Road	39.	1.4	3.15
Whitewood Creek at Lawrence - Meade County Line	*	1.0	1.25
Whitewood Creek at Bridge near Confluence with Belle Fourche River	33.	0.5	1.15

* No analyses run

C. RECENT EVALUATIONS

Water samples were collected by EPA from streams in the Lead-Deadwood area during March and May, 1971, for mercury and cyanide analysis. Sampling of bottom sediments and core drilling of buried tailings deposits was accomplished during May. A major water quality and biological survey of western South Dakota streams was conducted during May, June and July, 1971. The May and June sampling was done during abnormally high stream flows and frequent rains, while the July sampling period was during a period of normal climatic conditions. Biological and water quality findings are summarized in Appendix E. Survey methodology is discussed in Appendix F. Sampling locations are shown in Figure 1 at the back of this report.

The pollutants discharged to the streams investigated during this survey may be separated into three categories, toxic material, inorganic sediment and organic wastes. The following discussion of toxicity is taken from McKee and Wolfe[4/], and from "The Study Group on Mercury Hazards"[5/]. Toxic materials include such pollutants as cyanide, arsenic, and mercury. Cyanide toxicity is affected by pH, dissolved oxygen, temperature, and minerals in solution. Game fish cannot tolerate 0.2 mg/l of cyanide for 96 hours and 1.0 mg/l will inhibit organisms that exert biochemical oxygen demand. Invertebrate organisms can tolerate no more than about 4.0 mg/l of cyanide in water. Arsenic in water is toxic in the range of 2 to 3 mg/l to some of the fish known to inhabit the study area and may be harmful to insect larvae at 20 mg/l[4/]. The toxicity of mercury to aquatic biota depends upon its chemical state. Elemental mercury is relatively insoluble in water; therefore, aquatic organisms usually are not exposed to it in high concentrations. However, elemental mercury is readily methylated by microorganisms, and becomes quite water soluble. Methylated mercury compounds are readily taken up by aquatic organisms, and may be toxic or accumulative in the organisms. Thus, fish, exposed to minute mercury concentrations may accumulate it in their tissues to levels hazardous for human consumption. Mercury concentrations from 4 to 20 μg/l may be harmful to fish, while approximately 40 μg/l is harmful to invertebrates. The U. S. Food and Drug Administration recommends that fish containing 0.5 ppm mercury not be eaten.

The second category of pollutants is solid matter suspended in the water, primarily finely-ground and extremely dense mill tailings. These solids settle on stream bottoms, destroy habitats and smother aquatic organisms. The pollutional effect is deletion of organisms, and the result is difficult to distinguish from toxic effects.

The third category of pollutants, domestic and agricultural wastes, produce water quality conditions which tend to favor the growth of pollution tolerant organisms, to the exclusion of sensitive forms. The benthos often consist of sludgeworms, midge larvae, leeches, and snails rather than stonefly and mayfly nymphs. Fish populations are often represented by carp and suckers rather than game fish.

The following sections discuss by stream the water quality and biological conditions observed during the recent surveys.

Cheyenne River Drainage

A water sample collected from the Cheyenne River at Wasta, S.D. (Station 4235) during high runoff contained 0.4 µg/l of mercury, or 4.5 pounds of mercury per day. The sample did not contain detectable arsenic or significant quantities of other toxic metals. Mercury was not detected in samples collected in July, during normal streamflow. The mercury load in the June sampling resulted from leaching of mercury-bearing suspended sediment. A bottom sediment sample from the site contained only 0.04 ppm of mercury. This indicates that high mercury concentrations in the stream are not concommitant with normal stream flow.

Battle Creek (Station 4040) drains an area of previous mining activity, upstream of Hayward. A water sample from the creek contained 0.3 µg/l of mercury, or 0.07 pounds per day. Rapid Creek also drains an area of previous mining activity. A water sample collected from Rapid Creek below Pactola Dam (Station 4115) contained 0.2 µg/l of mercury, or 0.14 pounds per day. These findings indicate that previous mining sites are not significant mercury pollution sources.

Boxelder Creek heads in the Black Hills, flows by Ellsworth Air Force Base, and drains a large Cretaceous shale area. A water sample collected at Owanka (Station 4200.5) contained 0.6 µg/l mercury or 0.05 pounds per day of mercury. This concentration apparently resulted from leaching of shale washed into the stream during previous rainfalls. No detectable arsenic was found in the sample. Sediment from this station contained only 0.02 ppm of mercury, which indicates that mercury is not normally present in significant quantities in the stream.

The levels of mercury contained in the above streams during periods of runoff do not cause high mercury concentrations in resident fish. Fish collected from Angostura Reservoir (Station 4010), the Cheyenne River at Wasta (4235), and from tributaries, including French Creek (4025.5), Battle Creek (4060), Rapid Creek (4130), and Elk Creek (4255), all contained mercury concentrations less than half the FDA guideline. The biotic communities of each of these streams, except Rapid Creek, reflected the presence of organic wastes. No adverse effects of siltation or toxic substances were detected in any of the streams in this portion of the Cheyenne River drainage.

Nutrients made the Cheyenne River at Wasta and its upstream tributaries extremely fertile. This over-enrichment affected the aquatic life community. Benthos samples collected near Wasta contained high densities (764 per square foot) and low variety (10 kinds) of organisms. This reflected the presence of organic wastes and the absence of siltation or toxic materials.

Belle Fourche River Drainage

The farthest upstream station in the Belle Fourche River drainage system was located on Spearfish Creek downstream from Bridal Veil Falls, near Maurice (Station 4314.7). Here, the benthos consisted mostly of pollution-sensitive mayflies, caddisflies, and stoneflies, with large numbers of black fly larvae of intermediate tolerance, indicating little or no pollution. Two unfiltered water samples from this station, collected during a rainstorm, contained 0.5 and 2.3 μg/l of mercury. The wide variation in results indicates that the mercury was attached to sediment being washed into the stream, possibly from tailings piles located upstream along tributaries to Spearfish Creek. Brook trout and brown trout collected from this stream contained no detectable mercury, indicating that high mercury concentrations occur infrequently in Spearfish Creek.

The Redwater River (Station 4329.5), which receives drainage from Spearfish Creek, drains into the Belle Fourche River near Belle Fourche, South Dakota. The diversity of pollution-sensitive benthos indicated minimal damage from siltation or toxic materials. Trout collected here did not contain detectable mercury concentrations and the flesh of white suckers and creek chubs had mercury concentrations of less than 0.20 ppm. However, northern redhorse suckers collected from the Redwater River had moderate mercury concentrations in their flesh, averaging 0.29 ppm; and carp had unacceptably high mercury concentrations in their flesh, averaging 0.58 ppm. Apparently these fish migrated into the Redwater River from contaminated waters downstream.

Belle Fourche Reservoir (Station 4350) receives water diverted from the Belle Fourche River below the Redwater River confluence. Fish collected from this reservoir all contained mercury concentrations less than one-half the maximum limit recommended by FDA.

A water sample collected from the Belle Fourche River near Fruitdale (Station 4360), during the June period of high runoff, contained 0.4 μg/l of mercury. In subsequent samples, collected during normal streamflow, mercury was not detected. No arsenic was detected in the stream, even during periods of high streamflow. The Belle

Fourche River at this location (Station 4360) was biologically fertile, but not polluted. Benthos in this reach consisted of a variety (17 kinds) of primarily pollution-sensitive organisms, including burrowing mayflies, and low numbers of intermediate and tolerant forms. All fish collected from this river reach contained mercury concentrations less than 0.5 ppm. The highest mercury concentration detected was 0.29 ppm in one fish, a goldeye.

Whitewood Creek at the U. S. 85 bridge at Pluma (Station 4361) generally contained low levels of mercury. One sample, collected June 9, during a rainstorm, contained 1.7 μg/l of mercury, apparently the result of leaching from sediment washed into the stream. Arsenic was present in relatively low levels of 12 to 13 μg/l. Other metals were present as the result of the known mineralization in rocks upstream of this station. A sediment concentration of 0.54 ppm mercury is consistent with the mineralized nature of the drainage basin. The stream supported the greatest variety of benthic organisms encountered during the survey (26 kinds), including five stonefly genera, four mayfly and caddisfly genera, and many other forms in moderately high numbers. Fish collected from this reach (brook trout, white suckers, and longnose dace) did not contain detectable mercury concentrations.

Deadwood Creek above Deadwood (Station 4361.3) generally contained low levels of mercury. One sample, collected June 9, during a rainstorm, contained 1.5 μg/l of mercury, similar to levels in Whitewood Creek on the same day. These high levels result from erosion of sediment from the known mineralized area. During the three days of sampling in June, 1971, the stream carried an average mercury load of 0.04 pounds per day. Sediment contained 0.12 ppm mercury. Arsenic was present in low concentrations of 8 to 12 µg/l. Other metals were present in levels slightly higher than those in Whitewood Creek. The stream supported a diverse assemblage of 23 kinds of benthic animals, including many pollution-sensitive forms. Brook trout collected from Deadwood Creek contained no detectable mercury.

The quality of City Creek at Deadwood (Station 4361.4) was similar to that of Deadwood Creek and Whitewood Creek. Metals were present, but did not appear to harm the stream biota. Qualitative biological sampling of City Creek revealed the presence of many pollution-sensitive forms.

Flow in Gold Run (Station 4361.1) consisted of discharge from the Homestake Mining Company's sand dams, and sewage from the town of Lead. The stream contained extremely high concentrations of suspended sediment. Mercury concentrations in the water ranged from 3.8 to 12.0 µg/l. Cyanide was present at levels of from 0.5 to 3.6 mg/l. Arsenic levels of 138 to 1000 µg/l were present in the stream, as a result of oxidation of the vast amounts of arsenopyrite in the Homestake tailings slurry. The stream contained 0.39 mg/l of copper and 1.15 mg/l of zinc in one sample. No aquatic organisms inhabited Gold Run. The concentrations of cyanide, mercury, arsenic, and suspended solids detected in this reach were each sufficiently great to be independently destructive to fish and benthos. Therefore, it was not possible to attribute the destruction of aquatic biota to a single constituent contained in the Homestake Gold Mill effluent -- all were damaging.

The Homestake Mining Company slime plant effluent is discharged into Whitewood Creek immediately upstream from Deadwood Creek. Mercury in this effluent ranged to concentrations as high as 57 µg/l, as the result of leaching of mercury from the ore fed to the mill. No mercury was used in the process at the time. Cyanide, used in the leaching process, was escaping in the sluiced waste, at concentrations of from 3.8 to 9.9 mg/l. Arsenic was abundant in the effluent samples, with concentrations ranging to 1,000 µg/l.

Whitewood Creek, at the Deadwood Rodeo Grounds (Station 4361.5) was in marked contrast to the quality of the stream upstream from Gold Run, and to Deadwood and City Creeks. The creek was a leaden-gray stream of sand and slimes, resulting from the discharge in the two Homestake effluents of 2,735 tons per day of suspended solids, containing 9.5 tons per day of arsenic in the form of arsenopyrite. Mercury concentrations ranged from 2.1 to 8.0 µg/l, for an average mercury load during the June sampling of 2.5 pounds per day. Tributary flow added 0.15 pounds per day of this total load, with the remainder contributed by the leaching of mercury contained in the ore fed to the Homestake Mill. Additional mercury remains attached to the sediment discharged to the stream, but is available for leaching during high stages and for methylation and uptake by downstream biota. Cyanide concentrations in Whitewood Creek at the Deadwood Rodeo Grounds ranged from 0.50 to 1.1 mg/l, for an average load of 312 pounds per day during the June sampling. All the cyanide was from the Homestake mill. Arsenic was present in the water at concentrations of from 230 to 1700 μg/l. The stream carried a load of 72 pounds per day of copper and 241 pounds per day of zinc on June 10, 1971. Of this, less than 0.6 pounds per day of copper and 4 pounds per day of zinc were contributed by tributary inflow. The remainder was from the Homestake effluents. No aquatic organisms inhabited this station, as the result of the high concentrations of cyanide, mercury, arsenic, and suspended solids.

Stream sediment contained 0.18 ppm of mercury, which is approximately one-third of the concentration of 0.57 ppm of mercury in the ore fed to the Homestake Mill. The remainder of the mercury is leached from the ore during the milling process.

Water-quality conditions in Whitewood Creek at downstream stations (Stations 4361.6 and 4361.7) did not improve materially. Mercury concentrations remained high, although the load decreased as the result of adsorption on the tailings solids. Arsenic concentrations increased downstream to a range of 1270 to 1900 μg/l at the mouth. Cyanide concentrations were 0.58 mg/l downstream from Whitewood, and 0.16 mg/l at the mouth, near Vale. Copper, iron, and zinc were present. The stream supported no aquatic life downstream from the Homestake discharges. The destruction of all life in this stream is directly attributable to the high concentrations of cyanide, mercury, arsenic, and suspended solids resulting from the two Homestake discharges.

Horse Creek (Station 4368) and Bear Butte Creek (Station 4375) are the major tributaries to the Belle Fourche River in the vicinity of the mouth of Whitewood Creek. Water samples collected from these two streams during June contained low mercury concentrations, apparently as the result of leaching of decomposed shale washed into the stream. Neither sample contained detectable arsenic concentrations. Samples collected during July, at normal streamflow, did not contain detectable mercury concentrations.

The effects of the Whitewood Creek inflow were evident in the Belle Fourche River at Station 4370. Suspended sediment, resembling Homestake tailings, was clearly visible in the water, with a large amount of settled solids covering the stream bottom. Mercury concentrations in the stream during June were 0.6 μg/l, or 3.0 pounds per day. The arsenic concentration was approximately 0.5 mg/l. Arsenic levels were sufficiently high to be a source of chronic toxicity to aquatic organisms. The cyanide concentration was less than the detection limit of 0.02 mg/l. Suspended solids settled on the river bottom, destroying habitat. The benthos in this reach consisted of little variety (6 kinds) of organisms in a very low density of only 30 per square foot. The flesh of fish collected from this reach contained moderate-to-high concentrations of mercury, some of them bordering on 0.5 ppm.

Water samples were collected from the Belle Fourche River north of Elm Springs, Station 4380. As previously noted, the June sampling was conducted during a period of high, but declining, stream stages. Flow time between the Stations 4370 and 4380 was estimated at one day.

As a result, the net flow measured at the downstream station was much larger than the flow at the upstream station. This higher flow was responsible for the resuspension of previously-deposited Homestake tailings solids. A portion of the metals concentration contained in these tailings solids was leached into the stream, resulting in an increase in metals load in the downstream direction. The June samples at Station 4380 contained 2.8 µg/l of mercury, or 19.7 pounds per day, in contrast to the load of 3.0 pounds per day at the upstream station, Station 4370. This instream increase in mercury load, attributable to the resuspension of tailings, indicated the importance of removing mercury-laden tailings solids from the streambed and banks. Otherwise, the material will continue to be a source of mercury for years. The zinc concentration at Station 4380, north of Elm Springs, was double that at Station 4370, and also resulted from resuspension of the previously-deposited Homestake tailings solids.

Lower Cheyenne River Drainage

Water samples collected in June from the Cheyenne River downstream from Belle Fourche River contained 0.8 µg/l of mercury, or 15.1 pounds per day. Arsenic levels were approximately 0.2 mg/l, or four times the level which constitutes grounds for rejection as a domestic water supply. Thus, the Homestake discharges render the entire stream unsuitable as a source of domestic water supply. Samples collected during July, during normal streamflow, did not contain detectable mercury in solution. A moderate degree of siltation had occurred in the Cheyenne River at Station 4385, near Plainview. Here, the benthic types were similar to those at Wasta, but the density of organisms decreased by 75 percent. Some of the fish collected at Station 4385 were heavily contaminated with mercury. Sauger flesh had a mercury concentration of 0.82 ppm, the highest encountered during this study. Carp and channel catfish were also contaminated by high mercury concentrations.

A sediment sample from Station 4385 contained 0.83 ppm of mercury. This concentration reflects the previous use of mercury in the Homestake amalgamators and is indicative of the deposition and resuspension which occurs in the travel of tailings from Lead-Deadwood to Oahe Reservoir.

Samples of fish collected from the Cheyenne Arm of Oahe Reservoir by the U.S. Fish and Wildlife Service and analyzed by EPA personnel generally contained high mercury concentrations, many of which exceeded the guideline. Results of this sampling are reproduced in Appendix E, Table E-5. Mercury concentrations exceeding 0.5 ppm, were detected in the flesh of northern pike, walleye, sauger, white bass, black crappie, channel catfish, freshwater drum, shovelnose sturgeon, carpsucker, carp, and bigmouth buffalo. Mercury concentrations in fish flesh were highest in the upper Cheyenne Arm of Oahe Reservoir, near the River mouth, with over 25 percent of all samples exceeding the guideline. Mercury concentrations in fish flesh generally decreased with distance from the River mouth. Mercury was not detected in water samples collected from the Cheyenne Arm, but bottom muds contained excessive mercury. The mercury concentrations in muds were highest in the upper Cheyenne Arm near the Cheyenne River mouth, with generally decreasing concentrations toward the main reservoir body. The levels were highest in mid-channel and lower near shore. This indicates that mercury-laden sediment continues to be transported into Oahe Reservoir by high streamflow in the Cheyenne River. The sediment then deposits in Oahe Reservoir and contaminates fish.

D. TAILINGS DEPOSITS

Calculations indicate that at least 65 million tons of tailings solids have been discharged by the Homestake Mining Company during the history of the Company's Deadwood-Lead operation. At least nine million tons of tailings have been discharged since the completion of Oahe Reservoir. The discharge of this sediment has completely changed the hydrologic regime of the Whitewood Creek-Belle Fourche River-Cheyenne River system. Much of the material was deposited along the various streams, especially the lower reaches of Whitewood Creek and the Belle Fourche River in the first few miles below the mouth of Whitewood Creek.

A limited amount of core drilling was performed, to verify the presence of deposits of previously-discharged Homestake tailings. In one case, drilling in an abandoned stream meander seven miles east of Vale, disclosed that old Homestake tailings had been deposited, causing the stream to change its course. The meander contained up to nine feet of tailings at the holes drilled, for an estimated total volume of 30,000 cubic yards of tailings deposits. Assay of the buried material indicated that this deposit contains approximately

200 pounds of mercury. Several other abandoned meanders were observed in the same area. Representative logs of drill holes in the tailings deposits, with the concentrations of mercury in the material, are presented in Appendix E, Table E-8.

In lower reaches of Whitewood Creek, the flood plain is underlain by up to 10 feet of material which appears to be stamp-mill tailings, deposited during the early milling days in the Lead area. A sample was found to contain 1.2 ppm of mercury. If this is representative, each cubic yard would contain 1.8 grams of mercury. At the bridge downstream from Crow Creek, these deposits extend for at least one-quarter of a mile along the stream, with an average width of 100 yards. This section may contain 290 pounds of mercury.

Ground-water samples were collected from auger holes in the tailings deposits, and from nearby wells drawing water from the alluvium. Solids samples were collected from the auger holes, at various depths. Solids assay results are shown in Appendix E, Table E-8. Ground-water quality data are shown in Appendix E, Table E-9. The buried tailings solids contain mercury in concentrations of from two to four parts per million by weight. Those solids beneath the water table generally contain less mercury than those above the water table, indicating a leaching of mercury by ground water has occurred and is continuing. This conclusion is supported by data on mercury concentrations in the ground water. A sample of ground water from the tailings deposit contained 34 μg/l of mercury, nearly seven times the recommended PHS limit of 5 μg/l for drinking water. A sample of ground water from alluvium underlying the tailings solids contained 1.8 µg/l, which is more than background mercury levels of 0.2 to 0.3 µg/l. Water samples from some wells along the stream contain mercury at levels exceeding background concentrations, but less than 5 µg/l. These concentrations correlate with distance from the stream and buried tailings deposits.

Samples from four domestic water supply wells, which draw water from the alluvium along the streams, were analyzed for arsenic. No arsenic was detected, indicating that arsenopyrite in the buried tailings is not being leached to the ground water.

While the concentrations of mercury in the ground water are generally less than the proposed PHS standard, they do indicate a continuing degradation of quality as a result of the buried tailings solids. Ground-water conditions are such that mercury from these deposits will continue to enter the surface streams via ground-water inflow.

The deposits of buried tailings solids are of importance to future water quality. The rivers are eroding the deposited material. Thus, the deposits will gradually be moved downstream to Oahe Reservoir. This effect will be accelerated once discharge of solids from Homestake has ceased. At that time the affected streams will initiate a period of downcutting, to adjust to a new set of hydrologic conditions. The buried tailings deposits will continue to be a source of sediment and metals pollution, unless they are removed or stabilized.

Additional information is required on the location, extent, and composition of the buried deposits. The needed information can be secured by a combination of remote-sensing technology and an exploratory drilling program.

Presently research is in progress to develop techniques for recovery of mercury from sediments. If the techniques prove feasible, they should be employed to recover the mercury contained in the buried tailings deposits. If the techniques are infeasible the deposits should be stabilized, pending later technical developments.

VII. WATER POLLUTION CONTROL ALTERNATIVES

A Sanitary District has been formed to abate pollution from the discharge of sewage from the towns of Lead and Deadwood, and the Homestake Mining Company discharges. A system has been designed to collect the Homestake wastes and the sewage, and transport it via pipeline to a large tailings pond-oxidation lagoon to be constructed in Centennial Valley. An application for a construction grant was submitted to the Environmental Protection Agency on April 8, 1971. The schedule of construction calls for completion of the facility by November 1973.

There has been much local opposition to the project, on the basis of damage to scenic values and ground-water resources. The project will visually degrade the valley site. However, the overall environmental impact will be less than the existing situation, for miles of stream are rendered gray and lifeless and a health hazard exists. The planned facility should not damage the ground-water resource. The proposed Sanitary District project will be a marked improvement over the existing situation.

The present health hazard resulting from toxic materials in the Homestake effluent must be abated. Personnel of Homestake Mining Company and EPA investigated alternative techniques which could be utilized for an interim pollution-control measure. Primary considerations in the selection of interim control measures were rapidity of construction and control of sediment discharge.

Whitewood Creek flow is highly variable, with known discharges in excess of 5,000 cfs. During 8 months of the year the flow is less than 30 cfs, and consists largely of sewage from Lead and Deadwood and of

Homestake Mining Company tailings slurries. Substantial water-quality improvement would result from construction of a system to divert and impound the Whitewood Creek flow, especially when such flow is less than or equal to 30 cfs. Higher flows could continue downstream with relatively little effect.

A suitable diversion site is available on Whitewood Creek downstream from the town of Whitewood. Crow Creek, a small intermittent stream, almost intersects Whitewood Creek before turning and flowing parallel to Whitewood Creek (Figure 2). A small diversion canal could be constructed through the intervening ridge, and a simple diversion dam constructed across Whitewood Creek. Flows less than 30 cfs would then be diverted to Crow Creek and the tailings solids settled in an impoundment. Clarified water would overflow the impoundment, continue down Crow Creek, and rejoin Whitewood Creek. Flows in excess of 30 cfs would overflow this diversion dam and travel down Whitewood Creek. The proposed project would remove approximately 80 percent of the pollutants carried by Whitewood Creek currently. The project, as envisioned, would be of simple construction and could be completed in a short time. Following completion of a permanent treatment facility it will be necessary to stabilize the impounded tailings in the temporary facility, to prevent erosion to Lower Crow Creek and the downstream waterways.

Homestake Mining Company reports encountering inflated land prices in their discussions with land owners in the Crow Creek area. Because the Company does not have the right of condemnation, the practice of asking inflated prices for land in the project area threatens the establishment of the interim tailings pond which will significantly reduce the existing health hazard caused by Homestake's discharge. The Crow Creek diversion and tailings pond is a necessary and technically feasible interim-control measure pending the completion of the Sanitary District facilities.

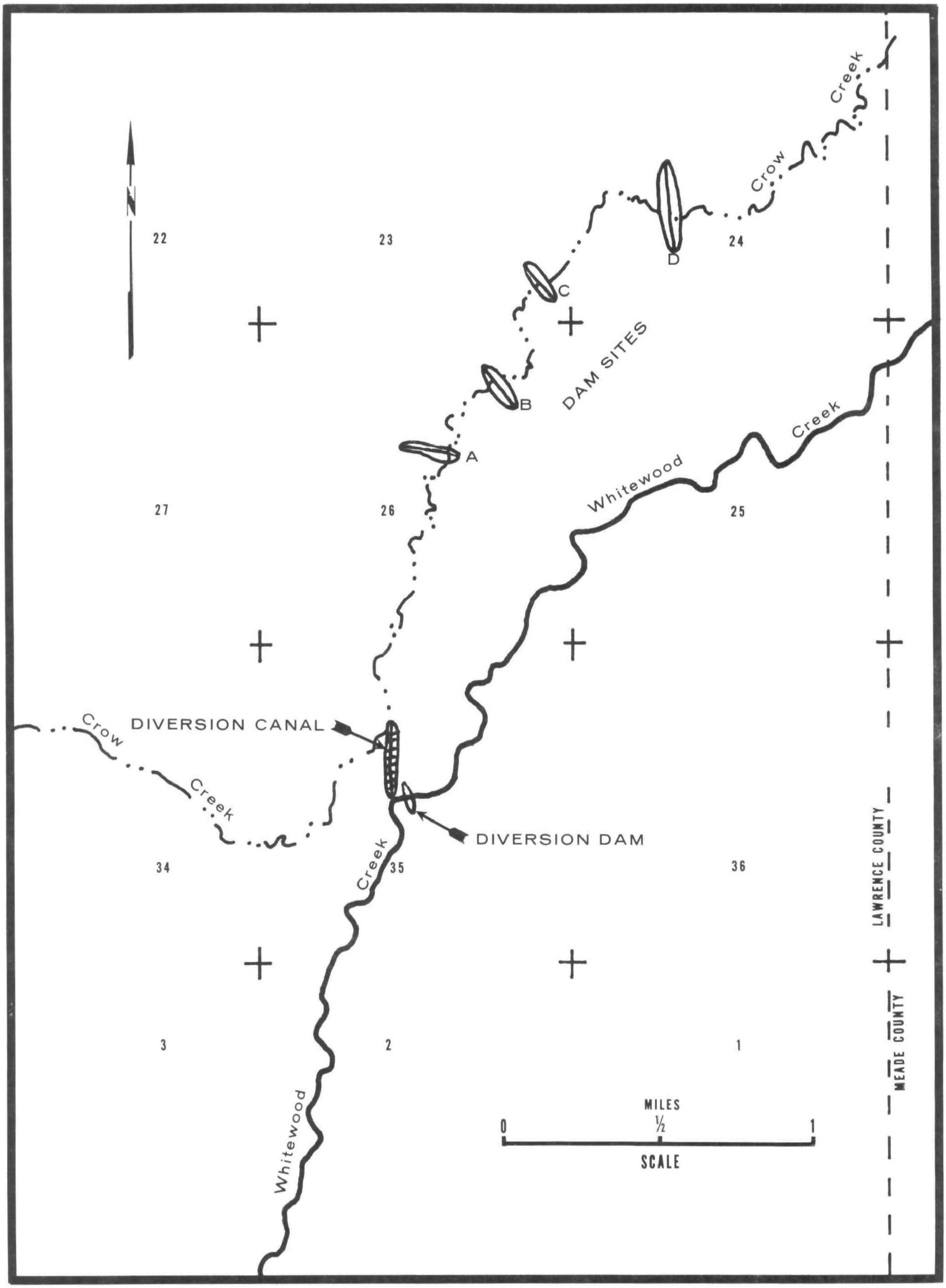

Figure 2. Crow Creek Diversion

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5. Study Group on Mercury Hazards, 1971, "Hazards of Mercury, Special Report to the Secretary's Pesticide Advisory Committee", Department of Health, Education, and Welfare, November, 1970; Environmental Research 4(1), 1-69.

APPENDIX A

April 23, 1971, Letter from Richard F. Kneip,
Governor of the State of South Dakota

to

William D. Ruckelshaus, Administrator,
Environmental Protection Agency

STATE OF SOUTH DAKOTA

RICHARD F KNEIP
GOVERNOR

EXECUTIVE OFFICE

PIERRE
57501

April 23, 1971

William D. Ruckelshaus, Administrator
Environmental Protection Agency
Washington, D.C. 20460

Dear Mr. Ruckelshaus:

As you know, testing over the past year has revealed a potential mercury problem in western South Dakota. The problem stems from naturally-occurring mercury and from previous industrial discharges.

Industrial discharges of mercury began about 1876 when prospectors began using the metal for amalgamation of gold in placer mining operations on a number of Black Hills streams. How much mercury was discharged to the various streams by the early operators is not known; however, geologists of the South Dakota School of Mines and Technology report seeing free mercury in the sediments of several streams.

Though mercury is no longer being used in gold recovery operations, undetermined amounts of the metal remain in the sediments of Black Hills streams, particularly in the Whitewood Creek-Belle Fourche River-Cheyenne River system. Also, naturally-occurring mercury has been found in all of the other major streams of western South Dakota, seemingly associated with shale formations; no industrial discharges are known which could account for the mercury found in these streams. Further, the occurrence of mercury in fish from an impoundment of the Cheyenne River far upstream from the confluence of the Belle Fourche River indicates a natural source of mercury or perhaps mercury contamination from the uranium-processing operation at Edgemont.

As noted above, discharges of mercury from gold-recovery operations have been eliminated; and, to the best of our knowledge, there are no other significant discharges of mercury in the State. There remains, however, the mercury in Black Hills stream sediments as well as the naturally-occurring mercury elsewhere. Also, there is some question as to the significance of the cyanides that have been used for many years to supplement mercury amalgamation in gold recovery and are now used for all gold recovery.

Now, present evidence does not indicate that fish populations and other aquatic life are directly affected by the mercury nor is there any evidence that wildlife and domestic animals are suffering from mercury toxicity. More testing and study may be needed to substantiate these conclusions, however.

In our opinion, then, the crux of the problem in South Dakota, if there is a problem, is whether or not the levels of mercury thus far observed in fish flesh and in our waters have affected or may affect the health of South Dakotans and others who catch and eat the fish and use the water from the Cheyenne River system, including the Cheyenne Arm of Oahe reservoir, and the other streams and impoundments of western South Dakota. As you know, the interim guideline level of mercury in fish flesh established by the Food and Drug Administration has not been substantiated by clinical evidence and is subject to some controversy in the medical profession and other scientific circles.

Therefore, as provided in Section 10(d)(1) of the Federal Water Pollution Control Act, I am requesting that you call a conference of representatives of South Dakota State agencies having direct interest and responsibilities in the matter and representatives of such Federal agencies as have direct interest and responsibilities provided that at least one of the Federal conferees represents the Department of Health, Education and Welfare, and further provided that the conferees primarily address themselves to the problem of actual or potential mercury toxicity to humans, and to methods of control if such health hazards are demonstrated, and secondarily to the significance of the cyanide discharges. The occurrence, distribution, and significance of heavy metals other than mercury may concern the conferees as well.

In regard to State agency representatives, I am requesting that the following persons be appointed as conferees:

Dr. Robert H. Hayes, State Health Officer,
State Department of Health;

Robert A. Hodgins, Director
Department of Game, Rish & Parks; and

Joseph W. Grimes, Chief Engineer,
Water Resources Commission; and member,
South Dakota Committee on Water Pollution

I urge your favorable consideration of this request.

Sincerely,

RICHARD F. KNEIP
GOVERNOR

RFK/srd

cc: Dr. Robert H. Hayes
Robert A. Hodgins
Joseph W. Grimes

APPENDIX B

APPLICABLE WATER QUALITY STANDARDS

Excerpts from "Water Quality
Standards for the Surface Waters
of South Dakota, February 1967"

CHAPTER II - WATER QUALITY CRITERIA FOR SURFACE WATERS

Section II - Conditions Applying To All Surface Waters

1. Visible Pollutants. No raw or treated sewage, garbage, industrial wastes or agricultural wastes shall be discharged into any waters of the State which produce floating solids, scum, oil slicks, material discoloration, undesirable odors, visible gassing, sludge deposits, slimes, fungus growths or other offensive effects.

2. Toxic Materials. No materials shall be discharged to any surface water or watercourse in the State which produce concentrations of chemicals toxic to humans, animals or the most sensitive stage or form of aquatic life greater than 0.1 times the acute (96 hour) median lethal dose for short residual compounds or 0.01 times the acute median lethal dose for accumulative substances or substances exhibiting a residual life exceeding 30 days in the receiving waters.

   Acute median lethal concentrations shall be based on the results of the most recent research results for the material being studied or, in case of disagreement, by bioassay tests simulating actual stream conditions run in accordance with procedures outlined in "Standard Methods for the Examination of Water and Wastewater - 1965" published by the American Public Health Association and using test animals or organisms specified by the Committee.

   Concentrations specified for toxic materials shall be based on daily averages, but the concentrations shall not exceed 125% of the value specified at any time or in any section of the receiving water.

   These provisions shall not apply to those toxic materials for which specific limits are specified in the criteria for given beneficial uses.

3. Radioactive Materials. Radioactive materials shall not be permitted in the waters of the State unless these materials are readily soluble or dispersible in water and in quantities determined by the Committee to be in accord with criteria of the South Dakota State Department of Health or other appropriate State or Federal Agency.

4. Taste and Odor Producing Chemicals. No materials shall be discharged which will result in concentrations in the receiving water sufficient to impart objectionable tastes and odors to edible aquatic life.

5. Acids and Alkalis. With the exception of those watercourses in the Intermittent Stream category, no materials shall be discharged from any one source which shall affect the pH of the receiving waters by more than 1.0 unit within the limits specified herein.

CATEGORY NUMBER 2 - FISH LIFE PROPAGATION

Description: All waters in this category shall be such that they will provide a satisfactory environment for the class of fish described and for all other aquatic life essential to the maintenance and propagation of fish life. There shall be separate quality criteria for each of the following five sub-categories:

a.	Cold water permanent	All lakes, streams and reservoirs in this category shall be capable of supporting a good permanent trout fishery from natural reproductions or fingerling stockings.
b.	Cold water marginal	All lakes, streams and reservoirs in this category shall be suitable for supporting stockings of catchable size trout during portions of the year but due to low flows, siltation and warm temperatures will not support a permanent cold water fish population.
c.	Warm water permanent	Lakes, streams and reservoirs in this category shall be suitable for permanent maintenance of warm water fish including walleyes, black bass or blue gills.
d.	Warm water semi-permanent	Lakes, streams and reservoirs in this category shall be suitable for a quality warm water fishery but may suffer occasional fish kills because of critical natural conditions. Principal species managed in these waters will include walleyes, perch, northern pike or channel catfish.

e. Warm water marginal	Lakes, streams and reservoirs in this category shall be suitable for supporting more tolerant species of fish with frequent stocking and intensive management. Principal species managed in these lakes include perch, northern pike or bullheads.

Criteria:

Criteria for each of the described sub-categories are presented in tabular form on the following page.

Criteria: (Fish Life Propagation-continued)

Parameter	a	b	c	d	e	Frequency Code
			Sub-Categories			
Chlorides	100					c
Cyanides	0.02	0.03	0.02	0.02	0.05	a
Dissolved Oxygen (greater than)	6.0	5.0	4.0	4.0	2.0	a
Hydrogen Sulfide	0.3	0.5	0.5	1.0	1.0	a
Iron (total)	0.2	0.2	0.2	0.2		b
pH*	6.6-8.6	6.5-8.8	6.5-8.8	6.3-9.0	6.0-9.3	a
Suspended solids	30	90	90	90	150	c
Temperature (degrees F)	68	75	85	90	93	a
Turbidity**	25	50	50	100		c

Note: All values in mg/l unless indicated otherwise. The frequency code shown applies to all sub-categories.
* in pH units.
** Jackson Candle units.

Pesticides, herbicides and related compounds shall be treated as toxic materials and taste and odor producing chemicals and controlled under the provisions of Chapter II, Section II, subsection 2 and 4.

Temperatures shall not be affected by more than 4^{O}F. in sub-categories a, b and c, and 8^{O}F. in sub-categories d and e.

CATEGORY NUMBER 3 - RECREATION

Definitions: Water in this category shall be suitable for swimming, water skiing, skin diving, fishing, boating, sailing, picnicking and other water related types of recreation. There shall be separate quality criteria for each of the following two sub-categories:

a. Immersion Sports which would include swimming, water skiing, skin diving and other water sports.

b. Limited Contact Recreation which would include fishing, boating, sailing, picnicking and other water related recreation.

General: The criteria for recreation will normally apply only during the summer recreation season. However, if the receiving waters are used extensively for winter recreation, the criteria for limited contact recreation shall apply during the winter months.

Criteria:

Parameter	Limit	Frequency Code
a. Immersion Sports		
Coliform Organisms	Not to exceed a MPN or MF of 1000/100 ml as a monthly average; nor to exceed this value in more than 20% of the samples examined in any one month; nor to exceed 2,400/100 ml on any one day during the recreation season.	
Dissolved Oxygen	Greater than 2 mg/l	a
b. Limited Contact Recreation		
Coliform Organisms	Not to exceed a MPN or MF of 5000/100 ml as a monthly average; nor to exceed this value in more than 20% of the samples examined in any one month; nor to exceed 10,000/100 ml on any one day during the recreation season.	
Dissolved Oxygen	Greater than 2 mg/l	a

CATEGORY NUMBER 4 - WILDLIFE PROPAGATION AND STOCK WATERING

Definition: Waters in this category shall be satisfactory as habitat for aquatic and semi-aquatic wild animals and fowl and shall be suitable for watering domestic and wild animals and fowl.

General: No pollution shall be permitted to enter waters in this category which will produce inhibited growth, physical impairment or injurious effects on wild or domestic animals and fowl normally inhabiting or using the water.

Criteria:

Parameter	Limit	Frequency Code
Alkalinity (Total) (as $CaCO_3$)	750 mg/l	c
Total dissolved solids	2,500 mg/l	c
Electrical conductivity	4000 micromhos/cm @ 25° C.	c
Nitrates (as NO_3)	50 mg/l	b
pH	Greater than 6.0 and less than 9.5	a

APPENDIX C

WATER QUALITY DATA
WESTERN SOUTH DAKOTA
1959

Source: Report on
Water Pollution Studies
Gold Run Creek-Whitewood Creek
Belle Fourche River-Cheyenne River
1960

South Dakota State Department of Health
Division of Sanitary Engineering
Pierre, South Dakota

WATER POLLUTION ANALYSIS (1959) - GOLD RUN CREEK
STATION GR-0

Table C-1

Sampling Station	Collection Date	pH	Temp. °C.	D.O.		BOD	M.P.N.	CN	SO_3	SO_4	Solids	
				ppm	% Sat.						Suspended	Total
GR-0[1/]	6/23 *	8.6	17	6.4	66	80	11,000,000	0	0	379	112	1,000
GR-0	6/25 **	8.6	17	6.5	67	45	24,000,000		0	193	530	883
GR-0	7/6 ***							0.63				
GR-0	7/6 ***							2.53				
Average Values				6.5	66.5	63		1.05		286	321	942

Results in ppm for D.O., BOD, CN, SO_3, SO_4, Solids

* 3 hr. composite

** 4 hr. composite

*** grab samples (Homestake by-passing sand dams)

Samples for BOD, CN, SO_4, and solids composited, if not, otherwise indicated.

Note: Abbreviations for all Tables Nos. 1,2,3,4,5,6
D.O. = Dissolved Oxygen
ppm = parts per million
BOD = Biochemical Oxygen Demand (5 day)
MPN = Most Probable Number of coliform bacteria per 100 ml.
CN = Cyanide (all complex cyanides total reported as CN - by titration)
SO_3 = Sulfides
SO_4 = Sulfate
% Sat. = Percent Saturation

1/ Gold Run @ Lead Sewage Outfall

Table reproduced from South Dakota report.

WATER POLLUTION ANALYSIS (1959) - GOLD RUN CREEK
STATION GR-1

TABLE C-2

Sampling Station	Collection Date	pH	Temp. °C.	D.O.		BOD	M.P.N.	CN	SO_3	SO_4	Solids	
				ppm	% Sat.						Suspended	Total
GR-1[1/]	6/23 **	8.8	17	6.6	68	70	4,600,000	0.95				1,482
GR-1	6/25 ***	8.7	17	6.1	63	25	46,000,000				804	
GR-1	7/7-8							2.8		384		1,429
GR-1	7/10-11	8.6						2.3	0			1,108
GR-1	7/11	8.4						2.1	0			1,382
GR-1	7/11-12	11.7						9.1	0			1,737
GR-1	7/12	8.7						3.6				1,564
GR-1	7/12-13	8.5						2.1				2,630
GR-1	7/13	8.5	17	6.6	68	55		0.86				2,614
GR-1	7/14-15	8.5	16*	4.7*	47*	35	2,400,000	2.9				1,755
GR-1	7/15-16	8.0	17*	5.1*	52*	40		1.23				2,324
GR-1	7/16	8.4	17*	4.9*	50*	45		0.60				1,452
Average Values				5.7	54	45		2.60				1,770

* Average of 3 tests
** 3 hr. composite
*** 4 hr. composite
All other samples 14 hr. composite (BOD, CN, SO_4, Solids)

1/ Gold Run One Mile Below Sand Dam

Table reproduced from South Dakota report.

WATER POLLUTION ANALYSIS (1959) - WHITEWOOD CREEK
STATIONS WC-7, 9, & 10

TABLE C-3

Sampling Station	Collection Date	pH	Temp. °C	D.O. ppm	D.O. % Sat.	BOD	M.P.N.	CN	SO_3	SO_4	Solids Suspended	Solids Total
WC-7 1/	6/23 **	8.8	17					1.25				26,080
WC-7	6/25 ***	8.7	21									
WC-7	6/23 **	8.5	18	1.7	18	10		2.10		232	12,570	13,965
WC-7	6/25 **	8.6	22	3.1	35	100	430,000		0	209	15,466	15,750
WC-7	7/13	8.5	20*	1.5*	16.3*	45		1.03				24,175
WC-7	7/14-15	8.6	16*	3.6*	36.2*	65	11,000,000	1.10				26,916
WC-7	7/15-16	8.4	17*	3.2*	33*	60		0.69				18,205
WC-7	7/16	8.6	22*	3.7*	42*	75		0.78				22,056
Average Values				2.8	31	60		1.16		221	14,018	21,021
WC-9 2/	6/23 ***	8.4	18					0.69				25,810
WC-9	6/25 ***	8.2	25									
WC-10 3/	6/23 ***		25					0.69			23,350	
WC-10	6/25	8.0										
WC-10	7/14 ***	8.1	24*	5.4*	63*	40	1,500,000	0.62				35,497
WC-10	7/16 *** (1)	7.8	23*	6.2*	72*	8	93,000					1,898
Average Values				5.9	68	24		0.66				18,698

* Average 2 or 3 tests; ** 3 hr. composites; *** 4 hr. composites; others 12 hr. composites.
(1) Stream flow higher due to rain shower. Samples for BOD, CN, SO_4, and Solids composited.
1/ Whitewood Creek @ Deadwood
2/ Whitewood Creek @ Route 14 Bridge
3/ Whitewood Creek @ Bridge near Mouth

Table reproduced from South Dakota report.

WATER POLLUTION ANALYSIS (1959) - BELLE FOURCHE RIVER
STATIONS BF-1, 2, & 4

TABLE C-4

Sampling Station	Collection Date	pH	Temp. °C			BOD	M.P.N.	CN	SO_3	SO_4	Solids	
				ppm	% Sat.						Suspended	Total
BF-1[1/]	6/23		27	10.0	125	7	300				692	
BF-1	6/25	8.2	31	12.3	164	6	1,500				358	
BF-1	7/14	8.2	27*	6.7*	83*	5	93					2,425
BF-1	7/16	8.1	25*	7.9*	94*	5	93					2,063
Average Values				9.3	107	6.0					521	2,244
BF-2[2/]	6/23		27	1.3	16		460,000		0		10,650	
BF-2	6/25	7.9	29	2.0	26	17	1,500,000		0		8,980	
BF-2	7/14	8.0	25*	2.4*	28*	30	93,000					19,534
BF-2	7/16 **	7.8	24*	3.7*	43*	8	93,000					3,548
Average Values				2.3	31	18					9,815	11,541
BF-4[3/]	6/23		20	6.9	75	2	4,300		0		537	
BF-4	6/25	8.2	25	6.0	72	4	9,300				636	
BF-4	7/13	8.4	30	6.9	90	3	36	0.36				2,120
BF-4	7/15	7.9	29	6.8	88	4	2,400	0.5				2,179
Average Values				6.7	81	3.0		0.43			586	2,150

BF-1 and BF-2 (4 hr. composites) (BOD, CN, SO_4, and Solids)
BF-4 - grab samples

* Average of 2 tests
** Stream flow higher due to rain shower

1/ Belle Fourche River South of Nisland
2/ Belle Fourche River @ Route 79 Bridge
3/ Belle Fourche River North of Elm Springs

Table reproduced from South Dakota report.

WATER POLLUTION ANALYSIS (1959) - CHEYENNE RIVER
STATION CR-1 & 2

TABLE C-5

Sampling Station	Collection Date*	pH	Temp °C	D.O. ppm	D.O. % Sat.	BOD	M.P.N.	CN	SO_3	SO_4	Solids Suspended	Solids Total
CR-1 1/	6/23		18	7.9	83	1.0	430		0		532	
CR-1	6/25	8.2	22	7.0	79	6.0	24,000				10,978	
CR-1	7/13	8.2	29	4.8	62	3.0	9,300					2,040
CR-1	7/15	8.2	26	7.2	88	2:0	2,300					1,825
Average Values				6.7	78	3.0					5,755	1,935
CR-2 2/	6/23		21	7.5	84		4,300				1,370	
CR-2	6/25	8.4	17	7.0	72	3.0	9,300				352	
CR-2	7/13	8.2	30	7.3	96	5.0	3,900					7,246
CR-2	7/15	8.2	30	6.9	90	3.0	4,300	0.04				1,950
Average Values				7.2	86	4.0		0.04			861	4,600

* All grab samples
1/ Cheyenne River @ Wasta
2/ Cheyenne River @ Route 24 Bridge

Table reproduced from South Dakota report.

APPENDIX D

MERCURY CONCENTRATIONS IN FISH SAMPLES COLLECTED IN SOUTH DAKOTA IN 1970

Source:

South Dakota Department of Game, Fish, and Parks
South Dakota Department of Health

Table D-1

Mercury in South Dakota Fish Samples Collected During 1970 *
(in parts per million)

LAKES & RESERVOIRS:

Big Stone L., Roberts Co., 06-18-70 -

Carp	trace
White bass	0.12
Perch	0.06

Buffalo L., Marshall Co., 04-29-70 -

Northern pike	0.08
Sucker	0.03
Bullhead	0.06
Perch	0.02
Walleye	0.03

Clear L., Deuel Co., 04-29-70 -

Northern pike	0.07
Sucker	0.03
Bullhead	0.06
Perch	0.05

North Waybay L., Day Co., 04-29-70 -

Northern pike	0.11
Carp	0.03
Sucker	0.04
Walleye	0.11

Red Iron L., Marshall Co., 04-29-70 -

Northern pike	0.03
Sucker	0.02
Bullhead	0.06
Crappie	0.03
Perch	0.03

Shadehill Reservoir of Grand R., 10-14-70 (Analyses by Dow Chemical Co.) -

Catfish (2 fish)	0.26
Walleye (2 fish)	0.26

* Food & Drug Adm. analyses except as noted. FDA rejection level for fish flesh is 0.5 parts per million.

Dow Chemical Co. analyses provided by Homestake Mining Co.

Table prepared by South Dakota Department of Game, Fish & Parks, and South Dakota Department of Health, reproduced as provided.

Table D-1 (cont'd)

Mercury in South Dakota Fish Samples Collected During 1970
(in parts per million)

LAKES & RESERVOIRS (cont'd):

L. Traverse, Roberts Co., 06-23-70 -

Bullhead	0.04
White bass	0.06
Crappie	0.07

MISSOURI IMPOUNDMENTS (other than Oahe):

Garrison Reservoir, 10-13-70 (Analyses by Dow Chemical Co.) -

Northern pike (one fish)	0.51 **
Carp	0.16
Walleye (2 fish)	0.38

L. Francis Case (Ft. Randall Res.), Gregory Co., 08-12-70 -

Carp	0.12
Walleye	0.08

Lewis & Clark L. (Gavin's Point Res.), Bon Homme Co., 08-12-70 -

Carp	0.05
Sauger	0.06
Walleye	0.05

OAHE RESERVOIR:

Just below Bismarck, N.D., 07-?-70 -

Northern pike	0.34
Buffalo	0.23
Walleye	0.30

At U.S. 212 bridge (Whitlock's Crossing), 5-21-70 -

Northern pike	0.12
White bass	0.08
White crappie	0.10
Black crappie	0.22
Perch	0.09
Sauger	0.13
Walleye	0.17

** Exceeds FDA Guideline

Table D-1 (cont'd)

Mercury in South Dakota Fish Samples Collected During 1970
(in parts per million)

OAHE RESERVOIR (cont'd):

At U.S. 212 bridge, 08-?-70 -

Northern pike	0.10
Goldeye	0.16
Channel catfish	0.11
White bass	0.37
Black crappie	0.40
Perch	0.14
Walleye	0.13

Cheyenne Arm, Foster Bay area, 05-21-70 -

Northern pike	0.27
Carp	0.16
Smallmouth buffalo	0.14
Bigmouth buffalo	0.33
Channel catfish	0.14
White bass	0.32
White crappie	0.32
Black crappie	0.35
Sauger	0.27
Walleye	0.20

Cheyenne Arm, Foster Bay area, 08-?-70 -

Northern pike (one fish)	1.12 **
Goldeye	0.19
Channel catfish	0.26
White bass	0.84
Walleye	0.68

Cheyenne Arm, Foster Bay area, 10-13-70 -

Northern pike (two 4-lb. fish)	1.16 **
Northern pike (two 1½-lb. fish)	0.23
Carp	0.32
Channel catfish	0.38
White bass	0.54 **
Walleye	0.65 **

** Exceeds FDA Guideline

Table D-1 (cont'd)

Mercury in South Dakota Fish Samples Collected During 1970
(in parts per million)

OAHE RESERVOIR (cont'd):

Cheyenne Arm, Minneconjou Bay area, 10-14-70 -

Northern pike (one 4-lb. fish)	0.32
Goldeye	0.24
Carp (one 3-lb. fish)	0.38
Channel catfish	0.18
White bass	0.38
Walleye	0.38

CHEYENNE RIVER SYSTEM:

Angostura Reservoir, Fall River Co., 07-29-70 -

Channel catfish	0.08
Black crappie	0.12
Largemouth bass	0.20
Perch	0.10
Walleye (one fish)	0.52 **

S. Fork, Rapid Creek, 10-4-70 (Analysis by Dow Chemical Co.) -

Trout	0.07

Keyhole Reservoir of Belle Fourche R., Wyoming 10-20-70 -
(Analyses by Dow Chemical Co.) -

Perch (two fish)	0.18
Walleye	0.18

Belle Fourche R., near Fruitdale, 07-29-70 -

Goldeye	0.38
Carp	0.24
Sucker	0.08
Carpsucker	trace
Channel catfish	0.12
Green sunfish	0.06
Largemouth bass	0.40

** Exceeds FDA Guideline

Table D-1 (cont'd)

Mercury in South Dakota Fish Samples Collected During 1970
(in parts per million)

CHEYENNE RIVER SYSTEM (cont'd):

Belle Fourche Reservoir, 10-21-70 (analyses by Dow Chemical Co.) -

Carp (one fish)	0.12
Carp (one fish)	0.30
Sucker (one fish)	0.14

Spearfish Creek, 10-24-70 (Analysis by Dow Chemical Co.) -

Trout	0.23

Belle Fourche R., at S.D. 34, 07-28-70 -

Goldeye	0.32
Sauger	0.76 **

** Exceeds FDA Guideline

APPENDIX E

Results of Recent EPA Surveys in Western South Dakota

TABLE E-1. Distribution of Benthic Animals - Cheyenne and Belle Fourche Rivers, and Tributaries - May, June, and July 1971

Station No.	4314.70	4329.50	4360.00	6-4361.10	6-4361.30	6-4361.40	6-4361.00	6-4361.25	6-4361.50	6-4361.70	4370.00	4025.50	4060.00	4130.00	4255.00	4235.00	4385.00
Date	5/30	6/9	7/20	5/29	5/29	5/29	5/29	5/29	5/29	5/29	7/20	6/10	6/10	6/7	7/22	7/21	7/21
Diptera					1		21										1
Chironomidae	2	22	6		9		263				1	Q	Q	Q	1	253	1
Diamesinae	2						35							Q			
Diamesa							35										
Pentaneurinae							Q										
Pentareura												3					
Orthocladiinae	5	Q*			10	Q	165				2	Q		87			
Cricotopus		Q															
Eukiefferiella					Q												
Psectrocladius	4				Q												
Chironominae						Q											
Pseudochironomus														Q			
Tanypodinae					2		5										
Coelotanypus		Q															
Tipulidae		Q					11										
Antocha	12																
Hexatoma	Q																
Simuliidae	64		Q								4						
Simulium		2				Q						270	210	44	1	464	137
Stratiomyiidae					1												
Tabanidae					26		4										
Muscidae													1				
Tricoptera		2	16														1
Hydropsychidae																	
Hydropsyche	6	21	41		48		120						8	9	Q	1	
Cheumatopsyche		16	160		5		10				1				3	23	8
Brachycentridae																	
Brachycentrus	2						1										
Leptoceridae																	
Leptocella																Q	

* Q = Collected in qualitative sampling only. Arbitrarily assigned a value of one for counting.

TABLE E-1. **Distribution of Benthic Animals - Cheyenne and Belle Fourche Rivers, and Tributaries - May, June, and July 1971**

Station No.	4314.70	4329.50	4360.00	6-4361.10	6-4361.30	6-4361.40	6-4361.00	6-4361.25	6-4361.50	6-4361.70	4370.00	4025.00	4060.00	4130.00	4255.00	4235.00	4385.00
Date	5/30	6/9	7/20	5/29	5/29	5/29	5/29	5/29	5/29	5/29	7/20	6/10	6/10	6/7	7/22	7/21	7/21
Lepidostomatidae																	
Lepidostoma			Q		99		2										
Phryganeidae																	
Ptilostomis	2				Q												
Rhycophilidae	Q				Q												
Hydroptilidae		Q															
Plecoptera																	
Perlodidae																	
Isoperla		5			35		3						5	2			
Isogenus					Q		1										
Chloroperlidae					Q	Q	Q										
Chloroperla	Q											1					
Perlidae																	
Acroneuria	1				Q		1										
Perlinella							8										
Ephemeroptera																	
Ephemeridae																	
Potamanthus			19												1		
Ephoron			Q														3
Heptageniidae													2				
Iron	89				76	Q	106					Q	Q	2		Q	
Stenonema			3													3	
Cinygmula															2		6
Heptagenia			Q								17				Q		Q
Baetidae		1			2										4		
Baetis	79	10			97	Q	20				Q	13	51	11	34	15	Q
Caenis																	19
Tricorythodes		2	3										Q		Q	2	7
Ephemerella		7			31		125						2	17			Q
Paraleptophlebia					8		Q							1			
Pseudocloeon		27															
Neocloeon			Q														
Isonychia			Q								4						4

TABLE E-1. Distribution of Benthic Animals - Cheyenne and Belle Fourche Rivers, and Tributaries - May, June, and July 1971

Station No.	4314.70	4329.50	4360.00	6-4361.10	6-4361.30	6-4361.40	6-4361.00	6-4361.25	6-4361.50	6-4361.70	4370.00	4025.50	4060.00	4130.00	4255.00	4235.00	4385.00
Date	5/30	6/9	7/20	5/29	5/29	5/29	5/29	5/29	5/29	5/29	7/20	6/10	6/10	6/7	7/22	7/21	7/21
Coleoptera		3	Q		1		14						1			Q	Q
Dystiscidae																	
Hydaticus												Q					
Elmidae					1		5							6			
Stenelmis					2		1										
Dryopidae			2														
Gyrinidae																	
Gyrinus							1										
Odonata																	
Anisoptera																	
Erpetogomphus													Q				
Hemiptera			Q														
Lepidoptera																	
Paragyractis													1				
Oligochaeta		12	2		3		17					6	14				
Enchytraeidae														2			
Lumbricidae														1			
Gastropoda			1									2		Q	Q		
Physa					14		2										
Hirudinea													Q				
Hydracarina							1										
Amphipoda															Q		
Total Number of Organisms/sq. ft.	271	135	261	0	478	6	980	0	0	0	30	299	300	186	51	764	191
Total Number of Kinds	13	17	17	0	23	6	26	0	0	0	6	10	15	15	11	10	14

Table E-2. Arsenic and Mercury Concentrations in Stream Sediment Samples from Western South Dakota

Station Number	Station Location	Date Sampled	Arsenic mg/g	Mercury mg/kg (Dry weight)
4200.5	Boxelder Creek at Owanka, S.D.	6/10	0.0152-0.0211*	<0.02
4235	Cheyenne River at Wasta, S.D.	6/10	0.00823-0.0101	<0.04
4255	Elk Creek near Elm Springs	6/10	0.0202-0.0206	0.04
4361.0	Whitewood Creek at U.S. 85 Bridge	5/29	0.689-0.831	0.54
4361.3	Deadwood Creek above Deadwood, S.D.	5/29	0.618-0.789	0.12
4361.5	Whitewood Creek at Deadwood Rodeo Gr.	6/11	2.07-2.20	0.18
4361.6	Whitewood Creek below Whitewood, S.D.	6/11	2.93-4.26	0.23
4361.7	Whitewood Creek near Vale, S.D.	5/26	3.73-4.35	0.72
		6/11	1.19-1.29	0.10
4370	Belle Fourche River Sturgis, S.D.	6/10	3.60-3.99	0.75
		6/11	2.23-2.88	1.1
4375	Bear Butte near Sturgis, S.D.	6/10	0.0174-0.0201	0.06
4385	Cheyenne River near Plainview, S.D.	6/11	0.698-0.729	0.83
Homestake Mill Feed			3.32-4.01	0.57

* Numbers are range of results for triplicate analysis.

TABLE E-3

RESULTS OF LABORATORY ANALYSIS IN STREAMS SAMPLES COLLECTED IN WESTERN SOUTH DAKOTA DURING 1971

Sta. No.	Station Location	1971 Date	Time	Flow cfs	Mercury µg/l	Cyanide mg/l	Arsenic µg/l*	Antimony mg/l	Cadmium mg/l	Cobalt mg/l	Copper mg/l	Iron mg/l	Lead mg/l	Zinc mg/l
4020	Fall River at Hot Springs, S.D.	7/19	1530	18	< 0.3	-	-	-	-	-	-	-	-	-
4040	Battle Creek at Hayward, S.D.	6/12	1130	44	0.3	-	-	-	-	-	-	-	-	-
4115	Rapid Creek below Pactola Dam	6/12	1030	128	0.2	-	-	-	-	-	-	-	-	-
4200.5	Boxelder Creek at Owanka, S.D.	6/10	0930	15 Est.	0.6	-	N.D.	<1	0.05	0.0	0.00	2.1	<0.2	<0.02
4235	Cheyenne River at Wasta, S.D.	6/10	1045	1920	0.4	-	N.D.	<1	0.00	0.0	<0.05	5.9	<0.2	0.03
		7/21	1547	74	< 0.3	-	-	-	-	-	-	-	-	-
		7/22	1500	76	< 0.3	-	-	-	-	-	-	-	-	-
4255	Elk Creek near Elm Springs, S.D.	6/10	1200	114	2.0	-	N.D.	0.0	<0.05	0.0	<0.05	15.2	<0.2	0.08
		7/21	1620	6.3	< 0.3	-	-	-	-	-	-	-	-	-
		7/22	1430	6.3	< 0.3	-	-	-	-	-	-	-	-	-
4314.7	Spearfish Creek below Maurice, S.D.	5/30	0930		0.5-2.3	-	-	-	-	-	-	-	-	-
4360	Belle Fourche River near Fruitdale, S.D.	6/10	1545	511	0.4	<0.02	N.D.	<1	<0.05	0.0	0.00	3.2	<0.2	<0.02
		7/20	0830	5.5	< 0.3	-	-	-	-	-	-	-	-	-
		7/21	0810	4.7	< 0.3	-	-	-	-	-	-	-	-	-
		7/22	0735	5.7	< 0.3	-	-	-	-	-	-	-	-	-
4361.0	Whitewood Creek at U.S. 85 Bridge	3/31	-	5.8	< 0.2	-	<1000	1	0.002	0.007	0.03	5.3	0.56	0.08
		6/8	1115	35.0	< 0.2	<0.02	13-12	<1	0.05	0.0	0.00	0.9	<0.2	<0.02
		6/9	1010	35.0	1.7	<0.02	-	-	-	-	-	-	-	-
		6/10	1023	35.0	0.2	<0.02	-	0.0	0.05	0.0	0.00	1.0	0.0	0.02

TABLE E-3 (Continued)

RESULTS OF LABORATORY ANALYSIS OF STREAM SAMPLES
COLLECTED IN WESTERN SOUTH DAKOTA DURING 1971

Sta. No.	Station Location	1971 Date	Time	Flow cfs	Mercury µg/l	Cyanide mg/l	Arsenic µg/l*	Antimony mg/l	Cadmium mg/l	Cobalt mg/l	Copper mg/l	Iron mg/l	Lead mg/l	Zinc mg/l
4361.1	Gold Run below Homestake	3/30-31	Comp*	9.2	3.8	1.1	1000	2	0.001	0.006	0.41	50	0.21	0.57
	Sand Dam	5/5-6	Comp	12.9	4.2	2.1	-	-	-	-	-	-	-	-
		6/8	Comp	9.0	5.6	1.8	138-143	<1	0.07	0.0	0.69	185	<0.2	0.49
		6/9	Comp	10.4	12.0	3.6	420-340	<1	0.05	0.1	0.89	542	0.3	1.15
		6/10	Comp	14.5	2.8	0.5	-	-	-	-	-	-	-	-
4361.2	Homestake Slime Plant	3/30-31	Comp	4.0	0.8	9.8	1000	2	0.001	0.006	0.41	50	0.21	0.57
	Effluent	5/5-6	Comp	4.0	26.0	9.9	-	-	-	-	-	-	-	-
		6/8	Comp	4.0	22.0	7.1	27-ND-17	<1	0.07	<0.1	0.05	437	<0.2	0.94
		6/9	Comp	4.0	15.2	7.4	910-952	-	-	-	-	-	-	-
		6/10	Comp	4.0	57.0	3.8	-	-	-	-	-	-	-	-
4361.3	Deadwood Creek above	3/31	-	21.2	< 0.2	-	< 500	1	0.001	0.007	<0.01	0.31	0.65	<0.01
	Deadwood, S.D.	6/8	0830	12.0	0.3	<0.02	8.4-12.0	<1	<0.05	0.0	0.00	0.5	<0.2	1.11
		6/9	1100	11.1	1.4	<0.02	-	-	-	-	-	-	-	-
		6/10	0900	10.1	0.2	<0.02	-	0.0	0.05	0.0	0.00	0.4	<0.2	<0.02
4361.4	City Creek at Deadwood,	3/31	-	1.5	< 0.2	-	< 500	<1	0.001	0.002	0.01	2.3	0.65	0.02
	S.D.	6/8	1010	2.1	1.5	<0.02	N.D.	0.0	0.06	0.0	<0.05	1.7	0.0	<0.02
		6/9	1255	2.0	0.2	<0.02	-	0.0	0.00	0.0	<0.05	1.8	0.0	<0.02
		6/10	1045	2.1	0.8	<0.02	-	-	-	-	-	-	-	-
4361.5	Whitewood Creek at	3/30-31	Comp	31.9	8.0	1.1	1700	1	0.003	0.004	0.11	225	0.70	0.45
	Deadwood Rodeo Grounds	5/5-6	Comp	145.4	2.1	0.50	-	-	-	-	-	-	-	-
		6/8	Comp	68.9	6.4	0.82	970-880	<1	<0.05	<0.1	0.18	428	<0.2	0.60
		6/9	Comp	66.3	5.2	0.88	300-230	-	-	-	-	-	-	-
		6/10	Comp	74.3	7.6	0.79	-	-	-	-	-	-	-	-
4361.6	Whitewood Creek below	6/10	1250	90.3	-	0.58	1510-1420	<1	<0.05	<0.1	0.15	438	<0.2	0.59
	Whitewood, S.D.	6/11	-	73.5	4.0	-	-	-	-	-	-	-	-	-

*Comp = 24-hour composite

TABLE E-3 (Continued)

RESULTS OF LABORATORY ANALYSIS OF STREAM SAMPLES
COLLECTED IN WESTERN SOUTH DAKOTA DURING 1971

Sta. No.	Station Location	1971 Date	Time	Flow cfs	Mercury µg/l	Cyanide mg/l	Arsenic µg/l*	Antimony mg/l	Cadmium mg/l	Cobalt mg/l	Copper mg/l	Iron mg/l	Lead mg/l	Zinc mg/l
4361.7	Whitewood Creek near Vale, S.D.	6/10	1350	128.5	5.6	0.16	1900-1270	<1	0.00	<0.1	0.11	268	<0.2	0.33
		6/11	1105	101.1	3.2	-	-	-	-	-	-	-	-	-
		7/20	0915	20.4	1.0	-	-	-	-	-	-	-	-	-
		7/21	0850	20.4	0.6	-	-	-	-	-	-	-	-	-
		7/22	0815	20.4	5.0	-	-	-	-	-	-	-	-	-
4368	Horse Creek near Vale, S.D.	6/10	1510	157	0.4	<0.02	N.D.	<1	0.00	0.0	<0.05	11.4	<0.2	0.05
		7/20	1510	136	<0.3	-	-	-	-	-	-	-	-	-
		7/21	0917	133	<0.3	-	-	-	-	-	-	-	-	-
		7/22	0845	138	<0.3	-	-	-	-	-	-	-	-	-
4370	Belle Fourche River near Sturgis, S.D.	6/10	1610	931	0.6	<0.02	500-425-450	<1	<0.05	<0.1	0.05	31.6	0.3	0.08
		7/20	1615	348	<0.3	-	-	-	-	-	-	-	-	-
		7/21	1020	507	<0.3	-	-	-	-	-	-	-	-	-
		7/22	0945	378	<0.3	-	-	-	-	-	-	-	-	-
4375	Bear Butte Creek near Sturgis, S.D.	6/10	1630	62	0.2	-	N.D.	<1	<0.05	0.0	0.00	1.1	<0.2	0.02
		7/20	1605	22	<0.3	-	-	-	-	-	-	-	-	-
		7/21	1008	23	<0.3	-	-	-	-	-	-	-	-	-
		7/22	0930	26	<0.3	-	-	-	-	-	-	-	-	-
4380	Belle Fourche River near Elm Spring, S.D.	6/10	1300	1300	2.8	-	-	<1	<0.05	<0.1	0.07	58.8	<0.2	0.16
		7/21	1650	307	<0.3	-	-	-	-	-	-	-	-	-
		7/22	1400	291	<0.3	-	-	-	-	-	-	-	-	-
4385	Cheyenne River near Plainview, S.D.	6/10	1440	3500	0.8	<0.02	210-190	0.0	<0.05	<0.1	<0.05	15.7	<0.2	0.08
		7/21	1357	409	<0.3	-	-	-	-	-	-	-	-	-
		7/22	1305	415	<0.3	-	-	-	-	-	-	-	-	-
4393	Cheyenne River at Cherry Creek, S.D.	7/21	1300	424	<0.3	-	-	-	-	-	-	-	-	-
		7/22	1230	424	<0.3	-	-	-	-	-	-	-	-	-

*N.D. = None detected. Multiple numbers are results of multiple assay.

TABLE E-4

Mercury Concentrations in Fish Flesh - Belle Fourche and Cheyenne River Systems - May, June, and July 1971

Station No.	Location	Date	Kind of Fish	No. of Fish Analyzed (Composites)	Hg (ppm)
4314.70	Spearfish Creek	6/9/71	Brook Trout	5	<0.02
			Brown Trout (fingerling)	1	<0.03
4329.50	Redwater River	6/9/71	Brown Trout	1	<0.04
			White Sucker	3	0.17
			Northern Redhorse	3	0.29
			Carp	2	0.58
			Creek Chub	2	0.19
4350.00	Belle Fourche Reservoir	5/27/71	Carp	3	<0.04
			Carpsucker	1	<0.04
			Yellow Perch	3	<0.03
			Northern Redhorse	2	0.07
			White Sucker	2	0.13
			Walleye	2	0.22
			Channel Catfish	1	<0.03
			White Bass	6	0.18
4360.00	Belle Fourche River at Fruitdale	6/8/71	Goldeye	1	0.29
			Carp	3	0.04
			Smallmouth Bass	1	0.17
			White Sucker	2	<0.03
			Green Sunfish	1	0.06
			Northern Redhorse	1	0.13
			Black Bullhead	1	<0.04
6-4361.00	Whitewood Creek, 50-100 yards upstream from Gold Run	5/29/71	Brook Trout	3	<0.04
			White Sucker	1	<0.04
			Longnose Dace	2	<0.04

TABLE E-4 (Continued)

Mercury Concentrations in Fish Flesh - Belle Fourche and Cheyenne River Systems - May, June, and July 1971

Station No.	Location	Date	Kind of Fish	No. of Fish Analyzed (Composites)	Hg (ppm)
6-4361.10	Gold Run	5/29/71	No Fish Present		
6-4361.25	Whitewood Creek, 400 yards downstream from Gold Run	5/29/71	No Fish Present		
6-4361.30	Deadwood Creek	5/29/71	Brook Trout	5	<0.04
6-4361.50	Whitewood Creek at Rodeo Campgrounds	5/29/71	No Fish Present		
6-4361.70	Whitewood Creek near Vale, South Dakota	5/29/71	No Fish Present		
4370.00	Belle Fourche River at Highway 34, 15 miles downstream from Whitewood Creek	7/20/71	Carp	1	0.18
			Channel Catfish	1	0.16
			Creek Chub	2	0.39
4370.00	Belle Fourche River at Bear Butte Creek confluence (NOTE: Although these fish were collected from the mouth of Bear Butte Creek, they are considered Belle Fourche River fish because the creek becomes dry during the summer and fall. However, the period of their residence in the creek mouth is not known.)	6/8/71	Carpsucker	3	0.22
			Yellow Perch	1	0.03
			Carp	1	0.42
			Goldeye	1	0.47
			Creek Chub	6	0.22
			Northern Redhorse	1	<0.04
4010.00	Angostura Reservoir	5/26/71	Walleye	4	0.16
			Yellow Perch	6	<0.03
			Carp	1	0.03
			Crappie	6	0.14
			Channel Catfish	4	0.08

TABLE E-4 (Continued)

Mercury Concentrations in Fish Flesh - Belle Fourche and Cheyenne River Systems - May, June, and July 1971

Station No.	Location	Date	Kind of Fish	No. of Fish Analyzed (Composite)	Hg (ppm)
4025.50	French Creek	6/10/71	Longnose Dace	2	<0.04
			Carp	1	0.20
			Northern Redhorse	3	<0.02
			White Sucker	3	0.06
4060.00	Battle Creek	6/10/71	White Sucker	6	0.16
			Creek Chub	3	<0.04
4130.00	Rapid Creek	6/7/71	Brown Trout	6	<0.02
--	Cleghorn Springs Fish Hatchery, Rapid City, South Dakota	6/8/71	Brown Trout	6	<0.04
4255.00	Elk Creek	7/22/71	Longnose Dace	6	0.05
4235.00	Cheyenne River at Wasta, South Dakota	7/21/71	Channel Catfish	6	0.22
			Northern Redhorse	5	0.06
			Sauger	4	0.20
4385.00	Cheyenne River at Highway 34, 20 miles downstream from Belle Fourche confluence	6/9/71	Black Bullhead	1	0.19
			Sauger	3	0.82
			Goldeye	1	0.17
		7/21/71	Channel Catfish	1	0.41
			Largemouth Bass	1	0.20
			Carp	1	0.41
			Northern Redhorse	1	0.35
			Sauger	2	0.34

TABLE E-5

Mercury Concentrations in Fish Flesh
Oahe Reservoir, South Dakota - 1970-71

Location	Date	Kind of Fish	No. of Fish Analyzed (Composites)	Hg (ppm)
Upper Cheyenne	10/7/70	Northern Pike	5	0.38
		Walleye	6	0.54
		White Bass	6	0.39
		Black Crappie	3	0.24
		Goldeye	6	0.22
		Channel Catfish	2	0.73
		Freshwater Drum	2	0.60
		Carp Sucker	6	0.23
		Carp	6	0.35
	4/27/71	Northern Pike	6	0.81
		Walleye	6	0.42
		White Bass	6	0.43
		Goldeye	6	0.29
		Channel Catfish	6	0.29
		Freshwater Drum	6	0.47
		Northern Redhorse	1	0.20
		Carp Sucker	6	0.22
		Carp	6	0.35
		Bigmouth Buffalo	5	0.34
	5/11/71	Northern Pike	1	1.05
		Walleye	6	0.56
		Sauger	6	0.57
		White Bass	6	0.74
		Goldeye	6	0.31
		Channel Catfish	6	0.39
		Freshwater Drum	6	0.39
		Northern Redhorse	1	0.11
		Carp Sucker	6	0.21
		Smallmouth Buffalo	1	0.24
		Carp	6	0.43
		Bigmouth Buffalo	6	0.48

TABLE E-5 (Continued)

Mercury Concentrations in Fish Flesh
Oahe Reservoir, South Dakota - 1970-71

Location	Date	Kind of Fish	No. of Fish Analyzed (Composites)	Hg (ppm)
Foster Bay	12/3/70	Walleye	2	0.69
		Sauger	1	0.32
	5/1/71	Northern Pike	4	0.56
		Walleye	4	0.88
		Channel Catfish	4	0.53
		Black Bullhead	5	0.14
	5/19/71	Northern Pike	2	0.61
		Walleye	6	0.12
		Sauger	1	0.32
		White Bass	5	0.40
		Yellow Perch	1	0.08
		Goldeye	6	0.18
		Channel Catfish	6	0.21
		Black Bullhead	3	0.08
		Freshwater Drum	3	0.35
		Northern Redhorse	2	0.06
		Carp Sucker	5	0.11
		Smallmouth Buffalo	6	0.10
		Carp	6	0.20
		Bigmouth Buffalo	2	0.34
	6/4/71	Northern Pike	1	0.23
		Walleye	6	0.18
		Sauger	1	0.32
		White Bass	1	0.04
		Yellow Perch	1	0.04
		Goldeye	6	0.43
		Channel Catfish	2	0.13
		Black Bullhead	1	0.36
		Northern Redhorse	6	0.23

TABLE E-5 (Continued)

Mercury Concentrations in Fish Flesh
Oahe Reservoir, South Dakota - 1970-71

Location	Date	Kind of Fish	No. of Fish Analyzed (Composites)	Hg (ppm)
Foster Bay (Continued)	6/4/71	Carp Sucker	4	0.14
	(Continued)	Carp	1	0.21
Ruby Creek	11/24/70	Walleye	2	0.37
		Sauger	2	0.55
		Goldeye	4	0.23
Fish Gut Creek	4/23/71	Northern Pike	3	0.42
		Walleye	6	0.67
		White Bass	6	0.50
		Burbot	3	0.24
		Yellow Perch	6	0.24
		White Crappie	2	0.42
		Black Crappie	3	0.66
		Goldeye	2	0.20
		Channel Catfish	2	0.34
		Black Bullhead	5	0.23
		Freshwater Drum	1	0.51
		Northern Redhorse	1	0.09
		Carp Sucker	3	0.13
		Carp	6	0.27
	4/29/71	Northern Pike	6	0.24
		Walleye	6	0.16
		White Bass	2	0.27
		Yellow Perch	2	0.21
		Goldeye	2	0.18
		Channel Catfish	3	0.28
		Freshwater Drum	1	0.51
		Northern Redhorse	1	0.09
		Carp Sucker	3	0.13
		Carp	6	0.27

TABLE E-5 (Continued)

Mercury Concentrations in Fish Flesh
Oahe Reservoir, South Dakota - 1970-71

Location	Date	Kind of Fish	No. of Fish Analyzed (Composites)	Hg (ppm)
Fish Gut Creek (Continued)	5/13/71	Northen Pike	6	0.51
		Walleye	6	0.12
		Sauger	2	0.15
		White Bass	4	0.23
		Burbot	1	0.16
		White Crappie	2	0.48
		Black Crappie	2	0.60
		Goldeye	1	0.02
		Channel Catfish	6	0.17
Oak Creek	4/30/71	Northern Pike	3	0.11
		Walleye	6	0.30
		Sauger	3	0.22
		Yellow Perch	1	0.15
		Goldeye	7	0.24
		Channel Catfish	5	0.30
		Northern Redhorse	2	0.07
		Carp Sucker	1	0.21
		Smallmouth Buffalo	1	0.14
		Carp	6	0.24
	5/14/71	Northern Pike	2	0.76
		Walleye	6	0.27
		Sauger	4	0.32
		Goldeye	1	0.19
		Channel Catfish	6	0.27
		Shovelnose Sturgeon	3	0.18
		Freshwater Drum	1	0.50
		Northern Redhorse	4	0.08
		Carp Sucker	4	0.16
		Smallmouth Buffalo	2	0.27
		Carp	3	0.16
		Bigmouth Buffalo	3	0.33

TABLE E-5 (Continued)

Mercury Concentrations in Fish Flesh
Oahe Reservoir, South Dakota - 1970-71

Location	Date	Kind of Fish	No. of Fish Analyzed (Composites)	Hg (ppm)
Agency Creek	5/21/71	Northern Pike	1	0.13
		Walleye	6	0.21
		Sauger	3	0.47
		White Bass	1	0.43
		White Crappie	1	0.42
		Goldeye	6	0.27
		Channel Catfish	6	0.15
		Shovelnose Sturgeon	5	0.59
		Freshwater Drum	1	0.30
		Northern Redhorse	1	0.09
		Carp Sucker	2	0.58
		Carp	6	0.66
		Bigmouth Buffalo	2	0.40
	6/4/71	Northern Pike	1	0.30
		Walleye	6	0.10
		White Bass	1	0.12
		Shovelnose Gar	2	0.34
		Black Crappie	1	0.31
		Goldeye	6	0.09
		Channel Catfish	6	0.42
		Shovelnose Sturgeon	5	0.15
		Northern Redhose	1	0.09
		Carp Sucker	5	0.10
		Carp	6	0.23
		Bigmouth Buffalo	3	0.22
Whitlock Bay	4/22/71	Walleye	2	0.11
		Sauger	1	0.22
		White Bass	1	0.38
		Yellow Perch	1	0.67

TABLE E-5 (Continued)

Mercury Concentrations in Fish Flesh
Oahe Reservoir, South Dakota - 1970-71

Location	Date	Kind of Fish	No. of Fish Analyzed (Composites)	Hg (ppm)
Whitlock Bay (Continued)	4/22/71	Goldeye	1	0.19
	(Continued)	Channel Catfish	2	0.48
		Shovelnose Sturgeon	4	0.18
		Northern Redhorse	1	0.11
		Carp Sucker	2	0.16
		Carp	3	0.19
		Bigmouth Buffalo	3	0.61
	5/18/71	Northern Pike	2	0.55
		Walleye	6	0.17
		Sauger	3	0.26
		Burbot	1	0.30
		Yellow Perch	2	0.15
		Goldeye	6	0.68
		Channel Catfish	5	0.19
		Shovelnose Sturgeon	1	0.30
		White Sucker	2	0.07
		Northern Redhorse	6	0.10
		Carp Sucker	2	0.24
		Carp	6	0.29
		Bigmouth Buffalo	1	0.45
	5/25/71	Northern Pike	2	0.20
		Walleye	1	0.13
		White Bass	1	0.28
		Channel Catfish	6	0.20
		Shovelnose Sturgeon	6	0.20
		Carp	1	0.20

TABLE E-5 (Continued)

Mercury Concentrations in Fish Flesh
Oahe Reservoir, South Dakota - 1970-71

Location	Date	Kind of Fish	No. of Fish Analyzed (Composites)	Hg (ppm)
Whitlock Bay (Continued)	6/2/71	Northern Pike	1	0.52
		Walleye	6	0.16
		Sauger	3	0.13
		Shovelnose Gar	6	0.44
		Yellow Perch	2	0.14
		White Crappie	3	0.14
		Goldeye	6	0.17
		Channel Catfish	6	0.22
		Stone Catfish	1	0.15
		Freshwater Drum	1	0.40
		White Sucker	1	0.19
		Northern Redhorse	5	0.09
		Carp Sucker	2	0.14
		Carp	6	0.17
Oahe Tailwater	12/1/70	Northern Pike	2	0.20
		Walleye	6	0.10
		Sauger	6	0.17
		White Bass	1	0.02
		Burbot	3	0.24
		Yellow Perch	1	0.04
		Goldeye	5	0.13
		Carp Sucker	6	0.20
	4/23/71	Walleye	6	0.16
		Sauger	4	0.13
		Goldeye	6	0.18
		Channel Catfish	6	0.29
		White Sucker	1	0.08
		Northern Redhorse	3	0.19
		Carp Sucker	6	0.15
		Carp	6	0.16
		Bigmouth Buffalo	6	0.24

TABLE E-5 (Continued)

Mercury Concentrations in Fish Flesh
Oahe Reservoir, South Dakota - 1970-71

Location	Date	Kind of Fish	No. of Fish Analyzed (Composites)	Hg (ppm)
Oahe Tailwater (Continued)	5/19/71	Walleye	6	0.10
		Sauger	1	0.13
		Goldeye	1	0.13
		Channel Catfish	6	0.13
		Black Bullhead	6	0.17
		Blue Sucker	4	0.18
		Northern Redhorse	6	0.05
		Carp Sucker	6	0.14
		Smallmouth Buffalo	5	0.14
		Carp	1	0.11
		Bigmouth Buffalo	3	0.14
Blue Blanket	4/9/71	Northern Pike	6	0.27
Pollock, S. D.		Northern Pike	6	0.25
Grand River	4/7/71	Northern Pike	6	0.36

TABLE E-6

MERCURY CONCENTRATIONS IN BOTTOM MUDS.
OAHE RESERVOIR, SOUTH DAKOTA. APRIL - JUNE, 1971.

Location	Date	South Shore	200 yds of South Shore	400 yds of South Shore	300 yds of South Shore	Middle	400 yds of North Shore	200 yds of North Shore	North Shore
Upper Cheyenne	4/27/71	.068			.28	.30		.32	.056
		.094			.49	.48		.53	.076
	5/10/71	.055	.24			.24		.18	.038
		.075	.39			.39		.31	.057
Minniconju	4/29/71	.055		.24		.20	.33		.037
		.081		.41		.35	.62		.052
	5/12/71	.034		.066		.066	.070		.051
		.045		.11		.11	.12		.078
Oak Creek	5/14/71	<.03				.069	.26		.049
		<.04				.12	.50		.068
	5/13/71	.036		.078		.10			.12
		.046		.13		.17			.16
Agency Creek	5/20/71	.02		.02		.03	.16		.03
		.02		.04		.06	.30		.04
	6/4/71	.02		.02		.02	.02		.03
		.02		.03		.03	.03		.04
Whitlock Bay	6/7/71	.054		.026		<.03	<.02		<.02
		.089		.081		<.08	<.05		<.04

Upper Figure - ppm wet weight
Lower Figure - ppm dry weight
Table prepared by Region VII, E.P.A.

TABLE E-7

MERCURY CONCENTRATIONS IN WATER (μg/l)
OAHE RESERVOIR, SOUTH DAKOTA. JUNE, 1971

		Shallow Water			Deep Water		
Location	Date	1 meter of Surface	Mid-depth	1 meter of Bottom	1 meter of Surface	Mid-depth	1 meter of Bottom
Foster Bay	6/9/71	<.2	<.2	<.2	<.2	<.2	<.2
Fish Gut Creek	6/11/71	<.2	<.2	<.2	<.2	<.2	<.2
Oak Creek	6/11/71	<.2	<.2	<.2	<.2	<.2	<.2
Agency Creek	6/3/71	<.2	<.2	<.2	<.2	<.2	<.2
Whitlock Bay	6/7/71	<.2	<.2	<.2	<.2	<.2	<.2

Table prepared by Region VII, E.P.A.

Table E-8. Logs of Core Holes Along Belle Fourche River

Location	Depth	Description
Transect 1, Along Upstream Side of Road, 1 Mile East of Vale, S.D.		
Bank Material		Silt, clayey, sandy, blue-gray, very plastic (2.2 ppm Hg)
Hole 1, five feet north of north bank	0-2'	Sand, clayey, iron stained, mica, angular (0.82 ppm Hg)
	2'	Bottom of hole, alluvium, iron cemented
Hole 2, 35 feet north of north bank	0-1'	Sand, iron-stained, angular, medium
	1'-2.75'	Sand, medium to coarse, iron-stained, cemented, with stringers of gray clay resembling Homestake slime
	2.75'-3.75'	Sand, blue-gray, silty, resembles Homestake sands (1.9 ppm Hg)
	3.75'-5.0'	Sand, tan, fine, medium-rounded, filled with ground water (ground water contains 34 μg/l Hg)
Hole 3, 65 feet north of north bank	0-2.5'	Sand, iron-stained, angular, medium
	2.5'-4'	Sand, medium to coarse, iron-stained and cemented, angular, with 2" stringer of blue-gray plastic clay (3.6 ppm Hg)
	4'-5'	Sand, tan, medium-round, with shale fragments

Table E-8. Logs of Core Holes Along Belle Fourche River (cont'd)

Location	Depth	Description
Transect 2, County Road 7 Miles East of Vale, S.D.		
Bank Material		Silt, clayey, sandy, blue-gray, plastic (1.7 ppm Hg)
Hole 1, cut in north bank of river	0-1.2'	Sand, cross-bedded, brown, iron-stained
	1.2'-6.5'	Sand, very fine, silty, clayey, plastic, resembling Homestake tailings (3.5 ppm Hg at 3', 4.5 ppm Hg at 6')
	6.5'	Bottom of hole in clean stream alluvium
Hole 2, 30 feet north of north bank	0-1.75'	Topsoil, tan
	1.75'-2.0'	Sand, medium, angular, iron-stained
	2.0'-9.0'	Sand, clayey, silty, plastic, blue-gray, resembling Homestake tailings (2.6 ppm Hg at 2.2', 2.0 ppm Hg at 5', 1.6 ppm Hg at 7', and 0.18 ppm Hg at 9')
	9.0	Bottom of hole in clean, water-filled alluvium (ground water contains 1.8 μg/1 Hg
Hole 3, 60 feet north of north bank	0-2'	Sand, medium, angular, iron-stained
	2'-3'	Sand, tan, parent material of area

Table E-9

Mercury and Arsenic Concentration in Western South Dakota Ground-Water Samples Downstream from Homestake Effluents

Date	Sample Source	Mercury µg/l	Arsenic µg/l
6/11	Willard Gralapp Well	0.6	<1.0
6/11	Well east of Gralapp Well	0.3	<1.0
6/11	Richter Ranch Well	0.2	<1.0
6/11	Thompson Ranch Deep Well	0.2	<1.0
6/11	Anderson Well on Belle Fourche River	0.4	
6/11	Transect 2, Hole 2, Alluvium	1.8	
5/27	Transect 1, Hole 2, Tailings	34	

APPENDIX F

SURVEY METHODOLOGY

APPENDIX F

SURVEY METHODOLOGY

A. STREAM SAMPLING

A network of stream and biologic stations was designed to evaluate the pollution effects of natural and unknown sources, as well as the known pollution from Homestake Mining Company. The network of stations is shown in Figure 1 at the back of this report.

Where possible, stream sampling was done at existing U. S. Geological Survey gaging stations. At those locations a continuous record of stream flow was available. At some locations, especially on Whitewood Creek, no USGS station was available. In these cases a reference mark was established and stream stage determined at the time of sampling. Stream flow was gaged, utilizing established stream-flow measurement techniques. The flow at the time of sampling was determined by use of rating curves.

Water samples from most of the stream stations were grab samples. Aliquots were collected from effluent streams on an hourly basis and composited into a single sample representing the average quality of the discharges during the day. Samples were collected manually and by mechanical sample collectors. The samples were fixed with the proper preservative, and transported to the laboratory for analyses. Cyanide samples were iced and shipped by air express.

Samples of stream sediment were collected at each of the sampling stations. Where possible, an effort was made to collect samples of similar grain size from similar hydraulic zones. Samples were collected by hand or by dredge and sealed in a clean, sterile bag. They were examined at the time of colllection by a geological engineer, and were also examined microscopically at the DFI-DC laboratory.

B. BURIED TAILINGS SAMPLING

Holes were drilled through the various deposits of buried tailings material, utilizing a six-inch diameter hand auger. Logs of the holes were prepared at the time of the drilling. As in the case of the stream sediment samples, samples of the cuttings were sealed in clean bags. The samples were visually examined at the time of collection, and microscopically examined at the DFI-DC laboratory. Ground-water samples were collected from the holes by the use of a Kemmerer sampler.

C. BIOLOGICAL SAMPLING

Bottom dwelling invertebrate animals (benthos) were collected at each sampling station by means of a Surber sampler. These organisms, plus qualitative samples collected by use of a No. 30 U.S. Standard Series sieve, were preserved in 10 percent formalin solution. Benthos were separated from debris, sorted and identified using standard taxonomic references, and counted. Results of analyses were expressed as numbers of organisms per square foot of stream bottom. Qualitative samples were sorted and identified, but not counted; these were arbitrarily assigned a value of one per square foot.

Fish were collected from Angostura and Belle Fourche Reservoirs by means of 200-feet long floating gill nets, and by use of fyke nets. Fish were collected from river and stream stations by use of an electric shocker. Representative specimens were collected at each station for mercury analyses.

D. ANALYTICAL PROCEDURES

The water samples for metals analysis were preserved in the field with 5 ml concentrated HNO_3/l. Samples for cyanide analysis were field preserved with NaOH to pH 11, iced, and shipped air express to Denver; these samples were analyzed within 24 hours. Samples of stream sediment were sealed in clean, sterile bags at each of the stream sampling stations.

Samples sent to the DFI-DC Laboratory in Denver were analyzed by the procedures recommended in the EPA Manual, Methods for Chemical Analysis of Water and Wastes, 1971. Briefly, these were as follows:

Cyanide analysis - Samples were digested with acid and a catalyst to convert all cyanides to hydrogen cyanide. The hydrogen cyanide was distilled and trapped in sodium hydroxide solution. The resulting sodium cyanide concentrations were determined colorimetrically by the pyridine - pyrazalone reaction.

Mercury - Water samples were digested with acid permanganate to convert any mercury to the mercuric form. Excess permanganate was removed with hydroxylamine and stannous sulfate was added to reduce the mercuric ions to elemental mercury. Elemental mercury concentrations were determined in a closed system by atomic absorption (Flameless AA procedure).

Fish and stream sediment samples were also analyzed for mercury by this procedure after initial digestion with concentrated H_2SO_4 according to the method of Uthe, et al[1/].

1/ J. F. Uthe, F. A. J. Armstrong, and M. P. Stainton, J. Fisheries Research Board of Canada, 27, 805 (1970).

Total Solids - A known volume of well mixed sample was evaporated to dryness at 105°C. Total Solids were calculated on the basis of residue weight.

Suspended Solids - A known volume of well mixed sample was filtered through a tared gooch crucible. The crucible was dried at 105°C, cooled, and reweighed. Suspended solids were calculated from the weight gain.

Samples of water and stream sediment were shipped to the Southeast Water Laboratory in Athens, Georgia for arsenic analysis. Since sulfides in the samples interfered with the normal colormetric procedures, arsenic was determined by neutron activation.

Additional metals analyses were performed by the Midwest Research Institute, Kansas City, Missouri. Here, nitric acid preserved samples were tested directly by atomic absorption spectrophotometry.

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