

Chapter 1

Managing Earthmoving Operations

Earthmoving may include site preparation; excavation; embankment construction; backfilling; dredging; preparing base course, subbase, and subgrade; compaction; and road surfacing. The types of equipment used and the environmental conditions will affect the man- and machine-hours required to complete a given amount of work. Before preparing estimates, choose the best method of operation and the type of equipment to use. Each piece of equipment is specifically designed to perform certain mechanical tasks. Therefore, base the equipment selection on efficient operation and availability.

PROJECT MANAGEMENT

1-1. Project managers must follow basic management phases to ensure that construction projects successfully meet deadlines set forth in project directives. Additionally, managers must ensure conformance to safety and environmental-protection standards. The basic management phases as discussed in FM 5-412 are—

- Planning.
- Organizing.
- Staffing.
- Directing.
- Controlling.
- Executing.

EQUIPMENT SELECTION

1-2. Proper equipment selection is crucial to achieving efficient earthmoving and construction operations. Consider the machine's operational capabilities and equipment availability when selecting a machine for a particular task. The manager should visualize how best to employ the available equipment based on soil considerations, zone of operation, and project-specific requirements. Equipment production-estimating procedures discussed in this manual help quantify equipment productivity.

PRODUCTION ESTIMATES

1-3. Production estimates, production control, and production records are the basis for management decisions. Therefore, it is helpful to have a common method of recording, directing, and reporting production. (Refer to specific,

equipment production-estimating procedures in the appropriate chapters in this manual.)

PRODUCTION-RATE FORMULA

1-4. The most convenient and useful *unit of work done* and *unit of time* to use in calculating productivity for a particular piece of equipment or a particular job is a function of the specific work-task being analyzed. To make accurate and meaningful comparisons and conclusions about production, it is best to use standardized terms.

$$\text{Production rate} = \frac{\text{unit of work done}}{\text{unit of time}}$$

- **Production rate.** The entire expression is a time-related production rate. It can be cubic yards per hour, tons per shift (also indicate the duration of the shift), or feet of ditch per hour.
- **Unit of work done.** This denotes the unit of production accomplished. It can be the volume or weight of the material moved, the number of pieces of material cut, the distance traveled, or any similar measurement of production.
- **Unit of time.** This denotes an arbitrary time unit such as a minute, an hour, a 10-hour shift, a day, or any other convenient duration in which the unit of work done is accomplished.

TIME-REQUIRED FORMULA

1-5. The inverse of the production-rate formula is sometimes useful when scheduling a project because it defines the time required to accomplish an arbitrary amount of work.

$$\text{Time required} = \frac{\text{unit of time}}{\text{unit of work done}}$$

NOTE: Express the time required in units such as hours per 1,000 cubic yards, hours per acre, days per acre, or minutes per foot of ditch.

MATERIAL CONSIDERATIONS

1-6. Depending on where a material is considered in the construction process, during excavation versus after compaction, the same material weight will occupy different volumes (*Figure 1-1*). Material volume can be measured in one of three states:

- **Bank cubic yard (BCY).** A BCY is 1 cubic yard of material as it lies in its natural/undisturbed state.
- **Loose cubic yard (LCY).** A LCY is 1 cubic yard of material after it has been disturbed by an excavation process.
- **Compacted cubic yard (CCY).** A CCY is 1 cubic yard of material after compaction.

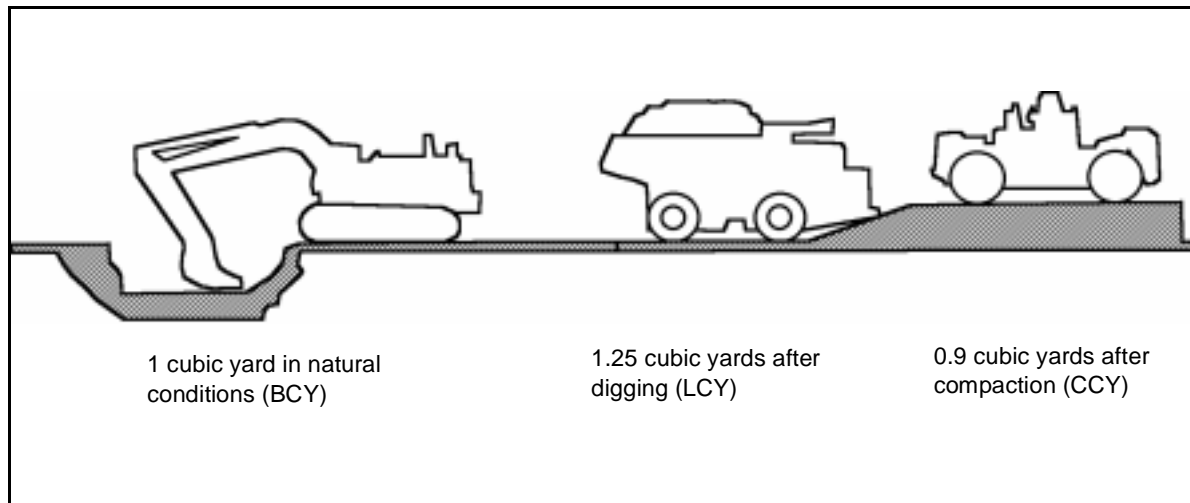


Figure 1-1. Material-Volume Changes Caused by Construction Processes

1-7. When manipulating the material in the construction process, its volume changes. (*Tables 1-1 and 1-2, page 1-4, give material-volume conversion and load factors.*) The prime question for an earthmover is about the nature of the material's physical properties; for example, how easy is it to move? For earthmoving operations, material is placed in three categories—rock, soil (common earth), and unclassified.

- **Rock.** Rock is a material that ordinary earthmoving equipment cannot remove. Fracturing rock requires drilling and blasting. After blasting, use excavators to load the rock fragments into haul units for removal.
- **Soil.** Soils are classified by particle-size distribution and cohesiveness. For instance, gravel and sands have blocky-shaped particles and are noncohesive, while clay has small, platy-shaped particles and is cohesive. Although ripping equipment may be necessary to loosen consolidated deposits, soil removal does not require using explosives.
- **Unclassified.** The unclassified (rock-soil) combination is the most common material found throughout the world. It is a mixture of rock and soil materials.

SOIL PROPERTIES

1-8. In an earthmoving operation, thoroughly analyze the material's properties (loadability, moisture content, percentage of swell, and compactability) and incorporate this information into the construction plan. Soil preparation and compaction requirements are discussed in *Chapter 11*.

Loadability

1-9. Loadability is a general material property or characteristic. If the material is easy to dig and load, it has high loadability. Conversely, if the material is difficult to dig and load, it has low loadability. Certain types of clay and loam are easy to doze or load into a scraper from their natural state.

Moisture Content

1-10. Moisture content is a very important factor in earthmoving work since moisture affects a soil's unit weight and handling properties. All soil in its natural state contains some moisture. The amount of moisture retained depends on the weather, the drainage, and the soil's retention properties. Mechanical or chemical treatment can sometimes change the moisture content of a soil. Refer to *Chapter 11* for information about increasing and decreasing the soil's moisture content.

Table 1-1. Material Volume Conversion Factors

Material Type	Converted From	Converted To		
		Bank (In Place)	Loose	Compacted
Sand or gravel	Bank (in place)	—	1.11	0.95
	Loose	0.90	—	0.86
	Compacted	1.05	1.17	—
Loam (common earth)	Bank (in place)	—	1.25	0.90
	Loose	0.80	—	0.72
	Compacted	1.11	1.39	—
Clay	Bank (in place)	—	1.43	0.90
	Loose	0.70	—	0.63
	Compacted	1.11	1.59	—
Rock (blasted)	Bank (in place)	—	1.50	1.30
	Loose	0.67	—	0.87
	Compacted	0.77	1.15	—
Coral (comparable to lime rock)	Bank (in place)	—	1.50	1.30
	Loose	0.67	—	0.87
	Compacted	0.77	1.15	—

Table 1-2. Material Weight, Swell Percentages, and Load Factors

Material Type	Loose (Pounds Per Cubic Yards)	Swell (Percent)	Load Factor	Bank (Pounds Per Cubic Yard)
Cinders	800 to 1,200	40 to 55	0.65 to 0.72	1,100 to 1,860
Clay, dry	1,700 to 2,000	40	0.72	2,360 to 2,780
Clay, wet	2,400 to 3,000	40	0.72	3,360 to 4,200
Earth (loam or silt), dry	1,900 to 2,200	15 to 35	0.74 to 0.87	2,180 to 2,980
Earth (loam or silt), wet	2,800 to 3,200	25	0.80	3,500 to 4,000
Gravel, dry	2,700 to 3,000	10 to 15	0.87 to 0.91	2,980 to 3,450
Gravel, wet	2,800 to 3,100	10 to 15	0.87 to 0.91	3,080 to 3,560
Sand, dry	2,600 to 2,900	10 to 15	0.87 to 0.91	2,860 to 3,340
Sand, wet	2,800 to 3,100	10 to 15	0.87 to 0.91	3,080 to 3,560
Shale (soft rock)	2,400 to 2,700	65	0.60	4,000 to 4,500
Trap rock	2,700 to 3,500	50	0.66	4,100 to 5,300

NOTE: The above numbers are averages for common materials. Weights and load factors vary with such factors as grain size, moisture content, and degree of compaction. If an exact weight for a specific material must be determined, run a test on a sample of that particular material.

Percentage of Swell

1-11. Most earth and rock materials swell when removed from their natural resting place. The volume expands because of voids created during the excavation process. After establishing the general classification of a soil, estimate the percentage of swell. Express swell as a percentage increase in volume (*Table 1-2*). For example, the swell of dry clay is 40 percent, which means that 1 cubic yard of clay in the bank state will fill a space of 1.4 cubic yards in a loosened state. Estimate the swell of a soil by referring to a table of material properties such as *Table 1-2*.

Compactability

1-12. In earthmoving work, it is common to compact soil to a higher density than it was in its natural state. This is because there is a correlation between higher density and increased strength, reduced settlement, improved bearing capacity, and lower permeability. The project specifications will state the density requirements.

SOIL WEIGHT

1-13. Soil weight affects the performance of the equipment. To estimate the equipment requirements of a job accurately, the unit weight of the material being moved must be known. Soil weight affects how dozers push, graders cast, and scrapers load the material. Assume that the volumetric capacity of a scraper is 25 cubic yards and that it has a rated load capacity of 50,000 pounds. If the material being carried is relatively light (such as cinder), the load will exceed the volumetric capacity of the scraper before reaching the gravimetric capacity. Conversely, if the load is gravel (which may weigh more than 3,000 pounds per cubic yard), it will exceed the gravimetric capacity before reaching the volumetric capacity. See *Table 1-2* for the unit weight of specific materials.

NOTE: The same material weight will occupy different volumes in BCY, LCY, and CCY. In an earthmoving operation, the basic unit of comparison is usually BCY. Also, consider the material in its loose state (the volume of the load). *Table 1-1* gives average material conversion factors for earth-volume changes.

LOAD FACTOR

1-14. Use a load factor (see *Table 1-2*) to convert the volume of LCY measured to BCY measured ($\text{LCY} \times \text{load factor} = \text{BCY}$). Use similar factors when converting material to a compacted state. The factors depend on the degree of compaction. Compute the load factor as follows:

If 1 cubic yard of clay (bank state) = 1.4 cubic yards of clay (loose state),

then 1 cubic yard of clay (loose state) = $\frac{1}{1.4}$ or 0.72 cubic yard of clay (bank state).

In this case, the load factor for dry clay is 0.72. This means that if a scraper is carrying 25 LCY of dry clay, it is carrying 18 BCY (25×0.72).

ZONES OF OPERATION

1-15. The relationship of specific zones of operation to various types of earthmoving equipment is significant when selecting earthmoving equipment. A mass diagram graphically depicts how materials should be moved and is a good tool for determining the zones of operation. Mass diagrams are explained in FM 5-430-00-1. There are three zones of operation to consider on a construction project.

POWER ZONE

1-16. In the power zone, maximum power is required to overcome adverse site or job conditions. Such conditions include rough terrain, steep slopes, pioneer operations, or extremely heavy loads. The work in these areas requires crawler tractors that can develop high drawbar pull at slow speeds. In these adverse conditions, the more traction a tractor develops, the more likely it will reach its full potential.

SLOW-SPEED HAULING ZONE

1-17. The slow-speed hauling zone is similar to the power zone since power, more than speed, is the essential factor. Site conditions are slightly better than in the power zone, and the haul distance is short. Since improved conditions give the dozer more power, and distances are too short for most scrapers to build up sufficient momentum to shift into higher speeds, both machines achieve the same speed. Considerations that determine a slow-speed hauling zone are as follows:

- The ground conditions do not permit rapid travel and the movement distance of the material is beyond economical dozing operations.
- The haul distances are not long enough to permit scrapers to travel at high speeds.

HIGH-SPEED HAULING ZONE

1-18. In the high-speed hauling zone, construction has progressed to where ground conditions are good, or where long, well-maintained haul roads are established. Achieve this condition as soon as possible. Production increases when the scraper is working at its maximum speed. Considerations that determine a high-speed hauling zone are as follows:

- Good hauling conditions exist on both grade and haul-road surfaces.
- Haul distances are long enough to permit acceleration to maximum travel speeds.
- Push tractors (also referred to as pushers) are available to assist in loading.

CAUTION

Operate equipment at safe speeds to prevent personal injury or premature failure of the machine's major components. Accomplish hauling operations safely as well as efficiently.