PRELIMINARY DRAFT

A STUDY OF THE COST IMPACT OF THE RESOURCE CONSERVATION AND RECOVERY ACT (RCRA) ON THE DISPOSAL OF NONHAZARDOUS WASTES FROM MINING

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A. <u>A STUDY OF THE COST IMPACT OF THE RESOURCE CONSERVATION AND RECOVERY ACT ON THE DISPOSAL OF NONHAZARDOUS WASTES FROM MINING</u>

The main objective of this study is to present estimated total capital and annual operating costs of mining solid waste disposal technologies that will satisfy the criteria prescribed in Section 4004 of the Resource Conservation and Recovery Act (RCRA). The study focuses on the following 10 mining industries: copper, iron ore, molybdenum, gold, lead, zinc, phosphate, clay, stone, and sand and gravel. These 10 industries contribute about 91 percent of all the nonhazardous mining solid wastes (excluding coal mining wastes), as shown in Table 1. This table also shows what portion of the wastes from an industry is considered nonhazardous. All mine wastes (overburden and waste rock) from these industries are considered nonhazardous, with the exception of about 30 percent of the phosphate overburden generated in Florida, which is considered hazardous. Only three of the industries--clay, sand and gravel, and gold (placer mines only) generate nonhazardous tailings (beneficiation wastes). Nonhazardous waste from all other domestic mining industries are shown in various tables in this study as from "other industries."

The costs are divided, for each criterion, into national baseline costs; national state- and other Federal-induced costs; and national RCRA (Criteria-induced) costs (Table 2). The baseline costs represent estimated costs of control methods already in use by the industry--tailings ponds, diversion ditches, closure practices--that satisfy or partially satisfy any of the six RCRA criteria. State-induced costs represent estimated costs of complying with state standards for the control of nonhazardous wastes; other Federal-induced costs represent those complying with Federal regulations other than RCRA. The Clean Water Act of 1977 covers surface waters and wetlands when an NPDES permit is denied; therefore, the costs of these controls are considered separate from the Criteria-induced costs. This report does not,

TABLE 1

ESTIMATED MINING INDUSTRY PRODUCTION AND NONHAZARDOUS WASTE QUANTITIES (1,000 metric tons)

Mining industry	No. of mines	Product	Nonhazardous wastes		
			Tailings	Mine wastes	Total
Copper	61	244,700		627,900	627,900
Iron ore	68	216,900		234,800	234,800
Molybdenum	3	55		10,740	10,740
Gold	99	0.021	108*	8,408	8,516
Lead/zinc	33/36	16,840		4,778	4,778
Phosphate	47	169,300		150,200§	150,200
Clay	1,249	39,770	2,275	33,760	36,035
Stone	5,584	815,400	Negligible	66,160	66,160
Sand and gravel	7,007	718,000	35,900	Negligible	35,900
Coal	6,459	573,300		¶	¶
Other		829,000	21,840†	97,730@	119,570
Total			60,123	1,234,476	1,294,599

*Represents tailings from gold placer mining. Other gold mining tailings are considered hazardous.

†Fifty percent of tailings from other mining industries are considered to be nonhazardous.

§Thirty percent of all phosphate mine waste in Florida is considered hazardous and thus is not included in this number.

¶SMCRA is responsible for coal mine wastes.

@All mine wastes from other mining industries are considered to be nonhazardous.

TABLE 2

ESTIMATED NATIONAL BASELINE AND REGULATORY COSTS FOR NONHAZARDOUS MINING WASTE CONTROLS
(1,000 dollars)

Costs	Ground water	Surface water	Wetlands: NPDES permit granted	Wetlands: NPDES permit denied	Floodplains	Closure	Total: NPDES permit granted	Total: NPDES permit denied
National baseline*								
Total capital	2,166	440,800				54,500	497,466	
Annual O&M	111	22,410				34,500	57,021	
Total annualized	411	98,530				49,500	148,441	
National state- and other Federal-induced*								
Total capital	295,900	110,500	30,300	250,100	208,300		645,000	864,800
Annual O&M	32,400	5,500	1,000	292,000	10,400		49,300	340,300
Total annualized	96,000	34,800	3,700	336,500	66,400		200,900	533,700
National criteria-induced								
Total capital	61,500		26,900		206,400	1,837,300	2,132,100	2,105,200
Annual O&M	6,800		2,700		10,300	159,300	179,100	176,400
Total annualized	19,900		8,900		66,500	505,700	601,000	592,100

*These costs do not include nonhazardous waste control costs for the coal mining industry.

however, include the costs of control methods for nonhazardous wastes from coal mining; these wastes are regulated by the Surface Mining Control and Reclamation Act of 1977 (SMCRA). Estimates of these costs are presented in the regulatory analysis report prepared to support the final SMCRA regulations (Federal Register, March 13, 1979). Criteria-induced costs, finally, are those costs of complying with RCRA that exceed the compliance costs for state and other Federal standards.

The three cost categories are total capital, annual operation and maintenance, and total annualized costs. The last is the sum of annualized capital and annual operation and maintenance costs.

Baseline costs for ground water are minimal when compared with the costs induced by state and Federal regulations. Baseline costs for surface water, however, are considerably greater because of the protection afforded by existing tailings ponds at mine sites. There are no baseline costs for floodplains and air quality because there are practically no controls specifically in use to satisfy these criteria. Some industries have measures that satisfy the RCRA closure criterion. The industries would have to incur an estimated additional capital cost of $1.84 billion to meet the RCRA closure criterion.

National baseline capital costs of nonhazardous waste control for all mining industries are estimated at $497 million. The annualized baseline control costs are an estimated $148 million. National state- and other Federal-induced capital costs are estimated at $645 million if NPDES permits are granted for facilities located in wetlands, and $865 million if these permits are not granted. Respective annualized costs are $201 million and $534 million. The total RCRA or Criteria-induced costs are estimated at $2.13 billion (NPDES permits granted) and $2.11 billion (NPDES permits denied). Respective annualized costs are $601 million and $592 million.

1. Development of Model Plants

Costs attributable to RCRA and other state and Federal legislation were determined by using the concept of a model plant, because a detailed, site-by-site study was beyond the scope of this report. For each of the 10 major mineral industries, a model plant was developed that represented the production level and the quantities of tailings and mine wastes generated. Production levels were obtained from the Minerals Yearbook, and solid waste tonnages were obtained from available sources and contacts within the mining industries.[1,2]

Figures 1 through 9 display the model plant sizes used in the study. The model plants include various steps within the process that generate significant quantities of solid wastes. They also reflect the control methods that are practiced to some extent within the industry. Each state was allocated a number of model plants based on the production levels for that industry within the state.

The model plant size for the copper industry (Figure 1) was determined on the basis of the total solid wastes generated within the industry, and from the fact that 25 out of 61 mines produce 93 percent of the Nation's copper.[2,3] The model plant, therefore, is a typical mine within the group of 25 major producing mines.

The iron ore model plant size (Figure 2) was determined by the same method, but with only 54 mines producing all of the Nation's iron ore.[3]

All of the primary molybdenum ore is produced at three mines, and three model plant sizes were thus developed from information on actual tonnages obtained from the respective mining companies. The tonnages represent a molybdenum mine that uses both surface and underground mining methods (Figure 3).

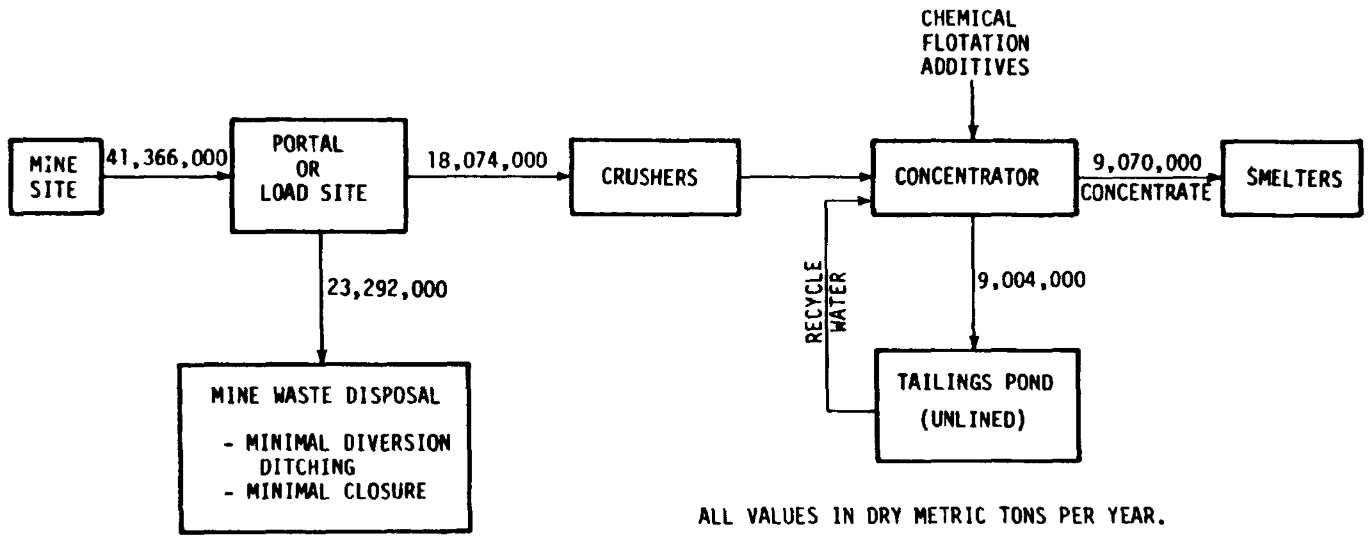

Figure 1. Copper mining and beneficiating model plant.

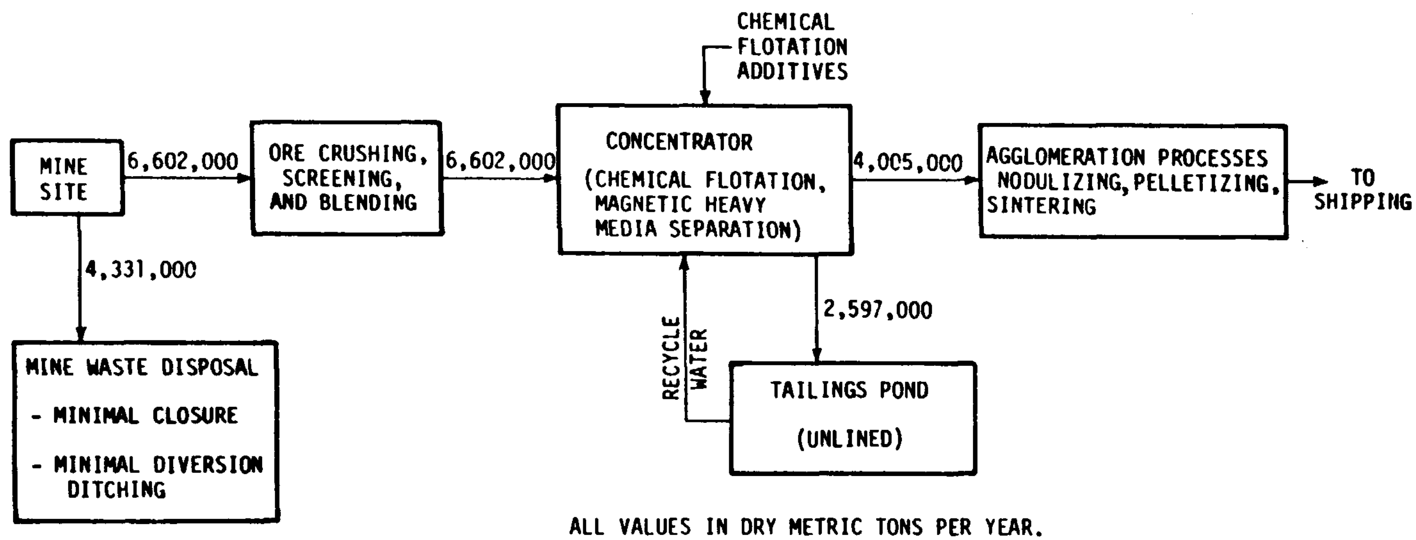

Figure 2. Iron ore mining and beneficiating model plant.

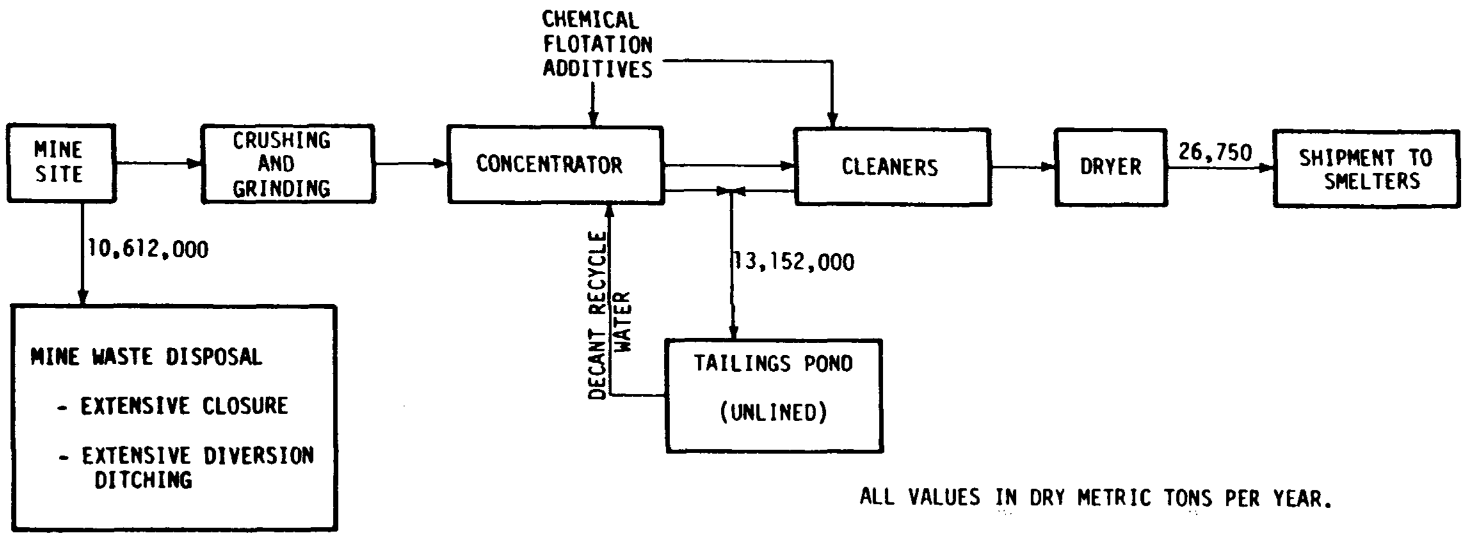

Figure 3. Molybdenum mining and beneficiating model plant.

The gold ore model plant size (Figure 4) was based on the production figures for only those sites that mine gold as the principal ore: i.e., actual gold mines.

The lead/zinc industry model plant size (Figure 5) was based on combined production levels for the two industries. It is an average of the model plant sizes for lead and zinc, as determined separately. The lead model plant size was based on 25 mines producing 99 percent of the Nation's lead, and the zinc model plant size was based on 25 mines producing 89 percent of the Nation's zinc ore.[3]

The clay model plant size (Figure 7) was determined by two methods. Mine waste tonnage was calculated as the average of the total mine wastes produced at all clay mines. Tailings tonnage was calculated as the average from the production of kaolin and fuller's earth, because these are the only clay processes that generate significant quantities of tailings.[4]

The model plant sizes for the remaining industries--phosphate rock (Figure 6); crushed, broken, and dimension stone (Figure 8); sand and gravel (Figure 9)--were calculated as an average production size based on the total number of mine sites within the respective industries.

2. Baseline and Criteria-Induced Control Methods for Tailings and Mine Wastes at Model Plants

Most mining industries are now using control methods that satisfy at least some portion of the Federal criteria. These baseline controls are indicated on the model plant block diagrams for each industry (Figures 1 through 9). The copper, iron ore, gold, lead/zinc, clay, and stone industries have minimal diversion ditching to prevent surface waters from interacting with overburden piles. These industries also have minimal closure practices for overburden, usually involving grading and revegetation. "Minimal" diversion ditching and closure means that 20 percent (for ditching) and 10 percent (for closure) of the individual facilities within the industry are using these practices. Diversion ditching and closure of overburden primarily protect surface water from pollution by suspended solids.

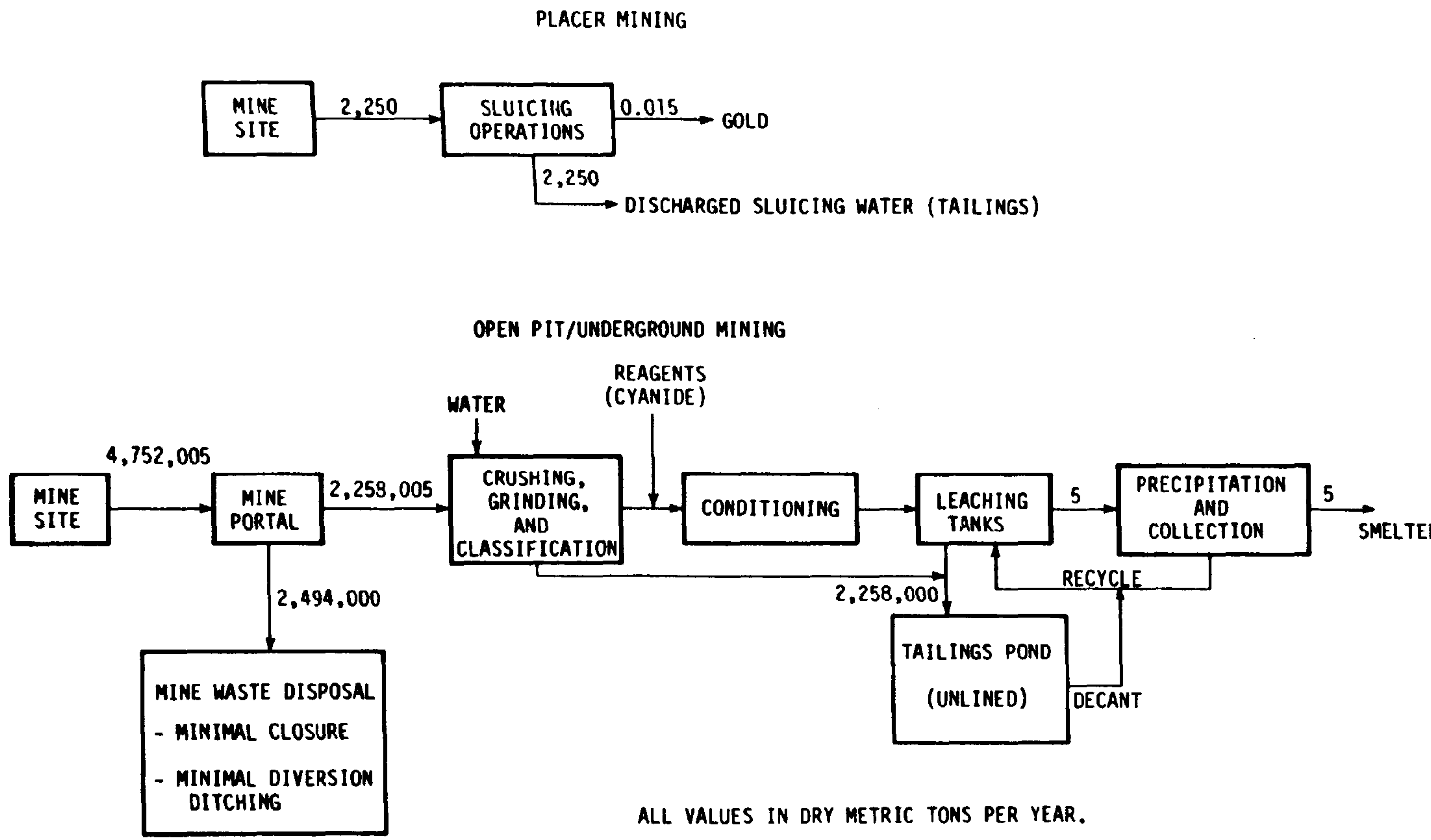

Figure 4. Gold mining and beneficiation model plant.

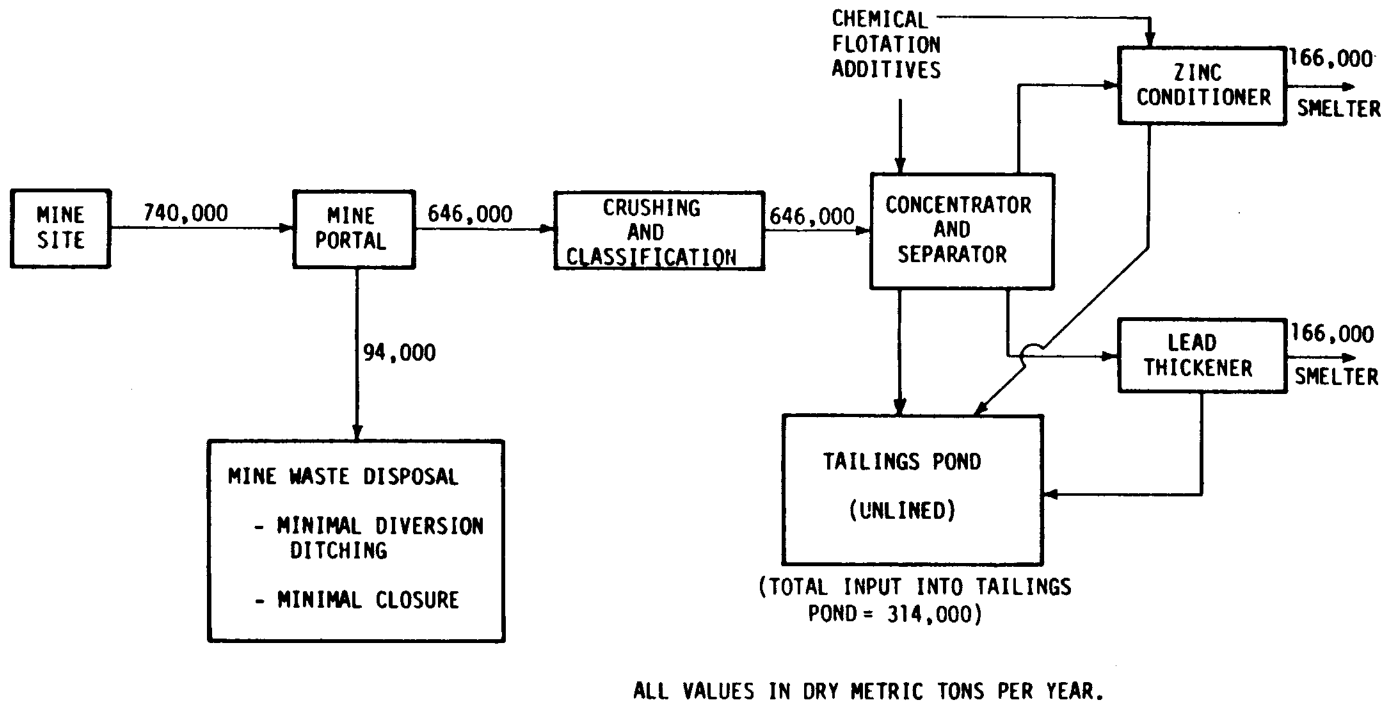

Figure 5. Lead/zinc mining and beneficiating model plant.

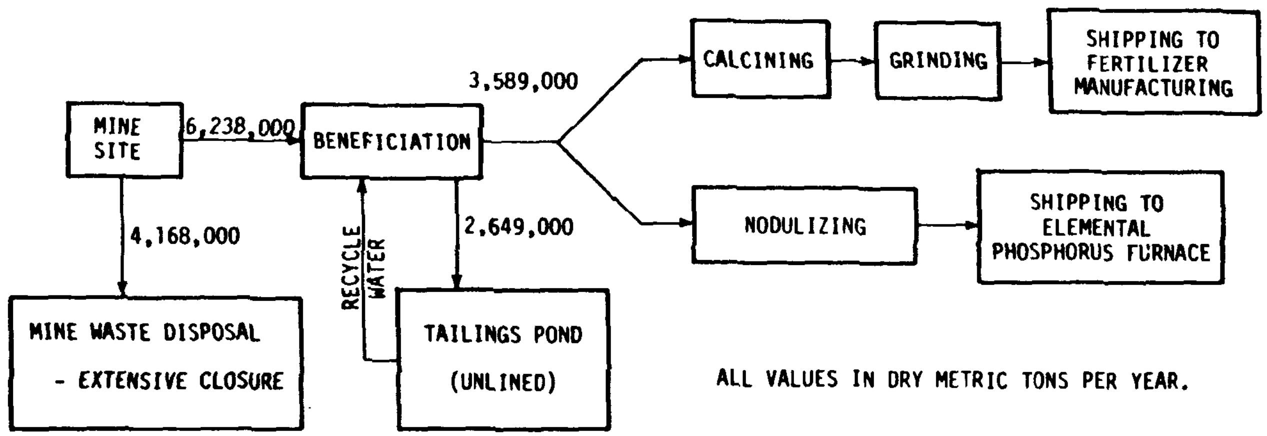

Figure 6. Phosphate mining and beneficiating model plant.

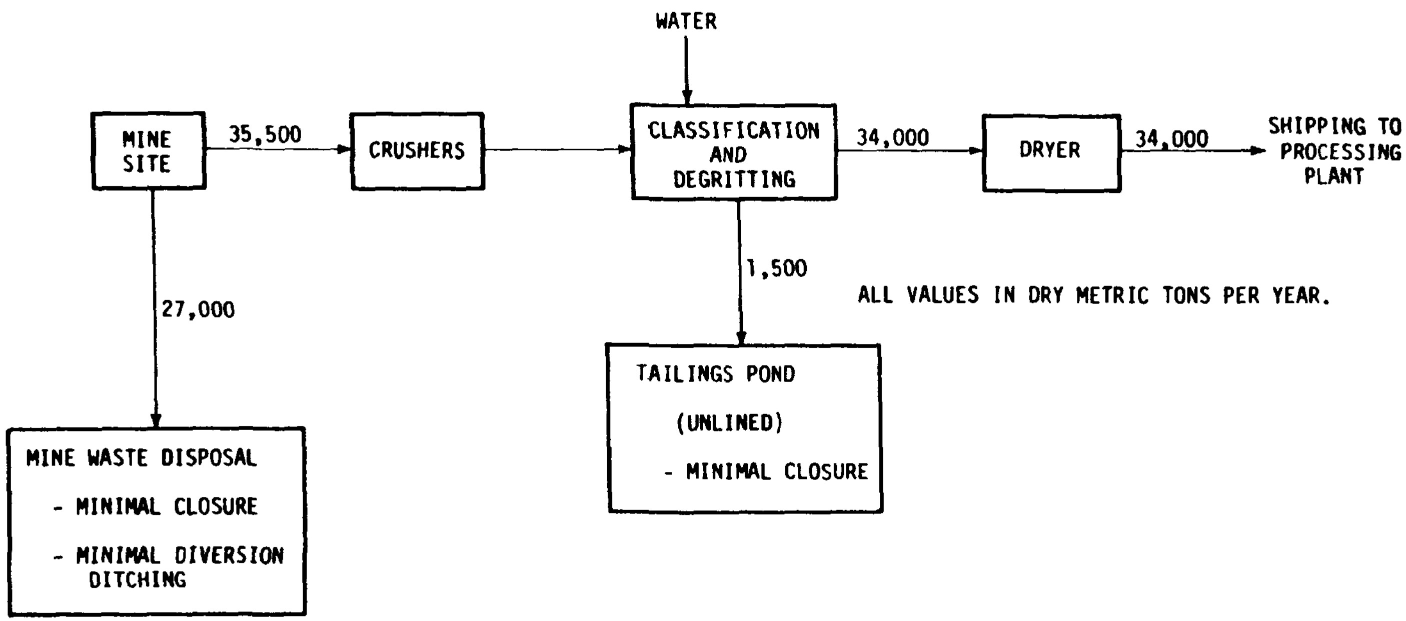

Figure 7. Clay mining and beneficiating model plant.

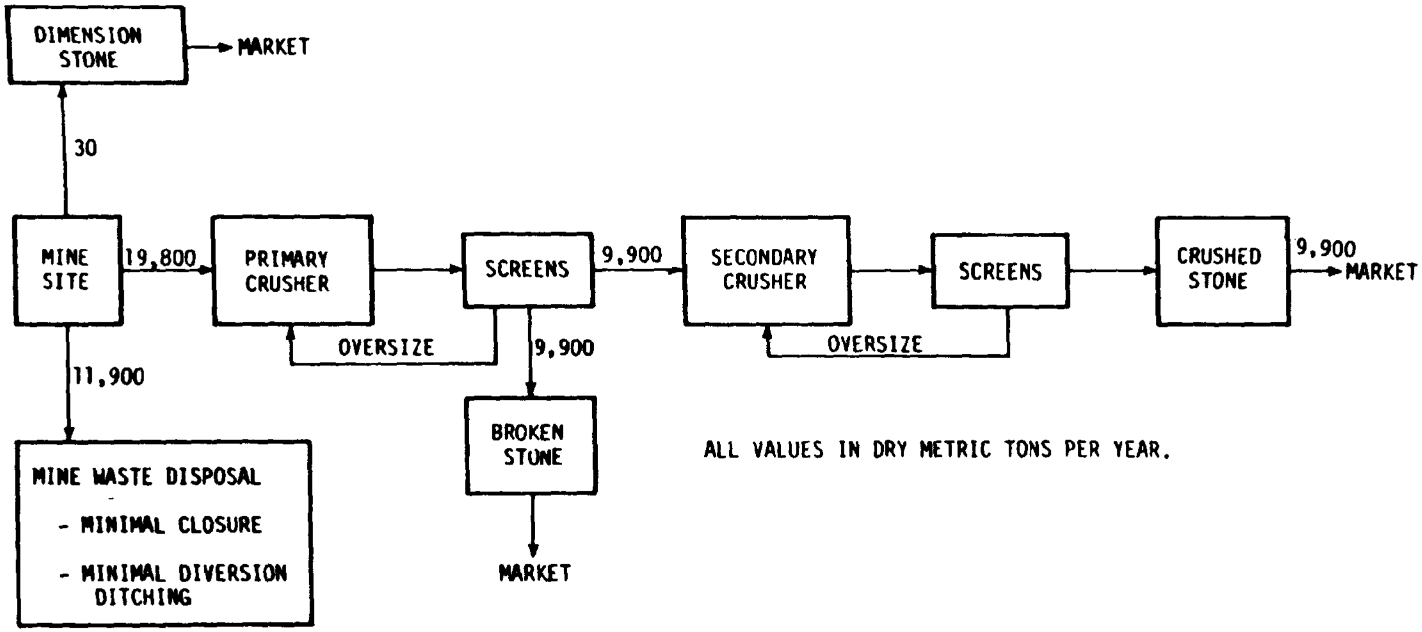

Figure 8. Crushed, broken, and dimension stone mining model plant.

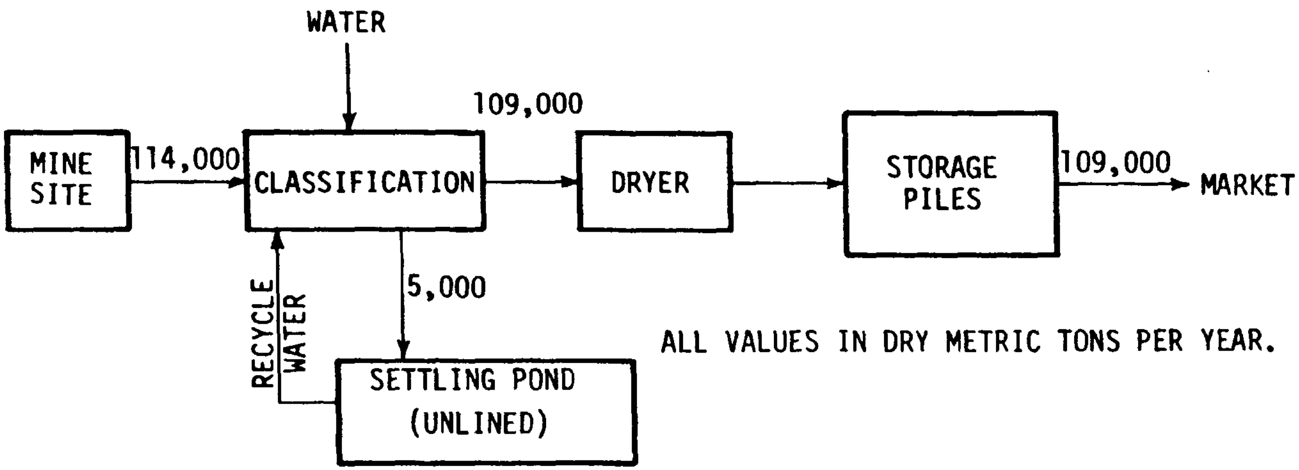

Figure 9. Sand and gravel mining model plant.

The molybdenum industry makes extensive use of diversion ditches, which are present in about 80 percent of the industry. Both the molybdenum and phosphate industries commonly grade and revegetate their overburden. Phosphate mining companies in Florida reclaim all or nearly all of their overburden.

Unlined ponds are the baseline controls used in the two major industries (clay, sand and gravel) that produce tailings classified as nonhazardous. In addition to the ponds, the clay industry practices minimal closure for tailings. The stone industry produces negligible quantities of tailings.

Control methods have also been formulated in response to RCRA. (See Figures 10 through 15.) These various controls are discussed below in terms of the criterion to which they apply.

a. <u>Ground Water</u>

Control methods that would meet the RCRA ground-water criterion (Figure 10) include the construction of diversion ditches to direct water away from the overburden and waste rock disposal areas. This control reduces the leaching of materials from these areas and subsequent pollution of the ground water.

Industries that generate nonhazardous tailings would first evaluate the water table to determine whether leachate from existing, unlined tailings ponds could adversely affect the quality of ground water. A high/low water table has been delineated for this purpose. In a particular industry, the degree to which the tailings ponds will have an adverse impact on the ground water depends on the region where the industry is located. This study assumes, for example, that in the southeastern section of the country 25 percent of the land has a low water table and 75 percent a high water table; and these percentages are assumed to be reversed in states in the Southwest. A national summary of these high/low water-table percentages was prepared for the Northwest, Southeast, Southwest, Northeast, and Midwest (Table 3).

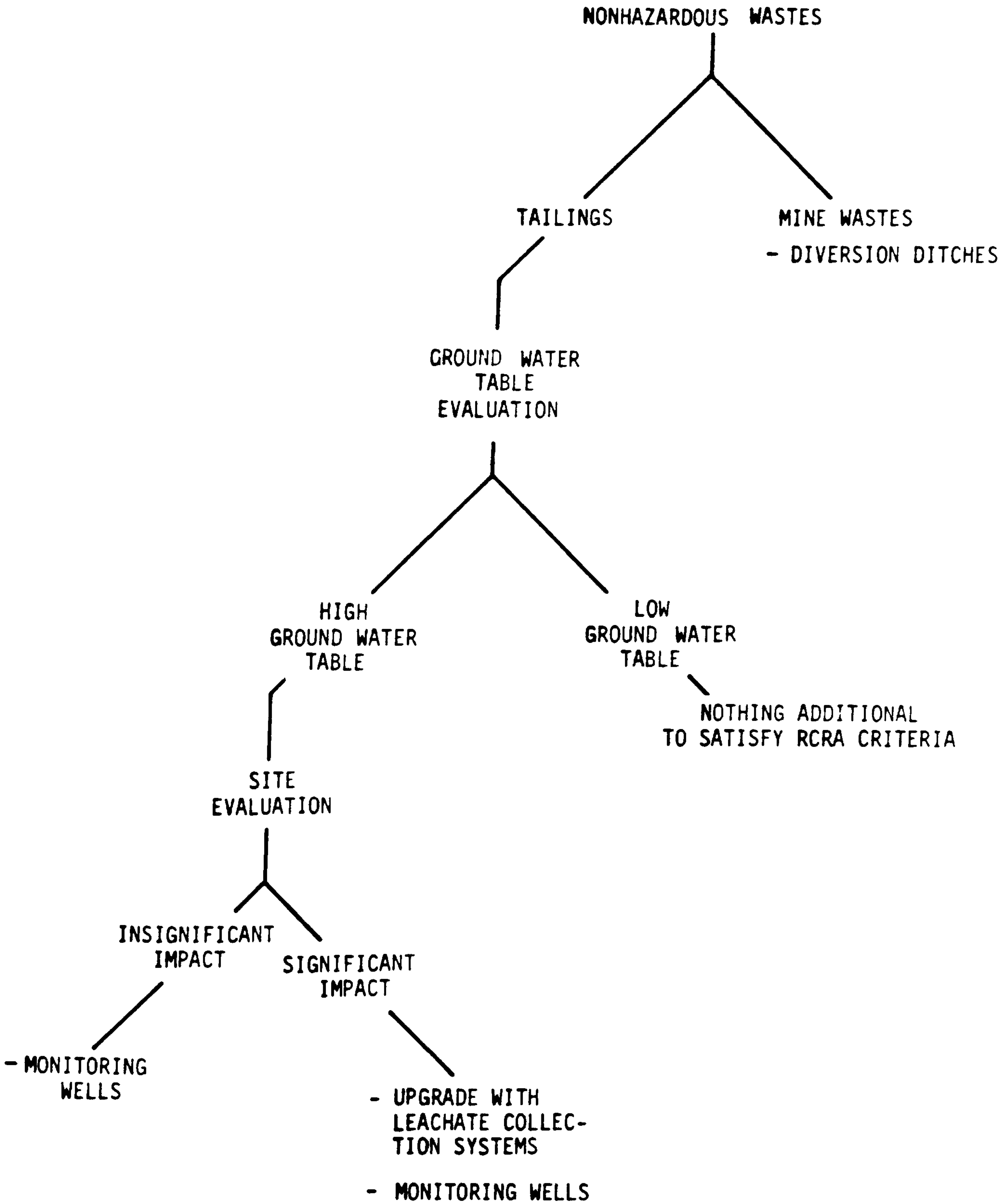

Figure 10. Controls induced by RCRA ground-water criterion covering nonhazardous wastes from the mining industry.

TABLE 3

REGIONAL PERCENTAGES OF LOW OR HIGH WATER TABLE USED IN ANALYSIS OF GROUND WATER CRITERION

Region	Low water table (%)	High water table (%)
Northeast	50	50
Southeast	25	75
Southwest	75	25
Northwest	75	25
Midwest	25	75

Nonhazardous tailings ponds located in areas with low water tables are assumed to need no additional controls to satisfy the ground-water criterion. Ponds in areas with high water tables could be subjected to a site evaluation (consisting of a hydrogeological survey, permeability tests, evaluation, and report) to determine the actual impact on the ground water. It is estimated that 80 percent of the site evaluations would show an insignificant impact, with the accompanying recommendation that monitoring wells should be installed and data collected quarterly at these sites. The remaining 20 percent of the evaluations would indicate significant ground-water impact, with the recommendation that these sites install further control measures. The controls would consist of collection wells for the leachate to prevent it from entering the ground water. In addition, monitoring wells would be installed in appropriate locations to perform quarterly checks of the leachate collection system.

b. Surface Water

Control methods to meet the RCRA surface water criterion are shown in Figure 11. Diversion ditches around mine waste piles would prevent surface runoff from interacting with the waste and carrying it, primarily as suspended solids, into surface waters. The tailings ponds is a baseline control method for nearly all mining industries; it contains the tailings and prevents surface water contamination. One exception to the use of tailings ponds is gold placer mining operations, which are primarily located in Alaska and California. Sluiced wastes (tailings) from these operations are the only nonhazardous tailings within the gold mining and beneficiating industry. In current practice, they are pumped directly to streams and rivers. Control of the tailings from gold sluicing operations could be accomplished by construction of tailings ponds.

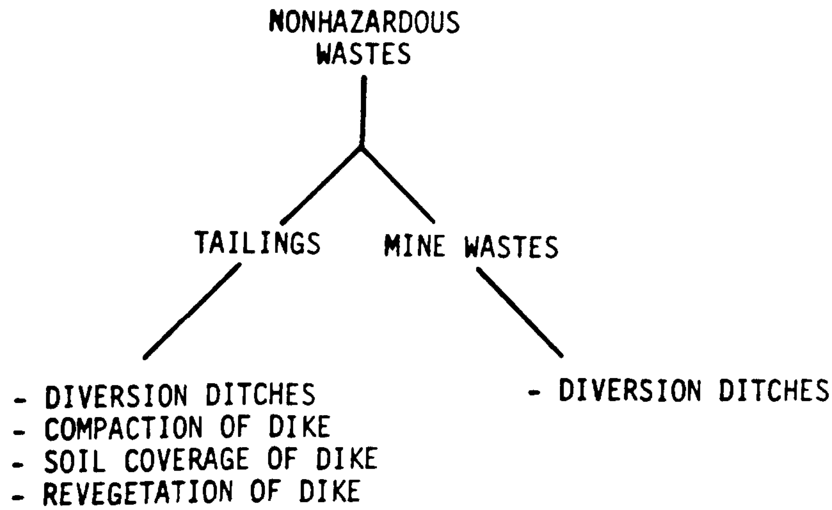

Figure 11. Controls induced by RCRA surface water criterion covering nonhazardous wastes from the mining industry.

For industries having tailings ponds, further controls to meet the surface water criterion include diversion ditches and upgrading of the pond dikes by compaction, soil coverage, and revegetation. The diversion ditches would direct waters away from tailings ponds to prevent the dikes from being weakened or washed out; and to reduce the chances of pond overflow. Either condition could cause suspended solids to contaminate surface waters.

c. Wetlands

Control methods to meet the RCRA wetland criterion are shown in Figure 12. Two scenarios are considered for tailings and other mine wastes. One scenario assumes that NPDES permits will be granted to all mining industries located in wetlands, allowing solid wastes to be disposed of within the area. The second scenario assumes that no NPDES permits will be granted and that all

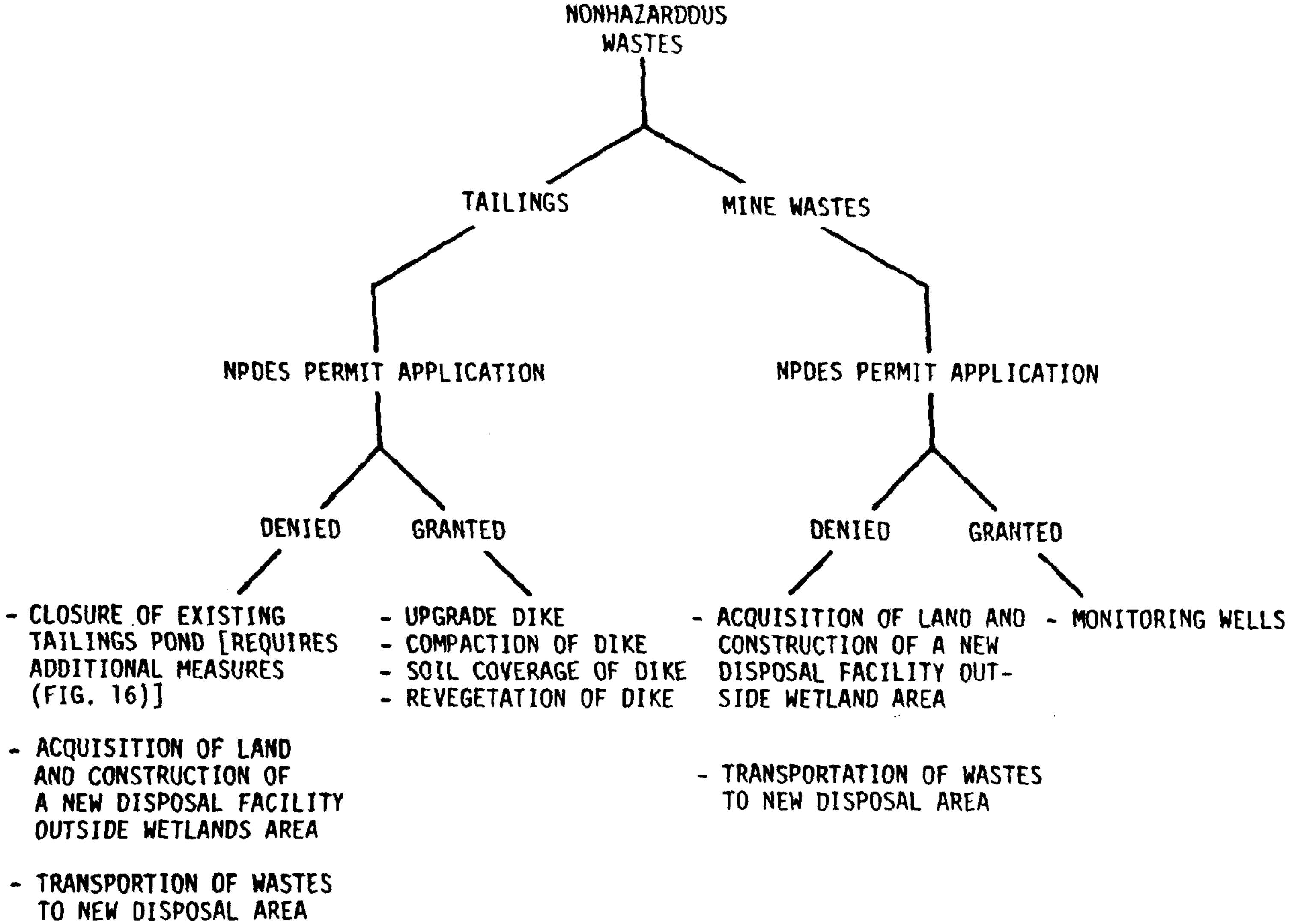

Figure 12. Controls induced by RCRA wetland crierion covering nonhazardous wastes from the mining industry.

mining wastes generated in wetlands will have to be transported out of the area. Control methods for the two scenarios are outlined in the following paragraphs:

NPDES permits granted: Monitoring wells, checked on a quarterly basis, would be installed around mine waste piles as a precautionary measure. The dikes around tailings ponds would be upgraded into a 3:1 sloped structure (3 horizontal, 1 vertical). This control would also include dike compaction, soil coverage, and revegetation (similar to the controls for the surface water criterion).

NPDES permits denied: This scenario would involve the purchase of land outside the wetlands to construct disposal facilities for tailings and mine wastes. The control system would include the transportation of these nonhazardous wastes to the new sites. With one exception, it is assumed that the wastes from all mining industries located in wetlands would have to be trucked a distance of 16 kilometers one way. The exception is the Florida phosphate industry, which is located in areas of extensive wetlands; the assumed trucking distance in this case is 32 kilometers.

Because of the distances involved, pumping the tailings to the new facility is not considered feasible. The control method described here includes thickening the tailings slurry to a 70 percent solids sludge before it is transported by truck. Overflow from the centrifuge would be pumped to storage tanks as recycle water.

In addition to trucking the newly generated tailings to new disposal facilities that meet RCRA criteria, the scenario includes closing the existing tailings ponds (pond free water pumped off, pond allowed to drain, 0.6 meters of soil uniformly graded over the pond, and revegetation). Closure measures for the relocated disposal facilities are described under the closure criterion.

The percentages of the specific industries located in wetlands were calculated from the percentages presented in Table 13 (page III-6) of the

Draft EIS; and from knowledge of the relative locations of these wetlands and the minerals industry facilities when this information was available. For example, although 46 percent of Florida is wetlands, most of the Florida phosphate industry is located within that portion; so a value of 90 percent was assumed to represent this case.

d. Floodplains

Control methods to meet the RCRA floodplains criterion are shown in Figure 13. Diking is the principal method selected, for both tailings and mine wastes, to satisfy this criterion. For mine wastes, this entails construction, compaction, soil coverage, and revegetation of dikes 3 meters high at a 3:1 slope. The dikes would be built around accumulated plus newly generated mine waste. On a national average, three sides of the mine waste piles (assuming roughly rectangular shapes) would require diking. In actuality, some waste piles are located against a ridge or ridges bordering the floodplains; these piles may be protected from floods on one, two, or three sides. Conversely, some waste piles are located in the middle of floodplains, and dikes would have to be built around their entire periphery.

For tailings ponds, the floodplain criterion would include upgrading the pond dikes to a 3:1 slope, compacting, covering with 0.6 meters of soil, and seeding and fertilizing to prevent erosion.

NONHAZARDOUS WASTES
(TAILINGS AND MINE WASTES)

- DIKE CONSTRUCTION
- COMPACTION OF DIKE
- SOIL COVERAGE OF DIKE
- REVEGETATION OF DIKE

Figure 13. Controls induced by RCRA floodplain criterion covering nonhazardous wastes from the mining industry.

The percentages of industries located in floodplains were determined on a state-by-state basis. Most of the states were assigned a value of 5 percent, which is the estimated average percentage of land in the United States that is within floodplains.

e. Air Quality

Control methods to prevent adverse impacts on air quality are shown in Figure 14. Fugitive dust from mine waste piles would be controlled by revegetating the piles. This method is discussed under the closure section.

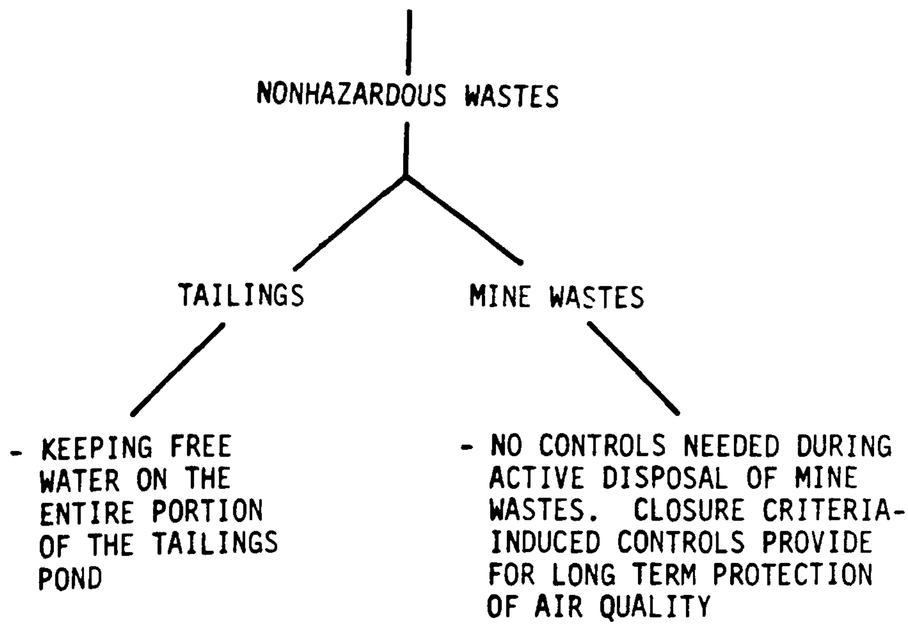

Figure 14. Controls induced by RCRA air quality criterion covering nonhazardous wastes from the mining industry.

Fugitive dust can also be generated by the action of the wind across dried areas of tailings ponds, particularly in arid regions of the West and Southwest. Tailings that are considered nonhazardous, such as those of the clay and sand and gravel industries, are contained in ponds that are smaller in size and are nearly all located in nonarid regions. As a result, the pond surfaces are wet most of the time (i.e., the addition of new tailings water and the precipitation rate exceed the evapotranspiration rate for these areas). Because the ponds do not dry out and create dust problems, no additional controls to protect air quality standards are considered necessary.

f. Closure

Control methods to meet the RCRA closure criterion are shown in Figure 15. The RCRA criterion requires that accumulated and newly generated, nonhazardous mine wastes be closed with 0.6 meters of soil cover, and that the soil be revegetated. With a few exceptions, such as Florida phosphate, most of the mineral industries have allowed mine wastes to accumulate in piles since the startup of the mines. The quantity of these wastes is considerable, depending on the type of industry and length of time the mines have been in operation; the copper model plant, for example, has an assumed life of 15 years. The control method for stabilizing these accumulated mine waste piles would involve regrading to provide adequately contoured slopes; compaction of this material; coverage with 0.6 meters of soil; soil amelioration; and seeding to revegetate.

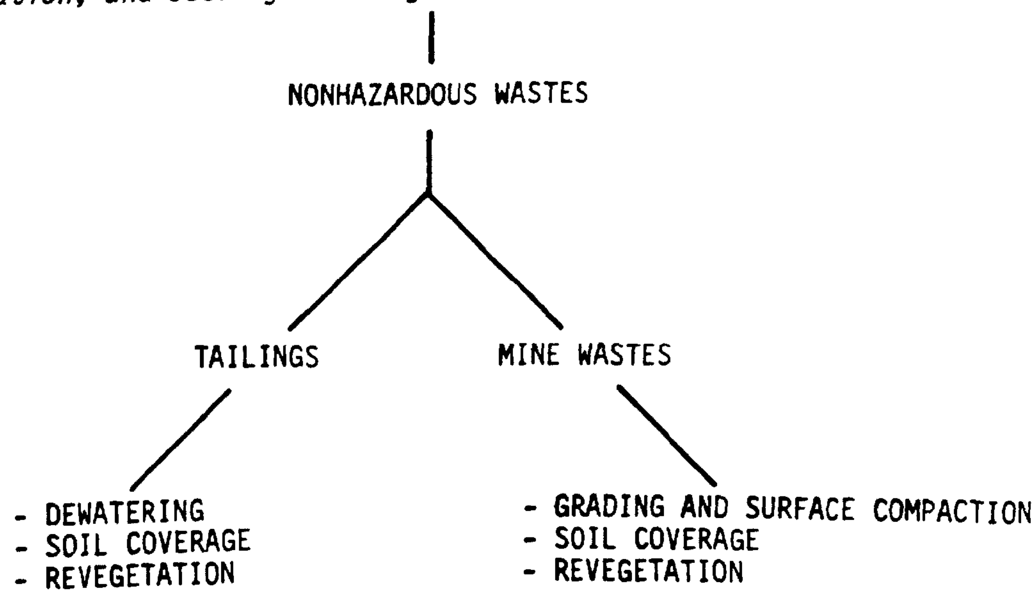

Figure 15. Controls induced by RCRA closure criterion covering nonhazardous wastes from the mining industry.

The newly generated mine wastes would be spread out, compacted, covered with soil, and revegetated on a continual basis. These procedures are similar to the reclamation that is practiced in some industries. Closure would thus occur regularly, so that the wastes would be "closed" on a weekly, monthly, or even an annual basis rather than be allowed to accumulate through the remainder of the mine life.

Procedures for closure of a tailings pond when it is full are also shown in Figure 15. Pond free water would be pumped to a pressurized filtering system to remove solids, and the clarified water would be discharged to a surface stream or river or used for operational purposes at the mine or mill. When the drained area was stable, 0.6 meter of soil would be used to cover the tailings, followed by compaction and revegetation.

3. Costs and Cost Methodology

This section presents and discusses baseline costs, state- and other Federal-induced costs, and Criteria-induced costs on a capital and an annualized basis. All the costs are given in 1978 dollars. The methodology used to determine these costs is also discussed. The two principal sources of cost data were Richardson and Means; other sources were used for certain unit costs.[5-8]

a. Baseline and Above-Baseline Costs

For each of the 10 mining industries, costs have been calculated for the baseline case and for the control methods attributable to government regulations (Table 4). Baseline costs include all the criteria; costs above baseline are figured separately for each criterion. In the copper industry, for example, the 61 mines have a total baseline capital cost (for all criteria) of $94,000; annual operating and maintenance costs are $3,216,000; and total annualized costs are $3,227,000. Capital costs above baseline to meet the ground-water criterion are estimated at $185,000, and total annualized costs are estimated at $37,000. Within this industry, the sum of the costs above baseline to meet all criteria is estimated at $433 million, and total annualized costs at $114 million.

b. Costs Per Unit of Waste and Product

The control method costs have also been calculated per metric ton of waste and of product, based on the total annualized costs for each industry (Table 5). For the baseline case, these costs in the copper industry are

TABLE 4

ESTIMATED TOTAL BASELINE AND GOVERNMENT-INDUCED COSTS BY INDUSTRY AND BY CRITERION (1,000 dollars)

		Costs attributable to government regulations (above baseline)*							
				Wetlands				Total	
Mining industry	Baseline costs	Ground water	Surface water	NPDES permit granted	NPDES permit denied	Floodplains	Closure	NPDES permit granted	NPDES permit denied
Copper									
Total capital	94	185	185				433,000	433,370	
Annual O&M	3,216	10	10				50,540	50,560	
Total annualized	3,227	37	37				114,000	114,074	
Iron ore									
Total capital	134	264	264	120	26,700	4,500	430,000	435,148	461,728
Annual O&M	2,408	14	14	19	15,800	224	43,000	43,271	59,052
Total annualized	2,424	50	50	35	19,200	823	100,700	101,658	120,823
Molybdenum									
Total capital	1,960	3	3				11,600	11,606	
Annual O&M	1,100	1	1				580	582	
Total annualized	1,340	1	1				2,000	2,002	
Gold									
Total capital	6	1,947	5,286			1,044	13,770	22,047	
Annual O&M	91	208	265			54	1,400	1,927	
Total annualized	91	628	1,042			110	3,420	5,200	
Lead/Zinc									
Total capital	26	52	52	13	30	419	8,742	9,278	9,295
Annual O&M	99	4	4	4	30	22	1,313	1,347	1,373
Total annualized	104	13	13	4	35	95	2,863	2,988	3,019
Phosphate									
Total capital	59	119	119	1,219	112,900	2,828	63,700	67,985	179,666
Annual O&M	9,282	7	7	174	238,400	141	9,600	9,929	248,155
Total annualized	9,292	28	28	390	258,000	650	20,800	29,896	279,506
Clay									
Total capital	46,800	9,109	4,003	22,720	16,320	7,891	107,700	151,423	145,023
Annual O&M	15,180	923	201	598	2,977	397	4,366	6,485	8,864
Total annualized	22,050	2,861	1,040	1,793	5,743	2,050	26,940	34,684	38,634
Stone									
Total capital	1,300	2,500	2,500	14,130	10,840	16,350	180,000	215,480	212,190
Annual O&M	2,693	125	125	1,863	5,000	822	34,000	36,935	40,072
Total annualized	2,827	650	650	4,909	7,200	4,250	72,000	82,459	84,750
Sand and gravel									
Total capital	401,900	310,800	87,970	13,860	60,590	345,100	421,800	1,179,530	1,226,260
Annual O&M	17,800	34,300	4,399	693	3,030	17,300		56,692	59,029
Total annualized	93,600	101,100	28,800	4,536	15,530	113,000	117,000	364,436	375,430
Other									
Total capital	45,200	32,500	10,040	5,206	22,740	37,810	167,000	252,556	270,090
Annual O&M	5,187	3,560	503	335	26,540	1,896	14,500	20,794	46,999
Total annualized	13,500	10,540	3,166	1,167	30,570	12,100	45,970	72,943	102,346
Total									
Total capital	497,479	357,479	110,422	57,268	250,120	415,942	1,837,312	2,778,423	2,971,275
Annual O&M	57,056	39,152	5,529	3,686	291,777	20,856	159,299	228,522	516,613
Total annualized	148,455	115,908	34,827	12,834	336,278	133,078	505,693	802,340	1,125,784

TABLE 5

ESTIMATED BASELINE AND REGULATORY COSTS PER UNIT BASIS

Mining industry	Current product value[*] ($/metric ton)	Baseline costs		
		National annualized costs ($1000/yr)	$/metric ton of waste	$/metric ton of product
Copper	1,325	3,227	0.005	0.013
Iron ore	24.70[†] and 0.67[§]	2,424	0.010	0.011
Molybdenum	10,990[¶]	1,340	0.125	24.4
Gold	6,770,000[@]	91	0.011	4,330
Lead/Zinc	Lead, 747; Zinc, 681	104	0.022	0.006
Phosphate	17.40	9,292	0.062	0.055
Clay	2.20 to 220[**]	22,050	0.612	0.554
Stone	2.85[††]	2,827	0.043	0.003
Sand and gravel	2.46	93,600	2.61	0.130

[*] 1978 dollars; 1979 Mineral Commodity Summaries, U.S. Bureau of Mines

[†] Natural ores, 51.5% Fe.

[§] Pellets, per metric ton unit of Fe.

[¶] Per ton of molybdenum in concentrate.

[@] Based on average selling price of $192.50/oz.

[**] Price varies with type and quality of clay.

[††] Dimension stone at $89.80/metric ton accounts for 0.15% of stone production.

(continued)

TABLE 5 (continued)

Mining industry	State-and other Federal-induced costs (NPDES permit granted)			State-and other Federal-induced costs (NPDES permit denied)		
	National annualized costs ($1000/yr)	$/metric ton of waste	$/metric ton of product	National annualized costs ($1000/yr)	$/metric ton of waste	$/metric ton of product
Copper	69	0.0001	0.0003	69	0.0001	0.0003
Iron ore	829	0.004	0.004	12,500	0.05	0.05
Molybdenum	1	0.0001	0.02	1	0.0001	0.02
Gold	1,745	0.21	83,100	1,723	0.20	83,320
Lead/Zinc	99	0.02	0.006	31	0.007	0.002
Phosphate	704	0.005	0.004	159,400	1.06	0.95
Clay	5,640	0.16	0.14	10,500	0.29	0.24
Stone	4,565	0.07	0.006	11,100	0.16	0.01
Sand and gravel	169,300	4.72	0.24	183,300	5.1	0.26

(continued)

TABLE 5 (continued)

Mining industry	Criteria-induced costs (NPDES permit granted) National annualized costs ($1000/yr)	$/metric ton of waste	$/metric ton of product	Criteria-induced cost (NPDES permit denied) National annualized costs ($1000/yr)	$/metric ton of waste	$/metric ton or product
Copper	114,200	0.18	0.47	114,200	0.18	0.47
Iron ore	100,800	0.43	0.46	100,800	0.43	0.46
Molybdenum	2,000	0.19	36.3	2,000	0.19	36.3
Gold	3,574	0.42	170,200	3,574	0.42	170,200
Lead/Zinc	3,020	0.63	0.18	3,020	0.63	0.18
Phosphate	21,210	0.14	0.13	20,800	0.14	0.12
Clay	29,150	0.81	0.73	28,200	0.71	0.71
Stone	77,710	1.18	0.10	73,960	1.12	0.09
Sand and gravel	199,500	5.56	0.28	196,450	5.47	0.27

estimated at $3.2 million; this figure equals $0.005 per metric ton of waste and $0.013 per metric ton of product. For state- and other Federal-induced annualized costs (NPDES permit granted), the estimate is $69,000; this figure equals $0.0001 per metric ton of waste and $0.0003 per metric ton of product. For Criteria-induced annualized costs (NPDES permit granted), the estimate is $114 million; this figure equals $0.18 per metric ton of waste and $0.47 per metric ton of product.

c. Cost Methodology

(1) Capital Costs

National baseline and above-baseline capital costs for each mining industry were based on the size of the model plant and the control methods chosen to meet the RCRA criteria. Unit costs were determined for components of control methods that are current or baseline and those that are above baseline to provide compliance with RCRA. The baseline and above-baseline control method component costs were subsequently calculated for the model plants. The sum of the control costs to meet a criterion for a model plant was then calculated, as applicable, for tailings and mine wastes. These costs were determined for each of the six criteria for each model plant. When one control strategy satisfied two criteria, such as surface water and ground water, the costs for the strategy were divided equally between them.

In each industry, the baseline costs to meet all criteria were determined from the product of the number of model plants and the sum of the model plant control costs. The total baseline costs per criterion were determined from the product of the number of model plants in the industry and the model plant cost of meeting that criterion. The individual industry criterion costs were summed to get the total mining industry criterion costs.

The criterion costs were used to develop the baseline and above-baseline costs by state. The number of model plants in each state by industry and by type of waste (tailings and mine wastes) were determined by proportioning total tailings and mine waste quantities among the states, based on industry production figures.[1,2] For each state, the cost increment was determined from the product of number of model plants per industry and the model plant control costs for a criterion. The sum of these incremental costs for all industries within a particular state is that state's total industry cost to meet one RCRA criterion. The sum of these costs for all states in the United States is the national mining industry's cost to meet a criterion; and the sum of these costs for all criteria is the national cost impact on the mining industry of meeting RCRA-level controls for nonhazardous wastes.

A contingency factor of 20 percent is included with the capital costs shown in the tables.

Costs of RCRA-level controls were calculated by state to determine the total state-induced costs. Control costs in each state having regulations equivalent to the RCRA criteria were added together, then deducted from the national total costs of RCRA-level controls. The matrix shown in another appendix (Economic Impact Analysis) to this document lists the states that have regulations equivalent to RCRA criteria. Other Federal-induced costs (in Table 2, and included in above-baseline costs in Tables 4 and 5) are those attributable to the Clean Water Act. They represent the controls installed to meet the surface water and wetlands criteria (NPDES permit denied) in the states that do not have equivalent regulations. State and other Federal-induced costs are combined and deducted from the costs of meeting RCRA-level controls to yield the actual Criteria-induced cost.

(2) Annualized Capital Costs and Trust Funds

Annualized capital costs were determined for each industry by amortizing the capital at 12 percent interest over the remaining life of the model plant. The equation for determining the annuity or capital recovery factor is:

$$\frac{[i(1 + i)^n]}{[(1 + i^n - 1]},$$

where i is the interest rate and n is the number of years. Annuity factors for the main industries considered in this study are shown in Table 6.

TABLE 6

ANNUITY FACTORS FOR MAJOR MINING INDUSTRIES WITH NONHAZARDOUS WASTES

Industry	Assumed remaining life of model plant (years)*	Annuity factor
Copper, gold	15	0.1468
Iron ore	20	0.1339
Molybdenum	30	0.1241
Lead/zinc, phosphate	10	0.1770
Clay, stone	7.5	0.2096
Sand and gravel	5	0.2774

* These remaining lives are assumed to be half of the full lives.

Another annualized capital cost is the establishment of trust funds to pay for the closure of tailings ponds at the end of a mining operation and the operation and maintenance of monitoring wells after closure. A closure period of 1 year was assumed for nonhazardous tailings ponds (dewatering, adding soil, and revegetating). The trust fund for the monitoring wells is based on the assumption that they will be operated and maintained for 5 years after closure. Equations were derived to determine the trust funds for closure and for the monitoring wells (Table 7). The equations take into account variations in remaining life among the model plants, and they include a 2 percent return (above inflation) on capital. In the equations, T is the capital cost of the trust fund; and S is the cost of closure and of well operation and maintenance for 1 year.

TABLE 7

EQUATION FOR TRUST FUNDS

Industry	Tailings pond closure	Monitoring well upkeep
Iron ore		T = 3.202 S
Lead/zinc, phosphate		T = 3.903 S
Clay, stone	T = 0.853 S	T = 4.101 S
Sand and gravel	T = 0.897 S	T = 4.309 S

(3) Other Annual Costs

In addition to annualized capital costs, the other annual costs include maintenance of the various control systems (assumed to be 5 percent of the applicable total capital costs); electricity to operate pumps, as during pond dewatering (assumed to cost 30 mills/kWh); labor to operate equipment, such as the front-end loader, is costed at $26.60 per man-hour, including supervision and overhead; trucking of tailings and mine wastes from wetlands when NPDES permits are denied (assumed to be done by a contractor); and annual costs of continuous overburden grading, soil spreading, and revegetating, (also assumed to be done by a contractor).

d. Configuration and Costs of Control Methods

The flow diagrams (Figures 1 through 9) and "tree" diagrams (Figures 10 through 15) in Sections 1 and 2 presented the different baseline controls and those that would meet RCRA criteria, respectively. This section discusses design parameters and components of the control methods. Unit costs are listed, where appropriate, in parentheses.

(1) Tailings Pond

The tailings pond is the principal method used to control mining beneficiation wastes. Most mines have tailings ponds; some, such as gold placer mines, discharge their waste sluicing water elsewhere. To determine the cost of constructing a tailings pond for nonhazardous beneficiation wastes, this study assumed the following design parameters: rectangular-shaped pond; depth of about 11 meters from the top of the dike to the bottom of the pond; dike around three sides of the pond (assuming a natural barrier on one side); and a slope of 2:1 (horizontal:vertical) except in floodplains or wetlands, where dikes are sloped 3:1. The dikes are constructed to have a 6-meter wide horizontal section along the top so that machinery can be driven and maneuvered there. Ponds are designed with a 1.5 meter freeboard above the water and an allowance of 1.2 meters of free water above the settled solids. Incoming slurry is assumed to be 30 percent solids, by weight; and settled tailings are assumed to be 65 percent solids, with an average specific gravity of 1.8. The excavated depth of a pond is based on the amount of material needed to construct the dike. The length to width ratio of the pond is 2:1.

With the exception of the sand and gravel industry, it is assumed that one pond will accomodate the beneficiation (tailings) wastes from the other subject mineral industries over the entire life of each model plant. Sand and gravel operations typically construct a small settling pond at the start-up of a mine to receive beneficiation wastes during the initial two or three years of operation; with subsequent employment of one or more excavated areas from the mining operation for this purpose; consequently, baseline control costs for tailings from the sand and gravel industry are based on this configuration, i.e., construction of a 3-year settling pond and operation and maintenance of this pond and the ponds created by the mining operation over the life of the mine. In a case where a new pond must be built (e.g., gold placer mining) the cost is calculated for a capacity adequate to handle tailings for half the duration of a mine life; it is assumed that the mines are halfway through their useful lives. For both baseline case ponds and new ponds, assumptions about the annual quantities of tailings received were shown in Table 1.

The capital cost of constructing a tailings pond includes the following components: land (rural undeveloped, $2,400 per hectare); land clearing ($1,300 per hectare); survey ($925 per hectare); excavation of pond area

($0.47 per cubic meter); hauling and dumping overburden at the dike area ($0.47 per cubic meter); dike formation and compaction ($1.88 per cubic meter); and fine grading ($0.69 per square meter).

(2) Ground Water Evaluation

This evaluation is the determination of the water table level. The main costs are for drilling temporary test wells, which in this study are assumed to be 6.35 centimeters in diameter. The cost of a 15-meter-deep well is $475, and each linear meter exceeding that depth is $25.

(3) Site Evaluation

A detailed site evaluation includes a hydrogeological survey to determine ground-water movement and flow nets ($5,000), and tests of borings to determine leachability and permeability ($3,000). Capital costs of such an evaluation, including engineering appraisal and a report, is estimated at $15,000.

(4) Leachate Collection System

The system considered here is a group of collection wells spaced at a density of one per hectare. Each well is equipped with piping and a pump located above ground level. The wells collect the leachate and pump it back to the tailings pond. Cost of a well, with pump and piping, is estimated at $4,500.

(5) Monitoring Wells

The monitoring wells are costed according to depth. The wells include casing 10 centimeters in diameter, schedule 40 piping 3.8 centimeters in diameter, and pumps rated at 5,700 liters per hour. The installed cost of a 15-meter deep monitoring well is estimated at $3,000; and a 30-meter-deep well, at $4,000.

(6) Diversion Ditches

Cost of construction of diversion ditches (1.8 meters deep by 0.6 meters wide at the top) with a trencher is approximately $2.10 per linear meter.

(7) Dike Formation, Soil Coverage, Revegetation

Dikes are the principal control method used in this study for protecting overburden in floodplains. They are also part of the construction of a tailings pond, when no natural barriers are available. In this study, tailings pond costs normally include dikes with 2:1 slopes (which are assumed to exist at all baseline case ponds). Costs of dikes for new ponds are attributable to RCRA, as are the costs of new dikes (3:1 slopes) around overburden in floodplains, and for modifying existing pond dikes in wetlands and floodplains to 3:1 slopes.

Unit construction costs used for dike construction and compaction were: $1.26 per cubic meter of dike material to build a floodplain dike around mine wastes (3:1 slopes, 3 meters high, constructed of overburden); and $1.88 per cubic meter to build a tailings pond dike (2:1 slope). The unit cost of dike formation for tailings ponds is based on the baseline case, which includes the cost of fine grading the dike.

Additional costs of $0.51 per cubic meter of dike material are needed to modify pond dikes in floodplains from a 2:1 to a 3:1 slope. These costs are for loading trucks and hauling overburden from the piles to the dike areas. Additional costs of $0.47 per cubic meter are needed for new tailings pond dikes not in floodplain areas. These costs are for hauling and dumping the excavated portion of the pond to the dike area.

The revegetation costs for dikes or for closing tailings ponds and mine waste piles include the cost of fill soil, top soil, seeding, and fertilizing. It was assumed that all of the soil would have to be purchased. When mine wastes are revegetated as an ongoing procedure (e.g., in the Florida phosphate industry), it is assumed that usable soil material could be segregated during mining operations so that only 50 percent of the soil would need to be purchased.

Unit costs of soils and revegetation used in this study are as follows: purchased fill soil (0.45 meters thick) is $3.40 per cubic meter delivered to dike areas, and $23,500 per hectare delivered to overburden piles and tailings ponds for closure; purchased top soil (0.15 meters thick) is $4.12 per cubic meter delivered to dike areas, and $8,800 per hectare delivered to the site for closure purposes. The surface areas used to determine costs, by industry, are shown in Table 8.

Where only the outer slope and horizontal portion of the dike are covered with fill soil and top soil, costs of spreading and compacting the two soils are $1.26 and $1.53 per cubic meter, respectively. The costs increase by fifty percent if both slopes (as on floodplain dikes) are covered with soil. Fine grading of the soil on dikes is costed at $0.69 per square meter. Revegetating, including seed and fertilizer, is costed at $2,500 per hectare. This revegetation cost applies to dikes and the closure of tailings and mine wastes.

(8) <u>Waste Transportation</u>

If NPDES permits are not granted to mines in wetlands, costs must be included for transporting newly generated mining wastes out of those areas. Capital costs include purchasing a front-end loader to load the newly generated mine waste from the piles onto 30-ton trucks. If the front-end loader is used full time for 8 hours a day, 5 days a week, 50 weeks a year, the cost of the equipment per hour is estimated at $52. Trucking of the waste from the mine site to the disposal facility is assumed to be done by a contractor, which makes it an operating cost. The unit cost of trucking is $1.05 per metric ton of waste, including fuel and labor and based on a round trip of 32 kilometers. This distance was assumed for all mines in wetlands except the Florida phosphate industry, which is located in extensive wetlands

TABLE 8

SURFACE AREAS OF NONHAZARDOUS
MINING WASTES BY INDUSTRY MODEL PLANT

Industry	Full life* Mine wastes (hectares)	Full life* Tailings pond (hectares)
Copper	716	NA†
Iron	355	NA
Molybdenum	5.28	NA
Gold	153	0.5§
Lead/zinc	7.73	NA
Phosphate	171	NA
Clay	1.67	2.3
Stone	1.42	Negligible
Sand and Gravel	Negligible	0.8
Uranium	NA	NA

* For model plant half life, values are half the number shown.

† Not applicable; wastes are considered hazardous.

§ Only tailings wastes from mining of placer deposits.

areas. A distance of 64 kilometers was assumed there, bringing the unit cost of trucking to an estimated $1.96 per metric ton of waste.

Other operating costs include labor and fuel to operate the front-end loader. Direct labor plus overhead is estimated at $26.60 per man-hour, and fuel at $6.00 per hour per loader (38 liters of fuel per hour at $0.16 a liter).

The capital costs of transporting tailings wastes include such major items as purchase of a centrifuge (to concentrate the slurry from 30 percent solids to 70 percent solids); a slurry feed pump plus spare; sludge conveying system/hopper; and recycle water tanks. The sum of these items for the clay industry model plant, for example, is about $205,000.

(9) Dewatering Tailings Pond for Closure

In this study, dewatering consists of pumping the free water off the tailings pond and allowing the retained surface water to drain until the ground is stable enough for machinery to work on it. The costs include pumping the water from the pond surface and purchase of a fine-mesh, backwash filter to remove suspended solids. The capital cost of the filtering unit, with pumps and piping, is $25,000. The main operating cost is for electricity (30 mills per kilowatthour) to run the centrifugal feed and backwash pumps.

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