SA/TSB-18

ENVIRONMENTAL EVALUATION

OF

MINES DEVELOPMENT, INC. URANIUM & VANADIUM

MILLING OPERATIONS

AT

EDGEMONT, SOUTH DAKOTA

TECHNICAL SUPPORT BRANCH

SURVEILLANCE AND ANALYSIS DIVISION

U. S. ENVIRONMENTAL PROTECTION AGENCY

REGION VIII

APRIL, 1973

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SUMMARY

Since the Mines Development, Inc., uranium mill located at Edgemont, South Dakota, began commercial operation in 1956, the resultant impact of waste management practices on environmental radiation levels has been the subject of several State and Federal studies. The first set of post-operational samples were collected during June, 1957. During the latter part of July, 1957, an intensive in-plant study was conducted to characterize the mill process and liquid effluents. Water quality studies conducted during September, 1966, and July, 1971, showed that process and waste liquors were being lost by seepage from mill ponds and entering surface waters - Cottonwood Creek and the Cheyenne River. Soil and bottom sediment samples collected during the 1971 study confirmed the loss of unstabilized sand tailings to the water environment by wind and water erosion.

Water quality degradation attributable to mill operations was considered at the Environmental Protection Agency - State of South Dakota Conference in the Matter of Pollution of the Navigable Waters of Western South Dakota (held in Rapid City, South Dakota on October 19 - 21, 1971). Based principally on the findings of the 1971 field study, the Conferees put forth recommendations calling for (1) curtailment of pond seepage, (2) development of a plan providing for the stabilization and ultimate disposal of sand tailings, and (3) the establishment of a water quality monitoring program (State in cooperation with EPA) to monitor and document the progress of abatement actions.

The mill was revisited October 3, 1972, to discuss the efforts undertaken by Mines Development, Inc., to abate radiological pollution and to assess the progress achieved in the year following the 1971 Conference. To eliminate seepage from mill ponds, the Company had instituted a program of operating the ponds at lower fluid levels and systematically abandoning old ponds. Although visual observations indicated that some reduction in the seepage flow to Cottonwood Creek had been achieved, water quality monitoring data for the period of May through September, 1972, showed no significant improvement.

As the result of the mill visit, it was concluded that little progress had been made on the crucial issue of sand tailings stabilization and ultimate disposal. Aside from two limited experiments to test potential stabilization procedures, no positive actions had been taken to prevent the loss of sand tailings to the environment by wind and water erosion. At the Pond No. 2 disposal area, sand tailings have drifted through the site Perimeter fence and are migrating down the Cheyenne River bank, toward the State Highway, and into the yard of a single family dwelling adjacent to the disposal site. A soil sample collected from a residential area to the east of inactive sand tailings pile No. 1 contained a high concentration of radium-226 indicative of wind transport from this pile. To eliminate these situations and prevent additional off-site contamination, a corrective action program should be implemented without delay.

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INTRODUCTION

Field studies to quantify the impact of waste disposal practices at the Mines Development, Inc., uranium mill on the quality of Cottonwood Creek and the Cheyenne River have been conducted on several occasions by Federal and State personnel - the most recent field study occurring in July of 1971. The findings of these efforts were the basis for the Environmental Protection Agency report(1) presented at the Conference in the Matter of Pollution of the Navigable Waters of Western South Dakota (held in Rapid City, South Dakota, on October 19-21, 1971). Consistent with the Environmental Protection Agency recommendations calling for improvement in waste management practices, the Conferees set forth the following requirements:

1. "By January 1, 1973, sealed storage for liquid uranium and vanadium mill wastes at Mines Development, Inc., at Edgemont, South Dakota, shall be provided to eliminate the seepage into Cottonwood Creek and the Cheyenne River. A progress report shall be made by Mines Development, Inc., and the State to the Conferees by July 1, 1972."

2. "A plan providing for the stabilization and ultimate disposal of sand tailings from Mines Development, Inc., shall be developed by February 15, 1972. One alternative for ultimate disposal that should be investigated is storage in the excavated portions of the open-pit uranium mine operated by Mines Development, Inc."

3. "By July 1, 1972, monitoring stations shall be established on Cottonwood Creek (at the mouth) and the Cheyenne River (downstream from the Mines Development, Inc., mill) by the State of South Dakota in cooperation with the Environmental Protection Agency to determine the extremes in chemical and radioactivity concentrations as well as the annual average radioactivity."

A map of the area covered by the water quality studies is shown in Figure 1.

The objectives of this report are three-fold:

1. To present all the analytical results from the July 1971 water quality study and discuss the significance thereof. As noted in the Conference report, only a limited number of the 1971 results were available at the time of the Conference.

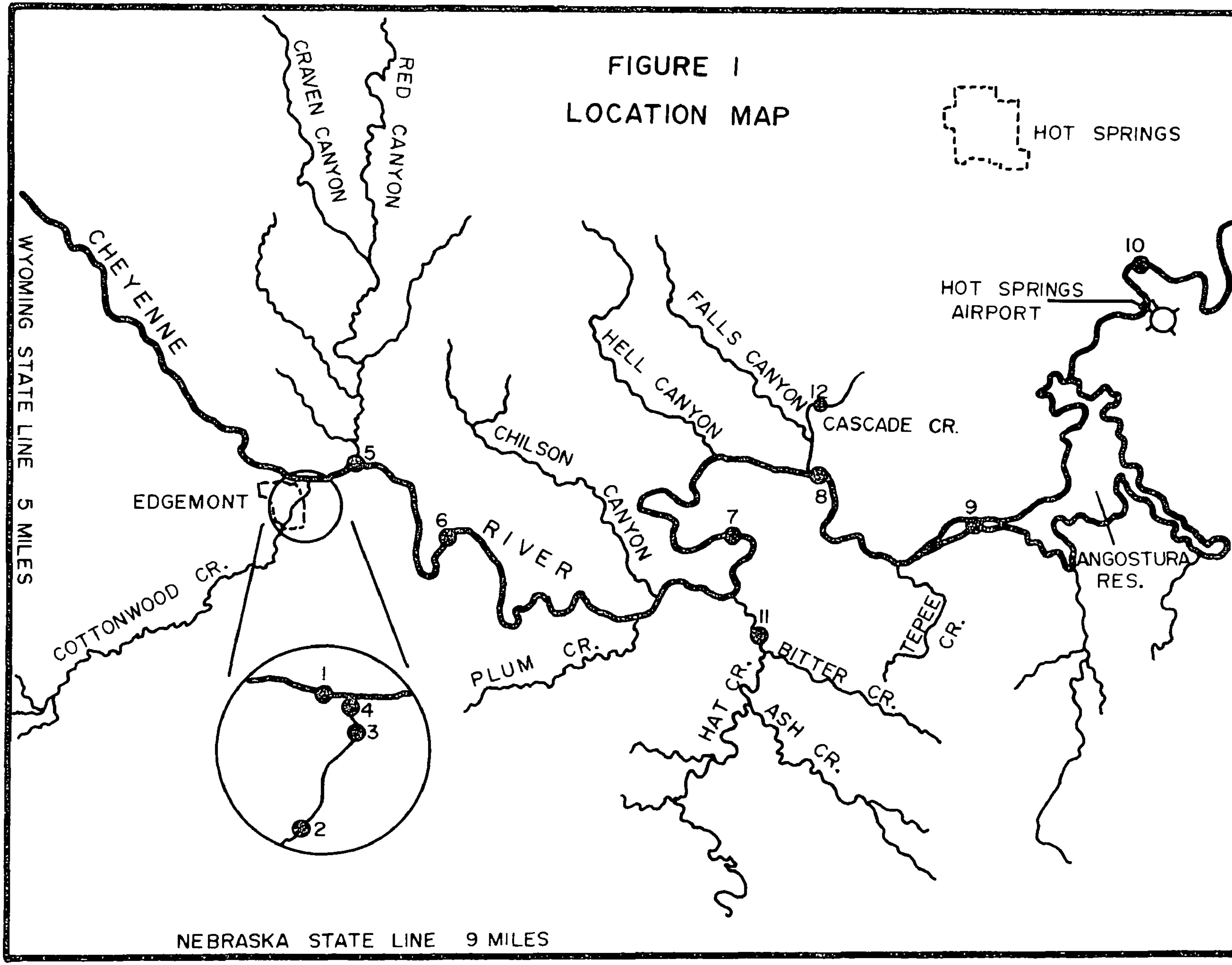


FIGURE 1
LOCATION MAP
HOT SPRINGS
CRAVEN CANYON
RED CANYON
CHEYENNE
RIVER
WYOMING STATE LINE 5 MILES
EDGEMONT
COTTONWOOD CR.
CHILSON CANYON
PLUM CR.
HELL CANYON
FALLS CANYON
CASCADE CR.
HOT SPRINGS AIRPORT
TEPEE CR.
ANGOSTURA RES.
BITTER CR.
HAT CR.
ASH CR.
NEBRASKA STATE LINE 9 MILES
1
2
3
4
5
6
7
8
9
10
11
12

2. Discuss the efforts expended and the progress achieved by Mines Development, Inc., in the abatement of seepage from mill ponds and the stabilization of on-site tailings piles.

3. Present the initial results of the "Edgemont" water quality monitoring program (five month period of May through September, 1972).

1971 FIELD STUDY

Detailed descriptions of the July 1971 field study and associated sample processing procedures were presented in the Enforcement Conference report. The study involved the collection of surface water, well water, seepage, soil, and bottom sediment samples. Summarized briefly, surface water sampling stations were established on the following:

Cheyenne River	-	7 Stations
Cottonwood Creek	-	3 Stations
Hat Creek	-	1 Station
Cascade Creek	-	1 Station
Angostura Reservoir	-	13 Stations

Water sampling stations for the Cheyenne River and three tributaries are listed in Table I and are shown in Figure I. Angostura Reservoir stations are shown in Figure II.

The collection frequency for water samples from Cottonwood Creek and the Cheyenne River was daily over the 5-day study period at all stations except Stations 9 and 10. At these latter two stations as well as at the stations on at Cascade Creek and Hat Creek, grab samples were collected only once during the study. In the case of Angostura Reservoir, grab water samples were collected at the surface and near the bottom of the water column at each station.

Flow data for the study period are summarized in Table II. Flow in Cottonwood Creek increased from an average 0.1 cfs upstream of the mill (Station 2) to 0.4 cfs at the road culvert and 0.5 cfs at the mouth. The approximate 0.3 cfs increase between Station 2 and the road culvert was largely due to overflow from the mill water tower and seepage from mill ponds. The small flow increase between the culvert and the creek mouth might represent the drainage into the creek from an abandoned railroad well. However, this small difference was within the limits of the metering procedure employed for flow measurements. Flow in the Cheyenne River was about 5 cfs at the upstream railroad bridge (Station 1) and approximately 132 cfs at the State Highway 71 Bridge. The increase was largely attributable to Hat Creek (100 cfs) and Cascade Creek. All other potential tributaries were dry.

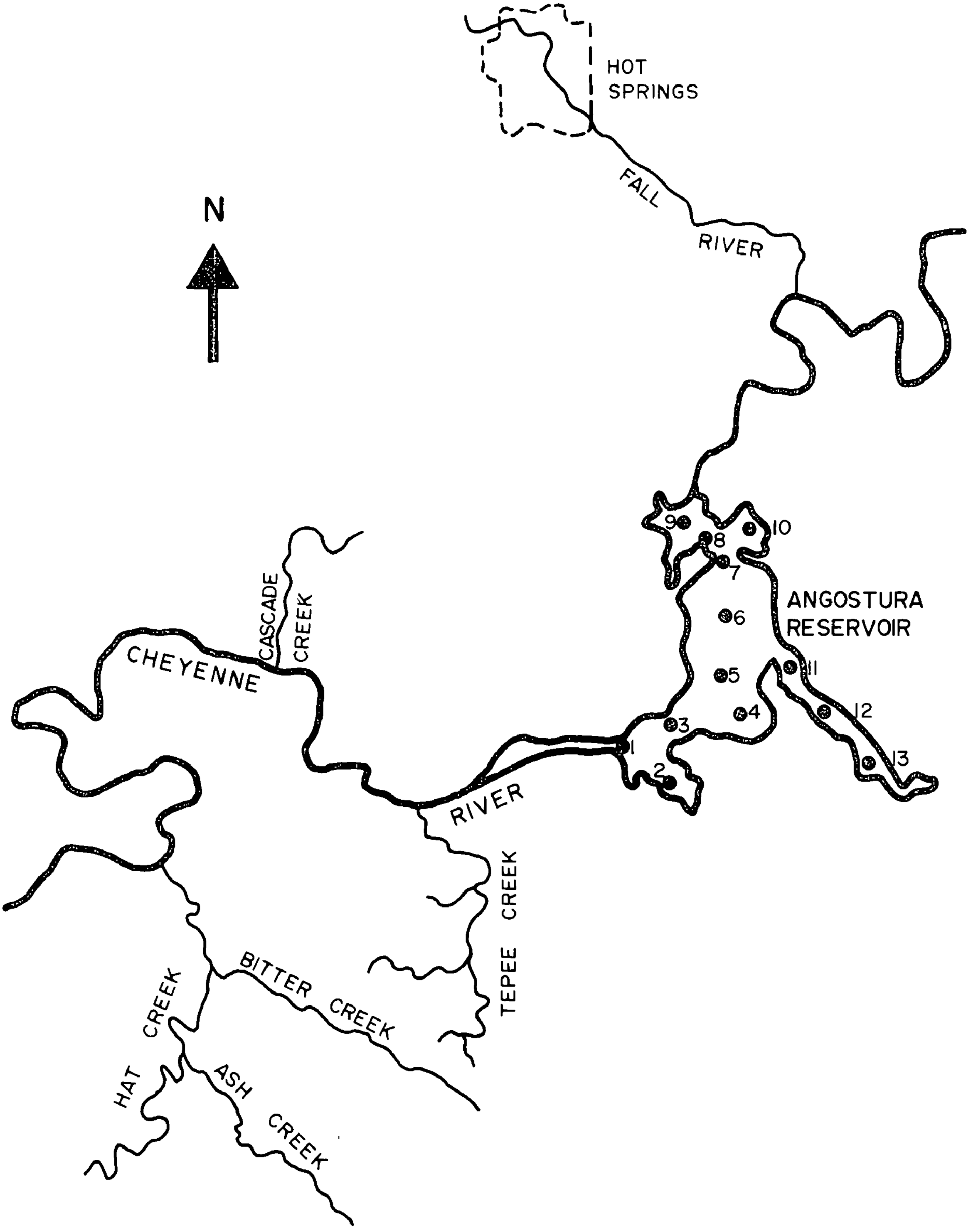
TABLE I

SURFACE WATER SAMPLING STATIONS
CHEYENNE RIVER AND TRIBUTARIES - 1971

Station	Description
1	Cheyenne River just upstream of the State Highway 18 Bridge outside of Edgemont; at the railroad bridge.
2	Cottonwood Creek upstream of mill property at the county road bridge; off State Highway 52.
3	Cottonwood Creek at the mill road culvert; downstream of sand tailings pile No. 2.
4	Cottonwood Creek at the confluence with the Cheyenne River.
5	Cheyenne River about 1.5 miles downstream of the mill.
6	Cheyenne River about six (6) miles downstream of the mill; at Gull Hill Park.
7	Cheyenne River at ford on County Road 11.
8	Cheyenne River at State Highway 71 Bridge.
9	Cheyenne River in the headwaters of Angostura Reservoir.
10	Cheyenne River below Angostura Dam.
11	Hat Creek at State Highway 71 Bridge.
12	Cascade Creek near Brainerd Indian School.

FIGURE II

ANGOSTURA RESERVOIR SAMPLING STATIONS



Surface Waters

Water quality results for the Cheyenne River, Cottonwood Creek, Cascade Creek, and Hat Creek are summarized in Tables III and IV. In the case of stations for which composite samples were prepared, complete radiochemical analysis was performed only on the composite sample (Table III) with analysis of the daily samples limited to dissolved radium-226 and uranium (Table IV). With the exception of the radium-226 results for Station 2, there was excellent agreement between the average results calculated for the daily samples and the corresponding results for the composite samples. Based on the separate results for the five (5) samples collected at Station 2, the background concentration of dissolved radium-226 in Cottonwood Creek was approximately 0.10 pCi/l instead of the 0.26 pCi/l indicated by composite sample analysis.

The radioactivity results for the Cottonwood Creek stations showed a significant degradation in quality as the creek traverses mill property. The level of dissolved radium-226 increased 30-fold from 0.10 pCi/l upstream of the mill to 3.1 pCi/l at the road culvert. Similarly, dissolved uranium increased from 26 ug/l to 147 ug/l. Field pH measurements also showed a small reduction in pH in the reach receiving seepage from mill ponds - 7.0 to 7.1 upstream at Station 2 as compared to 6.4 to 6.8 at the road culvert.

In contrast to the degradation of water quality in Cottonwood Creek, there was no detectable change in the radiological water quality of the Cheyenne River as the result of pond seepage. Concentrations of radium-226 and uranium at Station 5, approximately 1.5 miles below the confluence with Cottonwood Creek, were comparable to those at the upstream or baseline station (Station 1). This is consistent with results of mass balance calculations. Even by assuming complete conservation of the pollutants in the dissolved form (i.e., no loss by chemical precipitation, adsorption, etc.), the calculated concentrations for Station 5 for a complete mixing condition are not dramatically different than background levels - calculated values of 0.5 pCi/l and 31 ug/l of radium -226 and uranium, respectively. The fact that the mass balance approach is not totally accurate is undoubtedly attributable to several factors, including the possible transition of radium-226 and uranium from the dissolved to solid state. Dissolved radium-226 results for Stations 7 and 8 on the Cheyenne River indicated a contributing source in this reach as the average concentration increased from 0.25 pCi/l to 0.34 pCi/l (Table IV). Apparently, the source of this small increase was the small tributary, Cascade Creek. A single grab sample from this stream contained 1.7 pCi/l of dissolved radium-226.

Water quality data for Angostura Reservoir (Table V) showed no detectable impact of radioactivity-bearing seepage from the mill on dissolved radioactivity in the reservoir. Based on the collective analysis of the separate results, the average dissolved concentrations of radium-226 and uranium were 0.17 pCi/l and 8 ug/l, respectively. These values are comparable

TABLE II

STREAM FLOWS

Station	Date	Flow(cfs)	Method of Measurement
1 - Cheyenne River upstream of mill	7/26	6.6	Permanent USGS Gage
	7/27	3.8	
	7/28	4.4	
	7/29	5.6	
	7/30	4.4	
		Avg. - 5.0	
2 - Cottonwood Creek upstream of mill	7/26	0.14	Staff Gage
	7/27	0.12	
	7/28	0.12	
	7/29	0.05	
	7/30	0.07	
		Avg. - 0.10	
3 - Cottonwood Creek at mill road culvert	7/26	0.64	Staff Gage
	7/27	0.12	
	7/28	0.29	
	7/29	0.29	
	7/30	0.29	
		Avg. - 0.40	
4 - Cottonwood Creek near mouth	7/26	0.62	Staff Gage
	7/27	0.62	
	7/28	0.39	
	7/29	0.62	
	7/30	0.50	
		Avg. - 0.53	
8 - Cheyenne River at State Highway 71 Bridge	7/26	148	Permanent USGS Gage
	7/27	137	
	7/28	129	
	7/29	127	
	7/30	122	
		Avg. - 132	
11 - Hat Creek	7/26	100	Permanent USGS Gage

TABLE III

RADIOACTIVITY IN CHEYENNE RIVER, COTTONWOOD CREEK, CASCADE CREEK, AND HAT CREEK WATER SAMPLES

Station	Solids		Dissolved Radioactivity					pH
	Suspended (mg/l)	Dissolved (mg/l)	Total Alpha Radium (pCi/l)	Radium-226 (pCi/l)	Uranium (ug/l)	Total Alpha Thorium (pCi/l)	Thorium-natural (ug/l)	
1 - Composite	---	---	0.11	0.24	16	0.10	4	8.0 - 8.2
2 - Composite	---	---	0.67	0.26	26	0.80	3	7.0 - 7.1
3 - Composite	---	---	0.75	3.1	147	0.02	2	6.4 - 6.8
4 - Composite	---	---	0.09	2.6	177	0.38	1	6.7 - 7.1
5 - Composite	---	---	0.17	0.32	28	0.85	7	7.8 - 8.0
6 - Composite	---	---	0.32	0.28	14	0.06	5	8.1 - 8.4
7 - Composite	---	---	0.11	0.21	19	0.10	3	7.9 - 8.2
8 - Composite	---	---	0.10	0.31	14	0.10	3	7.9 - 8.2
9 - Grab (7/27)	32	1360	0.14	0.49	10	0.20	3	---
10 - Grab (7/26)	3	---	0.11	0.47	12	0.11	3	---
11 - Grab (7/26)	25	1560	0.08	0.37	23	----	3	7.7
12 - Grab (7/26)	2	1530	0.08	1.7	5	< 0.01	< 1	6.8

TABLE IV

RADIUM-226 AND URANIUM IN CHEYENNE RIVER AND COTTONWOOD CREEK WATER SAMPLES

Station	Collection Date	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Dissolved Radium-226 (pCi/l)	Dissolved Uranium (ug/l)
1	7/26	9	2540	0.34	17
	7/27	7	----	0.27	18
	7/28	6	----	0.22	24
	7/29	7	----	0.45	19
	7/30	4	----	0.26	15
				Avg. - 0.31	Avg. - 19
2	7/26	9	4050	0.02	26
	7/27	15	----	0.11	38
	7/28	6	----	0.10	22
	7/29	6	----	0.10	20
	7/30	5	----	0.07	18
				Avg. - 0.08	Avg. - 25
3	7/26	1422[a]	2950	3.6	67
	7/27	31	----	4.0	212
	7/28	85	----	3.2	194
	7/29	24	----	2.8	156
	7/30	37	----	2.5	233
				Avg. - 3.2	Avg. - 160
4	7/26	75	2810	2.0	158
	7/27	27	----	2.5	150
	7/28	86	----	3.7	228
	7/29	16	----	2.2	89
	7/30	11	----	2.1	135
				Avg. - 2.5	Avg. - 152
5	7/26	11	3850	0.34	33
	7/27	4	----	0.25	27
	7/28	4	----	0.40	14
	7/29	9	----	0.24	21
	7/30	21	----	0.29	20
				Avg. - 0.30	Avg. - 23

TABLE IV

(Continued)

Station	Collection Date	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Dissolved Radium-226 (pCi/l)	Dissolved Uranium (ug/l)
6	7/26	8	1800	0.22	---
	7/27	6	----	0.23	---
	7/28	8	----	0.28	---
	7/29	7	----	0.29	---
	7/30	5	----	0.30	---
				Avg. - 0.26	
7	7/26	4	2720	0.27	---
	7/27	5	----	0.27	---
	7/28	3	----	0.22	---
	7/29	3	----	0.21	---
	7/30	3	----	0.28	---
				Avg. - 0.25	
8	7/26	7	1720	0.31	---
	7/27	8	----	0.34	---
	7/28	5	----	0.37	---
	7/29	11	----	0.33	---
	7/30	6	----	0.33	---
				Avg. - 0.34	

(a) High result considered to be due to the channel disturbance caused by the 7/25 reconnaissance of the creek.

TABLE V

DISSOLVED RADIOACTIVITY IN ANGOSTURA RESERVOIR

Station [a][b]	Date	Solids: Suspended (mg/l)	Solids: Dissolved (mg/l)	Dissolved Radioactivity: Radium-226 (pCi/l)	Dissolved Radioactivity: Uranium (ug/l)	Dissolved Radioactivity: Total Alpha Thorium (pCi/l)	Dissolved Radioactivity: Thorium-natural (ug/l)
A-1:	7/26						
Surface		14	930	0.23	9	< 0.01	0.0
Bottom (12')		37	---	0.24	8	0.04	0.7
A-2:	7/26						
Surface		79	980	0.24	10	< 0.01	1.5
Bottom (22')		130	---	0.02	13	0.07	4.9
A-3:	7/26						
Surface		12	1260	< 0.01	6	< 0.01	0.7
Bottom (20')		28	---	< 0.01	-	0.02	0.7
A-4:	7/26						
Surface (30')		5	1230	0.21	8	< 0.01	0.5
Bottom (-)		10	---	0.19	10	0.06	0.5
A-5:	7/26						
Surface		7	1110	0.46	10	< 0.01	0.3
Bottom (-)		22	---	0.16	9	0.22	0.3

TABLE V

(Continued)

		Solids		Dissolved Radioactivity			
Station	Date	Suspended (mg/l)	Dissolved (mg/l)	Radium-226 (pCi/l)	Uranium (ug/l)	Total Alpha Thorium (pCi/l)	Thorium-natural (ug/l)
A-6:	7/26						
Surface		5	1090	< 0.01	11	< 0.04	0.0
Bottom (56')		7	---	0.05	9	0.08	3.4
A-7:	7/27						
Surface		8	---	0.23	9	0.05	0.0
Bottom (-)		9	---	0.14	6	0.08	1.5
A-8:	7/27						
Surface		4	---	0.13	7	< 0.04	0.3
Bottom (-)		6	---	0.18	9	0.08	1.2
A-9:	7/27						
Surface		---------- Sample Lost ----------					
Bottom (-)		8	---	0.12	8	< 0.04	0.7
A-10:	7/27						
Surface		4	---	0.15	8	< 0.04	1.7
Bottom (48')		9	---	0.23	8	0.06	1.1

TABLE V

(Continued)

Station	Date	Solids: Suspended (mg/l)	Solids: Dissolved (mg/l)	Dissolved Radioactivity: Radium-226 (pCi/l)	Dissolved Radioactivity: Uranium (ug/l)	Dissolved Radioactivity: Total Alpha Thorium (pCi/l)	Dissolved Radioactivity: Thorium-natural (ug/l)
A-11:	7/26						
Surface		6	1120	0.13	9	< 0.01	0.3
Bottom (45')		18	---	0.34	9	0.07	0.7
A-12:	7/27						
Surface		11	---	0.28	6	0.12	0.9
Bottom (34')		16	---	0.18	7	< 0.04	1.4
A-13:	7/27						
Surface		17	---	0.14	8	< 0.04	---
Bottom (14')		19	---	0.26	4	< 0.04	---

(a) Refer to Figure II
(b) Collection depth in parentheses

with the corresponding baseline concentrations for the Cheyenne River. No significant difference was observed between the "surface" and "bottom" concentrations of either radionuclide.

Well Waters

Seven wells in the Edgemont area were sampled (grab samples) to determine the concentrations of radium-226 and uranium in groundwater:

Mines Development, Inc., well - mill process water
City Airport well
City Park well
City Reservoir well
Railroad wells - "old" and "new"
Cheyenne River Campground well

All wells, excluding the campground well, were completed in a deep, confined aquifer. The campground well, located on the opposite side of the river from the other wells, was completed in a shallow aquifer under water table conditions. Radiochemical analysis was performed on the samples "as collected" without filtration.

The radium-226 concentration in groundwater used for municipal water supply and mill process water was substantially higher than the naturally-occurring concentration in area surface waters. Grab samples from the municipal, mill, and railroad wells contained 3.3 to 5.0 pCi/l; averaging 3.9 pCi/l (Table VI). For uranium, the opposite was the case with the groundwater level somewhat lower than the surface water level - 4 to 7 ug/l versus an average 19 ug/l at Station 1 on the Cheyenne River. Unlike the deep wells, the shallow campground well contained a low concentration of radium - 0.12 pCi/l. This difference indicates a lack of inter-connection between deep and shallow aquifers.

Although the radium-226 concentration in groundwater is sufficiently high to consider the water tower overflow and the "old" railroad well drainage as sources of increased radium-226 (dissolved) in Cottonwood Creek, the associated low flows of these discharges indicate that the actual impact is not great because of dilution by natural creek flow and seepage. The average daily flow of the water tower overflow is estimated by mill management to be on the order of 2 to 3 gpm. Such a flow was only about 1% of the creek flow at the road culvert during the field study. Similarly, flow measurements at the road culvert and the confluence showed the railroad well drainage to be less than 0.1 cfs.

TABLE VI

RADIOACTIVITY IN WELL WATER SAMPLES

Well Description	Radioactivity: Radium-226 (pCi/l)	Uranium (ug/l)	Total Alpha Thorium (pCi/l)	Thorium-natural (ug/l)
Mines Development, Inc., mill well	3.5	5.0	0.09	---
City of Edgemont				
Airport well	3.7	7.0	0.13	---
Park well	4.4	5.0	< 0.05	---
Reservoir well	5.0	5.0	0.07	---
Cheyenne River campground well - north of the mill; across the river	0.12	0.2	< 0.04	0.8
Railroad wells				
"Old" well	3.7	4.0	0.12	0.5
"New" well	3.3	5.0	----	0.0
(Both wells located within several hundred feet of the mill well)				

The Edgemont water supply was sampled in 1966 by Messrs. Hickey and Campbell(2) in their effort to identify population groups consuming water with a relatively high radium content (more than 3.0 pCi/l). Their reported finding for a single grab sample was 5.33 pCi/l which is consistent with the 1971 results. Assuming an intake of 1.0 liter per day of drinking water, radium-226 intake by Edgemont residents served by the municipal supply is on the order of 5 pCi per day from this source. This falls within Range II (2-20 pCi per day) of the Federal Radiation Council guidance(3) for radium-226 intake by the general public. For any level of intake within Range II, it is appropriate to undertake quantitative surveillance and routine control to ensure that the intake from all sources, not drinking water alone, does not exceed the upper limit - 20 pCi per day of radium-226. Although studies have not been conducted in Edgemont to determine the average daily intakes from other sources (air, foodstuffs, beverages, etc.), it is unlikely that these sources together with the drinking water supply produce a total daily intake in excess of 20 pCi. Despite the fact that the average dose received by Edgemont residents is apparently below the recommended limit, dose reduction through treatment of the water supply to remove radium-226 is desirable. Reduction in the radium concentration to near surface water concentrations should be achievable by centralized municipal water softening or "home" water softeners.

Seepage

Dissolved radioactivity results for seepage samples are summarized in Table VII. Based on the uranium content of groundwater samples (less than 10 ug/l), the high uranium concentrations in seepage samples collected in the vicinity of the pipeline suspension bridge indicated the mill ponds are the major source of seepage entering Cottonwood Creek. Similarly, the uranium concentration in direct seepage to the Cheyenne River just below the confluence with Cottonwood Creek indicated the source of this seepage is also the mill ponds. Although the sample collected from the seepage zone just upstream of Pond No. 1 was not analyzed for uranium, the source of this seepage was identified to be Pond No. 1 during the 1966 field study (1966 - 89 ug/l of uranium).

The concentrations of radium-226 and uranium in seepage collected at the base of the river bank adjacent to the Pond No. 2 sand tailings storage area are consistent with the premise that the source is the movement of drainage from the abandoned railroad well through the sand tailings. At the time of the field study, this drainage had formed a small pool at the south end of the storage area.

A comparison of the dissolved radioactivity in the ponded liquors and seepage samples shows substantial reductions in radionuclide concentrations as the solutions move through the soil to the surface waters (Tables VII and VIII). This is well illustrated by the results for Pond No. 3 and the seepage samples collected at the base of the east wall of the pond (wall thickness less than 50 feet). There was about a 100-fold difference in the dissolved radium-226 concentrations and only

TABLE VII

DISSOLVED RADIOACTIVITY IN SEEPAGE SAMPLES

Description	Dissolved Radioactivity			
	Radium-226 (pCi/l)	Uranium (ug/l)	Total Alpha Thorium (pCi/l)	Thorium-natural (ug/l)
Cottonwood Creek (along east bank);				
(a) Several hundred yards upstream of the pipeline suspension bridge (approximately 6 feet above the water surface) - two samples	0.18	332	0.31	0.8
	1.1	816	----	0.0
(b) 50-100 feet upstream of the pipeline suspension bridge (at the bank - stream bed interface)	0.54	---	----	---
Cheyenne River (south bank):				
(a) At base of bank adjacent to Pond No. 2; just downstream of State Highway 18 Bridge	2.3	5	0.26	3.0
(b) Approximately 100 yards downstream of the confluence with Cottonwood Creek	0.35	176	17	50

TABLE VII

(Continued)

Description	Radium-226 (pCi/l)	Uranium (ug/l)	Total Alpha Thorium (pCi/l)	Thorium-natural (ug/l)
	Dissolved Radioactivity			
Cheyenne River (south bank): Continued				
(c) Just upstream of Pond Number 1 (approximately 2 feet above the water surface)	1.1	---	----	---
(d) Approximately 1 1/2 miles downstream of the mill (just above water surface)	2.1	26	0.19	0.0
On Site:				
Seepage from Pond No. 3 across road toward Edgemont sewage lagoon	0.68	2320	0.94	3.0

TABLE VIII

RADIOACTIVITY IN MILL PONDS

	Solids		Dissolved Radioactivity				Bottom Sediment (dry weight basis)			
Description	Suspended (ppm)	Dissolved (ppm)	Radium-226 (pCi/l)	Uranium (ug/l)	Total Alpha Thorium (pCi/l)	Thorium-Natural (ug/l)	Radium-226 (pCi/g)	Uranium (ug/g)	Total Alpha Thorium (pCi/g)	Thorium-natural (ug/g)
Influent to Pond No. 1	587	---	98	1860	1240	110	---	---	---	---
Pond No. 1	---	---	61	1860	1400	180	1007	19	11	---
Pond No. 2	554	52,360	93	8090	---	180	46	140	63	180
Pond No. 7	---	41,300	726	56,000	---	650	75	33	67	---

about a 4-fold difference in the dissolved uranium concentrations. The higher affinity for radium-226 to be retained in the soil is an expected finding.

Bottom Sediment and Soil

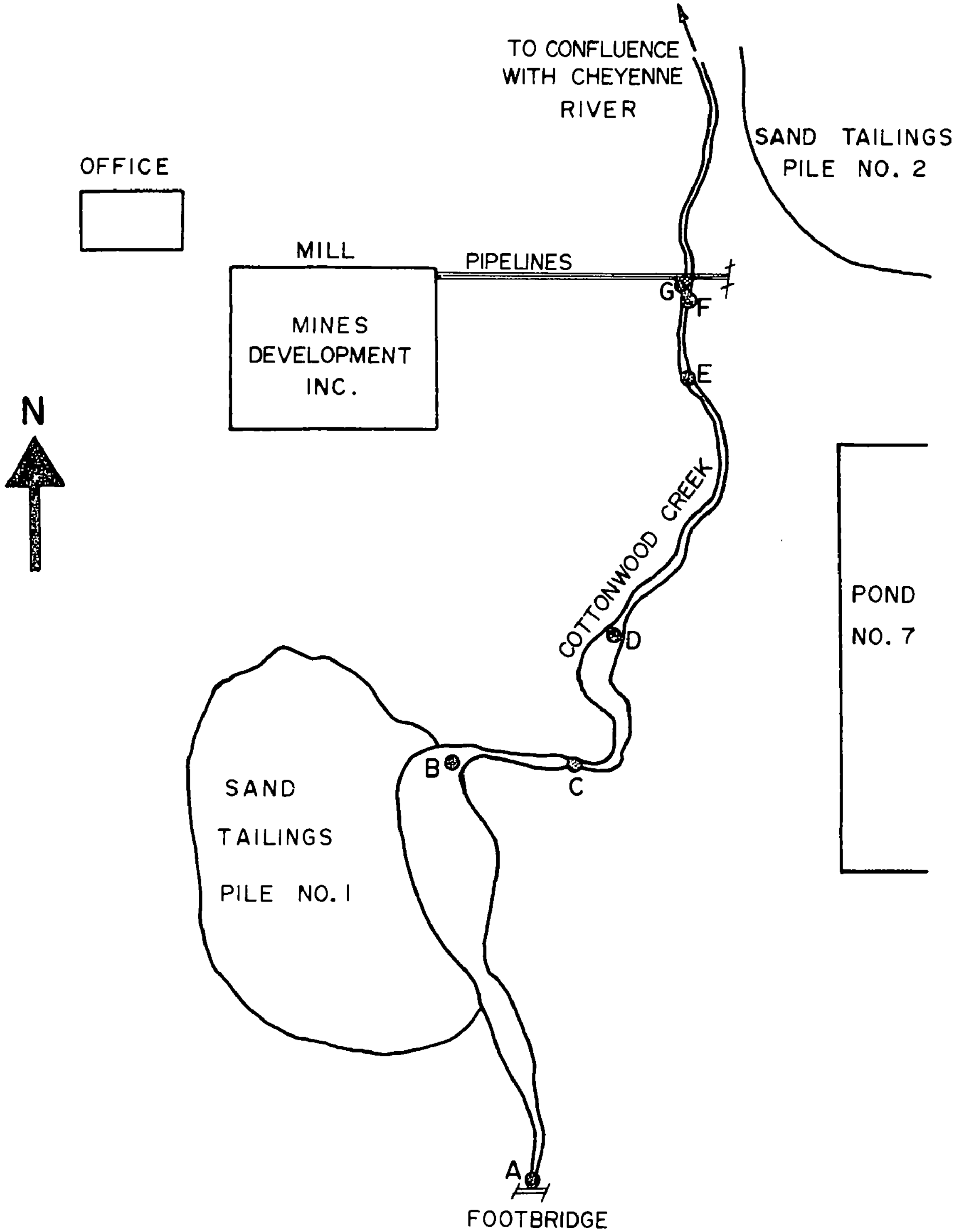
Radioactivity results for bottom sediments collected from Cottonwood Creek, the Cheyenne River, and Angostura Reservoir are presented in Table IX. These data showed the same contamination pattern as exhibited by the radioactivity results for water samples. Bottom sediment contamination in Cottonwood Creek occurred throughout the reach extending from the channel adjacent to sand tailings pile No. 1 downstream to the confluence with the Cheyenne River. Radium-226 and uranium concentrations in the contaminated reach of the creek ranged from 3 to 41 pCi/gram and 3.1 to 53 ug/gram, respectively. Comparatively, background levels range from 1.0 to 2.5 pCi/gram for radium-226 and 1.0 to 6.0 ug/gram for uranium. All sediment samples from the Cheyenne River and Angostura Reservoir showed background levels.

Contamination zones in Cottonwood Creek were not identical for radium-226 and uranium. Uranium contamination was largely confined to the lower portion of the creek; the seepage impacted stretch extending from a point just upstream of the pipeline crossing downstream to the mouth. Radium contamination included this stretch and the stretch extending upstream to the pool adjacent to sand tailings pile No. 1 (Figure III). This finding illustrated the difference between contamination attributable solely to the errosion of sand tailings piles versus the combined effect of radioactivity-bearing seepage and tailings pile errosion. Sand tailings material contains a high concentration of radium-226 (on the order of 200 pCi/gram), but is essentially depleted in uranium (>20 ug/gram). Thus, as shown by the results for Stations C, D, and E (Table IX; Figure III), the deposition of sand tailings from pile No. 1 in the creek has produced elevated radium-226 concentrations without a corresponding increase in the uranium content. The confinement of uranium contamination to the seepage-impacted stretch indicates that uranium entering the creek via the seepage flow undergoes mass transport from the dissolved to solid state by physical (adsorption/absorption) and/or chemical reactions (precipitation).

As was the case in previous studies, the sediment sample collected at the pedestrian bridge across Cottonwood Creek (Station A) contained radium-226 at a concentration slightly greater than the background level. The possible explanations are a natural source (spring flow) or periodic contamination of the site by windblown sand tailings from pile No. 1 (located several hundred feet downstream). Since the sediment was stained at this

FIGURE III

COTTONWOOD CREEK
BOTTOM SEDIMENT SAMPLING STATIONS



NOTE: DRAWING NOT TO SCALE

TABLE IX

RADIOACTIVITY CONTENT OF BOTTOM SEDIMENTS FROM COTTONWOOD CREEK
CHEYENNE RIVER AND ANGOSTURA RESERVOIR

Station	Radioactivity Content (dry weight basis) Radium-226 (pCi/g)	Uranium (ug/g)	Total Alpha Thorium (pCi/g)	Thorium-natural (ug/g)
Cottonwood Creek:(a)				
2 - Upstream of all waste sources	2.4	6.7	0.08	15
A - Pedestrian footbridge; Figure III	3.9	6.4	1.6	22
B - Ponded area; Figure III	24	8.2	8.4	15
C - Riffle area; Figure III	41	2.8	0.20	15
D - Ponded area; Figure III	11	3.1	3.3	6
E - Approximately 50 yards above the pipeline suspension bridge; Figure III	12	7.5	4.0	-
F - 50-100' upstream of the pipeline suspension bridge; Figure III	15	17	1.9	-
G - Pipeline suspension bridge; Figure III	40	53	---	-
3 -	19	13	0.38	15
4 -	4	28	0.29	16

TABLE IX

(Continued)

Station	Radioactivity Content (dry weight basis)			
	Radium-226 (pCi/g)	Uranium (ug/g)	Total Alpha Thorium (pCi/g)	Thorium-natural (ug/g)
Cheyenne River:				
1 - Upstream of all waste sources	1.0	2.4	0.08	9
H through M - Sampling locations spaced along the edge of the river channel; downstream edge of Pond No. 1 to approximately one mile downstream	1.0-2.6	1.5-4.4	0.8-1.5	-
5 -	1.0	3.1	0.08	16
6 -	2.5	3.1	0.11	18
7 -	1.0	---	0.09	10
8 -	0.90	---	0.11	12
9 -	1.6	---	0.43	17

TABLE IX

(Continued)

Station	Radium-226 (pCi/g)	Uranium (ug/g)	Total Alpha Thorium (pCi/g)	Thorium-natural (ug/g)
	Radioactivity Content (dry weight basis)			
Angostura Reservoir:[b]				
1 -	1.7	4.1	0.41	30
2 -	1.7	3.9	0.66	26
3 -	1.7	4.6	0.73	25
4 -	1.0	3.2	0.39	18
5 -	1.4	4.4	0.75	32
6 -	1.7	4.6	----	42
7 -	1.8	3.3	0.64	44
8 -	1.4	3.2	0.32	39
9 -	1.2	3.2	0.57	35
10 -	1.3	3.3	0.43	31
11 -	1.6	5.4	0.66	25
12 -	2.6	4.1	0.69	19
13 -	1.5	3.6	0.84	--

(a) Refer to Figure III
(b) Refer to Figure II

location (reddish-brown to reddish-orange discoloration), the former cannot be discounted as a contributing factor. However, as discussed in the following section of this report, a soil sample collected across the creek from pile No. 1 (to the east) showed a high level of contamination. This finding indicated that wind transport of sand tailings may well be the major source of the elevated radium-226 concentrations at Station A.

Sediment samples from the Cheyenne River contained radium-226 and uranium within the background ranges of 1.0 to 2.6 pCi/gram and 1.5 to 4.4 ug/gram, respectively. This included the special set of six samples collected along the channel edge from the downstream corner of Pond No. 1 to a point approximately one mile downstream (Stations H through M - Table IX). Since this stretch of river was characterized by sediment staining attributable to seepage from Pond No. 1, it had been anticipated that the radium and uranium concentrations of these samples would be slightly higher than the observed background levels. Angostura sediment samples contained radium-226 and uranium in concentrations comparable to those in the Cheyenne River.

The field study eliminated any question regarding the transport of sand tailings from pile No. 1 into Cottonwood Creek by errosive action during periods of high runoff and/or wind action. Such transport was documented by the analysis of bottom sediment samples as well as visual observation of the common boundary between the creek and the tailings pile for a distance of several hundred feet. One small section of this common boundary is shown in Figure IV (photograph taken on October 3, 1972-low flow condition). Similar documentation was obtained for the loss of sand tailings from the Pond No. 2 storage area. Soil samples collected at thirteen locations on the Cheyenne River bank and the dry stream bed adjacent to Pond No. 2 (Figure V) showed that sand tailings had breached the security fence and were beginning to migrate down the slope. Radium-226 concentrations in samples collected just outside the fence - Stations S1, S2, S3, and S4 - were indicative of sample compositions approaching 25 to 50% sand tailings (Table X). Along the line marking the sharp increase in bank slope - Stations S5, S6, S7, S8, and S9 - background concentrations of radium-226 were found. These data suggested that a loss of solids to the river had and continues to take place, but the magnitude of the loss has not been large. Slightly elevated radium-226 concentrations in the dry stream bed - Stations S11 and S12 - were probably caused by seepage as opposed to sand tailings.

Sand tailings have sloughed from pile No. 2 onto the flood plain of Cottonwood Creek. This was evidenced by the mounds of "white" sand on the bench between the tailings pile and the creek channel. A grab sample from one of the mounds showed the presence of "pure" sand tailings - 162 pCi of radium-226 per gram. During periods of high flow, this is undoubtedly a source of contamination to the Cheyenne River system.

FIGURE IV

SAND TAILINGS PILE NO. 1 ALONG
STRETCH OF COTTONWOOD CREEK
OCTOBER 1972

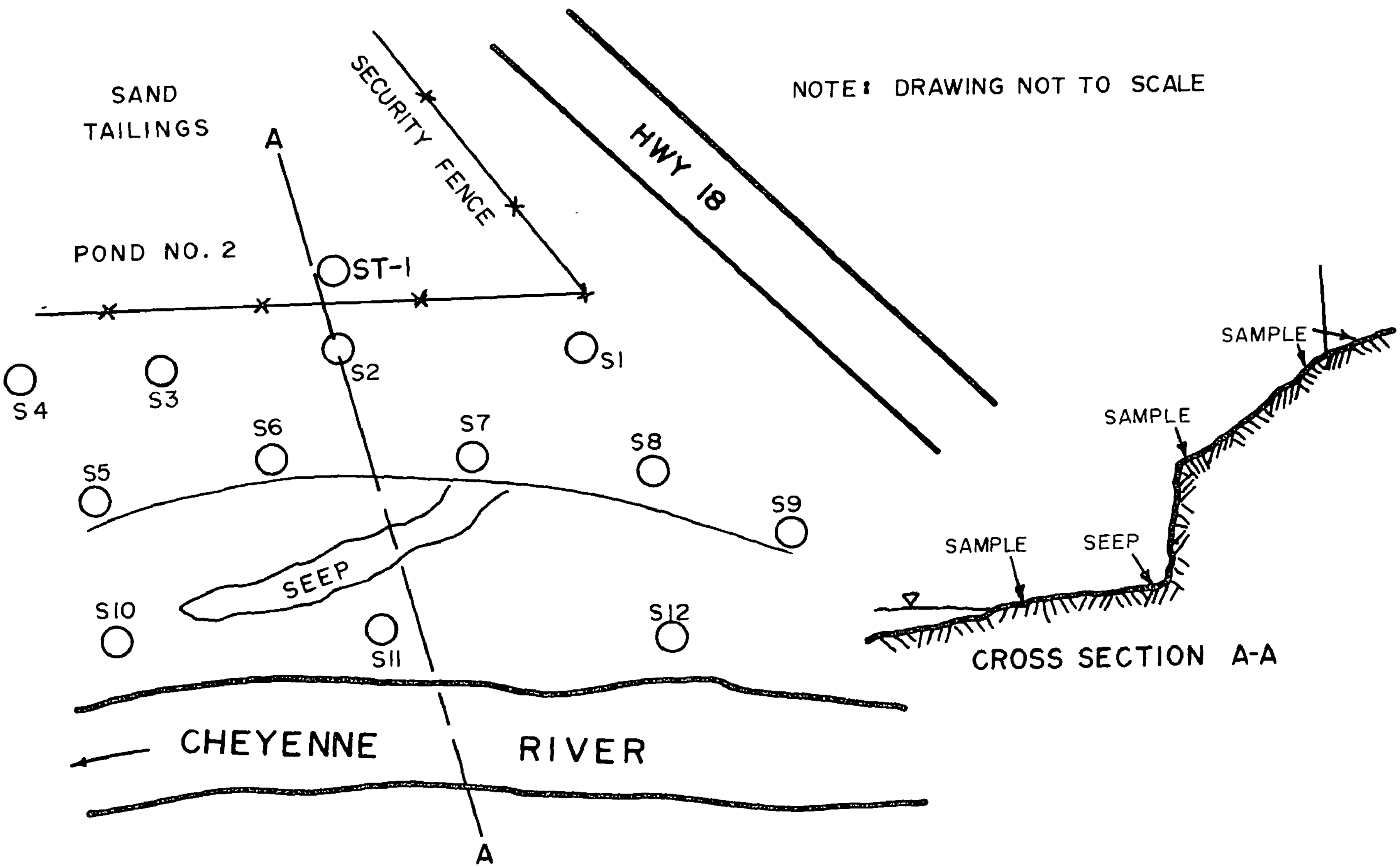


FIGURE V

SOIL SAMPLES COLLECTED FROM THE BANK
IN THE VICINITY OF POND NO. 2

TABLE X

RADIOACTIVITY CONTENT OF SOIL SAMPLES COLLECTED FROM THE CHEYENNE RIVER BANK ADJACENT TO THE POND NO. 2 STORAGE AREA

Station[a]	Radioactivity Content (dry weight basis) Radium-226 (pCi/g)	Uranium (ug/g)	Total Alpha Thorium (pCi/g)
ST-1	43	14	4.7
S1	96	16	6.4
S2	46	5.4	5.5
S3	56	23	12
S4	54	19	8.2
S5	1.8	3.3	1.0
S6	2.0	3.3	0.4
S7	1.9	3.2	2.6
S8	2.1	4.3	0.9
S9	1.3	4.5	0.5
S10	---	---	---
S11	5.4	0.6	2.5
S12	5.3	4.1	0.7

(a) Refer to Figure V

Fish - Angostura Reservoir

Consistent with the background radioactivity levels in the water and bottom sediments of Angostura Reservoir, the analysis of fish samples showed extremely low concentrations of radium-226 and uranium in bone and edible tissue (flesh). Summarized in Table IX, all radium-226 results were less than 0.1 pCi per gram (dry weight) and all but one uranium result were less than 0.1 ug per gram. These data are identical with the results for fish collected from the reservoir during the September 1966 study.[1]

TABLE XI

RADIUM-226 AND URANIUM IN ANGOSTURA RESERVOIR FISH
AUGUST 1971

Species	Number of Fish	Length (Inches)	Radium-226 (pCi/g)	Uranium (ug/g)	Radium-226 (pCi/g)	Uranium (ug/g)
Carp	1	--	<0.1	<0.1	<0.1	<0.1
Channel Catfish	1	--	<0.1	<0.1	<0.1	<0.1
	3	--	<0.1	<0.1	<0.1	<0.1
Crappie	7	<10	<0.1	<0.1	<0.1	<0.1
Perch	4	--	<0.1	<0.1	<0.1	<0.1
Walleye	1	15	<0.1	0.6	<0.1	<0.1
	1	16	<0.1	<0.1	<0.1	<0.1
	1	20	<0.1	<0.1	<0.1	<0.1
	1	21	<0.1	<0.1	<0.1	<0.1

(a) Results refer to live weight

PROGRESS TOWARD POLLUTION ABATEMENT

Environmental Protection Agency personnel visited the mill on October 3, 1972, to discuss the efforts undertaken by Mines Development, Inc., to abate radiological pollution from the milling operation. The Company's overall program generally follows the points expressed by Mr. K. L. Hudson, District Manager, in his statement prepared for the Enforcement Conference record.(4) Specific actions taken in the period of about one year following the Conference are described below together with an assessment of the probability of success in resolving the existing problems.

Liquid Waste Management

The operational changes instituted to eliminate seepage from mill ponds involve the operation of ponds at reduced static heads, i.e., smaller holding volumes than was the practice prior to 1972 and a long-term program of new pond construction. Mines Development, Inc., personnel view the seepage problem as one caused by the deterioration of the ponds with age complicated by excessive fluid pressure on embankments. Therefore, by operating the ponds with lower embankment pressures and systematically abandoning "old" ponds, it is believed that the seepage problem can be eliminated.

Several changes in the pond system have been made since October, 1971, consistent with the above analysis of the problem. Pond No. 10 (75 million gallon capacity) was constructed and became operational in February, 1972, replacing Pond No. 1 for vanadium raffinate storage. The reason for the abandonment of Pond No. 1 was to eliminate one source of direct seepage to the Cheyenne River. Although the stored raffinate was being pumped out of the pond at the time of the mill visit, the liquid level indicated that Pond No. 1 had been in a static state for the bulk of the year; consequently, a continued source of seepage. Pond No. 3 has been drained and the deposited slimes are being mined for vanadium recovery. Based on Mr. Hudson's statement to the Enforcement Conference,(4) this pond will also be abandoned at the completion of this mining activity. The two other significant changes involve Ponds No.'s 8 and 9 (formerly No. 10). These ponds were converted from a contingency status to active process ponds. Table XII summarizes the operational functions of the various ponds as of October, 1972, and the changes in the pond system since the 1971 field study.

Through October, 1972, significant improvement in the seepage problem was not evident. There was limited visual evidence to indicate that some reduction in the seepage flow to Cottonwood Creek had occurred since the high bank to the west and north of Pond No. 7 was dry in appearance. In 1971, this same area was observed as moist (and "dripping") to a height over six feet above the water surface. However, damp sections on the creek bank just upstream of sand tailings pile No. 2 indicated that the seepage

TABLE XII

MILL PROCESS AND RETENTION PONDS

Pond	Pond Use: October 1972	Pond Use: 1971
No. 1	Scheduled for abandonment; liquor is being pumped to No. 10.	Disposal of raffinate from the vanadium extraction circuit.
No. 2	Sand tailings storage.	Sand tailings storage.
No. 3	No liquid storage; deposited slime tailings are being mined for vanadium recovery.	Storage basin for vanadium-bearing liquor (blue liquor).
No. 4	"Polishing" sedimentation basin for vanadium-bearing liquor.	Not in use.
No. 7	Retention and storage of uranium sand tailings; water recycled for use as process water and repulping sand tailings for pumping to this pond.	Retention and storage of slime tailings and sand tailings; sedimentation basin to produce clarified blue liquor.
No. 8	Retention and storage of uranium slime tailings and flyash and slag residues from the vanadium circuit; sedimentation basin to produce clarified blue liquor.	Contingency.

TABLE XII

(Continued)

Pond	Pond Use	
	October 1972	1971
No. 9* (formerly No. 10)	Surge pond to receive and store liquor from No. 8.	Contingency.
No. 10	Disposal of vanadium raffinate.	(Constructed in 1972).

*The small pond designated Number 9 in 1971 has been abandoned.

flow had not been totally stopped. A comparative type observation of the previously observed areas of heavy bank seepage (1966 and 1971) in the vicinity of the pipeline crossing was not possible because these areas were inundated by downstream beaver dam construction. The lack of improvement indicated by the visual observations is substantiated by the water quality monitoring data (discussed in the following section) which show no reduction in the radiological contamination of Cottonwood Creek during 1972.

It is likely that the apparent lack of improvement in this seepage problem is partially attributable to a yet unsteady-state condition following the changes in the pond system. However, despite the abandonment of Ponds No.'s 1 and 3, the majority of the old ponds remain in service, albiet at reduced storage volumes. The resultant effect can be expected to be a reduction in seepage, but not total abatement. Total abatement will require the new ponds to be properly constructed to prevent fluid loss by seepage.

Unless the rate of evaporation is sufficiently high, the continued operation of the mill will require that an increasing amount of land be committed to waste storage. To prevent an undesirable sprawl of waste retention ponds, the alternatives of trucking spent ore solids (as emerging from the mill process) back to the open-pit mine and a system of sealed basins with a completely treated effluent should be investigated. It is entirely possible that the costs of these alternatives may be more economically attractive than those associated with new pond construction and land restoration following the cessation of milling operations.

Uranium Sand Tailings

The progress made on controlling and stabilizing stockpiled sand tailings to prevent wind and water errosion and the development of an ultimate disposal plan is not satisfactory. It is a matter of the Conference record that the Company considers the proposed ultimate storage of sand tailings in the open-pit mine to be economically prohibitive.(4) Instead, the Company has proposed on-site stabilization with a vegetative cover.

The only action of a positive nature undertaken during 1972 was the establishment of two small test plots (each approximately one and one-half acres) to investigate possible stabilization procedures. A brief progress report concerning this study was submitted to the South Dakota Department of Health by Mr. G. A. Fluke, District Engineer, in a letter dated November 28, 1972 (Appendix A). Briefly, the test plots involved the following work:

1. Sand Tailings Pile No. 1 - Pretreatment of the sloping plot (to the southeast, varying from 5 to 20 percent) consisted of blading to smooth the area, addition of lime to neutralize the latent acidity of the sand tailings, and spreading of manure. This was followed by seeding with a blended mix of rye grass and red clover and the application of fifteen pounds of ammonium nitrate. Native fireweed seed was also "thrown" on the plot. <u>No</u> irrigation.

2. Pond Number 2 Area - Same procedure as that for the sand tailings pile No. 1 test plot except irrigation was provided. The plot was watered by a sprinkler system on an average of onee every three days throughout the growing season.

From the standpoint of vegetative growth, both test plots were failures. Figure VI shows the growth of the rye grass on the Pond No. 2 test plot. Figure VII shows a sparse growth of only fireweed and sunflowers on the pile No. 1 test plot. As expected without routine watering, there was no germination of grass seed on this plot. Despite the sparsity of growth, the mere fact that fireweed could grow on the "treated" sand tailings is viewed optimistically by plant personnel as indicating that fireweed may provide suitable vegetative cover if the growth period is sufficiently long. As observed by Mr. Hudson, the sparsity of rye and clover growth may have been attributable, at least in part, to the late planting date - late June. However, it seems more likely that the major causative factor was the lack of a good topsoil base and adequate irrigation.

Additional testing of fireweed growth is planned for 1973. The plan calls for leveling additional areas, adding fertilizer at a loading greater than that used for the 1972 test plots, pumping Cheyenne River water into the areas during the spring period of high sediment transport in order to build-up a topsoil base, and encouraging the subsequent growth of native fireweed. It is envisioned that after two to three years, the fireweed could be burned to obtain the mulch required for the establishment of natural grass. The drawbacks to this plan are several:

1. Pumping water onto the stock-piled sand tailings creates the risk of solids loss to the Cheyenne River via runoff. Extreme caution will have to be exercised.

2. Without any assurance of success that could be immediately achieved by the conventional procedure of covering with top-soil, seeding, and irrigating, the proposal increases by several years the period of time that the stock-piled sand tailings will be subjected to wind and water errosion.

3. There is no provision for removing sand tailings which have drifted to locations along the banks of Cottonwood Creek and through the security fence surrounding the Pond No. 2 storage area.

If on-site stabilization is to be practiced, it seems appropriate that the conventional procedure mentioned above be employed.

Of immediate urgency for positive control action is the stabilization and control of sand tailings stock-piled in the Pond No. 2 storage area.

FIGURE VI

POND NO. 2 SAND TAILINGS
STORAGE AREA STABILIZATION TEST PLOT
OCTOBER 1972

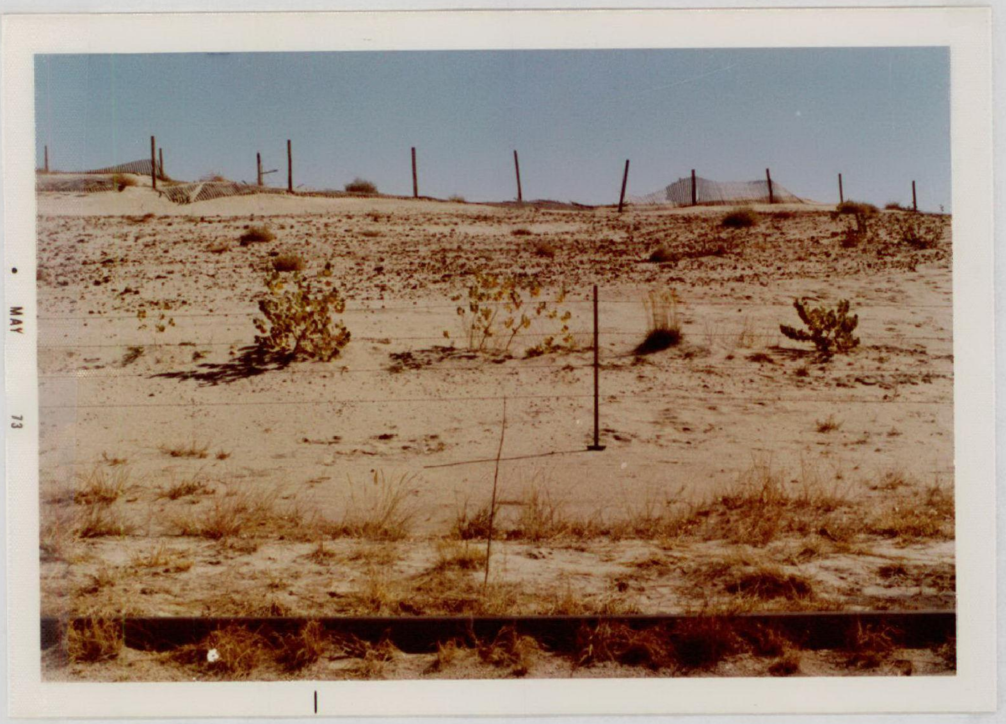


FIGURE VII

SAND TAILINGS PILE NO. 1
STABILIZATION TEST PLOT
OCTOBER 1972

Not only have the sand tailings drifted through the security fence to within a few feet of State Highway 18 (Figure VIII) and onto the river bank, but tailings now form a common boundary with the Martinez family property (Figure IX). The Martinez property immediately adjacent to the tailings storage area is used for a pig pen, chicken coop, and yard for a milk cow. (Small pigs were observed running on the tailings.) A soil sample collected in the chicken area just inside the fence - judged to be predominately sand tailings by visual observation - contained 34 pCi of radium-226 per gram; nearly twenty times natural background. More importantly, significant contamination was found in the soil sample collected in the play yard. The radium-226 content of this sample was 9.2 pCi/gram, or approximately five times the background level. Accordingly, the following control actions are recommended:

1. Sand tailings which have drifted through the security fence should be collected and stored at a suitable disposal site. Additionally, a tailings-free barrier (excess of 10 feet) should be created between the pile and the fence.

2. The pile should be contoured, covered with topsoil (an alternative to trucking the material to the open-pit), and seeded with rye grass or some other suitable grass or grain. Irrigation must be practiced.

3. A new fence should be installed which effectively prevents access to the stabilized pile.

In view of the nearness of the Martinez house, reworking the sand tailings will probably require working with "damp" material in order to prevent dust and subsequent wind transport.

Some insight to the environmental degradation which has occurred as the result of sand tailings storage in Pond No. 2 can be gained from Figure X which shows largely the same area as Figure VIII. The difference is that the photograph shown in Figure X was taken in September 1966 just after the start of sand tailings input to Pond No. 2.

To check on the possibility of wind-drift of sand tailings across the small residential area lying to the east of pile No. 1, a composite soil sample was collected from the sloping terrace area adjacent to a mobile home - across the creek channel. The area over which the sample was composited was used for children's play and received vehicular traffic. Although contamination was expected, the actual high level was surprising - 45 pCi of radium-226 per gram. This finding approached the concentrations found just outside the Pond No. 2 area fence. Admittedly, the sampling was biased toward emphasizing the presence of sand tailings by the collection of loose and/or sandy-type material. Nonetheless, the finding of contamination

FIGURE VIII

VIEW FROM STATE HIGHWAY 18 ACROSS POND
NO. 2 SAND TAILINGS STORAGE AREA
OCTOBER 1972

FIGURE IX

VIEW OF MARTINEZ PROPERTY SHOWING ENCROACHMENT
OF SAND TAILINGS FROM POND NO. 2 AREA
STATE HIGHWAY 18 IN IMMEDIATE BACKGROUND -
IDENTIFIED BY YELLOW ROAD SIGN AND BRIDGE
OCTOBER 1972

FIGURE X

VIEW FROM STATE HIGHWAY 18
ACROSS POND NO. 2
SEPTEMBER 1966

in this residential area further substantiated the existence of off-site land contamination and the need to take control actions. To eliminate any concern of the possibility of localized "hot spots," it is recommended that a soil sampling and analysis program be undertaken to delineate zones of contamination and the levels of radium-226 contamination therein. If areas of undesirably high concentration are found, a corrective action program will be required to remove the contaminated soil.

WATER QUALITY MONITORING PROGRAM

As directed by the Conferees, a water quality monitoring program was initiated in the Edgemont, South Dakota, area during May, 1972. The monitoring program consists of a network of four stations sampled for the purpose of determining the annual average concentrations (dissolved) and variations therefrom of radium-226, uranium, and selected heavy metals. Sampling locations are the following:

1. Cheyenne River at State Highway 18 bridge; upstream of Mines Development, Inc., mill.

2. Cottonwood Creek at County Road Bridge; east of State Highway 52; upstream of Mines Development, Inc., mill.

3. Cottonwood Creek downstream of road culvert on mill property.

4. Cheyenne River at Red Canyon; approximately two miles below the confluence with Cottonwood Creek.

Samples are collected by a local Edgemont resident under contract to the Environmental Protection Agency with shipment to the Region VIII laboratory for analysis. Samples for radiological analysis are shipped without pretreatment or filtration; "metals" samples are filtered shortly after collection and acidified. During January, 1973, the collection frequency was reduced from the initial weekly rate to bi-weekly.

Monitoring results for the period of May through September, 1972, are presented in Tables XIII - XVI. These data yielded the below findings:

Cheyenne River

1. With the exception of dissolved iron, there was no detectable impact on Cheyenne River water quality as the result of seepage from mill ponds - to Cottonwood Creek or directly to the river. As shown in Tables XIII and XIV, the five-month average concentration for each parameter, excluding iron, were equivalent at the two stations bracketing the mill. The dissolved iron concentration showed approximately a two-fold increase at the downstream station (Red Canyon). However, additional monitoring data will be required to verify this finding since the accuracy of the dissolved iron results was not high. This was attributable to the precipitation of iron and subsequent coating of the sample container walls in the time interval between sample collection and analysis.

TABLE XIII

EDGEMONT MONITORING PROGRAM

CHEYENNE RIVER AT STATE HIGHWAY 18 BRIDGE
UPSTREAM OF MINES DEVELOPMENT, INC., URANIUM MILL

		Suspended Portion		Dissolved Portion									
Collection Date	Flow (cfs)	Radium-226 (pCi/g)	Uranium (ug/g)	Gross Alpha (pCi/l)	Gross Beta (pCi/l)	Radium-226 (pCi/l)	Uranium (ug/l)	Arsenic (ug/l)	Iron (ug/l)	Lead (ug/l)	Manganese (ug/l)	Vanadium (ug/l)	Zinc (ug/l)
5/11/72	22	---	---	---	---	---	---	<10	---	---	---	---	---
5/16/72	36	---	---	---	---	---	---	<10	100	100	30	1	58
5/24/72	125	2.3	1.0	<1	8	0.3	20	<10	60	98	60	8	22
5/31/72	8.7	3.4	---	<1	8	<0.1	16	---	40	105	60	5	21
6/6/72	27	2.2	---	<1	6	<0.1	17	<10	40	112	80	2	20
6/13/72	18	1.6	0.4	<1	<1	0.1	14	---	3300	85	120	---	82
6/20/72	171	1.5	0.7	<1	17	0.2	10	---	3700	60	70	20	54
6/29/72	267	---	2.0	<1	<1.5	0.1	4	<10	470	60	320	23	50
7/7/72	33	3.5	---	25	<20	0.2	12	---	1900	87	260	100	105
7/15/72	4.7	---	---	<3	<20	0.3	16	---	310	67	170	2	49
7/24/72	3.6	---	---	<2	54	1.8	15	---	90	70	100	7	54
7/31/72	5.9	---	---	<2	<20	0.3	20	---	60	80	40	5	21

TABLE XIII

EDGEMONT MONITORING PROGRAM

CHEYFNNE RIVER AT STATE HIGHWAY 18 BRIDGE UPSTREAM OF MINES DEVELOPMENT, INC., URANIUM MILL

		Suspended Portion		Dissolved Portion									
Collection Date	Flow (cfs)	Radium-226 (pCi/g)	Uranium (ug/g)	Gross Alpha (pCi/l)	Gross Beta (pCi/l)	Radium-226 (pCi/l)	Uranium (ug/l)	Arsenic (ug/l)	Iron (ug/l)	Lead (ug/l)	Manganese (ug/l)	Vanadium (ug/l)	Zinc (ug/l)
8/7/72	64	2.2	1.8	<2	<20	0.2	5	---	---	---	---	---	---
8/14/72	2.9	22	---	<2	<20	0.4	16	----	420	60	60	7	56
9/2/72	8.1	---	---	8	<20	0.2	12	---	150	60	60	7	40
9/9/72	16	1.4	1.2	3	<20	<0.1	9	---	---	---	---	---	---
9/14/72	4.0	1.5	---	<2	25	0.7	19	---	150	60	80	4	54
9/23/72	4.0	2.3	---	<2	<20	0.3	19	---	70	70	60	4	30
5-Month Average	---	---	---	---	---	0.3	14	---	740	78	105	14	48

TABLE XIV

EDGEMONT MONITORING PROGRAM

COTTONWOOD CREEK UPSTREAM OF MINES DEVELOPMENT, INC., URANIUM MILL
AT COUNTY ROAD BRIDGE; JUST EAST OF STATE HIGHWAY 52

	Suspended Portion		Dissolved Portion									
Collection Date	Radium-226 (pCi/g)	Uranium (ug/g)	Gross Alpha (pCi/l)	Gross Beta (pCi/l)	Radium-226 (pCi/l)	Uranium (ug/l)	Arsenic (ug/l)	Iron (ug/l)	Lead (ug/l)	Mananese (ug/l)	Vanadium (ug/l)	Zinc (ug/l)
5/11/72	---	---	---	---	---	---	<10	---	---	---	---	---
5/16/72	---	---	---	---	---	---	<10	60	94	110	2	30
5/24/72	11	---	<1	15	0.2	16	<10	270	112	30	2	30
5/31/72	---	---	<1	7	0.2	23	---	60	152	60	2	30
6/6/72	---	---	<1	<3	0.1	34	<10	60	124	80	1	22
6/13/72	---	---	<1	7	0.4	21	---	60	130	40	---	64
6/20/72	---	---	<1	11	0.1	16	---	80	40	60	2	50
6/29/72	---	---	<1	10	0.1	27	<10	180	105	80	8	50
7/7/72	1.4	---	<1	<20	0.1	19	---	110	107	120	3	60
7/15/72	---	---	<2	<20	<0.1	25	---	340	87	420	3	65
7/24/72	---	---	<2	<20	0.7	32	---	160	80	80	5	112
7/31/72	---	---	<2	<20	0.1	57	---	260	100	160	8	59

TABLE XIV

EDGEMONT MONITORING PROGRAM

COTTONWOOD CREEK UPSTREAM OF MINES DEVELOPMENT, INC., URANIUM MILL
AT COUNTY ROAD BRIDGE; JUST EAST OF STATE HIGHWAY 52

	Suspended Portion		Dissolved Portion									
Collection Date	Radium-226 (pCi/g)	Uranium (ug/g)	Gross Alpha (pCi/l)	Gross Beta (pCi/l)	Radium-226 (pCi/l)	Uranium (ug/l)	Arsenic (ug/l)	Iron (ug/l)	Lead (ug/l)	Manganese (ug/l)	Vanadium (ug/l)	Zinc (ug/l)
8/7/72	0.1	---	<2	<20	<0.1	49	---	860	90	60	9	104
8/14/72	---	---	3	22	0.2	54	---	---	---	---	---	---
9/2/72	1.8	---	8	21	0.1	41	---	160	70	60	86	68
9/9/72	9.7	---	<2	<20	0.3	28	---	380	110	80	7	93
9/14/72	10	---	<2	<20	0.4	33	---	190	90	60	16	86
9/23/72	9.3	---	<2	<20	0.4	32	---	110	100	40	8	48
5-Month Average	---	---	---	---	0.2	32	---	213	99	96	11	61

TABLE XV

EDGEMONT MONITORING PROGRAM

COTTONWOOD CREEK DOWNSTREAM OF SEEPAGE
FROM MINES DEVELOPMENT, INC., URANIUM MILL

	Suspended Portion		Dissolved Portion									
Collection Date	Radium-226 (pCi/g)	Uranium (ug/g)	Gross Alpha (pCi/l)	Gross Beta (pCi/l)	Radium-226 (pCi/l)	Uranium (ug/l)	Arsenic (ug/l)	Iron (ug/l)	Lead (ug/l)	Manganese (ug/l)	Vanadium (ug/l)	Zinc (ug/l)
5/11/72	---	---	---	---	---	---	<10	---	---	---	---	---
5/16/72	---	---	---	---	---	---	<10	470	100	240	54	27
5/24/72	35	---	4	20	0.8	157	<10	110	80	340	56	10
5/31/72	---	---	2	11	0.4	82	---	30	120	130	470	31
6/6/72	---	---	2	26	0.3	203	<10	30	124	670	59	27
6/13/72	---	---	6	18	1.6	230	---	3600	110	430	---	35
6/20/72	---	---	8	27	1.8	270	---	1200	20	1110	2200	58
6/29/72	---	---	19	10	1.1	233	<10	2480	132	90	120	36
7/7/72	144	---	16	45	6.5	194	---	3600	117	1250	590	354
7/15/72	32	---	15	38	8.7	134	---	32000	27	15600	---	295
7/24/72	160	---	30	68	5.7	456	---	980	80	4880	47	126
7/31/72	54	---	12	37	10	331	---	6960	100	4180	102	108

TABLE XV

EDGEMONT MONITORING PROGRAM

COTTONWOOD CREEK DOWNSTREAM OF SEEPAGE FROM MINES DEVELOPMENT, INC., URANIUM MILL

Collection Date	Suspended Portion Radium-226 (pCi/g)	Suspended Portion Uranium (ug/g)	Dissolved Portion Gross Alpha (pCi/l)	Gross Beta (pCi/l)	Radium-226 (pCi/l)	Uranium (ug/l)	Arsenic (ug/l)	Iron (ug/l)	Lead (ug/l)	Manganese (ug/l)	Vanadium (ug/l)	Zinc (ug/l)
8/7/72	8.1	66	<4	<20	5.1	444	---	1860	120	2360	200	89
8/14/72	8.9	25	13	<20	9.8	500	---	1620	100	1820	180	96
9/2/72	54	---	33	41	1.9	400	---	1880	70	1840	7	148
9/9/72	55	---	8	21	5.5	300	---	1160	80	1160	122	73
9/14/72	76	46	8	21	4.3	245	---	300	90	1080	78	75
9/23/72	61	20	5	<20	8.8	300	---	860	110	900	122	77
5-Month Average	---	---	---	---	4.5	280	---	3480	93	2240	290	98

TABLE XVI

EDGEMONT MONITORING PROGRAM

CHEYENNE RIVER AT RED CANYON
APPROXIMATELY TWO MILES DOWNSTREAM THE CONFLUENCE WITH COTTONWOOD CREEK

	Suspended Portion		Dissolved Portion									
Collection Date	Radium-226 (pCi/g)	Uranium (ug/g)	Gross Alpha (pCi/l)	Gross Beta (pCi/l)	Radium-226 (pCi/l)	Uranium (ug/l)	Arsenic (ug/l)	Iron (ug/l)	Lead (ug/l)	Manganese (ug/l)	Vanadium (ug/l)	Zinc (ug/l)
5/11/72	---	---	---	---	---	---	<10	---	---	---	---	---
5/16/72	1.7	---	<1	10	0.2	14	<10	380	98	40	3	22
5/24/72	2.5	1.0	<1	17	0.4	23	<10	50	98	20	4	30
5/31/72	1.5	---	<1	7	0.1	21	---	30	94	60	2	12
6/6/72	2.9	---	1	8	0.2	14	<10	30	120	90	1	15
6/13/72	1.9	1.1	<1	10	0.3	10	---	9000	80	220	---	82
6/20/72	1.0	0.5	1	9	0.1	8	---	5100	50	90	8	70
6/29/72	---	0.6	<1	11	0.1	4	<10	545	53	190	8	54
7/7/72	14	---	---	---	0.6	---	----	2450	98	100	23	170
7/15/72	1.5	----	4	<20	0.3	15	---	140	80	50	1	40
7/24/72	15	---	<2	<20	0.3	20	---	60	80	60	6	54
7/31/72	---	---	<2	<20	0.3	19	---	20	80	40	5	16

TABLE XVI

EDGEMONT MONITORING PROGRAM

CHEYENNE RIVER AT RED CANYON
APPROXIMATELY TWO MILES DOWNSTREAM THE CONFLUENCE WITH COTTONWOOD CREEK

	Suspended Portion		Dissolved Portion									
Collection Date	Radium-226 (pCi/g)	Uranium (ug/g)	Gross Alpha (pCi/l)	Gross Beta (pCi/l)	Radium-226 (pCi/l)	Uranium (ug/l)	Arsenic (ug/l)	Iron (ug/l)	Lead (ug/l)	Manganese (ug/l)	Vanadium (ug/l)	Zinc (ug/l)
8/7/72	1.9	1.3	<2	<20	0.2	5	---	---	---	---	---	---
8/14/72	6.9	2.7	<2	<20	0.3	16	---	640	70	60	9	57
9/2/72	---	---	<2	<20	0.3	15	---	20	60	20	2	12
9/9/72	1.0	1.3	<2	<20	0.3	10	---	---	---	---	---	---
9/14/72	2.1	---	<2	<20	0.3	16	---	70	70	80	5	61
9/23/72	---	---	<2	<20	0.4	14	---	110	50	60	4	11
5-Month Average	---	---	---	---	0.3	14	---	1240	79	79	6	47

2. Dissolved radium-226 concentrations were low and within the range of 0.1 - 0.7 pCi/l; excluding the one anomolous result of 1.8 pCi/l at the State Highway 18 bridge (7/24). Similarly, low levels of dissolved uranium were observed with concentrations in the range of 5 to 20 μg/l. For both radionuclides, concentrations were independent of river flow and remained relatively constant throughout the five-month data period.

3. Concentration ranges for heavy metals were:

Arsenic	<10 μg/l
Lead	50 - 120 μg/l
Manganese	20 - 320 μg/l
Vanadium	1 - 100 μg/l
Zinc	12 - 170 μg/l

Cottonwood Creek

1. With the exception of dissolved uranium, water quality at the county road bridge was similar to upstream Cheyenne River water quality. Dissolved radium-226 results (Table XIV) showed a maximum of 0.7 pCi/l, and a 5-month average of 0.2 pCi/l. This average is the same as those calculated for the Cheyenne River stations. In contrast, dissolved uranium - on an average value basis - occurred at a concentration slightly greater than twice that found in the Cheyenne River - 32 ug/l versul 14 ug/l. Furthermore, the dissolved uranium data did not exhibit relative constancy over the 5-month period. Instead, the data showed a rise to a maximum in late-July and August, and subsequently declining values.

2. Attributable to seepage from mill ponds, average concentrations of dissolved uranium and radium-226 at the station downstream of the road culvert (Table XV) were substantially greater than background levels (10 and 20 times greater, respectively). For the 5-month data period, dissolved radium-226 showed a range of 0.4 to 10 pCi/l; dissolved uranium a range of 82 to 500 ug/l. The rise in concentrations during the monitoring period were undoubtedly caused by decreasing creek flow; hence, decreasing dilution of seepage flowing into the creek. The data do not support any claim to the effect that radioactivity levels upstream of the mill do, on occasion, exceed the corresponding levels downstream of the zones of active seepage.

3. Seepage also produced significant increases in the concentrations of dissolved iron, manganese, and vanadium (Table XV). Based on 5-month average values, the increases were on the order of 15, 20, and 30 times greater than naturally-occurring levels for iron, manganese, and vanadium, respectively. It is interesting to note

that despite the large increase in the dissolved iron concentration and the extensive precipitation that occurs in Cottonwood Creek, the maximum concentrations of dissolved iron were found in the Cheyenne River.

4. Seepage did not impact the concentration of arsenic, lead, and zinc. Consequently, analysis of these metals has been terminated.

Based on comparisons with the results of previous studies, no significant improvement in the water quality of Cottonwood Creek occurred through September, 1972. Although sufficient data have not been accumulated to reach a final decision, it is an obvious possibility that the actions taken to date may not be adequate for achieving demonstrable improvement in water quality. The other possibility is that the data are representative of a transitional phase and some improvement will be observed during 1973. Therefore, the actions taken by Mines Development, Inc., to abate seepage - although suspect in terms of overall adequacy - remain an open question at this time.

REFERENCES

(1) U. S. Environmental Protection Agency, "Evaluation of the Impact of the Mines Development, Inc., Mill on Water Quality Conditions in the Cheyenne River," Region VIII, Denver, Colorado (September 1971).

(2) Hickey, J. L. S., and S. D. Campbell, "High Radium-226 Concentrations in Public Water Supplies," in Public Health Reports, 83, 7, pp. 551-557 (July 1968).

(3) Federal Radiation Council, "Background Material for the Development of Radiation Protection Standards," Staff Report Number 2 (September 1961).

(4) U. S. Environmental Protection Agency, "Transcript of Proceedings in the Matter of Pollution of the Navigable Waters of Western South Dakota," Held at Rapid City, South Dakota (October 19-21, 1971).

APPENDIX A

MINES DEVELOPMENT, INC.

EDGEMONT, SOUTH DAKOTA

C
O
P
Y

November 28, 1972

Dr. Robert H. Hays
State Health Officer
South Dakota Department of Health
Pierre, South Dakota 57501

Dear Sir:

A progress report on the stabilization tests for the sand tailings at Mines Development, Inc., follows:

A test plot of approximately one and one-half acres was established north of the mill complex. Based upon a soil analysis made by the Brookings Lab., pretreatment consisted of blading the area smooth (the plot has a general slope of about 6% to the southeast), addition of one-half ton of lime per acre in the form of ¼" down, crushed rock; spreading of eight to ten tons of manure per acre and discing. A blend of brome grass and red clover was seeded, followed by the application of fifteen pounds of ammonium nitrate. The seed bed was watered by an overhead sprinkler system on an average of once every three days throughout the growing season. No reliable estimate of the water used is available.

The results were the establishment of a grass stand on approximately fifteen percent of the seed bed. No clover appeared to have germinated in this environment. The grass that matured was generally located down slope from the sprinkler locations.

The alternate test plot located south of the mill complex was prepared in the same manner. The slope, again to the southeast, varied from 20 to 5 percent. Here the growth of native annuals and bushes was promoted by the nutrients added. The results indicate that two species known locally as Fireweed and Sunflowers will grow in this environment. Sources for the Fireweed seed have not been found and further seeding will have to come from a mulch prepared from cuttings. The weed has a tough stock that should resist sand erosion but the root system is not too extensive for holding purposes.

Additional areas will be leveled and substantially more fertilizer added during the next growing season. The addition of some soil builders by flooding test plots with silted water from the creek at high water will be done in the coming spring.

Very truly yours,

MINES DEVELOPMENT, INC.

G. A. Fluke
District Engineer

gaf:lh
cc: Mr. Irvin L. Dickstein, Director
EPA, Enforcement Division
Denver, Colorado