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Design of Non-Impounding Mine Waste Dumps

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4 Geotechnical Site Investigation

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INTRODUCTION

Open pit mining involves moving large quantities of overburden to disposal areas which are usually located above ground near the mine. Large surface areas may be covered by the waste dumps created by this overburden placement. Geotechnical investigations conducted for civil structures usually concentrate a high level of effort into a relatively small area of interest. This effort is justified because of the value of the structure. A site investigation for a waste dump must be approached differently because the surface area is large and the value of the completed structure is low. The value of the engineering is related to minimization of operation and closure costs.

The purpose of a site investigation is to identify existing field conditions which may influence dump design or performance. The site investigation is usually the first step in waste dump design following the identification of potential dump sites by the mine planner. During the site investigation data is collected concerning the topography, geology, soil and vegetation cover, and hydrologic conditions. Samples of soil and rock are collected for identification and laboratory testing. The engineer can design or assess stability only after the geology and engineering properties of site materials are characterized.

Planning a successful site investigation involves understanding a few principles of waste dump behavior so that design problems can be anticipated, and then selecting a field program to collect data needed to solve the problems. Because of the large land areas involved, focusing a geotechnical site investigation into critical areas using existing geologic data can save much time and effort both in the field and later during design.

This paper describes the steps involved in planning waste dump investigations from a geotechnical standpoint. Other aspects of dump design such as hydrological and groundwater pollution assessment may need to be considered during the site investigation; however these have not been treated in this paper.

PLANNING A SITE INVESTIGATION

A waste dump site investigation should be conducted in three phases: data collection, preliminary assessment, and field work. Although these phases often overlap, a step-by-step completion will usually result in a more cost effective end product.

Data Collection

The objective of a data collection phase is to collect all available information which is pertinent to the design. The following information should be collected:

Topographic Maps: Topographic maps of the proposed dump areas are usually available from the mine operator and are available from the U. S. Geological Survey (USGS) for most regions in the United States. Topographic maps are available in most foreign countries through various local government agencies.

The scale and contour interval of the maps needed will depend upon the scale of the project. However, for a typical project in steep terrain 1:600 (1 in = 500 ft) horizontal scale with 3 m (10 ft) contour intervals are usually adequate for field mapping.

Sufficient maps should be collected to obtain coverage for the waste dumps, all haul roads, and the entire upstream drainage which will contribute run-off to the waste dump. If downstream sedimentation facilites are planned, maps covering their location should also be obtained.

Preliminary Mine and Dump Plans: Preliminary mine plans will indicate the location and general arrangement of the mine, haul roads, waste dumps and other surface facilities. These plans will help to define the extent of the site investigation and critical locations of study. Maps indicating proposed mining and dump phases are the most useful.

Geologic Maps: At most mines, detailed geologic information beyond the ore body has not been extensively developed; however some information is almost always available if the dump site is close to the mine. Other sources of geological information are USGS geological maps and open file reports, data collected for other licenses and permits, state geological survey maps, U. S. Soil Conservation Service maps, and college theses.

Aerial Photographs: Stereographic pairs of aerial photographs are often available for waste dump sites if the mine has had topographic maps made. Either black and white or color may be available and either may be used. Black and white may be more useful to identify structural contacts, while color is valuable to identify changes in vegetation which may indicate the presence of water.

Other Data: Other data may be available from the mine or other sources. One piece of valuable information is the character of the waste rock which will be placed in the dump. The type of rock(s) in the overburden is usually available from exploration drilling. If the waste has been core drilled, the Rock Quality Designation (RQD) may also be known. This data can be used to estimate the strength and particle size of the waste rock. The level of groundwater in exploration holes may also indicate regional hydrogeologic conditions and the moisture content of future waste materials.

Preliminary Assessment

After the available data is collected, the next phase is to perform an analysis of this data in regard to the preliminary dump plans in order to determine potential problem areas where the field investigation should be focused. In most open pit mining operations, the areas which may become covered with waste rock are extensive. These areas may be very steep, heavily forested, or otherwise inaccessible and difficult to map. A preliminary assessment will help concentrate the field investigation in areas of concern. The following steps may be useful in making this assessment:

Terrain Analysis: Using topographic maps and aerial photographs a preliminary terrain interpretation should be made. Some of the features which may be identified are listed in Table 1.

Table 1. Terrain Analysis

Geologic Feature	Description	Discussion
Landslides	Usually can be identified by characteristic spreading-cone shape of existing land mass or steep scarp and depression at the original mass location. A stream channel may have an abrupt change in direction. Springs may occur around the edge of existing slide mass accompanied by vegetation changes. If creep is still occurring, trees may be bent and deformed.	Landslides may represent areas of marginal stability which could become mobile upon loading. Crossing slides with haul roads may initiate uphill surface movement. In many cases, a dump can be planned to buttress old slide masses so that stability problems are minimized.
Faults	Often can be located as linear features on air photos. Sometimes accompanied by vegetation changes, seeps, or springs.	Usually not a major problem unless potentially active. May influence stability. May create localized problems with haul roads.
Springs	May be accompanied by vegetation changes.	May need to be positively drained from dump. May indicate a geologic contact.
Flat terrain	Relatively flat areas in mountainous terrain may indicate deeper soil formations	Fine grained soils may produce critical stability zones.

Geologic Review: Using available geologic maps and information, a generalized picture of the site geology can usually be obtained. The type of geologic units expected can be listed. Estimates of engineering properties can usually be made using known or published data about these units.

Conceptual Dump Plan Review: Combining the topographic and geologic review with conceptual dump development plans can provide a first approximation of potential problem areas. A waste dump is usually developed by constructing haul roads from the pit to the site and then advancing the dump in a predetermined direction. Potential problems may arise with construction of initial haul roads around steep terrain, with various interim stages of waste dump construction, or with the final configuration at dump closure. Some problem areas might be eliminated by coordinating with the mine designer and changing that portion of the plan. Other areas are assessed in the next step.

Preliminary Stability Assessment: The two most important factors influencing waste dump stability are usually the slope of the ground and the strength of the natural material on which the dump is placed. Using stability charts and assumed material strengths, the dump stages can usually be subdivided into regions which appear to be safe, marginal, or critical. The field program can then be focused in the marginal and critical areas with lesser effort being expended in confirming the safer areas.

The Field Work Plan

Following the preliminary assessment of geologic and topographic conditions related to the dump, a field program can be planned. A field program normally involves surficial geologic mapping, mapping subsurface profiles exposed by trenching or drilling, and sampling significant geologic units. A plan for these activities involves estimating the type and location of holes, planning equipment access, and scheduling the personnel and equipment to the project site.

It must be stressed that a field work plan is a useful tool for scheduling and budgeting; however, the field program must be kept flexible. The actual number and location of drill holes, test pits, etc. may need to change to obtain an understanding of actual conditions encountered in the field. Experienced engineers and geologists must be able to use their judgment to modify the original plan to maximize the usefulness of information which is collected.

The staged approach to a geotechnical site investigation may not be compatible with certain types of engineering services proposals. Many requests for proposals ask the consultant to submit a proposed work plan showing location and number of drill holes and test pits before data collection and assessment have been performed. If the proposed work plan is used to evaluate the level of effort recommended by the consultant, it has some value in the proposal stage. However, if a work plan submitted in a proposal is considered as an inflexible plan of action by the client, the work performed may not produce a satisfactory result. As an alternative, it may be helpful to request a work plan review meeting after the preliminary assessment is completed by the consultant. At this meeting, the results of the preliminary assessment can be reviewed and the parties can agree to any needed revisions to the conceptual work plan prior to beginning work. Additional meetings and work plan modifications may be required during the execution of the field work if unanticipated conditions are encountered.

FIELD INVESTIGATION TECHNIQUES

Field investigation techniques for waste dumps are similar to those for other geotechnical projects; however some modifications are often necessary because of topographic constraints and large areas covered by the waste dump. Standard techniques include surficial geologic mapping, test pits, and dozer trenches for near surface investigations, and drill holes and geophysical surveys for deeper investigations.

Near Surface Techniques

An analysis of topography will usually provide an indication of the depth of interest needed for the site investigation. Near surface techniques are usually more important and useful in steep terrain where soils are thinner and where potential failure surfaces are expected to be shallow. One exception is where weathering may produce deep soil development even in steep terrain.

Geologic Mapping: A surficial geologic assessment and map are valuable in waste dump design. Specific items to be located and inspected in the field may include:

1) Identification of Major and Significant Minor Geologic Units-- The location structure, orientation, and condition of these units will help to build an understanding of the geologic environment and controls.

2) Lineations-- Naturally occurring straight line features on aerial photographs may indicate faults or geologic contacts. Lineations may indicate a change in geologic unit, material type, or structural orientation which could affect stability. Many faults will have little significance in non-impounding waste dumps. If significant faults are located, it may be necessary to estimate the fault length and the age of most recent activity.

3) Landslides-- Field confirmation of ancient or more modern landslide forms may indicate areas which may be critical for stability. If movement is still occurring, trees located on the slide may be crooked. Although this is an excellent way to spot soil movement, all soil movements causing tree disformities are not landslides. Soil creep can also occur on steep slopes causing bent trees. The depth of the sliding surface can be useful in performing an assessment of current and future stability of an existing landslide. Depending upon the depth, either test pits or drilling may be used to locate the sliding surface. If the dump development will buttress an existing landslide, a detailed investigation may not be needed.

4) Springs-- The locations of seeps, springs, and wet areas are useful in the assessment of existing hydrogeologic conditions which may influence stability or long term water quality of the dump. The development of deep organic soils often accompany wet areas. The extent of these soils should be mapped in case removal is required for stability or reclamation reasons.

Test Pits: Test pits are an economical way to supplement geologic mapping by exposing subsoils near the surface. The soils exposed in the pit walls are described according to a classification system. Samples are usually collected at significant layers for laboratory classification and testing. Both disturbed and undisturbed samples may be obtained from the test pit walls.

A backhoe is most commonly used to dig test pits. An engineer or geologist is usually present to log the test pit as it is excavated. If this is not done simultaneously, the pit may cave in or fill with water before it can be logged. The depth of a test pit will depend upon the ground conditions and size of backhoe, but 3 to 4 meters is usually regarded as the practical limit for an unbraced excavation.

A commonly overlooked test pit excavation method is a hand-dug pit. In steep terrain, the cost of construction access to a particular site may be prohibitive, especially if the access road requires water bars and reclamation to satisfy agency requirements. Hand-dug pits are often more economical. The practical depth limit for an unbraced hand-dug pit is about 2 meters. Where labor is cheap, pits are often braced and taken deeper.

Dozer Trenches: Dozers may be used to construct trenches for near surface exploration. The principle advantage is that a tracked dozer can traverse relative rough terrain without substantial road building. Disadvantages include the large disturbance caused by the actual trench and difficulty of working in saturated or boggy conditions.

Road Cuts: Often existing roads traverse proposed dump locations. Digging into the cut slope with a shovel or backhoe at various intervals can rapidly supplement the near surface data collection.

Deep Investigation Techniques

As indicated in the previous section, near surface techniques are limited to the safe depth which can be economically excavated. Near surface techniques may also be limited due to groundwater. If the formation or feature being studied is deeper than can be reached with a pit, the answer is usually to sample from within a drill hole. Drill hole information may be supplemented with geophysical techniques such as seismic refraction or resistivity surveys.

Drilling: Drilling may be necessary to obtain geotechnical information deeper below the surface than can be obtained by excavating, for obtaining groundwater levels, for installing monitoring instruments, or to demonstrate that the proposed dump is not covering mineralized rock. Unless deep, unconsolidated soils are present, geotechnical drilling for a waste dump investigation are rarely taken to a depth exceeding 30 meters. Drilling for mineralization may be taken to a depth exceeding 300 meters. Because of the differences in purpose, different types of drilling equipment are usually advisable for geotechnical drilling than that used for exploration drilling.

Several texts are listed as references which describe drilling and sampling techniques in detail. Many types and methods of drilling have been developed to suit various geologic conditions. As a rule, auger drilling is preferable in soils, while rotary or core drilling is preferable in rock. In a soil containing boulders, a Pitcher sampler may be required in order to collect samples.

When hiring a drilling company, it is necessary to specify the type of formations which are expected

Table 2. In-situ Sampling and Testing Techniques

Material Type	Sampling Procedure	In-Situ Tests
Soft to firm cohesive soils	Shelby tubes or drive samples, piston sampler	Vane shear, Dutch cone, Standard penetration tests (SPT), self-boring pressuremeter
Cohesionless Sands and Gravels	Drive samples, bag or bulk samples	SPT tests, Dutch cone
Mixed soil, glacial tills and soils with boulders	Pitcher sampler, drive samples, bulk samples	SPT tests

and the type of sampling and in-situ testing equipment which will be required. A minimum length of each type of drilling or testing apparatus should be specified as well as spare cutting and driving heads. All miscellaneous equipment to be supplied by the driller such as core boxes, Shelby tubes, packers, piping, etc. should also be specified.

Access for truck mounted drilling rigs must be provided and a level drill pad prepared for each drill site. Mud pits may be required at each site. On government property, an approved plan is usually required before constructing access roads or drill sites. Upon completion, reclamation of disturbed areas is usually required. Bonding is often necessary. These requirements necessitate planning well in advance of bringing drilling equipment on site.

Geophysical Techniques: Seismic refraction and resistivity surveys can be useful to assist in determining subsurface profiles. When conducted between boreholes, the information obtained can be more accurately correlated and becomes more useful. Geophysical techniques have the advantages that little access preparation is required, fairly continuous profiles can be determined, and little clean up or reclamation is needed. Disadvantages include difficulty in interpreting data without supplemental exploration and sampling, and limitations in adaptibility to all types of geologic and topographic conditons.

Downhole geophysical techniques are also available to supplement drilling information, especially for hydrogeologic assessment. These techniques would not be considered normal in a waste dump site investigation plan but may be required to answer a specific problem.

SAMPLING AND IN-SITU TESTING

Sample collection and in-situ testing are an integral part of the site investigation. Samples are collected for laboratory identification, classification and materials testing in order to determine engineering properties. In-situ testing is performed to determine engineering characteristics in the field environment. Detailed descriptions of sampling and in-situ testing procedures may be found in numerous texts such as those listed in the references; however, Table 2 is included to provide a listing of techniques for sampling and in-situ testing of various materials commonly encountered in a waste dump site investigation.

The number of samples collected for laboratory testing or number of in-situ tests should be sufficient to determine the range of variability of significant material properties. One field or laboratory test of a particular geologic unit is usually not adequate. More variable units should be tested more than units which are relatively uniform.

SUMMARY

A site investigation for a waste dump usually involves assessment of geologic conditions over a large area. Maximizing the use of available data and focusing the field effort into the most critical stability areas can produce more cost effective results. The site investigation must be planned and executed with respect to the waste dump plans so that information needed for design is collected. Experienced engineers or geologists should be used to supervise the field investigation so that significant features can be identified and work plans modified if necessary during the execution of the field program.

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