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MAY 1977

Muck Utilization Planning

DEPARTMENT OF TRANSPORTATION ★ UNITED STATES OF AMERICA ★

Urban Transportation Tunneling

a handbook of
rational practices
for planners and designers

prepared for
Transportation Systems Center
by
Haley & Aldrich, Inc.
Cambridge MA 02142

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16. Abstract

This handbook alerts transportation system planners and designers to planning methods which can lead to more efficient utilization of earth and rock materials produced during excavation for transportation tunnels and large excavations. The earth and rock materials produced from tunnel operations are commonly described by the miner's term, "tunnel muck". Tunnel muck has been traditionally treated as a waste product of the construction process. This handbook documents the results of a study of alternative uses for tunnel muck including utilization of muck as backfill materials within the transit project. The suggested utilization procedures are consistent with construction methods and project management procedures.

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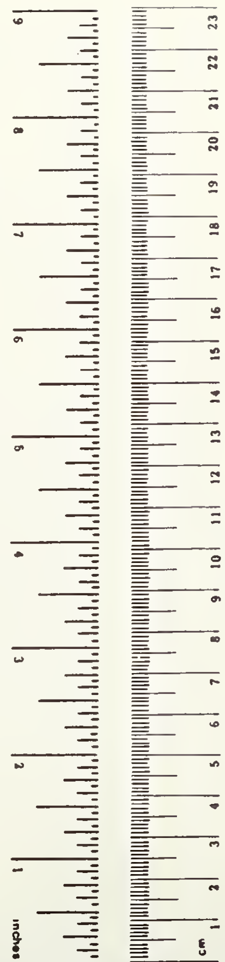
METRIC CONVERSION FACTORS

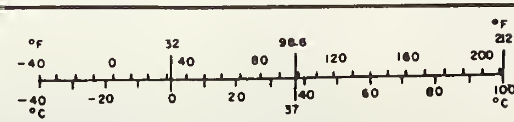
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	metsrs	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	squsre centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square milss	2.6	square kilometers	km^2
	acres	0.4	hectarss	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	scres	
		MASS (weight)		
g	grams	0.036	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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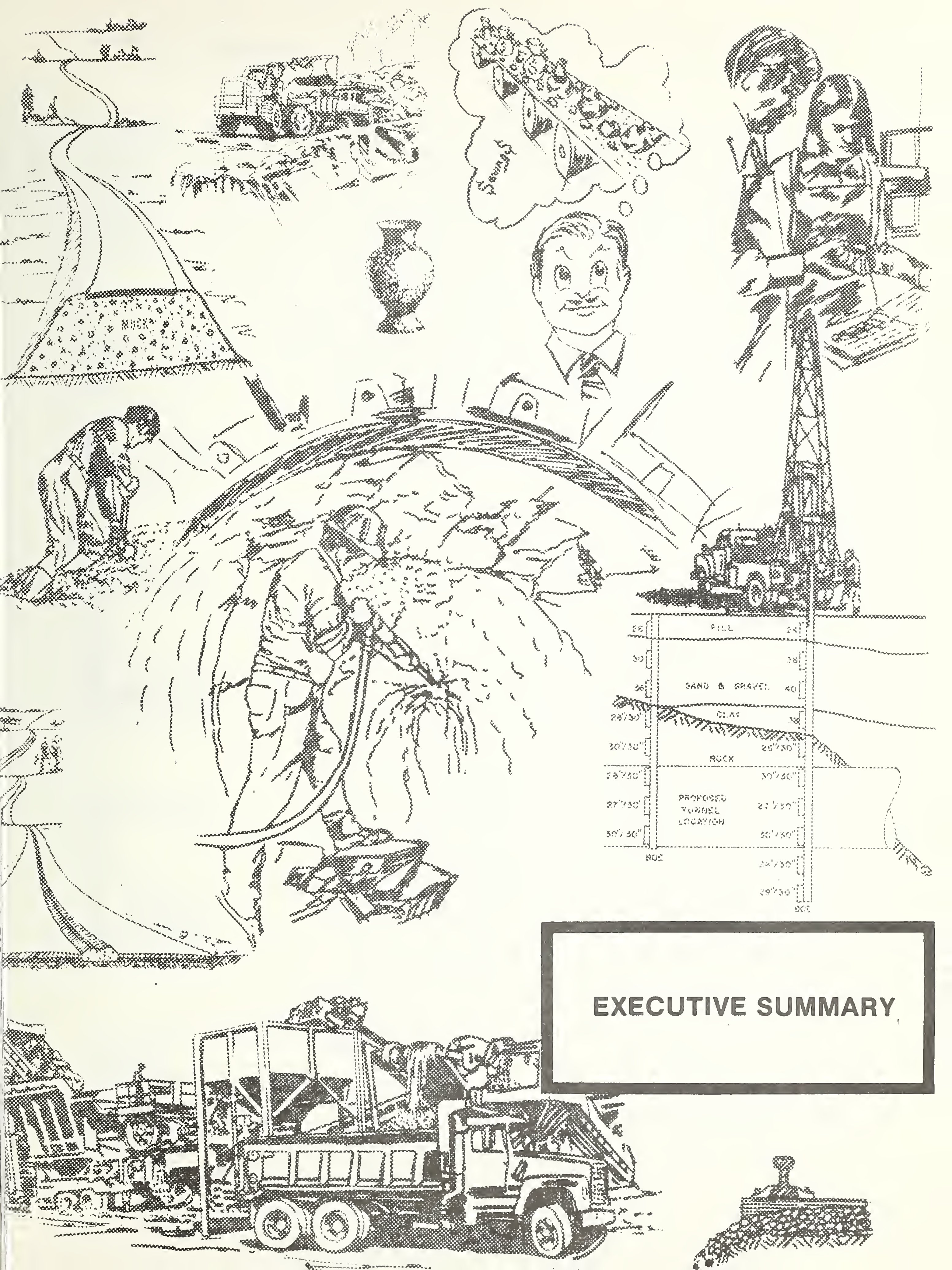
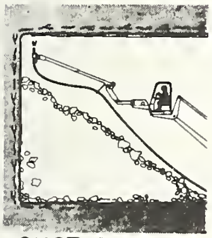


EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

BLASTING

All types of soil and rock materials excavated from tunnels are commonly known by the miners' term "tunnel muck". Tunnel muck produced from construction of urban transportation tunnels has been traditionally treated as a waste product. However, a 1974 study of the properties of muck generated from urban transit tunnel operations indicates that the material has great potential for re-use as an engineering material in transit and other civil works projects.



SHOTCRETING

Potential uses of these soil and rock materials include compacted fill for support of structures, backfill materials, aggregates for roadway base course construction, fill for grading operations, and cover material for sanitary landfills. Some muck is suitable for specialized uses such as manufacture of clay products, bricks, and cement.

This muck utilization handbook alerts transportation departments, transit agencies, city planners, engineers and contractors to the potential uses of soil and rock materials typically encountered in transportation tunnel operations, and provides technical and administrative guidelines for using them to benefit both the transit agency and the public.

MUCKING OUT

Previous methods of handling muck disposal have often led to environmentally unacceptable dumping practices. Establishment of a muck utilization program will help foster public acceptance of the transit program and eliminate delays and conflicts brought on by environmental groups.

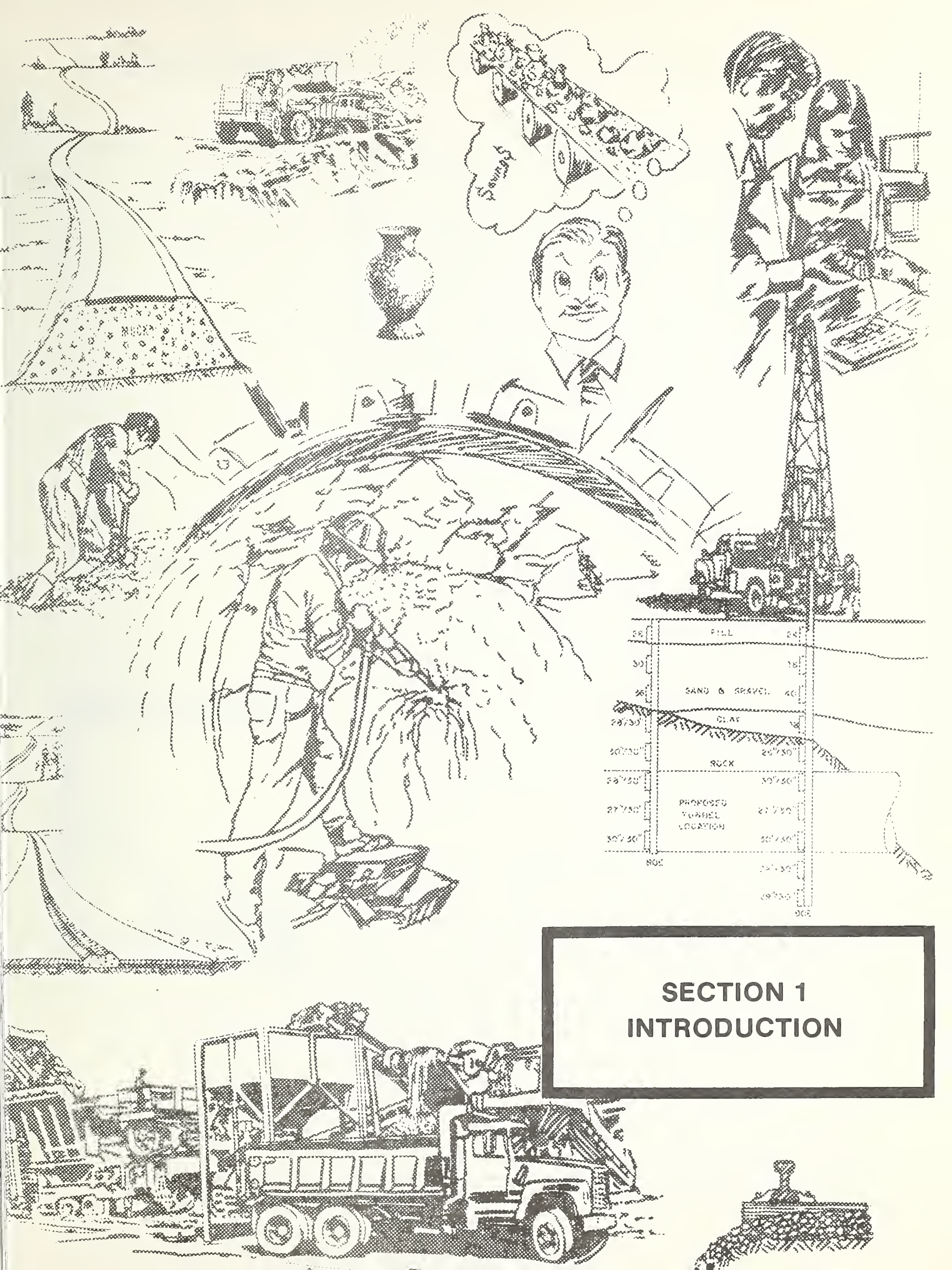
DRILLING AND CHARGING

The key to utilizing tunnel muck is thorough planning. This planning must be accomplished by the transportation departments, transit agencies, engineers and other organizations associated with the initial conceptual planning for the entire project. The knowledge that tunnel muck is a useful by-product rather than a disposal problem will generate interest and plans for utilization. It is important that this interest be stimulated in the early stages of the project so that muck utilization plans will be developed along with other project design concepts.

BLASTING

Technical assessment of the types and quantities of soil and rock materials requires knowledge of the soil profile along the route and an understanding of the tunnel mining process and how that process affects properties of the tunnel muck. This information is normally developed in the design process. General technical guidelines are presented in Sections 2 and 3 of this handbook.

Sections 4, 5, and 6 describe a recommended planning process, including the recommendation to assign the planning effort to a designated staff group or committee. This committee will complete the technical assessment of muck properties and uses, coordinate utilization plans with the timing of the transit construction program, and produce specification documents to inform the contractor of the utilization plans. The planning committee must realistically assess difficulties resulting from changes in muck properties or unexpected time delays and develop alternative utilization plans. Methods of handling contingency planning are discussed in detail in Section 5.



SECTION 1
INTRODUCTION

SECTION 1—INTRODUCTION

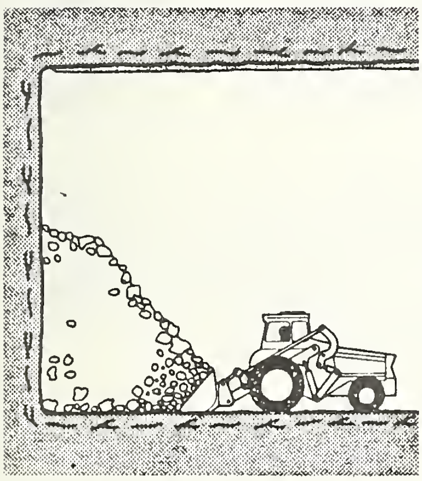
GENERAL

Traditionally, excavated material (muck) removed from tunnels has been considered to be waste material of little or no value. Its disposal is normally delegated to the contractor. This handbook describes how planned utilization of excavated materials from tunnels can produce both economic and environmental benefits. Economically, the owner profits by re-using or selling waste materials or by disposing of them at a reduced cost compared to the traditional method of disposal. Environmentally, unsatisfactory disposal practices are eliminated, and marginal land areas can be transformed into desirable recreational, housing, industrial, and wildlife preserve areas.

This handbook presents guidelines to help agencies plan and implement programs to utilize muck removed during tunnel excavations. A muck utilization planning effort should become an integral part of the overall planning effort necessary for the development of a transit system involving major excavations.

TUNNEL MUCK - WHAT IS IT?

Tunnel muck is traditionally defined as all material removed from a tunnel during the construction process. For this study, the definition has been expanded to include excavated materials from cut and cover tunnel construction as well as excavated materials from station construction. It includes soil or rock materials and construction debris. Soil or rock material forms the largest percentage of the muck and can vary from soft clay or inorganic silt to the hardest of granite. Debris includes discarded equipment and materials used for construction, such as concrete, wood or steel. The water content of muck can also vary as a result of groundwater seepage, rain, or water from construction equipment.



Tunnel construction is usually divided into either soft ground or hard ground classifications.

Tunneling through soft ground (gravels, sands, silts, and clays) is usually accomplished using shields which may or may not be equipped with mechanical excavating equipment. Mining can also be accomplished by manpower aided by jackhammers, clay knives, or shovels. Soft ground tunneling methods drastically change the strength, compressibility, and permeability characteristics of the soil. These methods do not normally alter grain size, surface texture, or chemical properties.

Tunneling through hard ground (rock) can be done by either conventional drill and blast methods or by the use of the newly developed tunnel boring machine. Rock fragmentation of drill and blast muck depends largely on drill hole characteristics, amount and type of explosive, blasting pattern, overall geometry, and rock mass characteristics. Typically, the drill and blast muck ranges in size from two feet to fine sand materials, and particles are generally very angular. Tunneling machines produce much smaller sized particles which are typically flat and elongated.

The debris in tunnel muck usually comprises a very small percentage of the total volume. Sources for this debris include in-situ fill and construction materials. A thick layer of fill is common in urban areas due to previous demolition or construction activities. This fill may form a significant portion of the muck, especially in the early stages of a cut and cover project. Construction materials accumulate in the muck as construction proceeds. Some specialized uses of muck require a homogeneous material and are negatively affected by the presence of debris. For these uses, a special screening process may be required.

THE BENEFITS OF MUCK UTILIZATION

Advantages to Owner

Competitive Bidding. The owner, by providing a conveniently located, easily accessible site for disposal of tunnel muck, enables all contractors to bid on an equal basis. Alternative bid items should also be provided to allow for comparison of costs for disposal via the utilization program or disposal by the contractor's methods.

Since major tunneling projects often attract out-of-town contractors, the preplanned disposal program eliminates the practical problem of locating a disposal site in an unknown area. The owner thus reduces the number of contingency items carried by the contractor, thereby reducing anticipated costs.

Community Acceptance. Tunnel construction in urban areas always necessitates temporary inconvenience to the public. Problems often occur when contractors haul muck to a variety of locations selected without regard to community convenience. A well selected muck disposal area can reduce the number of trucks traveling through residential areas, spilling debris on streets or blocking traffic, and thereby minimize public discontent. Additionally, if it can be demonstrated that the muck is being used for the public benefit, for example, in the creation of a park, residents will be more likely to accept the annoyances caused by the tunneling project.

Cost Savings. Utilization of the muck as aggregate, backfill, track ballast, or other use in the transit construction will reduce the volume and total cost of imported materials. Also, the owner may profit from the sale of better quality tunnel muck as a raw material or for use by others as landfill.

Revenue Increases. If vacant land can be improved by filling with tunnel muck to accomodate commuter parking, industry, or housing near mass transit, the transit system will benefit from the increased number of users with access to the system.

Advantages to Contractors

Simplify Bidding Process. Contractors without access to a convenient disposal area can calculate costs accurately without having to consider where or at what cost they will dump this material. The muck utilization plan thus reduces an area of potential loss due to factors beyond the contractor's control.

Permits by Owner. With proper muck utilization planning, the owner will arrange for the necessary trucking or land use permits. Often the time required for bureaucratic processing of permit applications or negotiations for land use can equal or exceed the bidding period. Although the contractor must abide by the permit regulations, he is relieved of the burden of obtaining these permits.

Maximum Utilization of Equipment. Since the location of the muck disposal site is known, the contractor can schedule his equipment to optimum advantage. For example, since site availability will no longer change from day to day, the trucking fleet can be in constant use.

Advantages to Public

Housing Opportunities. Landfills can be used to create areas for housing in urban areas. In many cases the high cost of suitable fill material prohibits land development. Tunnel muck provided at low cost (possibly without charge) can make these housing developments economically possible.

Job Opportunities. Large employment centers can be created on landfills in urban areas.

Recreational Potential. Tunnel muck is recommended as landfill for additional leisure time facilities in urban areas, such as parks and golf courses.

Environmental Improvement. Geotechnically marginal tracts of land which have been used as disposal areas for trash and garbage need no longer be eyesores or

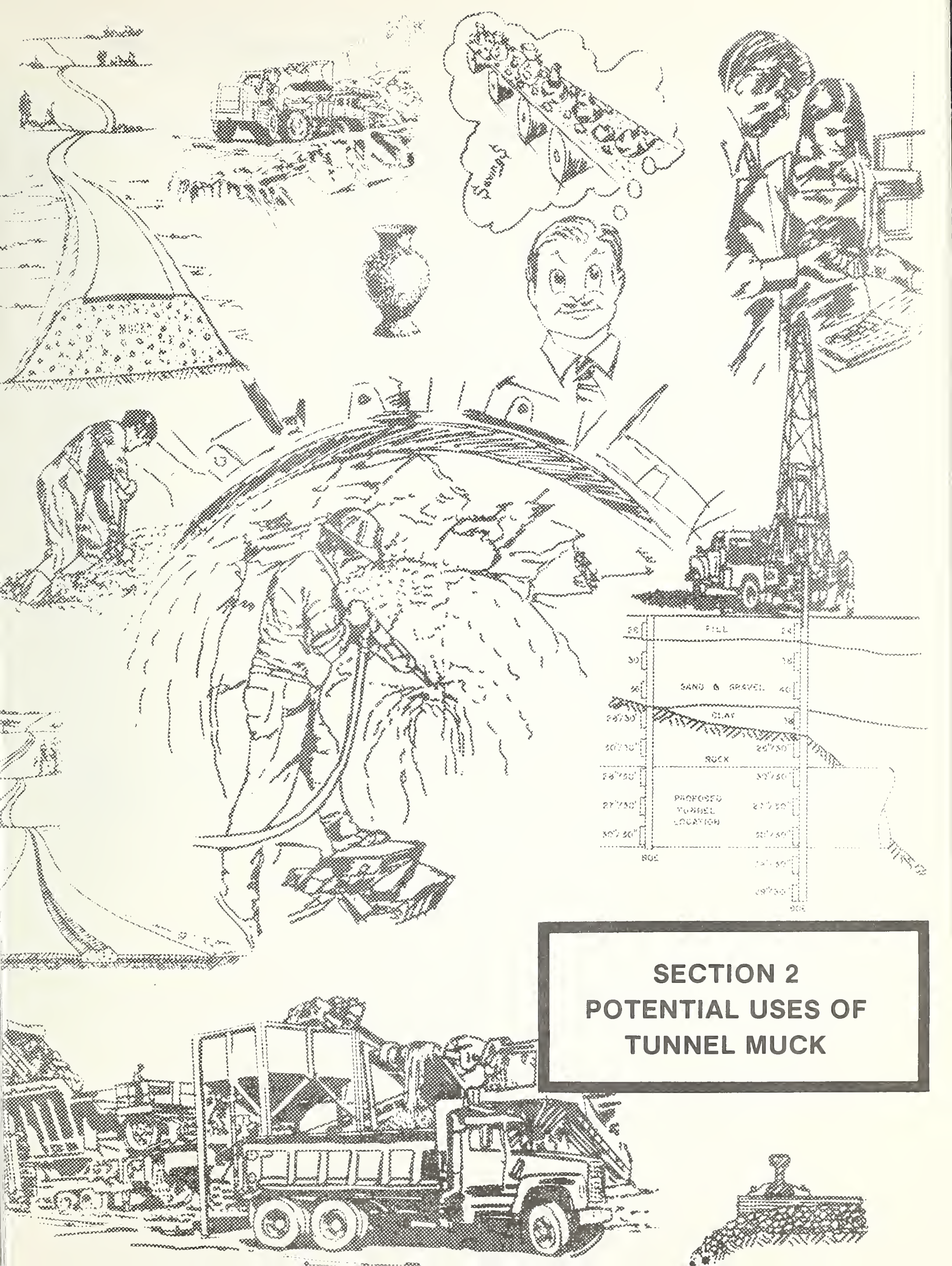
health hazards. Properly filled, these areas can be upgraded to become visually appealing.

Increase of Tax Base. Creating housing or industrial facilities on marginal lands can afford cities and states with substantial revenues from real property taxes, sales taxes, payroll taxes, etc. For example, a 100 acre landfill* could accommodate approximately 2 million square feet of industrial buildings with an approximate value of $30 million. Based on a conservative estimated tax rate of six percent, property taxes would amount to $1,800,000 annually. This same 100 acre landfill site could also accomodate a potential 4,000 employees. If these workers were paid an average of $200 per week, a total annual payroll in excess of $40 million is indicated.

The development of housing (16 units per acre at $20,000 per unit) on this landfill site would yield $1,920,000 in real property tax revenues, based on a six percent tax rate.

Site preparation and placement of rock muck as landfill for apartment complex in New York City

*For 1,600,000 cubic yards of tunnel muck, 100 acres of land can be developed having an average fill height of 10 feet.

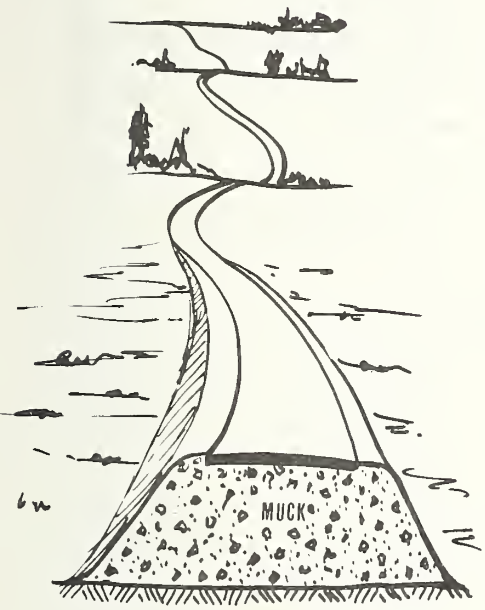


SECTION 2 POTENTIAL USES OF TUNNEL MUCK

SECTION 2—POTENTIAL USES

INTRODUCTION

This section identifies potential uses of tunnel muck materials according to their engineering properties and reviews methods for improving muck quality. The following section presents methods for evaluating muck quality.



The potential uses for tunnel muck can be divided into two major categories: (1) use of muck as a construction material and (2) use of muck as an ingredient in a specialized manufacturing process.

Muck has been and will continue to be used predominantly as a construction material. These uses encompass the entire range of building and earthwork projects including general filling to develop marginal lands, and more specialized uses, ranging from construction of highway embankments to foundation support for buildings and other structures.

The normally stringent requirements on quality and uniformity of raw material in the manufacturing process generally limit the use of tunnel muck in manufacturing. The unpredictable aspects of tunnel construction, related not only to type and quality but also to rate and duration of muck production, are the primary roadblocks to its specialized use. Specialized uses of muck to date have been limited primarily to the production of portland cement, fired clay products and concrete aggregates.

Several examples of muck utilization from completed tunnel projects are shown in Exhibit 2-1.

MUCK AS A CONSTRUCTION MATERIAL

The general civil engineering applications of tunnel muck as a soil or rock material are related to the soil engineering properties of strength, compressibility and permeability. Material classification, based primarily on particle size (e.g. gravel, sand, silt, clay) provides an initial indication of the suitability of a material for a potential use.

Cohesionless soils, such as sands and gravels, display relatively high strength, high permeability and low compressibility when compared to clays. Sands and gravels, which are relatively high in strength, can be used to support buildings and other structures. Since granular soils have low compressibility, settlement of a properly compacted cohesionless fill material under structure loads will be within tolerable limits. Their high permeability values provide good drainage, both during and after construction. Granular soils are relatively easy to place and compact.

EXHIBIT 2-1. EXAMPLES OF MUCK UTILIZATION

Project Name and Location	Type of Tunnel	Type of Material Excavated	Muck Utilization
Crosstown Wastewater Interceptor, Austin Texas	Sewer	Soft rock	Landfill for buildings
Storm Sewer Tunnel Houston, Texas	Water	Clay and sand	Embankment fill
Sonnenberg Tunnel Lucerne, Switzerland	Vehicular	Sandstone and sandy to clayey marl	Filling of a nearby lake
Railway Tunnel Vancouver, British Columbia	Railroad	Granodiorite rock	Embankment fill for highway
St. Gotthard Tunnel Switzerland	Vehicular	Schist and granite rock	Embankment fill for highway
BART Subway, San Francisco, California	Subway	Soil and rock	Landfill for building sites; BART structure backfill
Fleet Line and Victoria Line Railways, London	Subway	Clay	Quarry fill and brickmaking
Kannon Tunnel, Kitkyushu City, Japan	Railroad	Hard rock	Concrete aggregate

Silt and clay soils, on the other hand, are weaker and more compressible under building loads, and have poor drainage characteristics. The low permeability, however, can be useful when levees or dikes are required to hold out flood waters or as a leachate barrier for a sanitary landfill. These soils can also be used as roadway or structural fills in areas where sands and gravels are in short supply, provided the placement procedure is carefully specified and controlled.

Exhibit 2-2 summarizes the major applications of muck utilization and the suitability of various types of muck for the given uses. The following paragraphs explain and emphasize the information presented in Exhibit 2-2.

Engineered, Compacted (Structural) Fill

Soil and rock materials used to support structures or to construct significant earthwork structures such as earth or rockfill dams must be carefully placed and compacted to assure proper structural behavior. The term "engineered, compacted fill" implies that engineering design and control of material quality and construction methods have been exercised in construction of the fill. After constructing a compacted fill, either to raise the site grade or to replace unsuitable materials, the building foundations can bear in the fill at nominal depths. A recent survey of engineering practice in the New England area indicates that engineered, compacted fill has performed satisfactorily under buildings up to 22 stories in height (2-1).*

The construction of an engineered, compacted fill requires proper design and construction procedures. Specifications for engineered, compacted fill projects generally establish the requirements for: (1) acceptable materials, (2) method of placement, and (3) compaction or density criteria. Thus, structural fills are costly because only select materials are used and because the material is placed in thin layers and thoroughly compacted. Due to cost, a structural landfill would be constructed only at a site for which specific development plans have been formulated.

As Exhibit 2-2 shows, "sand and gravel" tunnel boring machine muck (generally equivalent to a well-graded sandy gravel material) is best suited for use in engineered, compacted fills. Silts and clays are generally unsuitable for structural fill.

Controlled Fill

Controlled fill can be defined as the placement of soil and rock materials to construct a stable embank-

*Numbers in parentheses ( ) indicate entries in the list of references.

EXHIBIT 2-2. MUCK UTILIZATION - SUITABILITY CHART*

Category	Rock Muck**		Soft Ground Muck	
	Tunnel Boring Machine	Drill and Blast	Sand and Gravel	Silt and Clay
A. <u>Construction Material</u>				
Engineered, Compacted Fill	1	2	1	3
Controlled Fill	1	1	1	2
Uncontrolled Fill	1	1	1	1
Sanitary Landfill (cover material)				
(1) Daily cover material	2	3	2	1
(2) Permanent cover material	3	3	3	1
B. <u>Specialized Material</u>				
Bituminous Concrete Aggregate	1	1	1	3
Portland Cement Concrete Aggregate	1	1	1	3
Pavement Base and Subbase Aggregate	1	1	1	3
Track Ballast	2	1	3	3
Lightweight Aggregate	2	2	3	2
Portland Cement	1	2	3	1
Fired Clay Product	3	3	3	1
Riprap	2	1	3	3

Legend: 1 = Excellent
2 = Satisfactory
3 = Poor

Notes: *Based on particle gradation and typical soil engineering properties.

**Muck produced by tunneling machines is more fine grained than drill and blast muck, maximum particle size is usually less than 5 inches.

ment or soil structure conforming to design requirements. The controls on material quality and compaction are not as restrictive as the requirements for engineered, compacted fill for support of structures. More settlement can be tolerated and less strength is required of controlled fill. Examples of controlled fill include construction of highway and railway embankments, trench and structure backfill, and subgrade preparation for parking lots.

Uncontrolled Fill

General landscaping, site grading, backfilling of basements from demolished structures, and construction of surcharges are suitable uses of uncontrolled fill. No significant controls are placed on the filling operations with respect to either type of material or their method of placement. The sign advertising "Solid Fill Wanted" typifies this category of earthwork construction. Any material is suitable for uncontrolled fill, which is often placed unsystematically, with no compaction. Accordingly, engineering properties of uncontrolled fills are poor and unpredictable.

Frequently, uncontrolled fills are placed to upgrade marginal lands for site development. Although miscellaneous uncontrolled landfills are convenient for the hauling contractor and may save money for the project under construction, they may present serious problems for site utilization. The cost saving realized by uncontrolled filling can be more than offset by the increased expense associated with constructing building foundations. For example, uncontrolled rock fill placed over a site can render the site unsuitable for almost all building purposes. Uncontrolled fill for land development is not recommended unless its placement is consistent with definite plans for land use and structure siting.

Sanitary Landfill

Sanitary landfills are used by many urban areas for waste disposal. In this disposal method, trash is dumped systematically over a site in layers of limited thickness. At the end of each day a layer of inorganic soil is placed to cover the trash. When the entire site is filled, the final soil cover layer is placed, graded and seeded.

Tunnel muck can be stockpiled at a landfill site for use as a cover material. Although almost any inorganic soil can be used for cover material, some soils are more suitable than others. Clayey soils provide good barriers for moisture and gas but have poor trafficability. In general, well graded sandy soils with fines are the best cover materials. Boulders should be avoided because they are difficult to compact.

SPECIALIZED USES OF TUNNEL MUCK

As mentioned previously in this section, there are many obstacles to the specialized use of tunnel muck. A summary of major problems follows:

1. Tunnel and trucking contractors, the traditional muck handlers, normally do not have the expertise or the capital to establish a specialized processing plant for refinement of tunnel muck. For an individual construction project, outright disposal of muck is an easier and cheaper procedure.

2. Transit tunnel construction schedules would not permit the introduction of a time consuming muck processing program in the critical path of activities. Thus the tunnel contractor would stockpile the material to satisfy the demands for no lost time. Stockpiling, not processing, then becomes the disposal method for the tunnel contractor.

3. An expensive processing operation must be capitalized for extended periods of time and needs a continuous and long-term supply of raw materials. Tunnel muck is usually not supplied continuously, and the duration of supply is certainly limited.

4. Raw material cost is very often less important than raw material quality in complicated manufacturing processes, and quality of tunnel muck cannot be assured.

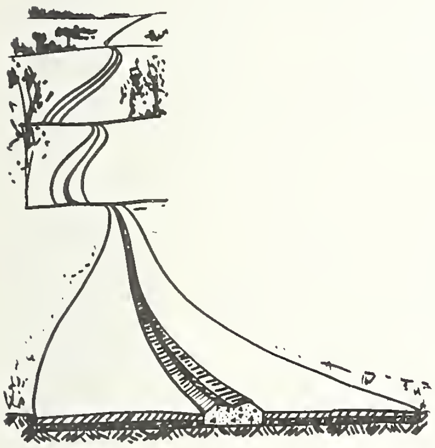
5. Processors find that the debris in muck is an expensive nuisance.

Despite these limitations, specialized use of muck can be a viable and profitable alternative in a particular situation, if the muck can meet all the requirements of the manufacturer.

Many specialized uses of tunnel muck require only moderate processing. Possible uses of clay-based muck include fired clay products such as brick, clay pipe, and lightweight aggregate. It may also be used as a raw material in the manufacture of Portland cement. Sand and gravel based muck can be used in highway and airfield subbases, concrete, and bituminous pavement. Crushed stone can be used for all of the sand and gravel uses, as well as macadam and railroad ballast for which an angular material is preferable. Blast rock is suitable for riprap and shore protection. Certain types of tunnel muck can be used in the production of loam.

Bituminous Concrete Aggregate

Asphalt paving mixtures may be produced from a wide range of aggregate combinations. The primary constituents besides asphalt are (1) coarse aggregate, (2) fine aggregate, and (3) mineral dust. The suitability of aggregates for use in paving is determined by particle gradation and shape, resistance to abrasion, soundness, cleanliness and purity, surface properties, and internal friction. Tunnel muck which meets the specified gradation limits can be a suitable source for paving aggregates, particularly since much of the initial crushing of rock is completed during the tunneling process.



Standard gradation specifications have been established, but variations from the standards are usually permitted provided acceptable performance is maintained. Asphalt mix designs are often altered to produce a dense aggregate gradation which improves strength and minimizes use of asphalt. Similarly, standards are also varied to permit the use of local aggregates with satisfactory experience records.

The rock muck produced by a tunneling machine operating in a metropolitan city transit tunnel was used for bituminous concrete aggregate. In order to utilize the muck, the processor had to screen out oversized rock, remove metallic and other types of debris, and crush the remaining material to a maximum size of 1.5 inches. The crushing was required to eliminate the long, thin rock particles characteristic of tunneling machine muck.

Additional crushing of rock muck or screening of sand and gravel muck can also produce acceptable fine aggregate. Natural sand deposits are usually the primary sources of fine aggregate. Once again, the material is screened and washed to remove any construction debris.

Portland Cement Concrete Aggregate

Aggregates for portland cement concrete are divided into two general categories: (1) coarse aggregate and (2) fine aggregate. Coarse aggregate consists of crushed rock, crushed stone, crushed slag, or other approved material such as lightweight aggregate. Fine aggregate consists of natural sand or manufactured sand-crushed rock. Tunnel muck is a potential source for each type of aggregate. Also, since concrete aggregates are normally processed (i.e. crushed, screened and washed), the construction debris normally found in muck would be easily removed. Whenever tunneling or excavation for structures will pass through a geologic deposit such as sound rock or sand and gravel, samples of the material should be tested to determine its suitability for aggregates.

Acceptability tests conducted on aggregates include: gradation, silt content, organic or other undesirable material content, soundness, resistance to abrasion, chemical reaction, and petrographic analysis. The general purpose of the tests is to verify that the aggregates consist of clean, hard, strong, and impermeable particles that are resistant to wear and frost and free from deleterious amounts of organic matter, loam, clay, silt, and weak grains. Also, coarse aggregate should not be long and thin, and sand particles should be nearly spherical and have gritty surfaces.

All types of rock and coarse sand muck can be processed simply by washing and screening to meet the gradation requirements. Thus, little work remains to produce a useful product provided the muck satisfies abrasion, soundness, chemical and other requirements. The tests, such as chemical and abrasion tests, can be completed on soil and rock samples obtained during the subsurface exploration program.

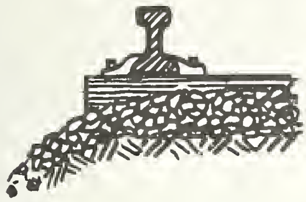
Concrete processors must carefully analyze new sources of concrete aggregate for both physical and chemical acceptibility in portland cement concrete. For this reason, the processors may be reluctant to change aggregate sources once they have established a reliable source.

Pavement Base and Subbase Course

Crushed rock, crushed slag or cinders, and other processed materials are often used as a base course beneath pavements. In heavy duty highway pavements, the material must consist of hard stone which will not break up with repeated cycles of wetting and drying or freeze-thaw. Because of the "kneading" action of wheel loads transmitted through the pavement to the base course, the material must meet abrasion and soundness requirements similar to the requirements for bituminous concrete pavement aggregates. The gradation limits are often flexible in order to allow utilization of locally available materials. Tunnel muck which meets the basic chemical and soundness tests can be utilized for base course materials.

Railroad Track Ballast

Railroad ballast is a high quality structural material. In view of its importance, ballast is almost always made from the highest quality materials available. Crushed stone is preferred because of its higher strength from increased frictional resistance



and interlocking. Ballast generally varies in size from 0.5 to 3.0 inches. Soft, friable and deleterious materials are not permitted.

Hard rock muck is a potential source of railroad ballast. Since ballast must be a processed material, processing normally required of tunnel muck is not an added cost factor. Tunneling machine muck normally contains long thin rock particles which may require secondary crushing to produce the desired shape. Drill and blast muck also require additional crushing. In both cases, however, the initial crushing or blasting is completed during tunneling, reducing the remaining processing work.

Lightweight Aggregates

A variety of methods exists today for the production of lightweight aggregate. Blasting of volcanic deposits yields a natural lightweight aggregate, usually exhibiting very low strength. It is suitable for use in insulating concrete or for manufacture of concrete for masonry units. Tunnel muck which contains certain clays, shales or slates can be expanded or bloated to form a synthetic aggregate which can then be used in concrete for structural members and as lightweight earth fill over highly compressible soils.

Perhaps the simplest method to determine the potential utilization of tunnel muck as a bloating material is to perform a test run in a small stationary kiln. Materials which do not bloat may be improved by blending them with a bloating material or by adding relatively cheap materials which contain the needed gas forming or fluxing compounds. An important criterion to be met in the production of lightweight aggregate is uniformity. A prime cause for nonuniformity is differences in sources of the raw material. It may therefore be necessary that, in addition to the removal of obviously undesirable material such as metal, rock chunks, and wood pieces, clay tunnel muck may have to go through a second screening process to further purify the raw material. As with fired clay products, quality demands required of raw materials for lightweight aggregate production limit the usefulness of tunnel muck for this purpose.

Portland Cement

Muck from either soft ground or hard ground tunneling operations may be used in the manufacture of portland cement, provided the necessary chemical compounds are present in the desired proportionate amounts. The muck or raw material must supply one or more compounds containing lime, silica, or alumina.

A few special materials, such as argillaceous limestone, commonly called "cement rock," contain some proportionate combinations of all three compounds. In some instances where a particular raw material may lack any of the required compounds, supplemental materials of suitable composition may be used to adjust the raw mix.

In addition to lime, silica and alumina, most of the above mentioned materials contain additional substances such as iron, magnesium, alkalines and phosphates. Although iron is a useful ingredient, the other substances, if present in a large enough quantity, may harm the finished product. On occasion, a special preliminary process may have to be employed in the overall manufacturing process to regulate the presence of some of these substances.

Fired Clay Products

The most fundamental properties of clay relative to fired clay processing are plasticity, shrinkage, tensile strength and fusability. Each of these must be carefully analyzed to determine if a clay is suitable for production. In most instances the clay will not be entirely satisfactory, and production trade-offs will be necessary to obtain the most economical procedures. For example, although highly plastic clays improve workability, they also result in the largest amount of shrinkage. Low-plasticity clays are avoided for fired clay production because they either liquefy or crumble within a small range of water content and greatly restrict workability. High tensile strength minimizes warping and cracking during processing and breakage during shipment of the finished product. Impurities such as iron, magnesium, potassium and lime can affect color and strength and can leave deposits inside kilns and dryers, necessitating increased maintenance work.

As a result of the complexity of fired clay processing, manufacturers are concerned with the quality and reliability of the raw clay ingredients. Tunnel muck can rarely meet these two critical requirements.

Other Uses

In addition to the specialized uses discussed above, tunnel muck is suitable for slope protection and riprap and as an ingredient in loam. Other specialized uses of tunnel muck may be developed depending on muck type and the needs of particular industries in the vicinity of a given tunnel project.

<u>IMPROVING THE QUALITY OF TUNNEL MUCK</u>

The concept of "improvement" of tunnel muck includes all processes whereby the raw excavated material is altered, either physically or chemically, permitting it to be utilized in a more productive or specialized manner. The intended use of the muck will dictate both the particular method and degree of improvement.

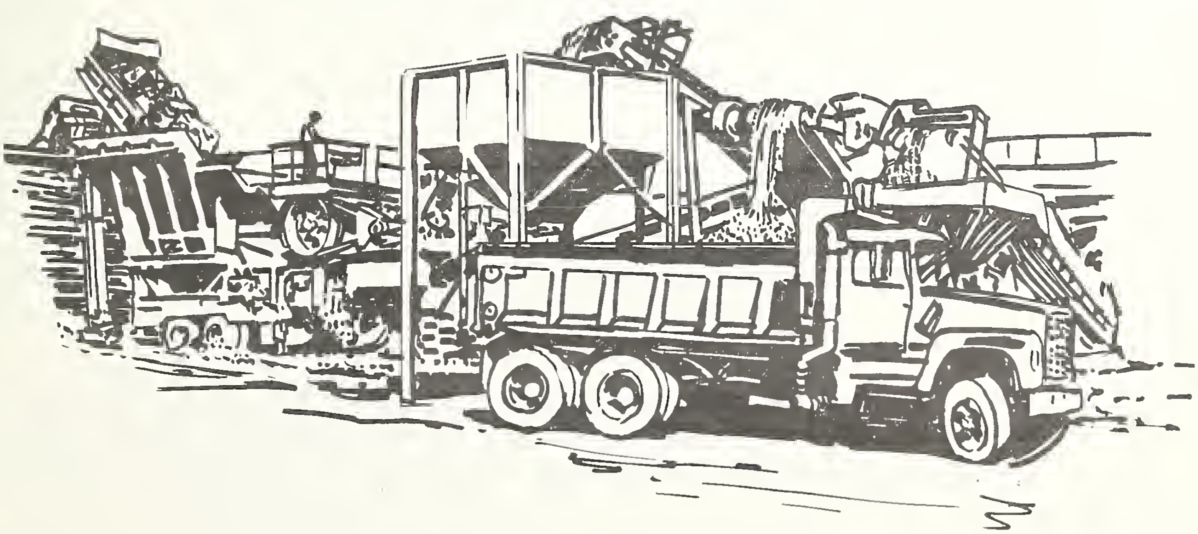
Basic muck improvement techniques which may be easily implemented by the tunneling contractor involve sorting, crushing, screening, and washing. In many instances, there may be an economic incentive to improve the muck characteristics by any of these methods, with the intent of producing a more valuable commodity for commercial sale. All of the improvement techniques are applicable to rock, and sand and gravel based muck, whereas sorting and possibly screening may be used to improve clay based muck. The following paragraphs briefly summarize the basic methods available to upgrade tunnel muck.

Sorting

One of the most basic improvement techniques involves the removal, or sorting out, of unwanted materials from the raw muck. This unwanted material typically represents the debris portion of the muck (e.g. wood, steel, cement bags). Sorting of debris is quite often an essential step when it is desired either to prepare the muck for processing through crushers or to utilize the muck in a controlled type of filling operation. Sorting can be accomplished manually, with magnetic devices or mechanical separators.

Crushing

Excavated rock or sand and gravel that is oversized for a particular use can be reduced in size by processing the material through a crusher machine. Crushing is also an effective means to alter rock texture from smooth to angular. Crushers are classified as primary, secondary, and tertiary, according to the stage of crushing that they accomplish. Material ranging in size from over six inches down to sand particles can be produced from crushing operations.



Screening

The screening process enables the separation of a material into different small size ranges. This operation permits the fabrication of a particular size material which, for example, will meet a required gradation specification. The screening process is also an integral part of the many crushing operations described previously, providing a means for selectively removing certain stone sizes from the muck.

Washing

It is sometimes necessary to remove a film of material from the muck prior to final processing. For example, when excavating a glacial till material, clay or silt films commonly adhere to the larger gravel size particles. Excavation of rock by tunnel boring machines frequently produces a slurry material which can leave film on the rock pieces. A film can also result during the crushing process when dust size particles coat the crushed rock. These films are particularly harmful when the rock is to be used for concrete aggregates in which a good bond is required between aggregate and cement. A common procedure for washing involves jet sprays which direct water over a thin bed of material. This procedure is often performed in conjunction with the screening operation.

IMPROVING TUNNEL MUCK PLACED IN LANDFILL AREAS

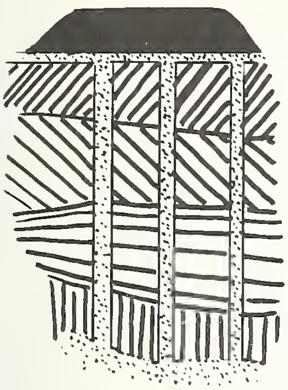
Tunnel muck is commonly used for fill to develop marginal land areas. Depending on the characteristics of the muck and the method of placement, the completed landfill area may or may not be able to safely support structures. A wide range of techniques presently used in the foundation construction industry can improve unsatisfactory landfill areas. The improvement methods have been developed to accomplish one or more of the following:

1. Improve soil strength.
2. Reduce settlement of the fill.
3. Secure a more watertight condition.

Almost all the methods involve some sort of material compaction.

Surface compaction, by rolling or vibrating the surface of the fill with heavy construction equipment, is the least expensive and most common method. Since surface compaction generally is not effective below several feet in depth, it is used to compact each layer of fill as it is placed.

Uncompacted landfills, 10 feet or more in thickness, can be improved by various methods, of which surcharging, with or without sand drains, and vibroflo-

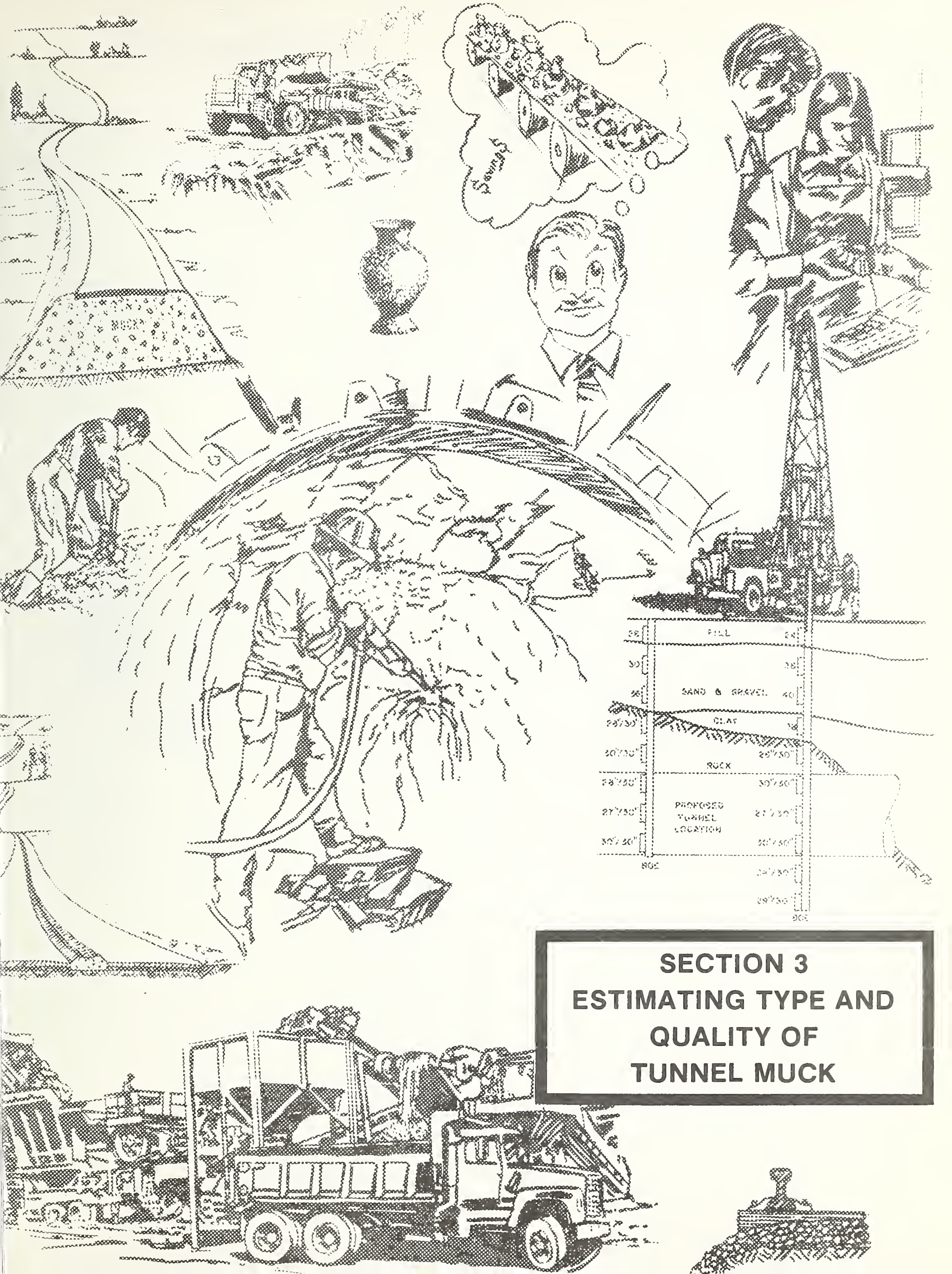


tation are the most common. Surcharging involves placing a temporary earth fill of specified height over the landfill area until settlement observations indicate that the landfill has been sufficiently stabilized. The time required depends primarily on the soil properties of the landfill material, and may range from several weeks to over a year.

Vertical drains such as sand drains, paper drains, and plastic wicks may be used in conjunction with surcharging to accelerate the rate of settlement of soft, saturated soils. Drainage techniques would normally be applied only when the muck or underlying natural soil deposits are saturated so that removal of excess water (or water pressure) will significantly improve the strength and settlement characteristics of the soil.

Vibroflotation has been used extensively to compact relatively deep deposits of loose granular soil. Grain sizes typical of rock muck (obtained from tunneling machines and from drilling and blasting) and sand and gravel muck generally are within the range of materials which can be compacted by vibroflotation. Vibroflotation consists of jetting a vibrator, held by a crane, into the fill to the required compaction depth. The vibrator is then withdrawn at a constant rate, compacting adjacent soil by its vibrating action. The construction industry has recently extended the use of the vibroflotation technique to include compaction of clay and silt materials.

Many other less common, more complicated and expensive techniques are used for compacting loose tunnel muck placed for landfill. These are often required under special circumstances and are accomplished by specialty contractors. Mitchell (2-2) has prepared a detailed summary of soil improvement methods presently used in foundation construction.



SECTION 3
ESTIMATING TYPE AND QUALITY OF TUNNEL MUCK

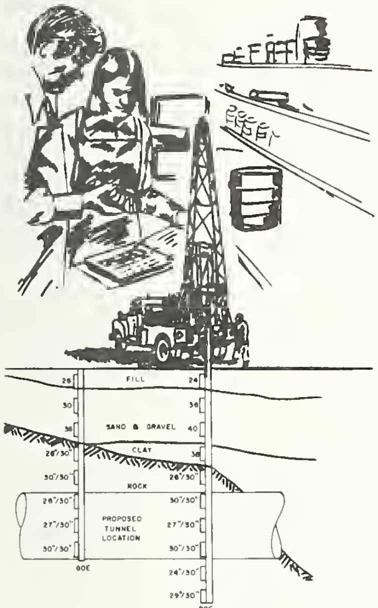
SECTION 3—TYPE & QUALITY

INTRODUCTION

The potential uses of tunnel muck are determined by a thorough geotechnical engineering assessment of the characteristics of the material to be excavated. This assessment is founded on results of subsurface explorations and laboratory testing of soil and rock samples, together with an evaluation of the tunneling methods and the resulting typical muck properties.

LOGS OF SUBSURFACE EXPLORATIONS

Test borings drilled along the tunnel alignment to depths equal to or below the proposed invert level provide nearly all of the subsurface information utilized by the geotechnical engineer to design a tunnel project. The test borings provide samples of soil and rock materials at specified depth intervals. The samples are classified according to soil and rock type, and a log is prepared for each boring which summarizes the various soil or rock strata and groundwater conditions encountered at the borehole location. The basic muck type (rock, sand and gravel, silt, or clay) can be determined from test boring samples obtained at the tunnel depth. Special in-situ borehole testing is generally not required for the evaluation of muck properties.



Due to the length of most tunnels, a variety of soil and rock types are normally encountered in a tunnel excavation. In addition to determining the types of muck to be obtained from the project, an engineer must make an accurate evaluation of the quantities of various types of muck relative to potential utilization. The accuracy of such an evaluation is dependent on the spacing of test borings along the tunnel route. Boring layout is determined by anticipated soil conditions, tunnel design requirements, and the allocated budget for explorations. Test borings are commonly spaced from about 200 feet to over 600 feet.

Large diameter explorations, such as caissons on the order of 3 feet in diameter, are sometimes used in subsurface investigations to provide more detailed information of soil stratification and groundwater conditions and to obtain large diameter samples for laboratory testing. Due to the relatively high cost of such explorations, their use is limited to investigating critical areas on major tunneling projects. Such explorations can be extremely beneficial in determining type and quality of tunnel muck. An augered caisson over 2.5 feet in diameter can be entered to permit logging of soil or rock conditions continuously over the caisson depth. Also, large size samples can be obtained for laboratory testing.

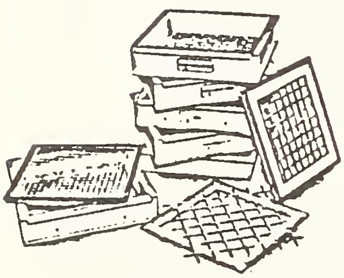
LABORATORY TESTING

Soil Testing

Soil testing programs are usually developed to provide engineering data on the in-situ, undisturbed properties of the soil deposits. Much of these data, including basic "index" and classification tests, can be used directly to evaluate muck characteristics. In addition to testing undisturbed samples, it is recommended that remolded samples be tested in order to model the properties of the muck. Strength, compressibility, and permeability tests should be completed on representative samples.

Rock Testing

Rock testing programs are usually developed to provide engineering data on the in-situ, undisturbed properties of the rock. The basic strength, hardness and unit weight tests conducted on rock core samples are also necessary for prediction of the rock muck properties. Methods useful for predicting the gradation of the rock muck are discussed in the section dealing with tunneling equipment.



Strength and compressibility parameters of rockfill have been determined by laboratory tests on very large test specimens. Triaxial test specimens are prepared in cylinders typically 2 to 3 feet in diameter and 4 to 6 feet high. Smaller samples, about 3 inches in diameter and 6 inches high, have been used to test rock muck from tunneling machines. However, very few laboratories are equipped to handle the large scale tests required for crushed rock samples. It is recommended that estimates of the strength and compressibility of crushed rock samples be determined by comparison with typical data as presented in the literature (3-1).

Standard Acceptability Tests for Aggregate

Sand and gravel or rock muck may be acceptable as aggregates for Portland cement or bituminous concrete. In order to determine the feasibility of these specialized uses, tests must be conducted to evaluate properties such as specific gravity, soundness, scratch hardness, abrasion loss, and reactivity. A petrographic analysis, in which rock samples are examined by microscope or X-ray diffraction, should be completed to determine mineral type, particle shape, and general physical condition of the rock. Large sample volumes, e.g. 25 to 50 pounds, are needed for these tests. Samples may be prepared by combining a number of standard soil samples or rock cores, or by obtaining large volume samples in the field.

Other Tests for Specialized Uses

Industries which might utilize certain muck types in production processes have stringent requirements on purity and quality of raw materials. Thorough tests for suitability are generally conducted by the manufacturer and would have to be completed on an individual basis.

Costs of Supplemental Exploration and Testing for Muck Utilization

Costs associated with the supplemental field and laboratory tests will depend on several factors including the extent or thoroughness of the standard design exploration program, soil and rock conditions, and the anticipated use for the muck. If a thorough design exploration program is completed, then a minimum of supplemental tests would be required. In this minimum category, costs for supplemental tests would range from 1 to 2 percent of the standard exploration costs. Similarly, if two or three alternative uses for the muck are investigated, then testing costs will be slightly higher, about 3 to 5 percent of the design exploration costs. If, however, additional field explorations and extensive laboratory testing are required, then the costs will become significant, ranging from 30 to 50 percent of the cost of the subsurface investigation program for the entire project.

It is anticipated that the primary use for muck will fall into the landfill category. For this use, the only data required can be obtained from simple gradation and standard compaction tests. Testing costs will be in the minimum category, ranging from 1 to 2 percent of the boring and laboratory testing costs for the project. As the potential uses increase in number and complexity, then additional testing costs are incurred.

Based on actual costs of explorations and laboratory testing for design of subway tunnels for Washington and San Francisco, the following design program costs are estimated in terms of 1974 dollars: rock tunnel - $10,000 per 1,000 feet; soft ground tunnel - $7,000 per 1,000 feet. Thus, additonal costs for supplemental testing for muck utilization may be roughly estimated from these figures for similar major tunnel projects with appropriate consideration for location, inflation, etc.

EFFECTS OF TUNNELING METHOD ON MUCK TYPE

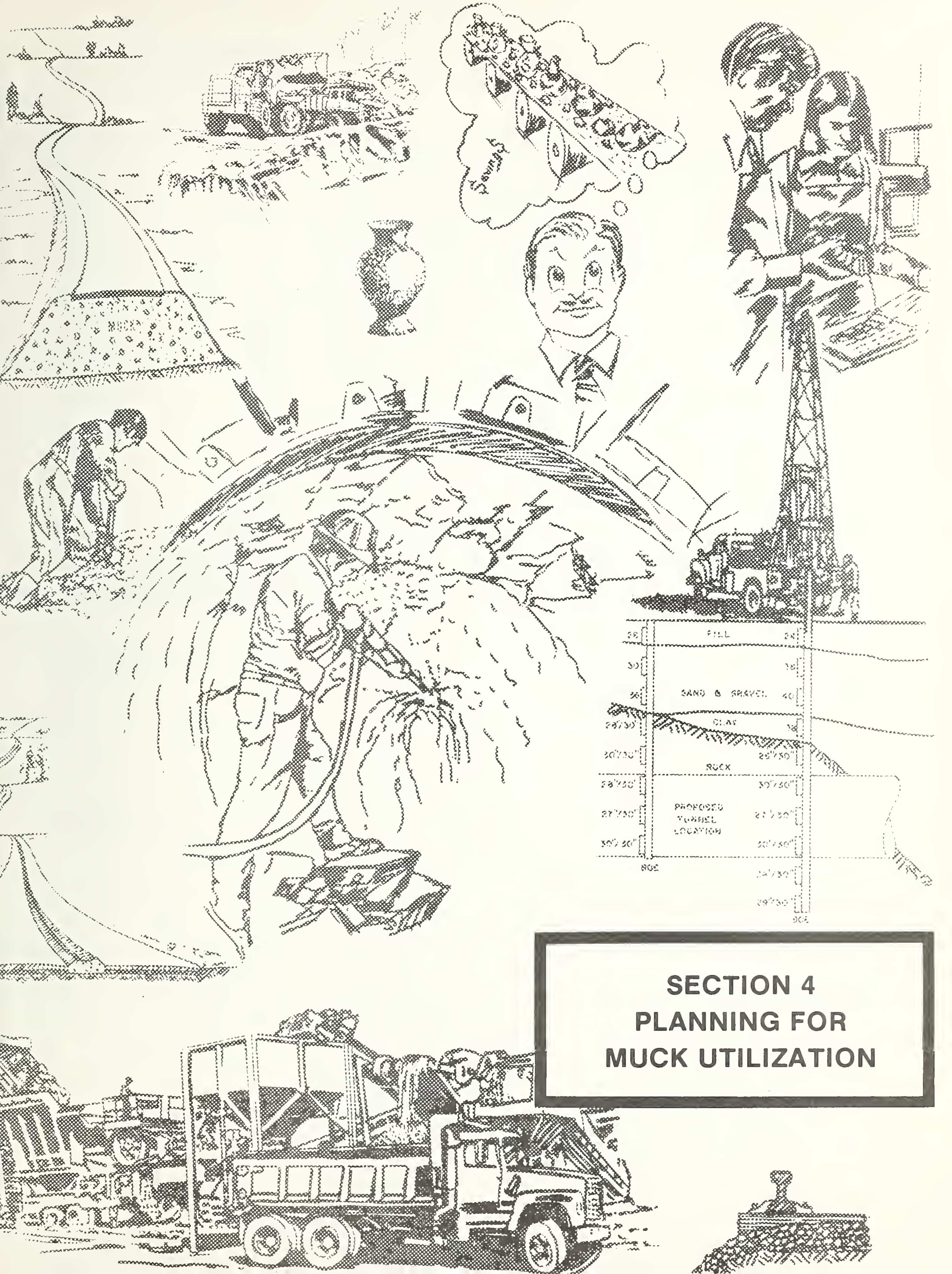
Various methods of excavation may be used to tunnel through different soil and rock materials. The method selected by the contractor will be the most economical available to the particular contractor, consistent with tunnel design and construction requirements. It is not always possible for the engineer to predict the tunneling method in advance, since the choice of method is largely a function of the contractor's experience and available equipment. Therefore, planning for muck utilization should consider muck types that may be generated by several possible construction methods. The following is a short review of the influence of rock tunneling methods on muck properties.

In general, maximum particle size for tunneling machine muck ranges from 3 to 5 inches. The muck consists primarily of coarse to fine sand and fine gravel, with less than 15 percent silt size particles. Tunneling machine rock muck is considered to be cohesionless, with little or no clay material. The type of cutting bit used will affect particle shape and gradation. For example, if mining is done with disc cutters, a larger percentage of coarse particles may be produced than if roller bits were used. Machine thrust is also a factor. A high thrust will cause some crushing of the rock, resulting in smaller muck particle sizes. Also, there is some indication that particle sizes are increased as the rate of machine revolution is decreased. For a particular rock cutter type, the proper thrust and speed will be that combination that provides the best drilling production. Drill and blast muck is coarser than tunneling machine muck and includes blocks as large as 36 inches or more and particles as fine as rock flour. Some silt and clay-sized particles may occur due to either weathered rock areas or fault zones within the rock mass and from crushing of rock around the drill hole. Sound rock masses with few joints tend to generate well-graded muck with reproducible gradation from each blast. On the other hand, jointed or folded rock masses can produce large boulders which involve secondary drilling and blasting.

Drill and blast muck characteristics are determined by the following major factors: drill hole characteristics (size, depth), amount and type of explosive, blasting pattern, overall geometry, and rock mass properties. Due to the number of variables, no method can be assured for predicting the degree of fragmentation or size distribution of blast muck as a function of these variables.

Recently, a technique has been developed which shows promise for predicting grain size distribution of rock muck excavated by either tunnel boring machines or drill and blast methods. The system relates a "Muck Designation Number" (MDN) to a range of grain size distributions (4-1). A predictor equation is used to compute mathematically the muck designation number.

Variables considered include in-situ rock properties and parameters of the excavation system, such as thrust and advance rate for tunneling and powder factor for drill-and-blast techniques.



SECTION 4
PLANNING FOR MUCK UTILIZATION

SECTION 4—PLANNING

INTRODUCTION

This section outlines the planning steps which are recommended in order to develop technically suitable muck utilization plans. The overall planning process is described in Section 6. Muck utilization must be considered during the preliminary design phase so that recommendations can be incorporated into subsequent design decisions. For example, additional field or laboratory tests required for analysis of muck properties should be conducted as an extension of the normal subsurface investigation program. This input from the muck utilization program must be prepared at an early stage in the system design program.

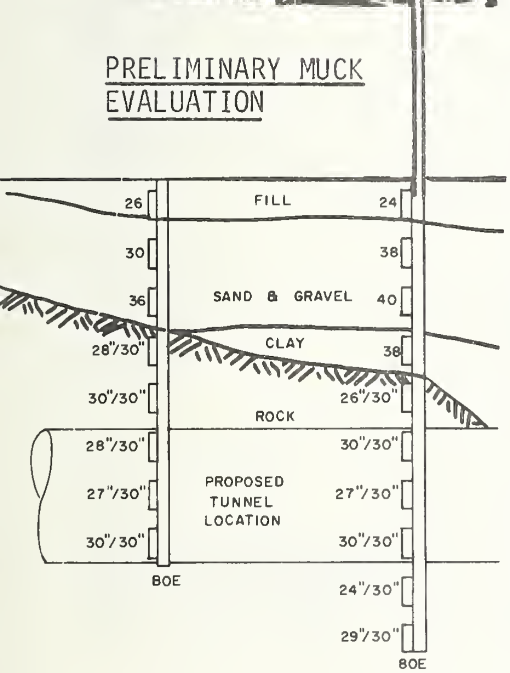
The recommended planning steps are listed in sequence in the following guidelines:

Utilization Guidelines

1. Perform preliminary muck evaluation.
2. Complete subsurface explorations and laboratory testing.
3. Evaluate construction methods and their effect on muck characteristics.
4. Evaluate potential uses for the muck.
5. Make recommendations for muck utilization.

PRELIMINARY MUCK EVALUATION

The preliminary muck evaluation is an important step in the overall muck utilization planning effort. It establishes anticipated potential uses and formulates field and laboratory testing programs.



During the early planning stages for a tunnel, generalized subsurface profiles are developed along the proposed transit routes. The preliminary profiles are usually based upon a limited number of pilot borings, available boring records from previous projects, and knowledge of local geology.

Based on the preliminary design profiles, the various muck types can be predicted and assessed according to the basic categories of clay, sand and gravel, and rock muck. This information is then used to evaluate potential uses for the muck and to prepare recommendations consistent with the proposed vertical and horizontal route alignment.

Any special subsurface explorations or laboratory testing that may be required for the muck utilization study can be identified when the final route alignment and profile has been determined. The additional field and laboratory tests required for muck evaluation will depend on the anticipated soil and rock conditions.

Large volume samples are required in order to complete certain tests such as aggregate acceptability and representative gradation analysis, and also to preserve a representative sample after destructive testing of a portion of the original sample. These larger volume samples can be obtained from test pits or exploratory drifts or by increasing the volume of samples retained during the standard test boring program. The completion of test pits or exploratory drifts may not be justified for muck utilization alone. However, in combination with other requirements,such as an evaluation of dewatering or other tunneling problems, the test pits may be a reasonable approach.

SUBSURFACE EXPLORATIONS AND LABORATORY TESTING

The completion of the entire field and laboratory soil and rock testing may require six months to two years. During this period, subsurface profiles should be prepared and examined as the borings are completed. Boring locations, depths, sampling and field testing procedures can be adjusted to meet unusual conditions.

As the detailed subsurface profile along the route is prepared, the laboratory testing program for final design and muck utilization can also be completed. The testing program for muck utilization will vary depending on the anticipated use for the muck. Additional strength and compressibility tests may be required on remolded samples to determine the properties of the materials after excavation. Special tests should be completed to determine suitability of muck for specialized uses such as aggregates.

CONSTRUCTION METHODS AND THEIR EFFECT ON MUCK CHARACTERISTICS

The method of excavation, (e.g. tunneling machine or drill and blast) will influence muck characteristics. It is therefore necessary to estimate the probable construction method or methods to be used before evaluating the potential uses for the muck.

The gradation of rock muck, discussed in Section 3, is affected by the method of mining. In a soft ground tunnel, dewatering problems in sand and gravel might be solved by grouting which would directly affect muck properties. The selection of the equipment is normally determined by the contractor, based upon past experience and the cost and availability of equipment.

The use of a particular method may be affected by factors such as noise and vibration control, settlement of adjacent structures, and the economics of mobilizing expensive equipment for a short section of tunnel. These problems are usually reviewed by the owner and the general engineering consultant during the design studies. After this review, the most likely alternatives can be used to evaluate muck properties.

POTENTIAL USES FOR THE MUCK

The potential uses identified during the preliminary stage should be re-evaluated to confirm all technically feasible uses. The market value or economic feasibility of the options will be evaluated at a later stage. For each option, the following information should be developed:

1. Quantity.
2. Quality.
3. Specifications for use.
4. Processing equipment.
5. Method of delivery, placement, and treatment.

Accurate determination of muck quantity and quality for each potential use is essential. Also, the specification requirements for each proposed use must be established. Landfill specifications may be tailored to the material and proposed land use, and should be prepared for the specific tunnel muck product. Backfill specifications for the transit construction may impose different gradation requirements. These specification requirements must be established in order to assess accurately the feasibility of each alternative use.

When the muck is used in a landfill operation, the method of placement versus future stabilization treatment should be considered. Compaction during placement may not be practical, and surcharging or other stabilization methods may be necessary to permit full utilization of the landfill.

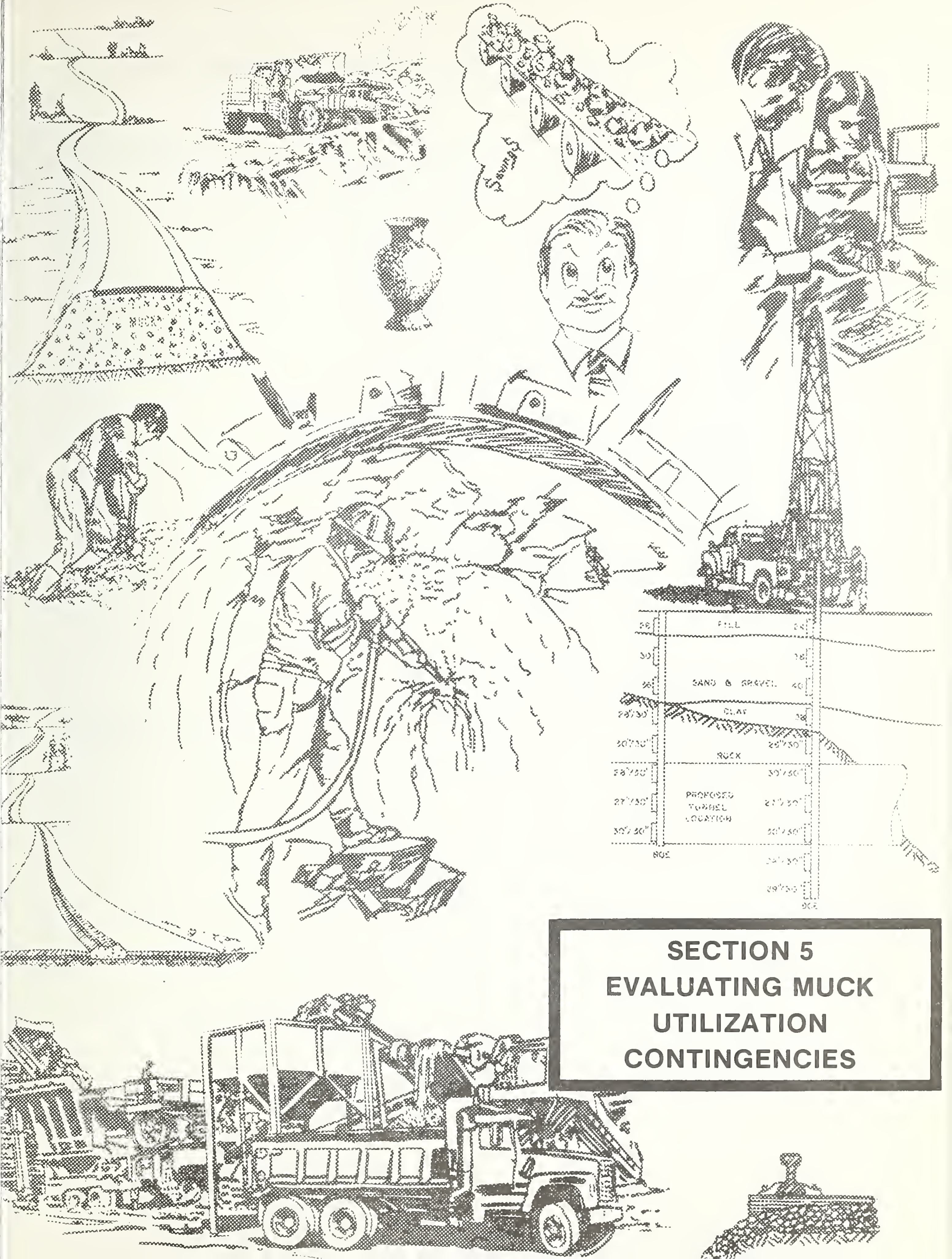
The method of transporting the muck from the portal to the utilization site should be considered, since transportation costs may be significant. Transportation methods include trucking, train, and barge; trucking is the most common.

RECOMMENDATIONS FOR MUCK UTILIZATION

The final list of recommendations should include all muck uses which are technically feasible. The uses should be ranked in order of the most probable schemes.

Recommendations should also be prepared which will affect the preparation of the contract documents. For example, if sand muck will be used for aggregate, then grouting may have to be prohibited as a method of groundwater control. If the muck will be utilized in a special manufacturing process, then the responsibility for delivery and possibly the method of measurement (e.g. by weight, by volume) must be established.

These recommendations for muck utilization will then be incorporated into the overall planning process described in Section 6.



SECTION 5
EVALUATING MUCK UTILIZATION CONTINGENCIES

SECTION 5—EVALUATING CONTINGENCIES

INTRODUCTION

Because of the inherently unpredictable nature of subsurface conditions, underground work involves more contingencies or risks than any other type of construction. Thus, tunneling contractors are familiar with calculated risks but are not anxious to increase their exposure to risk. This point was emphasized at a conference sponsored by the National Science Foundation, where it was concluded that risks and incentives control the introduction of new technology to underground construction more than technological feasibility (5-1). Introduction of muck utilization, either as a new concept or as a new contractual condition, must be accomplished without imposing undue risks or hardships.

The most probable use for tunnel muck will be as a construction material, as backfill on the tunnel project and as a material in landfill construction. Two key items must be reviewed and coordinated with the utilization plan: (1) the project specifications and (2) the establishment of control (via ownership permits or agreements) over the landfill area. Failure to consider these key items will readily nullify the development and implementation of a utilization plan.

This section outlines some of the contingencies which might develop during a tunneling project. Recommended planning actions are also provided.

SUBSURFACE CONDITIONS

A primary requirement of planning for contingencies in muck utilization is to consider possible changes in subsurface conditions, as they would affect type and quantities of muck removed from the tunnel. Test borings for tunnels are often spaced at least several hundred feet apart, and subsurface conditions between borings are commonly assumed by straight line interpolation of soil strata disclosed by the adjacent borings. As nature does not always follow such orderly patterns, quantities and types of muck may be encountered during tunneling that could not have been predicted from the test borings. Since transit tunnels are generally not more than 20 to 25 feet in height, a relatively modest dip in a sand/clay boundary between borings may significantly affect the quantities of sand and clay muck types to be obtained from that section of tunnel. The only way to reduce unexpected conditions of this nature is to provide a very thorough program of subsurface explorations.

METHOD OF CONSTRUCTION

Selection of Excavation Method

Generally, the owner should accept the method of excavation suggested by the contractor (5-2). The selection of the method is based on geologic conditions, available equipment, anticipated rate of progress, and other factors which influence the project completion time. In soft ground tunneling, the various conventional methods of excavation will have little effect on the muck gradation or properties. In rock tunneling, the obvious alternatives are drill and blast and machine tunneling; each produces significantly different muck gradation. In some instances minor changes in the final method of excavation might be beneficial. For instance, if drill and blast patterns were adjusted to produce smaller rock muck particles, the cost for additional rock drilling equipment, drilling time, and explosives could be insignificant in the total project schedule. But to limit the contractor to a tunneling machine just to produce crushed rock could be very expensive, particularly on a short tunnel. Therefore, the muck utilization program should be based on the likely method of construction but should be flexible and adaptable to a range of excavation methods.

Effects of Changed Conditions

Changes in groundwater conditions may result in major changes in muck quality. Options available to the contractor to control groundwater flow include compressed air, dewatering, freezing, and grouting. The first three methods do not affect the physical properties of the muck, but the last method will add grout to the muck product.

A sewer interceptor was constructed in a major metropolitan area using chemical grout to stabilize soil below the water table. The other alternatives of compressed air, freezing, and dewatering were ruled out because of cost, utility obstructions, and specifications (settlement due to dewatering), respectively. Thus, grouting was the only alternative. If grouting is a likely alternative for groundwater control, and if it might affect the quality of the muck, then a test program should be completed to evaluate the properties of the grouted soil or rock.

DELAYS IN THE CONSTRUCTION PROGRAM

Funding

Coordination of muck utilization programs can be curtailed or halted if funds are limited. The effect of the timing of funding on construction activities must be considered also. Major construction activities require Federal assistance, and the scheduling of an entire project can be affected by factors which are not under local control. Adjustments simply have to be made.

For example, the muck utilization plan for a future Chicago, Illinois, project includes simultaneous activities in (1) boring a deep tunnel, (2) constructing a subway extension, and (3) reactivating a harbor dredging program. Without simultaneous funding from different Federal sources, the muck utilization project must be scaled down. However, since no one on the local level can guarantee the actions of the Federal agencies, the planning must account for potential problems.

Legal or Environmental Problems

Noise and vibration produced by construction operations or even the final subway system may result in environmental objections to the proposed transit system. Unexpected or last minute environmental suits may affect the overall construction program and thus change the muck utilization program. For example, a last minute objection to the possible subway vibrations along a particular stretch of tunnel forced the owner to shorten the proposed contract tunnel length pending resolution of the complaint. As a result of the shortened tunnel length, the tunnel contractor elected to use drill and blast methods rather than mobilize an expensive tunnel boring machine as originally anticipated. The change in equipment caused a significant change in muck properties. The proposed muck utilization program must be flexible enough to absorb these changes.

Normal Delays

Strikes, weather, utility relocations, equipment breakdowns, and subcontractors' activities cause delays for a tunnel contractor. It is impossible to predict the nature or extent of these delays, but it is prudent to assume that a job will be delayed for periods of a few days to several weeks. The muck utilization program must be able to survive the inevitable delays caused by these factors.

SATISFYING UTILIZATION SPECIFICATIONS

Criteria

The specifications for muck utilization programs must clearly establish acceptable limits for the quality of the muck to be supplied. These specifications can be prepared by an engineer or consultant retained to analyze the muck qualities and likely uses, or by a prospective commercial user.

The requirements governing material types and placement methods for backfill materials used in the transit construction project or in other controlled landfills must be established based on engineering evaluation of the intended use of the fill. Thus, gradation, compaction requirements, and allowable water content are factors which will affect the acceptability of muck. Within reasonable engineering limits, these typical requirements can be adjusted to accommodate most of the soil and rock materials comprising tunnel muck.

Certain industries, such as brick manufacturing, cannot tolerate wide variances in the quality of the raw clay. Thus, a set of specifications used by brick-making plants can be used to evaluate the acceptability of clay muck as a raw material.

On the other hand, manufacturers or processors of sand and gravel, concrete ready-mix, and asphalt concrete may all have varying criteria for acceptable raw materials such as aggregate. Criteria may vary locally depending on the available aggregates and gradation specifications.

Most tunnels will produce varying muck types as soil or rock conditions change at the face. Accordingly, a muck utilization program may designate several uses for the muck, with specifications governing muck quality for each use. In order for the utilization program to function effectively, the muck type and quality must be evaluated in the field as it is produced so that it can be hauled to the proper location. A resident engineer or technician representing the owner should be responsible for evaluating the muck and designating its use.

Debris

Construction debris can contaminate the muck and render it unacceptable. Care on the part of the contractor can prevent most severe debris problems. Some debris cannot be removed from the muck once it has been introduced. For example, shotcrete methods will result in surplus concrete being mixed with the muck. The basic shotcrete constituents - aggregate, sand, and cement - may not affect the use of the muck in a landfill, but the debris could affect the use of muck for aggregate. The volume of debris normally produced by shotcrete methods is usually a very small percentage of the total volume, so minimal attention should prevent severe problems from developing. Contingency planning must consider the potential effects of construction debris from various types of operations on muck quality.

CONTINGENCY PLANNING FOR MUCK UTILIZATION

The key factors controlling or minimizing contingency problems are (1) thorough planning and (2) flexibility.

Planning Efforts

Environmental considerations, economic factors, and land acquisition or control of land use will influence planning activities from the start of a project. Some concerns include: proper storage and/or disposal of excavated material, minimum environmental disruption, and a finished product consistent with community and environmental goals (5-3). Proper muck utilization planning will prevent last minute project delays caused by objection to random dumping or disposal processes.

Since most muck is used as a backfill or landfill material, it is imperative that access to the land or fill area be positively confirmed. Any utilization plans which might involve land acquisition must be reviewed early in the design phase program so that legal or jurisdictional problems can be settled prior to construction. This applies to any land, whether it is to be purchased by the transit agency or by another public or private group. Without clear ownership or control over the land, further detailed planning may be stymied.

If the concept of muck utilization is introduced in the early planning stages, then it will become an integral part of the project and will not have to be tackled near the end of design. By providing time for planning, the economic value of the muck can be determined, whether it is used for land reclamation or as a raw material for aggregate or some other specialized use. The following example describes a utilization program that failed for lack of contingency planning.

The contract documents for a metropolitan city water tunnel provided that the contractor could, at his option, dump the rock muck to join two existing islands in the bay. A rock dike system would be constructed on each side and used to contain solid waste generated by the city's sanitation department. The project was abandoned, however, because the blast rock particles produced during mining operations were too small for use as riprap. Thus, although the planning effort was in force from the beginning of the project and the bid documents provided for muck utilization, the project was abandoned due to a last minute contingency problem. Since no alternative utilization plans had been prepared, the contractor disposed of the muck in other landfill projects and as slope protection in other more sheltered areas of the bay.

The planning effort must be thorough, it must be initiated during the project feasibility studies, and it must be flexible, providing at least two methods of utilization or disposal.

Flexible Utilization Plans

At least two options should be evaluated during the planning stages for muck utilization. The options should consider uses appropriate for good quality muck and poor quality muck. If neither of the utilization plans are feasible, then outright disposal can be implemented. For example, muck can be incorporated into a variety of landfill projects ranging from high quality engineered, compacted fill to sanitary landfill cover or quarry backfilling. Then, as the muck quality varies due to anticipated or unforeseen changes in ground conditions, the material can be sent to the appropriate fill site.

PLAN "A"
USE IT UP.

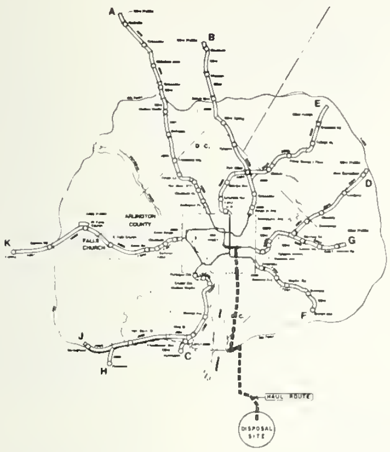
The timing or rate of muck production will vary during the job. Therefore, customers for muck must be alerted to the possible delay in the day to day variations. Overall planning may indicate that an average of 1,000 cubic yards per day of muck will be produced, but the daily delivery rate may vary from 0 to 2,000 cubic yards. Due to variable timing of muck delivery, compaction equipment used at a fill site may not be 100 percent efficient.

PLAN "B"
PUNT!

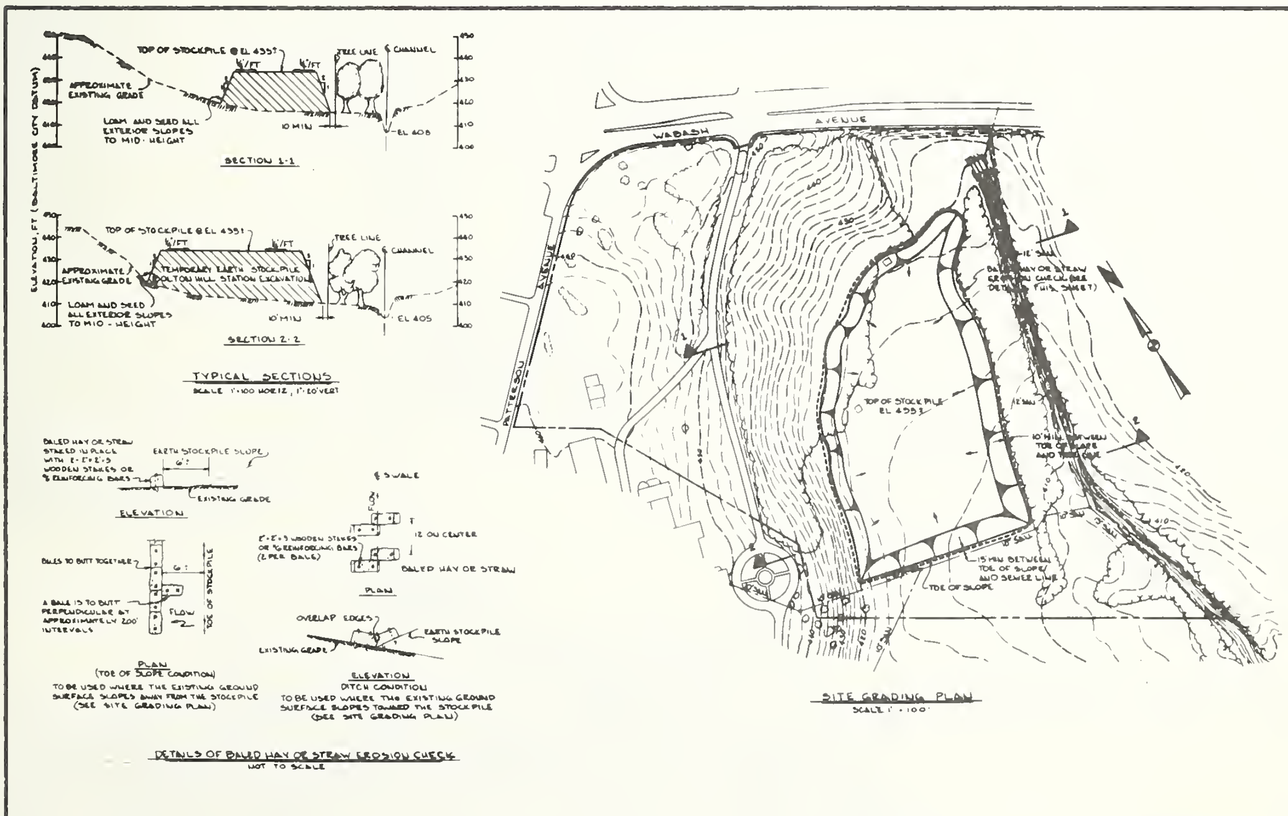
Stockpiling of muck is an excellent method for providing additional time or "float" in the delivery schedule. Rock muck could provide a long-term source of aggregate for extension of surface rail lines (track ballast) or extension of parking facilities (bituminous concrete aggregate). By stockpiling the rock on a marginal land site, soft, compressible soils could be preloaded. Preloading would develop surface settlements, improving site stability for future development. The rate of delivery of materials to a stockpile would be inconsequential, thus eliminating contingencies based on rate of advance problems. An appropriate storage site is required and should be located during the early planning stages to insure that lengthy land acquisition problems do not hinder the utilization scheme.

Contract Documents

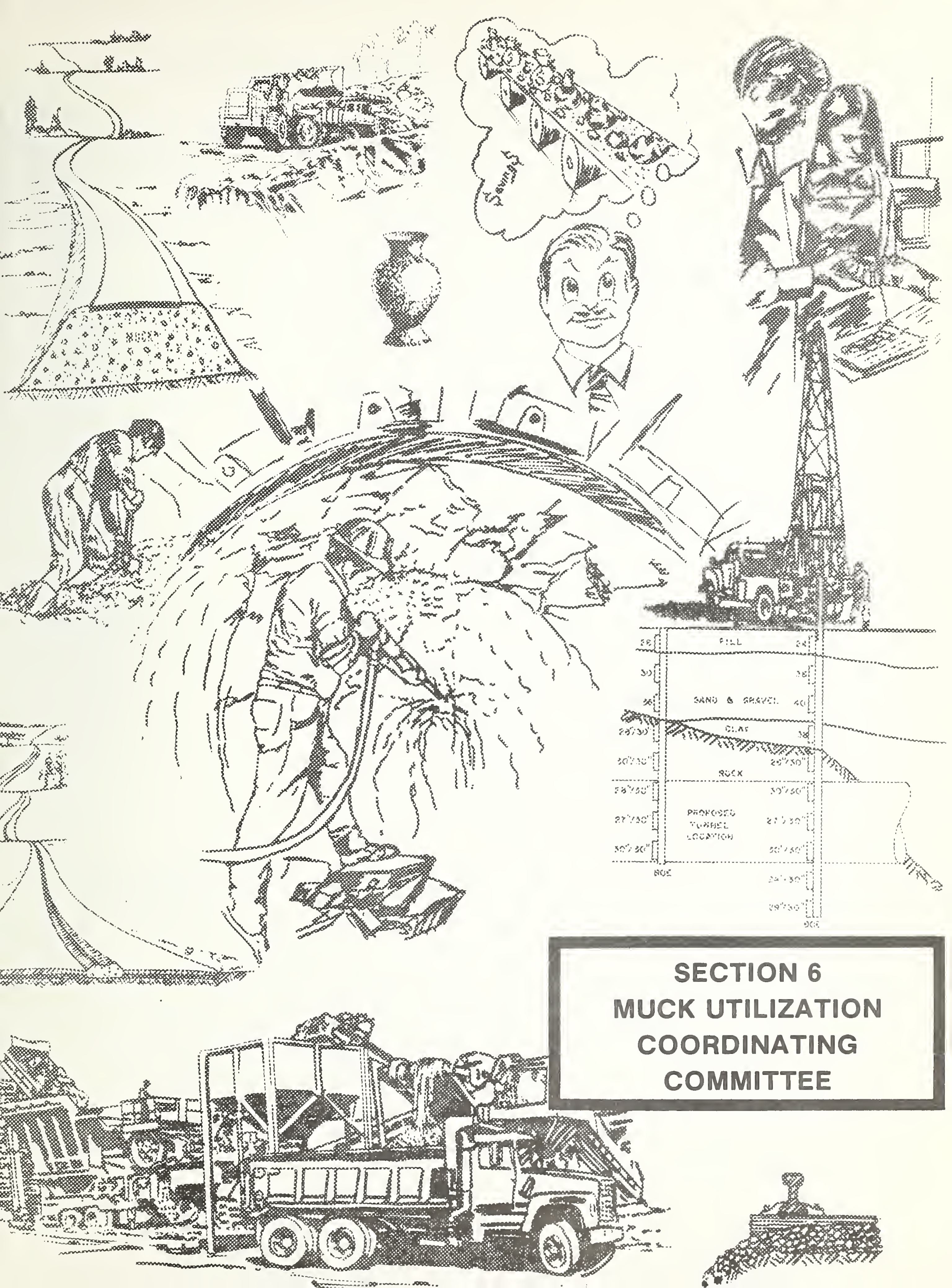
The contract documents must clearly establish the contractor's role and responsibility in the muck utilization process. Location of the disposal area, prescribed trucking routes, method of placement, the sorting of debris, and other pertinent information and requirements must be provided in order to prevent confusion during the bidding period. A unit pricing schedule should indicate the costs for hauling muck to



different sites, in accordance with the alternative muck utilization schemes, and should include the cost of outright disposal by the contractor. The method of measurement of quantities should also be established, whether it be volume measured in place in the tunnel, truck volume, weight measure, or volume measured in place at the disposal site. The owner's representative would therefore be responsible for evaluating the muck on a daily basis and then implementing one of the utilization schemes. By providing several choices in the documents, the owner retains the flexibility needed to match the variations, foreseen or otherwise, which can develop in underground construction.



SITE GRADING PLAN



SECTION 6
MUCK UTILIZATION COORDINATING COMMITTEE

SECTION 6—UTILIZATION COMMITTEE

INTRODUCTION

The development and implementation of a muck utilization program requires three key elements: education, planning, and commitment.

Education

The transit authority and all other organizations associated with the construction of the new system must realize the potential value of earth and rock materials removed from tunnels and foundation excavations. These materials should no longer be viewed as waste materials but should be treated as valuable construction materials.

Planning

Planning of a muck utilization program must be initiated during the preliminary stages of project design so that the concept becomes an integral part of the design procedure. Lead time is required in order to complete a preliminary assessment and prepare recommendations for additional subsurface investigations and laboratory soil and rock testing. The utilization plans must be flexible. Alternative muck utilization programs must be prepared to provide for unanticipated changes in project construction schedules or construction methods or for other reasons.

Commitment

Commitment to the muck utilization program will be reflected by contract documents which no longer require the contractor simply to dispose of all excavated materials. Cooperation of local, city, state, and Federal organizations will greatly help the implementation of the program. Cooperation, however, must include a commitment to provide assistance, access to land, or other services according to the project schedule. Private industries who might be utilizing muck as a raw material in a manufacturing process must also cooperate.

ESTABLISH A MUCK UTILIZATION COORDINATING COMMITTEE

The transit authority contemplating a muck utilization program must delegate the organizational and planning responsibilities to staff members, planning agencies, or consultants. In this manual, the group is to be identified as the Muck Utilization Coordinating Committee (MUCC). The MUCC would be responsible for the implementation of the goals represented by the education, planning, and commitment concepts. The committee could be formed by the transit staff, city or state planning agencies, engineering consultants, or a combination of these.

The organizational structure best suited to a particular project would depend on the local transit and government agency experience and capabilities. The transit authority should assume the leadership role in all cases.

The following paragraphs outline the reasons for including a particular organization in the committee and suggest a funding arrangement.

Transit Authority Staff

A muck utilization program will have a direct effect on the planning, design, and construction of a transit system. Since members of the transit authority staff will be most familiar with the proposed system, the anticipated soil and rock conditions, the construction schedule, and the contracting practices, it is logical for the transit authority to assume the leadership role in the muck utilization program. The transit authority will benefit from the utilization efforts by simplifying the bidding process and eliminating environmental problems associated with indiscriminate muck disposal practices.

Government Agencies

Local planning boards or land development commissions should be included in the MUCC organization. A representative who is familiar with the overall regional land planning would be able to guide the land access and land use activities of the MUCC. Participants should include agencies which normally utilize fill materials, such as the highway department. Conservation groups should be encouraged to participate.

Consulting Engineer

On a major project, the transit authority normally retains an engineering firm to serve as the general consultant for the development and coordination of the design and construction of the entire system. The potential for utilization of muck or other excavated materials in the new construction must be considered by the consultant. It follows, therefore, that a representative from the consulting engineering firm should participate in MUCC activities.

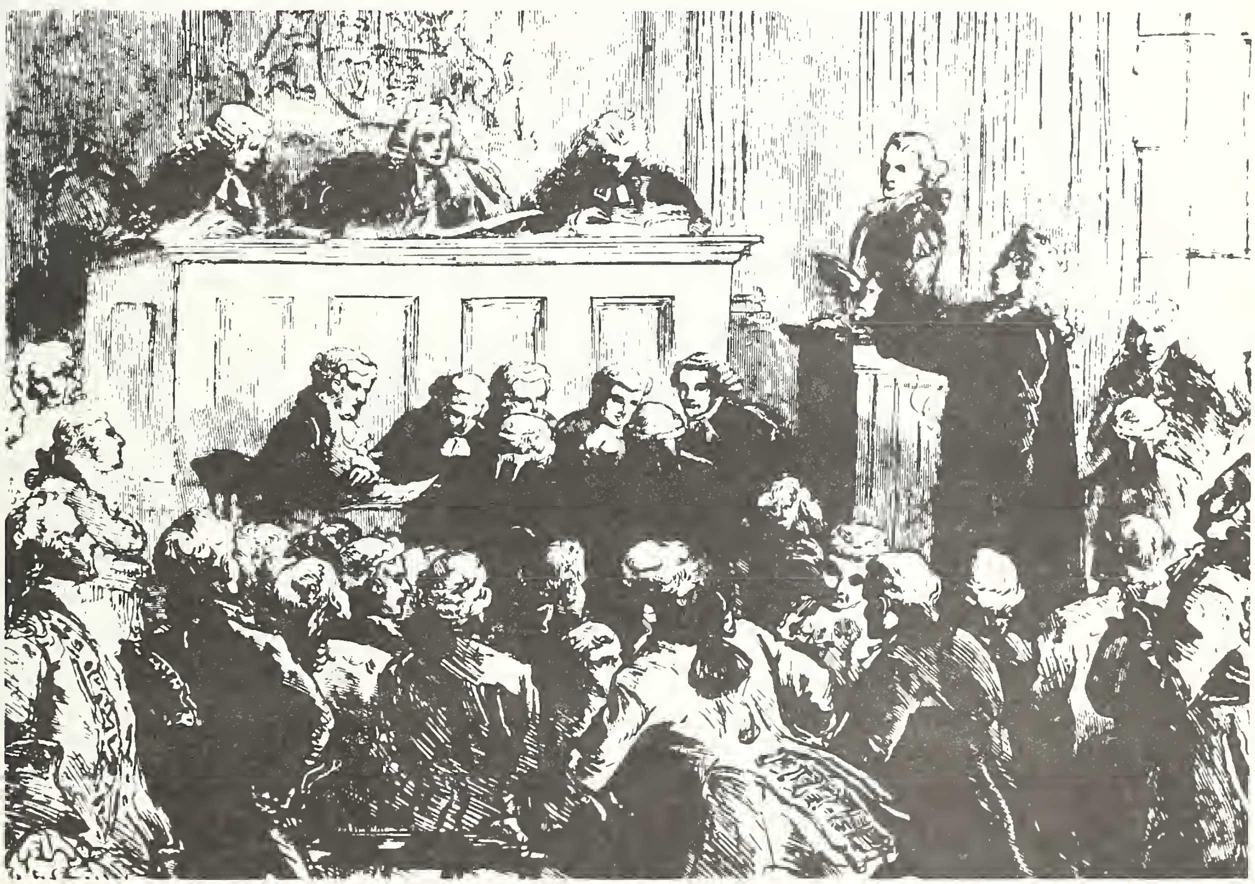
Alternatively, the transit authority may prefer to retain a consultant to specifically analyze the potential for muck utilization.

Funding of MUCC Activities

The manpower required to complete an analysis of the potential for muck utilization will naturally vary with the scope of the project. For example, on a major project, the potential for community disruption resulting from muck disposal prompted the city planning department to retain a consultant to prepare a muck utilization program. In other cases, muck utilization planning has been completed by the local transit authority.

Depending on the complexity and duration of the project and the number of general construction projects which might also be coordinated in the utilization program, the manpower requirements could range from one to three man-years. Financial support for the planning effort should be shared by the organizations that will ultimately benefit from use of the material, such as the transit authority, park development commission, harbors, highways, and other public works agencies.

Federal support through multi-project grants should also be considered. If, for example, Federally supported recreational or housing projects will benefit from the use of low cost muck fill, then a proportionate share of the muck utilization planning costs should be funded by a Federal grant.



MUCK PLANNING COMMITTEE

INITIAL CONTACT AND DATA ACQUISITION BY MUCC

Public and Private Land Development Projects

The short and long-term land use planning for urban development must be reviewed. Tunnel muck is suited to many types of landfill projects which may be proposed by city planners, urban renewal, highway, airport, and other public organizations. The MUCC must survey these organizations to (1) educate the organizations about the value of muck and (2) develop feasibility guidelines. Low cost fill materials made available through urban transit construction may mean that abandoned development schemes can be reactivated.

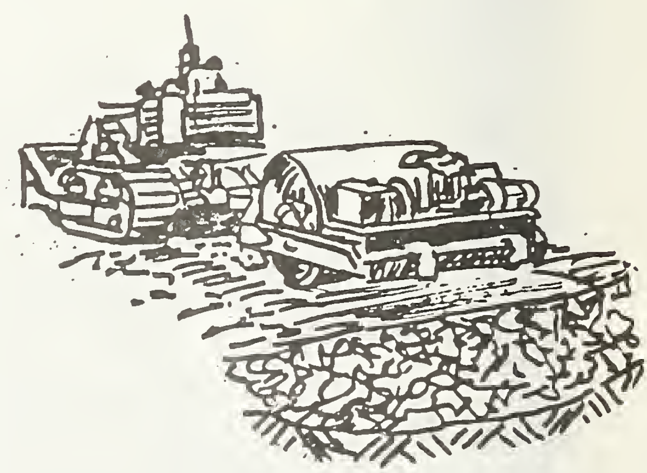
Private land development projects should also be investigated. Land developers and contractors may be very receptive to the availability of fill materials in the urban area.

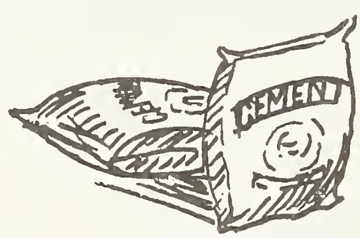
Overall Patterns of Construction Activity

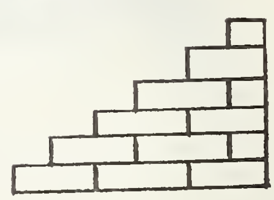
The MUCC must be aware of other construction projects which may also result in a surplus of excavated materials. Other tunnel construction activities, harbor dredging, or general foundation construction could result in the need to organize a city-wide utilization or disposal program.

Specialized Uses

Local industries utilizing soil and rock as raw materials should be surveyed to determine their requirements for the raw materials. The processors must also be given time to consider the use of soil and rock muck.







MUCC PLANNING RESPONSIBILITIES

The MUCC will be responsible for all planning related to muck utilization, including technical, scheduling, and contractual aspects. The final step in the planning process is the selection of one or more muck utilization schemes. All planning must be flexible.

The following paragraphs outline some of the general areas of planning responsibility.

Implement Utilization Guidelines

The MUCC must complete a technical evaluation of the muck properties including estimates of quantity and quality. The steps involved in the process are called the "utilization guidelines" and are described in detail in Section 4. Significant key phrases are listed below for reference:

Utilization Guidelines

1. Perform preliminary muck evaluation.
2. Complete subsurface explorations and laboratory testing.
3. Evaluate construction methods and their effects on muck characteristics.
4. Evaluate potential uses for the muck.
5. Make recommendations for muck utilization.

By following these utilization guidelines, the MUCC will determine the technically feasible uses for the excavated materials. The most promising uses should be selected for additional study. Final selection would be based on a benefit-cost analysis which would be conducted later in the evaluation process.

Market Analysis

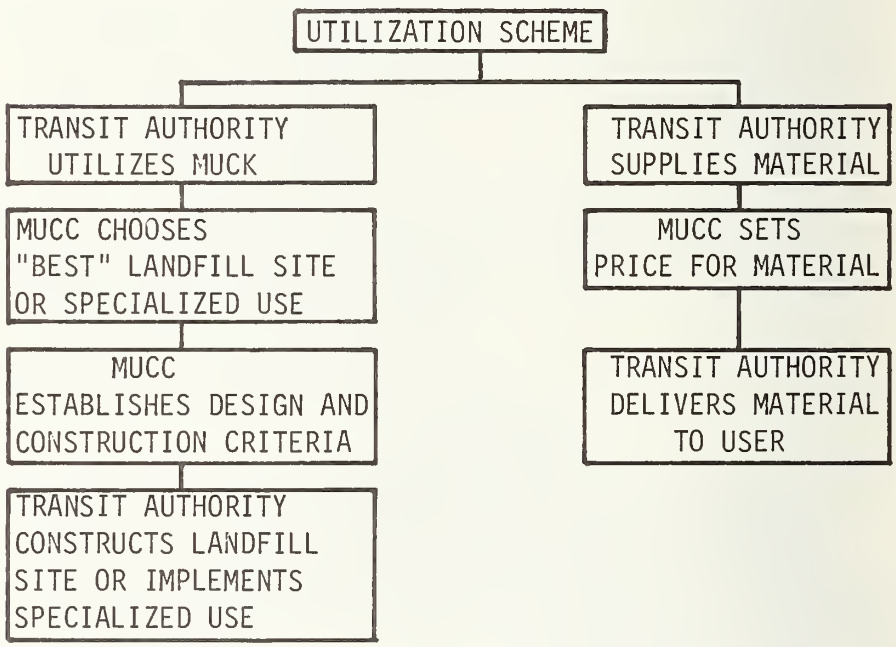
The MUCC must evaluate the feasibility and economic planning details affecting the proposed utilization schemes. Practical engineering or construction problems must be solved, and the market value of the muck as a commodity must be established.

First, a basic approach must be defined. Will the transit authority simply supply materials, or will it control the use of muck in the landfill or specialized use activity? For example, if the muck is technically suitable for use in an engineered, compacted fill, the transit authority may be able to utilize the material on the transit project and thus will have to control the placement and compaction operations. On the other hand, the muck could be sold as a fill material for use by other contractors. In the latter case, the transit authority would have no interest in the final placement or compaction of the material. Similarly, the transit authority may or may not desire to process the muck to produce aggregate or track ballast. The

MUCC must establish the goals of the utilization program. Exhibit 6-1 illustrates these options in the form of a flow chart.

The feasibility and economic studies can be divided into two categories: (1) landfill schemes and (2) specialized uses. The feasibility and economic studies are used to determine the most practical and economical uses for the muck within each category. Sample checklists of feasibility and economic factors affecting utilization schemes are presented in Exhibits 6-2 and 6-3, respectively. These suggested checklists may be modified to satisfy local needs.

EXHIBIT 6-1. FLOW CHART OF MUCK UTILIZATION OPTIONS



It is apparent that selection of the option simply to supply muck as a construction material involves a minimum of planning effort. This applies to both the landfill and specialized use schemes. This option is desirable because of its inherent simplicity, provided the muck qualifies as an acceptable material.

EXHIBIT 6-2. FEASIBILITY AND ECONOMIC FACTORS AFFECTING LANDFILL UTILIZATION SCHEMES

I. OPTION: Landfill Operated by the Transit Authority

A. Available Sites

1. Locate available sites, including transit property projects
2. Determine present ownership (public vs. private).
3. Establish land value (purchase price).
4. Complete site evaluations (wet or dry, coastal, etc.).
5. Establish zoning and/or environmental restrictions.

B. Intent of Landfill

1. Predict potential land use (park, business, residental).
2. Estimate land value after filling (industrial tax base).

C. Site Development

1. Determine steps required to prepare site for filling.
2. Prepare design and construction controls, estimate quantity, placement, and treatment methods.
3. Identify factors affecting construction (e.g. truck routes, noise, etc.).

D. Development Costs

1. Establish market value for muck fill compared to other sources (gravel pit, quarry, etc.).
2. Estimate land development costs using muck compared to other sources.

II. OPTION: Landfill Operated by Others

A. Market Demand for Materials

B. Supply Price of Materials

1. Establish market price for muck supplied "as-is".
2. Establish market price for muck which has been processed (sorted, screened, washed, etc.).

EXHIBIT 6-3. FEASIBILITY AND ECONOMIC FACTORS AFFECTING SPECIALIZED USES

I. OPTION: Transit Authority Processes Muck

A. Product Use

1. Identify potential uses (track ballast, concrete aggregate, bituminous concrete aggregate, etc.).
2. Establish quality control requirements.

B. Processing Equipment

1. Identify equipment (sorting, screening, crushing, etc.).
2. Locate processing site and stockpiling area.
3. Determine operational requirements (power, labor, etc.).

C. Production Costs

1. Establish market value of processed muck and compare with commercial products.

II. OPTION: Transit Authority Supplies Raw Materials

A. Raw Materials

1. Survey possible users to determine need for the muck "as-is".
2. Establish quality requirements, if any, for each use.

B. Price of Materials

1. Determine transportation costs.
2. Establish market price of muck "as-is".

The final product of the feasibility and economic study will consist of a list of muck utilization alternatives ranked according to feasibility and cost.

Prepare Contingency Plans

It is difficult, if not impossible, to predict all possible variations in the design, funding, and construction process which could affect the muck utilization program. The key factor is flexibility. Contingency problems, identified in Section 5, are listed below for reference:

Contingency Problem Areas

1. Subsurface conditions.
2. Method of construction.
3. Delays in construction program.
4. Satisfying utilization specifications.

A method or procedure for allowing a transition between alternative muck utilization programs must be established by the MUCC in case one scheme is abruptly cancelled. Alternative bid items would be provided in the contract documents for this purpose. In this way, the transit authority will not lose control of the situation and thereby jeopardize the normal owner-contractor relationship. Additional recommendations will be presented in a subsequent section on contract documents.

Through the contract documents, the owner maintains control of the muck utilization program. The documents must be clearly written to indicate that alternative disposal areas will be made available to maintain a continuous muck disposal program. A careful analysis of potential problems combined with a flexible utilization program will enable the MUCC to handle contingency problems.

Environmental Planning and Public Relations

A muck utilization program will indicate to the public that the transit authority is concerned about the disposal of excavated materials and is anxious to eliminate the adverse effects of an uncontrolled disposal program.

For each of the proposed utilization schemes, particularly the landfill programs, the MUCC will have to assess the potential environmental impact. The MUCC can publicize the fact that excavated materials will be utilized and not simply "dumped in the river." During the preparation of the Environmental Impact Statement, for example, the MUCC on behalf of the transit authority can outline preliminary utilization plans, thus promoting the concept of utilization from the start of the project.

The MUCC will have to inform local environmental groups of its plans for utilization and deal with the objections of these groups. However, by starting the entire planning process early in the design program, last minute environmental suits will be avoided.

A checklist of Federal, state, and local agencies which may be concerned with environmental planning is shown in Exhibit 6-4. Local or regional agencies will probably be more concerned with the details of a utilization program, particularly if landfill schemes are involved.

Permits and Approvals

In order to avoid last minute delays, the MUCC must investigate the need for special permits or approvals to conduct landfilling or other processing operations. Landfilling operations, for instance, may be required to meet building code requirements, satisfy gravel pit restoration requirements, or obtain approval of a park or public works department.

Restoration of sand and gravel pits in one particular county required that plans be prepared showing final contours and operations and that an occupancy permit be obtained so that men and equipment could occupy the site. City and county governments often require hauling permits for trucking over secondary roads and guarantee bonds for maintenance or repair of roadways.

The MUCC must identify the required permits associated with each proposed utilization scheme. Eventually the transit authority should obtain the permits for the utilization schemes which are finally selected for implementation.

Benefit-Cost Analysis

The completion of a benefit-cost analysis will provide the MUCC with additional information to help in the final determination of the muck utilization program.

In the normal contracting practice, the contractor is required to dispose of all excavated materials outside the right-of-way. The cost of disposal is passed on to the owner as part of the excavation price. The muck utilization program will affect this hidden contract cost. During the planning stage, the disposal must be estimated. The real cost can only be confirmed by establishing alternative bid items in the bid documents. An example of alternative bid items is shown in Exhibit 6-5. The differential between the options, utilization program versus contractor disposal, will establish the immediate benefit or cost to the transit

EXHIBIT 6-4. AGENCIES CONCERNED WITH ENVIRONMENTAL PLANNING FOR URBAN TRANSIT SYSTEMS

1. U.S. Department of Transportation, Assistant Secretary for Environment, Safety and Consumer Affairs.

2. The Council on Environmental Quality.

3. Environmental Protection Agency, Regional Office.

4. Department of Housing and Development, Regional Office.

5. Department of Interior.

6. Department of Health, Education and Welfare.

7. Department of Agriculture.

8. Department of Commerce:
   - Economic Development Administration.
   - Office of Economic Opportunity.

9. Army Corps of Engineers.

10. Federal Highway Administration, Regional Office.

11. State Clearinghouse: Office of Planning and Budget.

12. Regional Clearinghouse: Regional Commission.

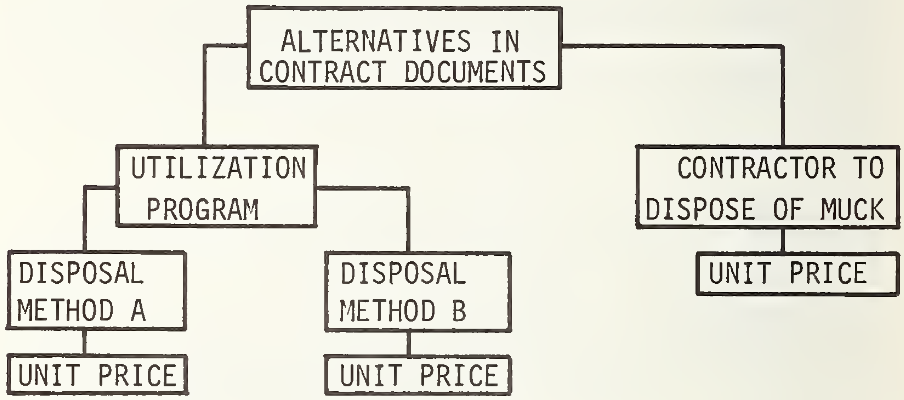
13. State Government: Land Planning and Soil Conservation Service, Department of Natural Resources.

14. County Government: (Land Planning) County Engineering, Department of Public Works.

15. City Government: (City Planning) City Engineering, Department of Public Works.

authority. The MUCC will have to consider these factors when evaluating the effect of the muck utilization program on the transit construction cost.

EXHIBIT 6-5. ALTERNATIVE MUCK UTILIZATION BID ITEMS



A benefit-cost analysis typically produces three options:

1. Costs are lower than direct benefits: program accepted.
2. Costs exceed direct benefits, but non-quantifiable advantages are worth the cost: program accepted.
3. Costs greatly exceed direct benefits: program not accepted.

As Exhibit 6-5 shows, if the unit price for Method A or B is less than the price of contractor disposal, then the utilization program will be accepted. If the cost of the utilization program falls into Option 2, listed above, then the benefits of the utilization program must be evaluated. Alternatively, the additional cost may be absorbed by special funding grants or by payments from other agencies that would benefit from the program.

Consider the following example. Method A involves the development of a city park area. Alternative bids indicate an additional cost of $2.00 per cubic yard for the utilization program compared to disposal by contractor. But, since the city cannot buy commercially available fill at a lower price, the city is therefore willing to pay the transit authority the $2.00 differential. Thus, the cost to the transit authority for disposing of the fill in the park area would match the cost of disposal at the contractor's option, and the city obtains fill material at less than the market price.

When utilization program costs greatly exceed the contractor disposal price, then the utilization program will not be accepted.

The benefits associated with Methods A and B must be determined by the MUCC using a qualitative, cost-benefit analysis. The market analysis will have already identified those schemes consistent with local construction and manufacturing capabilities. Basic costs are also available, measured, for instance, by purchase of land or equipment. Benefits may be more difficult to quantify, particularly when environmental, recreational, or restoration values are introduced. A landfill used for an industrial park or shopping center can be evaluated in terms of increased tax base and job opportunities. Recreational areas or environmental improvement can be assessed in terms of community needs. By investing time and money in environmental aspects, the transit authority may find that the resulting goodwill increases community acceptance of the project, particularly during the construction period when traffic and business activities may be disrupted.

Selection of Muck Utilization Alternatives

The final planning step involves the selection of alternative utilization schemes to be included in the contract package. At this stage, the MUCC will have accumulated sufficient quantitative data to make a realistic appraisal of the alternatives and to arrive at realistic, practical decisions.

MUCC SCHEDULING RESPONSIBILITIES

Limitations of Control

The actions of Federal, state, and local agencies are beyond the control of the MUCC. The MUCC must maintain liaison with the critical government agencies to convince them of the validity of the muck utilization program and the need to coordinate planning, funding, and construction activities. In the final analysis, however, major shifts in Federal funding allocations or state or county land use requirements may drastically affect the overall transit construction schedule.

Establish Utilization Program Time Schedule

Preliminary construction schedules can be used to coordinate muck utilization programs. Wherever possible, the final program schedule should be established after major transit planning and funding policies have been confirmed. The MUCC can then coordinate the rate of muck production from transit construction activities with the muck processing or landfill construction schemes. In order to account for variations in the daily rate of muck production, scheduling may have to be based on average weekly or monthly construction activities. The timing must be established, but it must not be so rigid that construction delays will result in collapse of the utilization program.

Interagency Coordination of Construction Schedules

In order to insure maximum benefit from the muck utilization program, the MUCC must coordinate construction activities among the transit property, other government development projects, and the private sector. Based on the data obtained from a general analysis of public and private construction activities, the MUCC will have to prepare a more detailed coordination plan. If the transit authority is to act as a supplier of fill material for a highway project, then the highway department must be able to provide the disposal area. Calendar dates must be established and written commitments obtained. These written commitments will force each agency to realistically evaluate its own schedules and eliminate problems after transit construction has been started.

CONTRACT DOCUMENTS

The MUCC must either prepare the contract provisions for muck utilization or else provide recommendations which will help others prepare the contract documents. In both cases, the MUCC must review the final contract package for consistent muck utilization planning.

Information Package

The contract documents must clearly outline the roles of the owner and the contractor in the utilization program. An information package should be included in the documents or issued separately. The package would contain a description of the project, a list of participants other than the transit authority, plans indicating the location of the disposal sites and acceptable trucking or transportation routes, a list of permits required for the work (identifying those permits to be obtained by the owner), special instructions for sorting or processing the muck at the tunnel portal, special test data, and other significant information.

Alternative Bid Items

Specifications have typically required the contractor to submit a unit price which includes excavation and disposal of soil or rock. With the introduction of the muck utilization program, the procedure must be changed to provide separate prices for excavation and disposal. The muck utilization program will form the base bid item for disposal, while the standard disposal by the contractor will become the alternative. A sample bid comparison sheet is shown in Exhibit 6-6. The format and number of alternatives can be changed to suit any special requirements.

ADMINISTRATION OF MUCK UTILIZATION PROGRAM

Administration of the muck utilization program can be accomplished either by the MUCC or through the normal contract administration process. The choice will depend on the complexity of the muck disposal process.

If, for example, the muck is sold as a fill material and no elaborate processing is required, then control of the program can be delegated to the construction supervision staff which will maintain records of quantities for payment purposes. On the other hand, if the muck will be stockpiled on the transit authority property for future processing (e.g. crushing for ballast), then the utilization program may extend beyond the completion of tunnel construction. In this case, administration of the program should be delegated to the member of the MUCC representing the transit authority.

EXHIBIT 6-6. COMPARISON BID SHEET FOR DISPOSAL OF EXCAVATED MATERIALS

I. Base Bid: Utilization Program			
Scheme	Description	Estimated Quantity (Cubic Yards)	Deliver to Site (Unit Price)
A	Engineered, Compacted Fill	75,000	
B	Aggregate	50,000	
C	Controlled Fill (General Disposal)	125,000	
	Total Volume:	250,000	
II. Alternate Bid: Disposal by Contractor			
A	Disposal by Contractor	250,000	

REFERENCES

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