7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.7. TRANSPORTATION

7.1.7.3. LONG-DISTANCE BARGE HAULAGE

Shipping large tonnage commodities by barge can be an effective method of transportation if access points are available and high speed is not important. It is even possible to ship mineral materials a short distance by rail and then transfer the material to barge and still save money over rail haulage alone.

With the deregulation of the barge industry, there has been an increase in competition and a decrease in the number of operators. Those companies still operating have found themselves overequipped for the amount of material that is presently being hauled.

As of January 1984, typical costs for transportation of bulk cargoes have been between \$0.0027 and \$0.0030 per metric ton kilometer, with the average cost being near \$0.0028 per metric ton kilometer.

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.7. TRANSPORTATION

7.1.7.4. LONG-DISTANCE RAIL HAULAGE

The following tabulation gives the average cost, in cents per metric ton-kilometer, for shipping mineral materials from the Mountain-Pacific territorial area (including Denver, CO), to any of the five territorial areas within the continental United States. This information is valid as of January 1984.

AVERAGE SHIPPING COSTS FOR MINERAL MATERIALS, cents per metric ton-kilometer

Material shipped from Mountain-Pacific area	Area destination					
	Mountain-Pacific	Western	South-western	Southern	Official	U.S. average
Metallic ores	2.53	1.04[e]	2.87[e]	NA	NA	2.33
Iron concentrates	1.47	1.04[e]	NA	NA	NA	1.47
Copper precipitates	3.01	NA	NA	NA	NA	3.01
Bauxite ore	2.65	NA	2.91[e]	NA	NA	2.67
Alumina calcine	2.66	NA	2.87[e]	NA	NA	2.66
Nonmetallic minerals[1]	2.94	1.55	2.18	1.96	2.02	2.68
Crushed stone	4.13	NA	NA	NA	NA	4.11
Sand or gravel	2.73	4.75	NA	NA	NA	2.74
Industrial sand	2.54	1.01[e]	1.68[e]	NA	NA	2.54
Refractories	1.83	NA	NA	1.89	NA	1.85
Clay minerals	2.94	NA	NA	1.89	NA	2.37
Fertilizer minerals	3.47	2.65	1.49	2.05	2.25	2.09
Borate, crude	3.39	2.85	NA	1.89	NA	2.67
Sulfur	3.82	3.09	1.99	2.12	2.62	2.34
Gypsum crude	3.30	NA	NA	NA	NA	3.30
Diatomaceous earth	4.31	2.03	2.05	2.31	2.32	2.22
Nonmetallic minerals n.e.c.[2]	2.35	1.84	1.49	1.58	1.47	1.63
Coal	1.87	1.25	1.13	1.30	1.33	1.26

[e]Estimated. NA Not available.
[1]Most nonmetallic ores, except fuels.
[2]Includes agate, crude chalk, lithium, earth or soil, coral, rubidium, graphite, sericite, nepheline syenite, shale, well drilling cores, crude topaz, vermiculite-unexpanded, slag, perlite, cornwall, crystal quartz rock, quartzite, silaceous fluxing ore, silica rock, and zeolites.

Source: 1983 Carload Waybill Sample data collected by Dep. of Transportation, Federal Railroad Administration, Office of Conrail.

For example, copper precipitates traditionally are never shipped out of the Mountain-Pacific area.

To determine the total cost of transporting a specific mineral material, first select the appropriate cost from the tabulation, then multiply that value by the distance, in kilometers, the material is to be shipped, and also by the metric tonnage to be shipped. Finally, divide the answer by 100 to get a value in dollars.

Example: The cost for shipping 100,000 mt of fertilizer minerals from Denver, CO, to a point in the Southern Area, 2,500 km away, is

$$[(2.05¢/mt\cdot km)X(100,000mt)X(2,500km)/(100¢/\$) = \$5,125,000$$

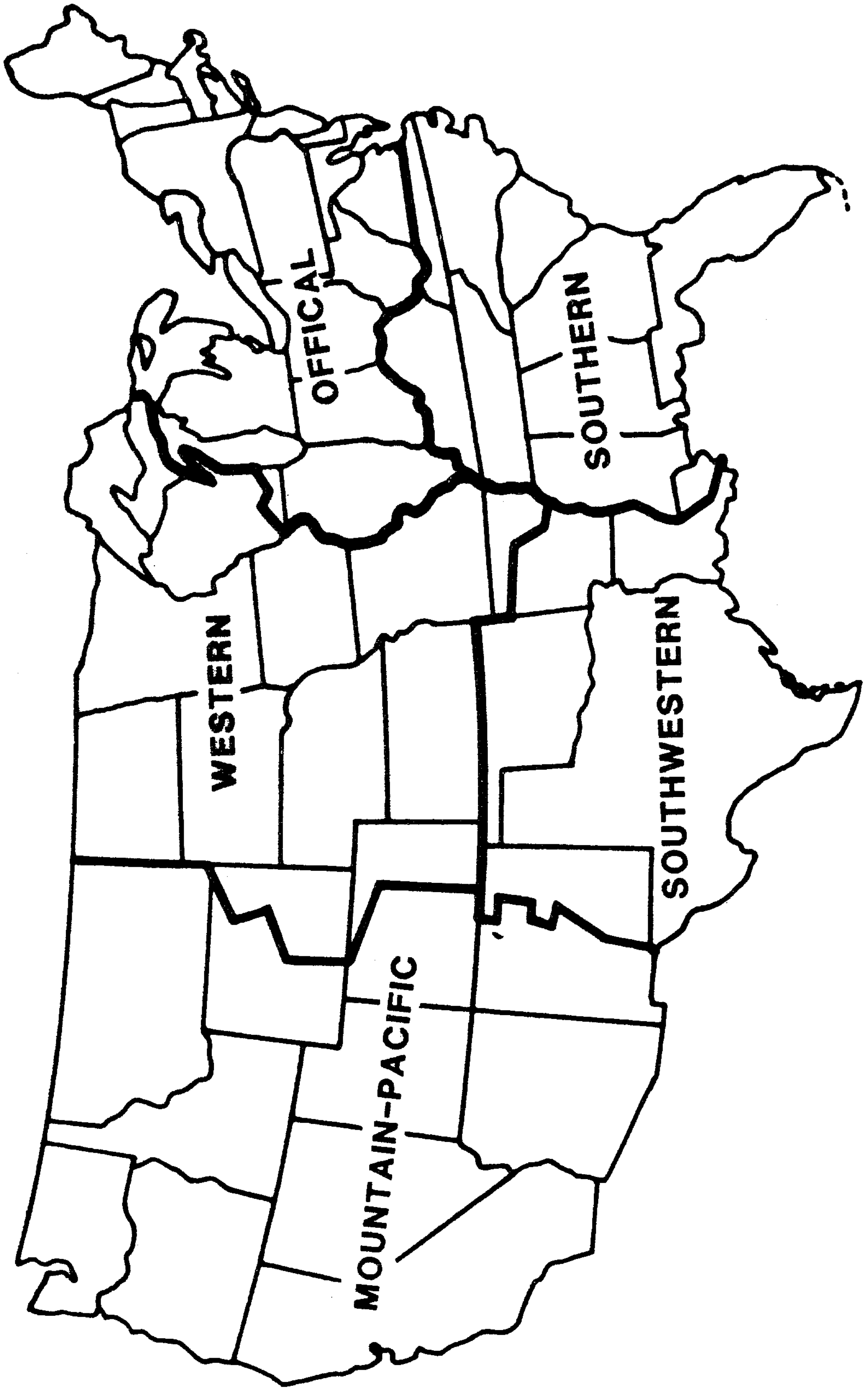
The following map shows the boundaries for the different territorial areas.

To estimate the cost for shipping mineral materials from one point to another, irrespective of territorial zones, use the following equation:

$$Y = [15.359(D)^{-0.275}]/100$$

where D = distance the material is to be shipped, in kilometers,
and Y = cost, in cents per metric ton kilometer.

The resultant answer must be multiplied by the tonnage and the distance it is to be hauled to get a total cost in dollars.


OFFICAL
SOUTHERN
WESTERN
SOUTHWESTERN
MOUNTAIN-PACIFIC

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.7. TRANSPORTATION

7.1.7.5. LONG-DISTANCE SURFACE CONVEYOR

These curves cover the cost of transporting material from the mine via a single-flight conveyor belt reinforced with high-strength steel and cover a capacity range of 15,000 to 150,000 mtpd. The material is conveyed up a 10^{o} slope for a distance of 1 Km. The conveyor availability is 94%. Usually, the material is crushed or screened at the mine site before being conveyed. Screen and crusher costs are not included in this cost but are covered in separate sections.

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons material transported per day. The curves are valid for operations between 15,000 and 150,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with the conveyor operation.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 7.429(X)^{0.464}$
The operating labor costs are distributed as follows:

	Small (15 to 50,000 mtpd)	Large (50,000 to 150,000 mtpd)
Direct labor................	71%	47%
Maintenance labor...........	29%	53%

The direct labor costs consist of the following typical range of personnel:

	Small (15 to 50,000 mtpd)	Large (50,000 to 150,000 mtpd)	Av salary per hour (base rate)
Operator....................	64%	54%	$16.25
Assistant operator..........	36%	46%	13.97

The average wage for labor is $15.32 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.068(X)^{0.933}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 2.226(X)^{0.358}$
The equipment operating cost consists of 95% for repair parts and 5% for lubrication for the idlers and mechanical parts.

ADJUSTMENT FACTOR

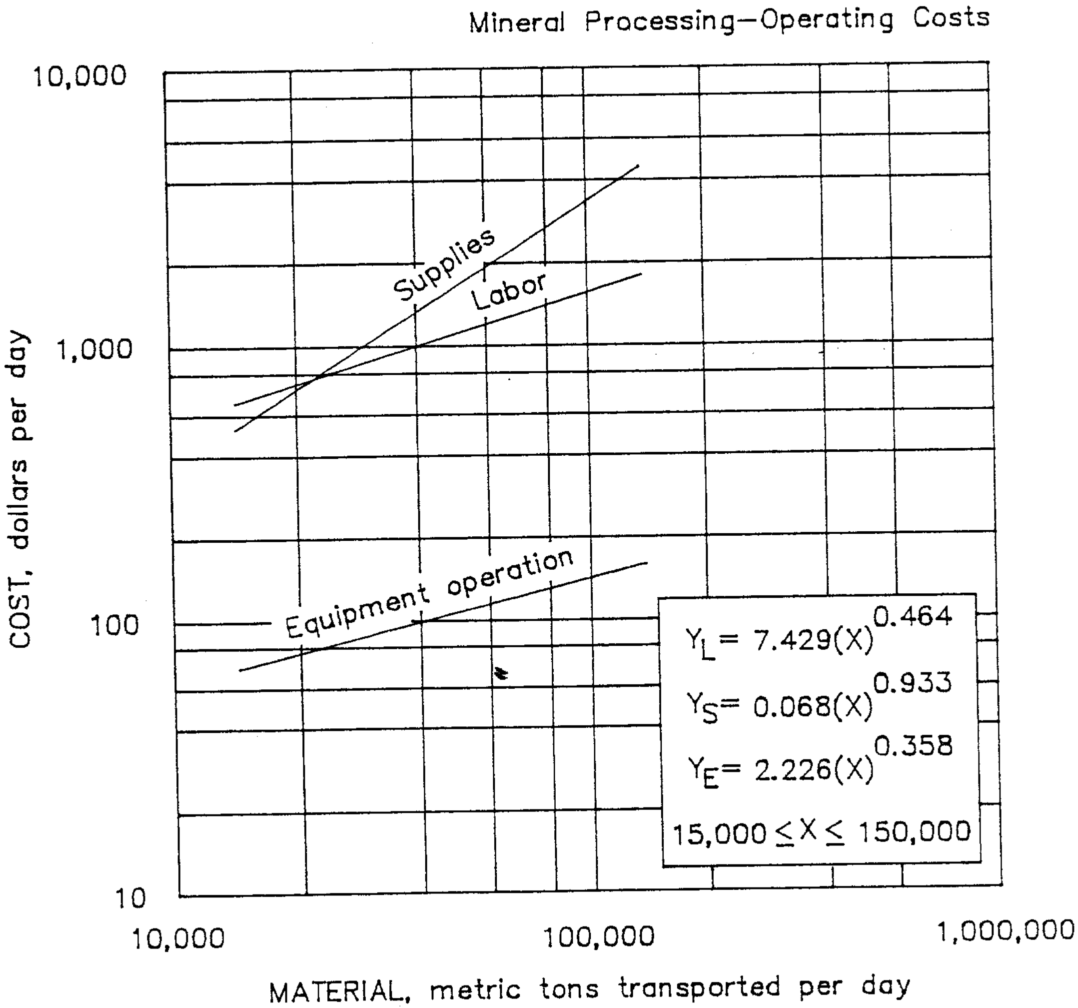
Length and Slope Factor To determine costs for varying conveyor lengths and slopes, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.815+0.190(L)$

Supply factor $(F_S) = [0.208+0.0794(S)][L]$

Equipment operation factor $(F_E) = L$
where L = length of conveyor, in kilometers,
and S = slope of conveyor, in degrees (S is between 0° and 15°).

The cost for a decline conveyor is equal to that for a horizontal conveyor (0° slope).



7.1.7.5. Long distance surface conveyor

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.7. TRANSPORTATION

7.1.7.6. LONG-DISTANCE TRUCK HAULAGE

The trucking industry has undergone intensive change since its recent deregulation. Truck transportation of mineral materials has shifted predominantly away from the class rate system to the bulk commodity method. This has corresponded with a decrease in the number of carriers and an increase in competition. Each carrier now determines his or her own rate and tariff schedules.

Truck transportation costs as shown here cover the transportation of mineral materials by 23 mt rear-dump trucks. The area covered includes the western contiguous United States.

BASE CURVE

The base curve determines costs for the transportation of each metric ton of mineral materials via county-and State-maintained roads with less than or equal to 3% grades. The curves are based on the one way distance (X), in kilometers the material is hauled. The curves are valid for operations between 20 and 200 Km.

(T) Truck transportation $(Y_{T\ 0\%-3\%\ GRADE}) = 0.227(X)^{0.715}$

Costs determined using this curve must be multiplied by the total tonnage to be hauled to obtain the final cost.

When the average grade of road is greater than 3%, but less than 6%, a tariff factor is included with the base curve equation.

(T) Truck transportation $(Y_{T\ 3\%-6\%\ GRADE}) = 0.180(X)^{0.909}$

Costs determined using this curve must be multiplied by the total tonnage to be hauled to obtain the final cost.

When the average road grade is equal to or greater than 6%, a different tariff factor will have to be included with the base curve equation, modifying it to:

(T) Truck transportation $(Y_{T\ +6\%\ GRADE}) = 0.179(X)^{0.963}$

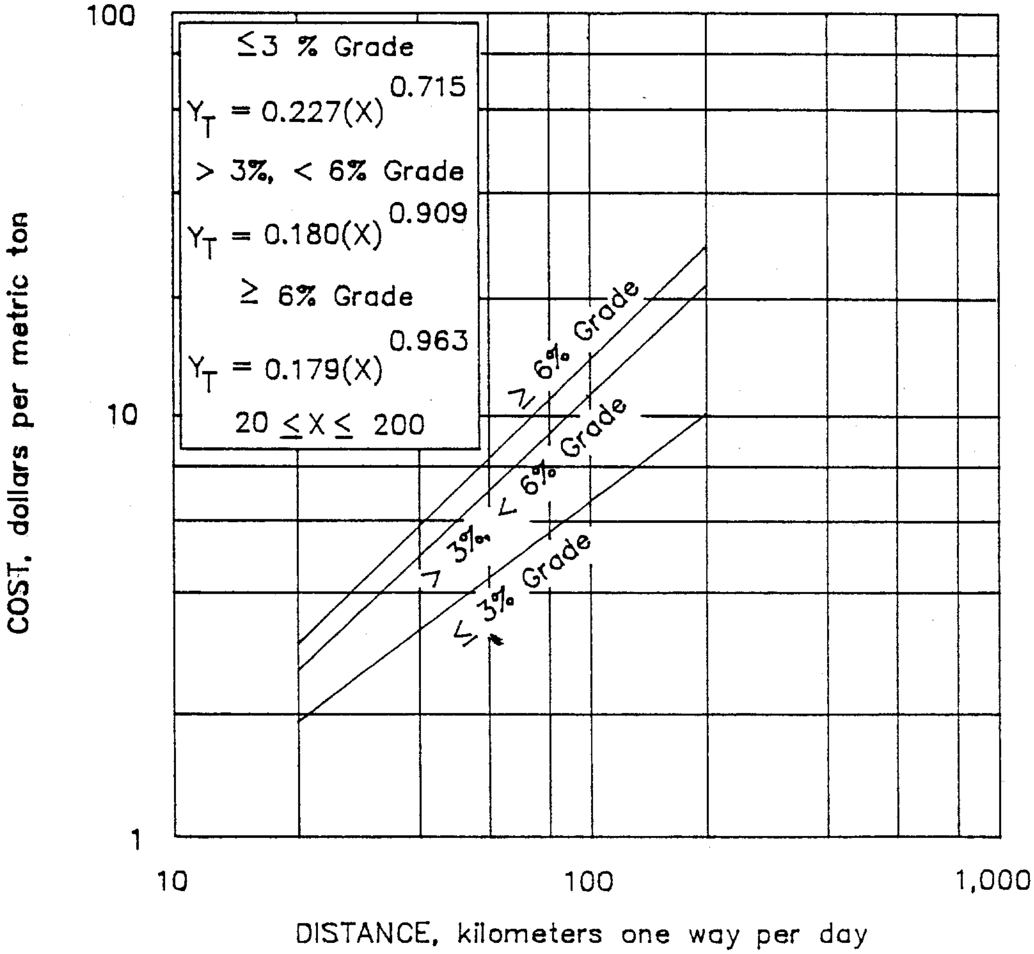
Costs determined using this curve must be multiplied by the total tonnage to be hauled to obtain the final cost.

ADJUSTMENT FACTORS

Long-Term Contract The final values arrived at through multiplying the tonnage by any of the three curves can be reduced by 10% to 20% if long-term hauling contracts are to be used.

Tonnage If trucks with carrying capacities greater or less than 23 mt are used, the cost per metric ton should be modified accordingly.

Mineral Processing—Operating Costs



7.1.7.6. Long distance truck haulage

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.7. TRANSPORTATION

7.1.7.7. MARINE TERMINAL

Costs derived from these curves apply to the operation of a deep-water, export bulk ore marine terminal. Operation cost does not reflect actual terminal charges, but actual costs for railcar or barge receiving, open storage (approximately 10% of the annual throughput), reclaiming, and shiploading.

The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on the terminal facility capacity (X), in millions of metric tons of material per year. The curves are valid for capacities between 0.9 and 16.0 million mt, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 161.474(X)^{1.558}$
The operating labor costs are distributed as follows:

Direct labor................	60%
Maintenance labor...........	40%

The average wage for labor is $15.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 4.792(X)^{2.301}$
The supply curve consists of 50% electric power and 50% fuel.

(E) Equipment Operating Cost $(Y_E) = 178.148(X)^{1.195}$
The equipment operating cost consists of 100% for maintenance repair parts and materials.

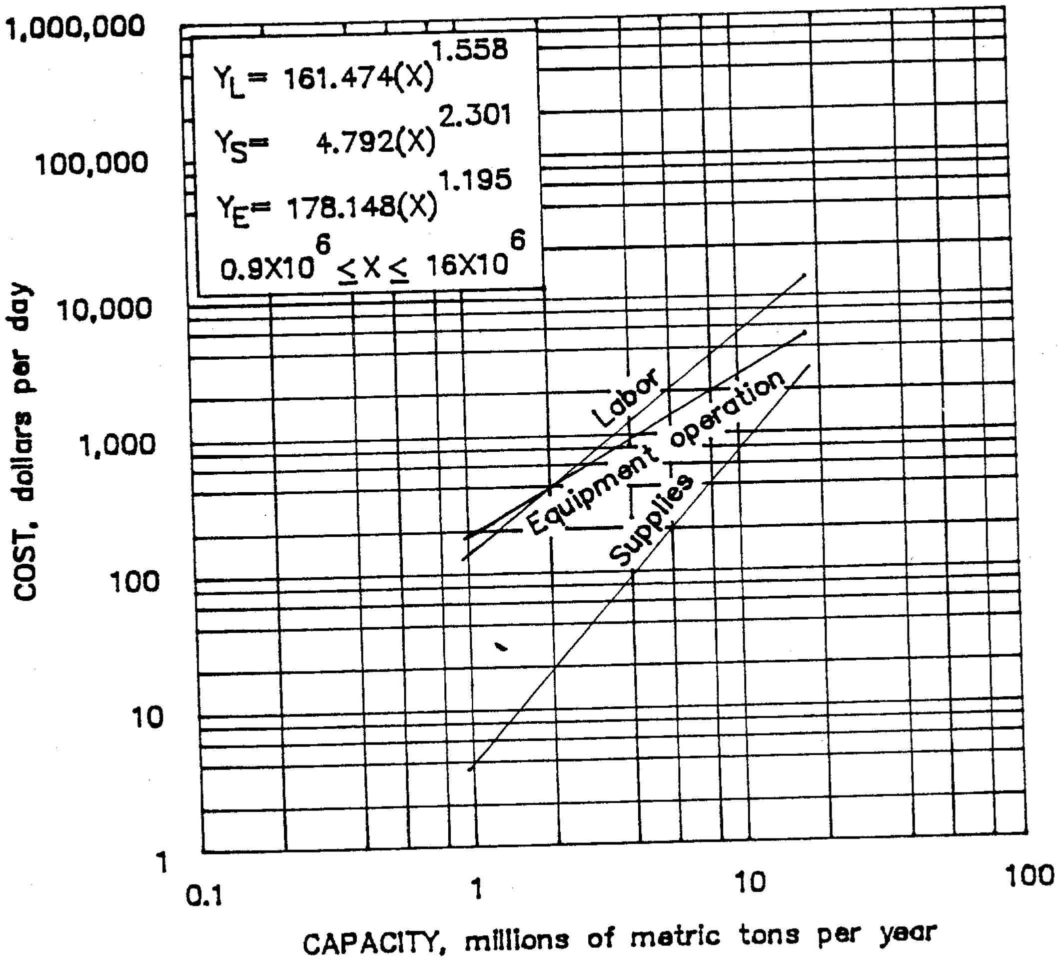
ADJUSTMENT FACTOR

Density (Loose) Factor Lightweight commodities occupy more space and thus require larger handling equipment than more dense commodities. Therefore, an adjustment is required to lower the capital cost for a terminal designed to handle more dense (higher loose density) commodities and to increase the capital cost of a terminal designed to handle commodities of less loose density. To adjust the base curve for differences in weight per unit volume, multiply the costs obtained from the curves by the following factor:

Density factor $(Y_D) = 3.418(D)^{-0.167}$
where D = loose density, in kilograms per cubic meter.

An estimate of loose density can be made from table A-2 in the appendix.

Mineral Processing—Operating Costs



7.1.7.7. Marine terminal

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.7. TRANSPORTATION

7.1.7.8. SLURRY PIPELINE

The operating cost curves for slurry pipeline cover the cost of transporting a slurry. The base curves are based on a slurry pipeline of 10 Km in length with a lift of 150 m pumping solids at specific gravity of 4.3. The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) at an adjusted feed rate (X), in metric tons material transported per day. The curves are valid for operations between 900 and 32,000 mt, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 13.940(X)^{0.445}$
The operating labor costs are distributed as follows:

Direct labor................	31%
Maintenance labor...........	69%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Control room operator.......	6%	$17.23
Mill operator...............	49%	16.78
Mill helper.................	15%	13.66
Mill laborer................	30%	11.68

The average wage for labor is $15.11 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 4.259(X)^{0.676}$
The supply cost consists of 89% electric power and 11% lime.

(E) Equipment Operating Cost $(Y_E) = 3.652(X)^{0.458}$
The equipment operating cost consist of 100% for repair parts and materials.

ADJUSTMENT FACTORS

Slurry Pipeline Lift Factor The base curve was calculated for a slurry pipeline with a lift of 150 m. To adjust for different slurry pipeline lifts, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.00163(L)+0.755$

Equipment operation factor $(F_E) = 0.00104(L)+0.844$
where L = lift, in meters.

Slurry Pipeline Length Factor The base curve was calculated for a slurry pipeline of 10 km in length. To adjust for different slurry pipeline lengths, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.0026(P)+0.974$

Supply factor $(F_S) = 0.0172(P)+0.828$

Equipment operation factor $(F_E) = 0.011(P)+0.890$
where P = length of pipeline, in kilometers.

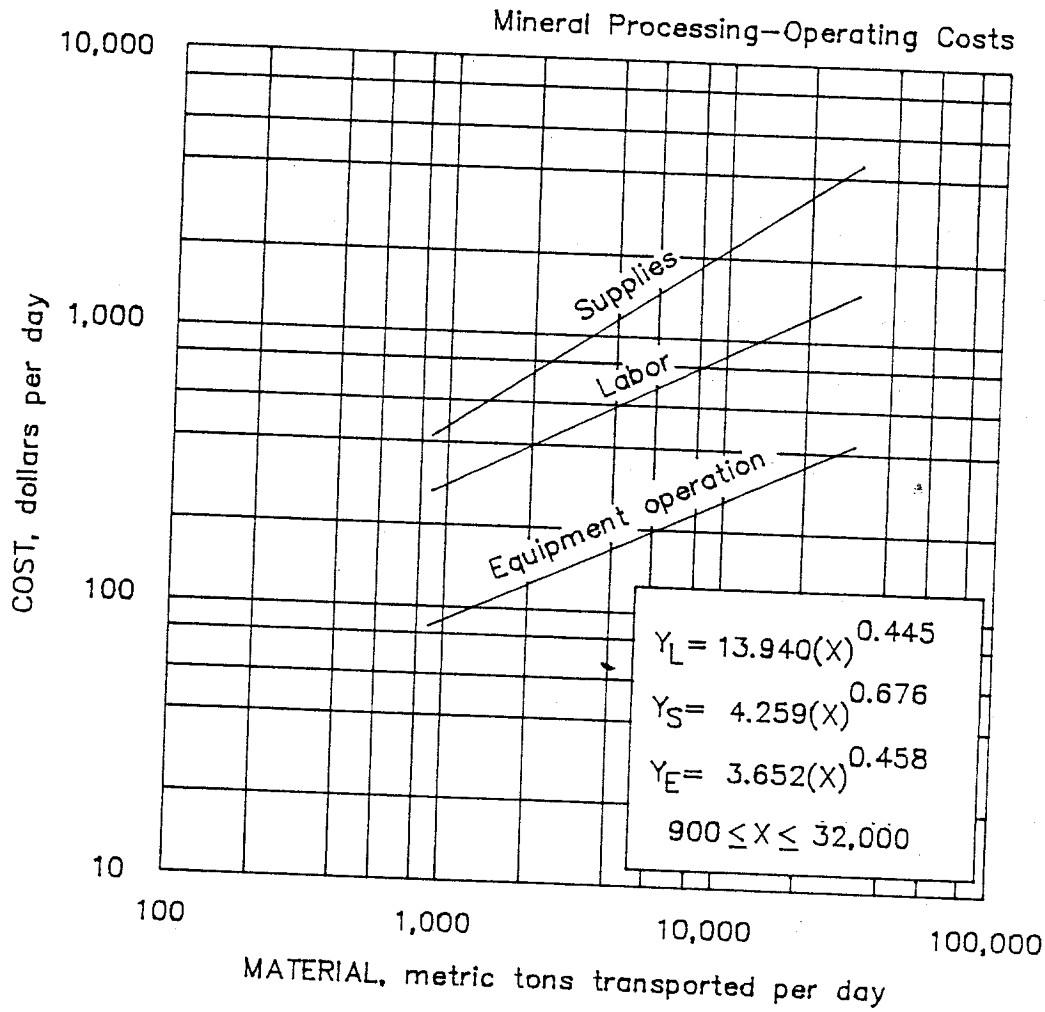
An estimate of average pipeline lengths can be made from table A-3 in the appendix.

Specific Gravity Factor The base curve was calculated for a slurry pipeline pumping solids with a specific gravity of 4.3. To adjust the base curve for a different specific gravity, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.0681(S)+0.707$

Equipment operation factor $(F_E) = 0.074(S)+0.683$
where S = specific gravity of the solids.

An estimate of average specific gravities can be made from table A-3 in the appendix.



7.1.7.8. Slurry pipeline