DESIGN AND LAYOUT OF HAUL ROADS

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The two major functions of haul roads are to promote
(1) efficient transport and
(2) safety.

Haul road design factors must ensure:

1. Minimum costs on a net present value basis for the transport of mineral and waste throughout the life of the mine.
2. A minimum of traffic congestion and the maintenance of safe, ready access to the mining operations.
3. The avoidance of areas where slope stability problems could occur.
4. The use of long-life haul roads rather than short-life roads. This reduces haul road overall construction costs and operating costs as well as reducing the demand for haul road construction materials which may not be available in sufficient quantities from the overburden.

Other factors include the locations of mineral preparation plants, stock yards, external waste dumps, environmental constraints, etc. All these factors direct attention to:

1. Haul road layout.
2. Haul road geometry.
3. Haul road construction materials.

TYPICAL HAUL ROAD LAYOUT

Table 13.4.1. Typical Truck Haulage Costs for Surface Mines

Operation	% of total costs
Strip	7–15
Bench	20–40*
Open pit	30–50

* These figures represent shovel/truck mines. Costs for bucket wheel excavator/conveyor mines are much less.

Strip Mine Haul Layout

Because of the flat aspect of strip mines, the bottom-dump truck is the preferred haulage unit. For gradients greater than 6% (3.5°), however, rear-dump or alternatively unitized trucks may be essential. Careful attention to dips, pavement contours, etc., is therefore needed during layout.

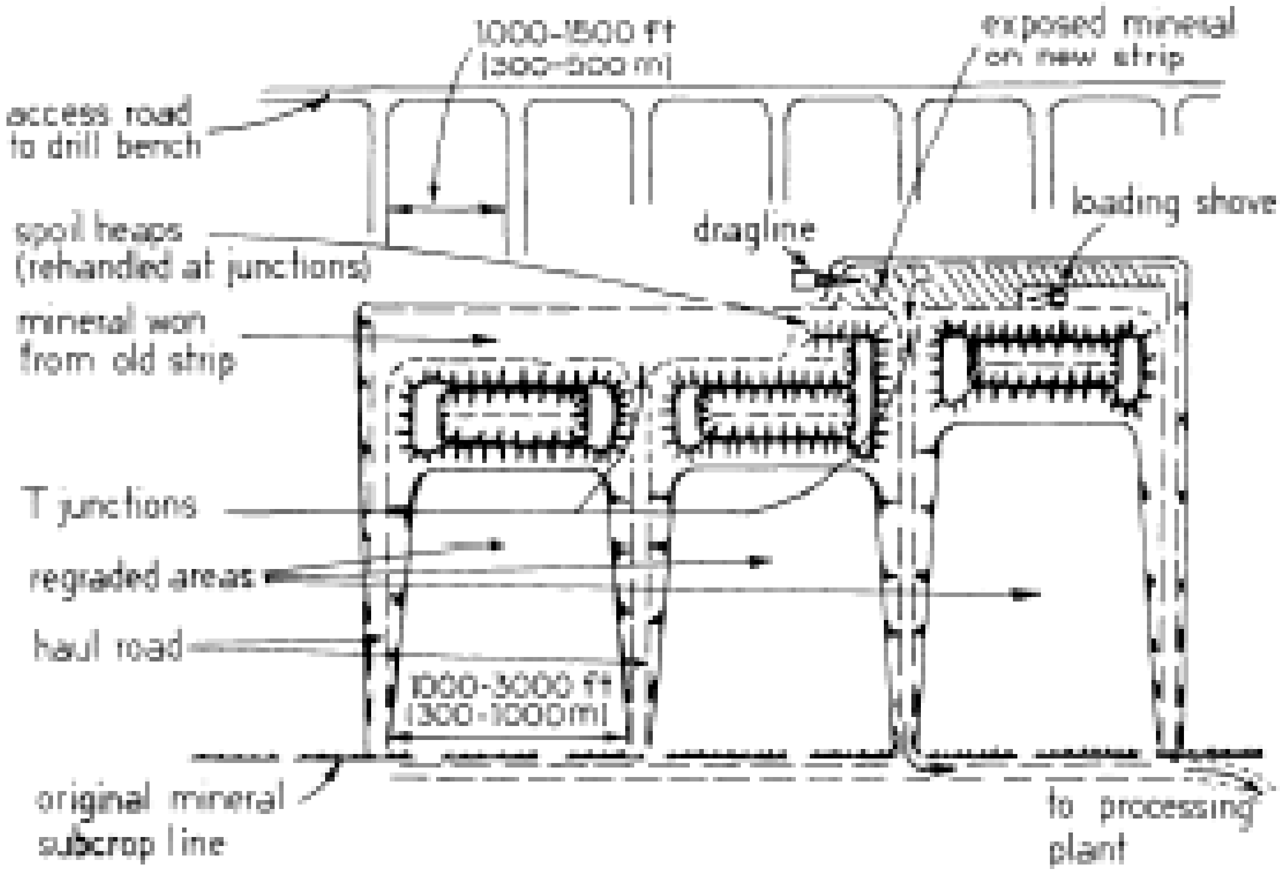

Fig. 13.4.1. Diagrammatic strip mine layout.

Terrace Mine Layout

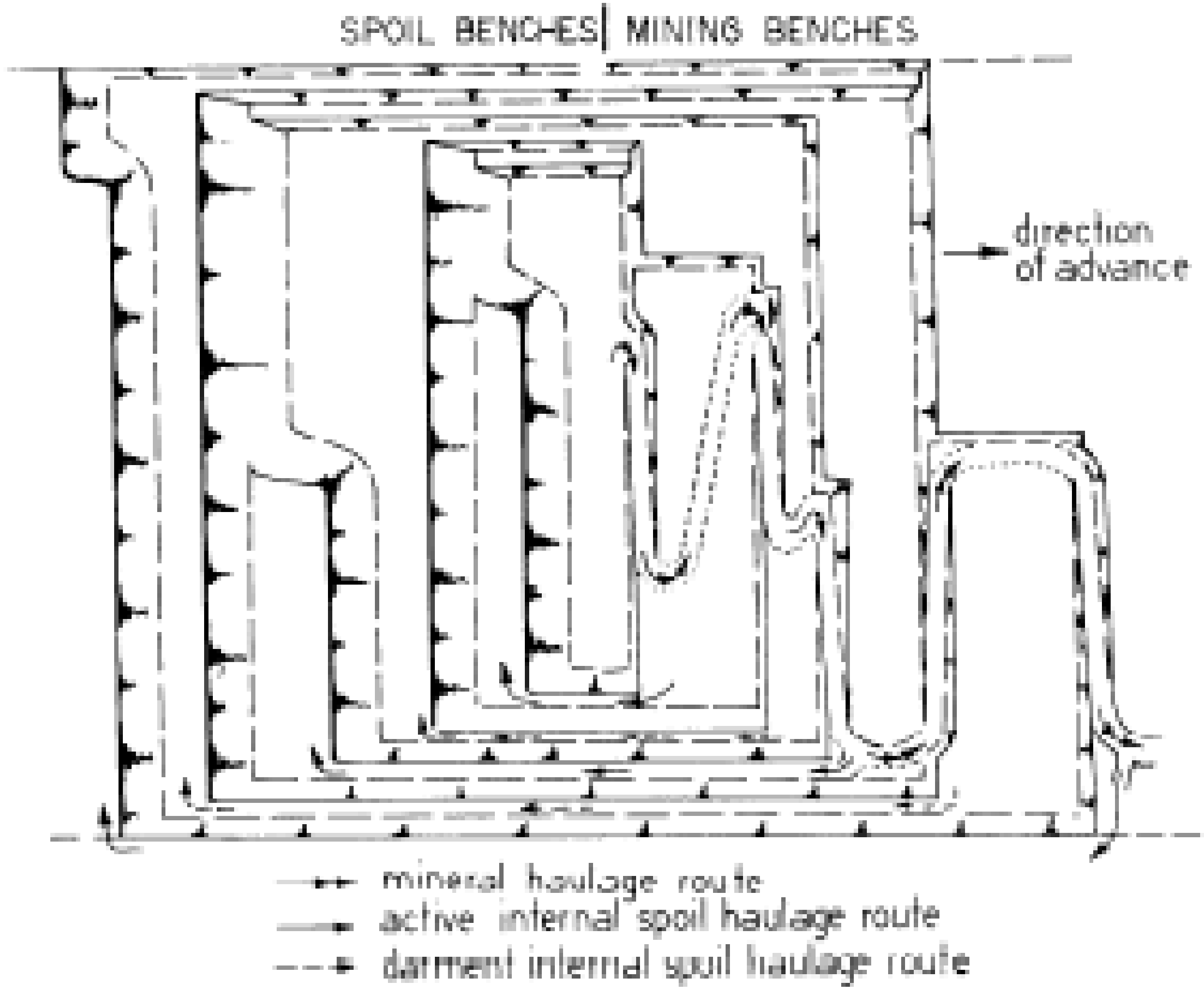

Fig. 13.4.2. Diagrammatic terrace mine layout.

Terrace Mine Haul Road Layout

Shovel/truck terrace mines (Fig. 13.4.2) require major haul road construction, mostly of a temporary nature. Stratiform deposits with dips in excess of 14% (8°), where spoil stability problems could occur if down-dip strip mining is adopted, are increasingly being considered for terrace mining. In general, the strata dips are too steep for efficient truck haulage on the full dip, and it is necessary to form haul roads in the overlying strata.

Open Pit Layout

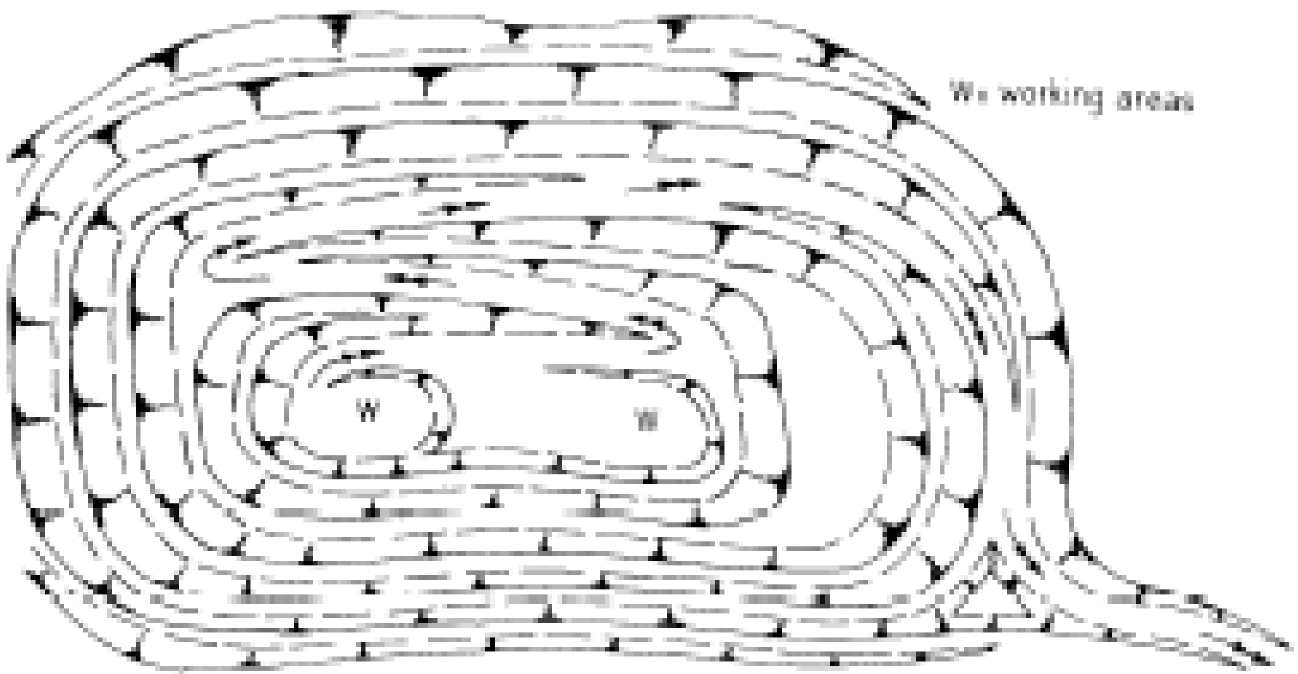

Fig. 13.4.3. Diagrammatic open pit layout with switchback haul road. W = working areas

Open pit Haul Road Layout

The in-pit access haul road (Fig. 13.4.3) may be a clockwise or a counter-clockwise spiral, or a switchback or zig-zag (where the haul road turns back on itself). The main factors deciding the selection of layout are:

1. It may be possible to locate permanent access haul roads on a “tight” side of a pit.

2. In large pits, the haulage distance may be too great if a spiral layout is used.

3. Areas where potential slope stability hazards exist should be avoided, possibly eliminating a spiral layout.

4. The pit walls may be too steep to allow suitable bends to be formed for the switchback layout without greatly increasing the stripping ratio. In this case, the spiral layout would be adopted. Similarly, branching haul roads may exert an influence on the choice of layout.

Open pit Haul Road Layout

Gradients of 8 to 10% (4.5 to 6°) are usually adopted, and rear-dump trucks are the preferred haulage unit, but a 12% grade may be adopted for trolley trucks.

HAUL ROAD GEOMETRY

- Pit roads may be single lane-unidirectional traffic, OR Bi-directional-two lane traffic.
- Haul roads from the pit to external waste dumps, preparation plants, etc., however, may require more than a single lane per direction.
- The number of lanes may be determined from the relation as in next slide:

$$n = \frac{t \, d_b}{550 \, v} \tag{13.4.1}$$

where n is number of lanes for unidirectional travel, v is vehicle speed in mph, t is traffic density in vehicles/hr, and d_b is normal safe distance between trucks in ft. In SI units,

$$n = \frac{t \, d_b}{100 \, v} \tag{13.4.1a}$$

where v is vehicle speed in km/h, and d_b is normal safe distance between trucks in m.

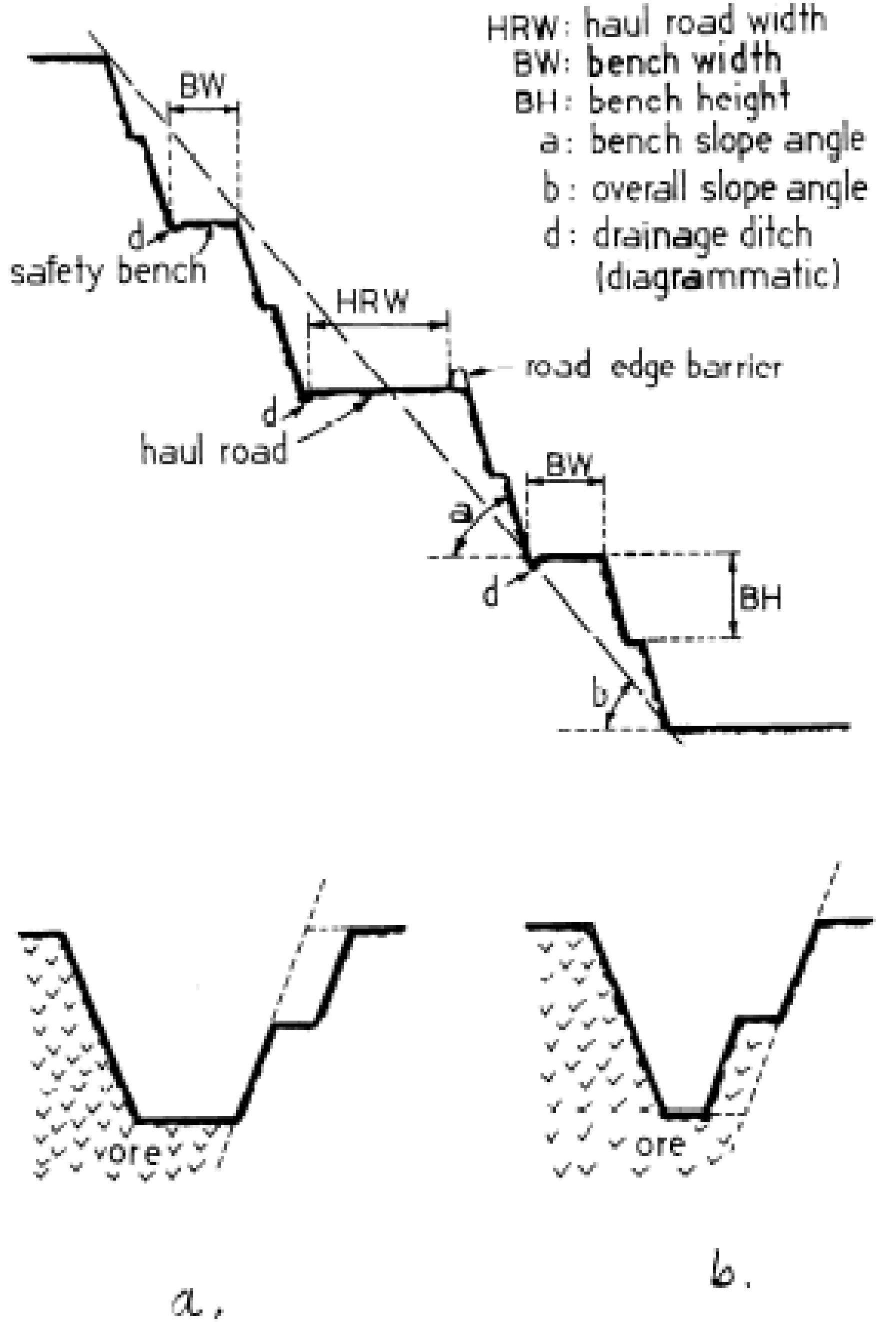

Fig. 13.4.4. Haul road geometric considerations.
a. Haul road outside ore body. b. Haul road in ore body.

- Safe Distance Between Trucks
- The safe distance between trucks depends upon driver reaction time (usually taken as 2.0s), the gradient, and the road surface plus an allowance (usually 16.5 ft or 5 m). The safe distance can be determined from:

$$d_b = \frac{v}{1.08} + \frac{v^2}{91.5\,(C_t \pm i)} \qquad (13.4.2)$$

where C_t is coefficient of traction (less than unity), and i is steepest haul road gradient expressed as a fraction. In SI units, it becomes,

$$d_b = \frac{2.0\,v}{3.6} + \frac{v^2}{254\,(C_t \pm i)} + 5.0 \qquad (13.4.2a)$$

- Haul Road Width
  Can be use typical values as described in table below:

Table 13.4.2. Minimum Haul Road Width

No. of Lanes	Factor × Maximum Vehicle Width
1	2.0
2	3.5
3	5.0
4	6.5

Table 13.4.3. Additional Allowances

	% of Table 13.4.2 (Inside Radius)*		
Vehicle	20 ft (6 m)	150 ft (45 m)	200 ft (60 m)
Rear-dump and unitized Trucks	125	118	110
Articulated trucks	155	135	115

* Percentages for other radii may be interpolated.

Super-Elevation of Haul Roads

- Trucks negotiating tight curves are subjected to an outward centrifugal force, which is opposed by the side friction between the tires and the road surface. Obviously, a good surfacing material is essential on sharp curves, and super elevation of the road surface is normally included in the haul road design. There are practical limitations to super elevation.

Table 13.4.4a. Super Elevation Rates e Expressed in (in./yd)

Truck Speed (mph)	10	15	20	25	30	> 35
Radius (yd)						
5	1.5	1.5	—	—	—	—
10	1.5	1.5	1.5	—	—	—
15	1.5	1.5	1.5	1.8	—	—
25	1.5	1.5	1.5	1.5	2.2	—
30	1.5	1.5	1.5	1.5	1.8	2.2
60	1.5	1.5	1.5	1.5	1.5	1.8
100	1.5	1.5	1.5	1.5	1.5	1.5

Table 13.4.4b. Super Elevation Rates e Expressed in (mm/m)

Truck Speed (km/h)	15	25	35	40	50	> 60
Radius (m)						
15	40	40	—	—	—	—
30	40	40	40	—	—	—
50	40	40	40	50	—	—
75	40	40	40	40	60	—
100	40	40	40	40	50	60
200	40	40	40	40	40	50
300	40	40	40	40	40	40

Haul Road Gradients

- Maximum gradients may be statutorily limited to between 8 to 15% (5 to 8.5°) for sustained gradients, but in general when considering the economics of uphill haulage, as well as downhill safety, the optimum gradient for most situations is about 8% (4.5°) but up to 12% (6.8°) for trolley-assist trucks.
- For safety and drainage reasons, long steep gradients should include 150-ft (50-m) long sections with a maximum gradient of 2% (1°) for every 1500 to 1800 ft (500 to 600 m) of severe gradient.

Safe Sight Distances

Sufficient sight distance must be possible to ensure that a truck can stop when traveling at its operational speed before reaching a hazard.

Road Signs

Road signs should be adequately set

Road Lighting

Lighting is usually provided at crushers, dump points, etc., to improve efficiency, but the level of illumination must be gradually reduced from an illuminated area to a non-illuminated area to help drivers’ eyes to adjust safely to these changes in illumination.

Haul Road Drains and Culverts

Run-off water can create major problems due to washouts, mud slides, and saturation, making provision of drains and culverts essential. The degree of drainage is dependent on rainfall, catchment area, ground conditions, depth of road base, storm water disposal requirements, etc.

V -drains are generally more easily constructed and maintained, and the following features are desirable:

1. Drains should not be excavated in weak spoil (unless lined with flumes).

2. On benches, the cross slope should drain inward with drains excavated along the toe of the slope above. In cuts, drains should be excavated on both sides of the haul road.

3. Where the haul road is constructed on fill materials, drains should be excavated on each side of the embankment.

4. The ground between the edge of the haul road and the drain should be graded towards the drain and must not be obstructed by debris.

5. The sides of the V drains should have slopes of 4:1 where possible, with 2:1 as a minimum.

Table 13.4.6. Culvert Discharge Protection

Discharge Velocity		Slope Angle	
fps	m/s	%	Method
< 3.0	< 1.0	< 10	Divide outlet
< 3.0-10.0	1.0-3.0	> 10	Broken rock mat*
> 10.0	> 3.0	> 10	Divide discharge to broken rock fan

Culverts are required to conduct run-off water beneath and away from haul roads. Culvert location, size, etc., is site specific