OIL SAND TAILINGS
INTEGRATED PLANNING TO PROVIDE LONG-TERM STABILIZATION

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ABSTRACT

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Processing oil sand involves material handling on an unprecedented scale, and creates vast quantities of waste or tailings. Large retaining structures are constructed from the sand tailings and used to retain the finer-grained waste products.

Service demands of the retaining structure are reviewed along with a study of factors that affect the long-term stability.

The retaining structure must remain intact during construction and resist erosion until protective vegetation is established. Then it must support the fine-grained waste products until they consolidate and are able to stand by themselves. Finally, the retaining structure must erode at a controlled rate that avoids release of large quantities of sand into the surrounding area.

Present construction methods appear adequate for short-term stability considerations, but the support will be required for 1000 years or more until fine-grained wastes consolidate and are able to stand by themselves. Eventually, the tailings retaining structure will succumb to natural erosion by running water and wind. Because of the concentration of fine sand in the retaining structure, erosion, once started, is likely to be quite rapid. Consequently, it is doubtful if the present structures will be able to meet long-term stability requirements.

Methods of reducing the rate of erosion and of reducing the required support time are explored. The key lies in planning that integrates long-term needs, operational considerations, and reclamation requirements.

Alternate construction methods that are more likely to meet long-term stability requirements are identified. The main considerations include accelerated consolidation of the fines, controlling surface runoff even while the overall structure is eroding, and introducing barriers to prevent rapid erosion of the sand. Adoption of these construction methods would enhance overall performance. Operating costs may be reduced because of the increased storage capacity that results from accelerated consolidation of the tailings fines.

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1. INTRODUCTION

Processing bituminous sand from open pit mining operations involves handling volumes of ore and creates volumes of waste that are without precedent.

Individual plants now under design or construction will produce one quarter million tons of waste per day. The waste will be stored in tailings ponds that rise 100 feet or more above the original ground surface, and 300 feet or more above the mine floor. Eventually, 20 to 30 square miles of tailings ponds will be created at each mine site.

Design guidelines exist for the design of conventional tailings structures (1) (2). These have been applied to oil sand waste handling. Complications arise, however, from the immense size of the operation.

The paper which follows outlines the goals of waste handling. Then it identifies problems peculiar to oil sand waste handling and processes that affect stability of the waste deposit. Methods of slowing erosion and stabilizing storage facilities are explored.

2. BACKGROUND

To produce each barrel of synthetic crude oil, one cubic yard of oil sand must be mined and processed, and more than two cubic yards of sand, clay and water disposed of.

Waste products are usually pumped to a nearby disposal area. In warm weather sand is extracted from the waste effluent and used to construct retaining dykes. The remaining clay-water suspension is discharged into the central tailings pond. In winter weather, dyke construction is not feasible so all waste products are discharged into the tailings pond without separation.

In its natural state, oil sand contains 10% clay and 90% sand. The volume doubles during processing, and because of an affinity of clay for water, the clay occupies 45% of the waste volume.

To accomodate the increase in volume between oil sand in situ and in waste, the tailings structure will rise well above the original surface of mined out areas. Typical cross sections of tailings ponds are shown in Figure 1.

Rehabilitation plans for the waste areas vary. Typical plans submitted to licensing bodies involve stabilizing the sand dyke and pond surface with protective vegetation. To stabilize the pond surface, weak near-surface materials are removed and the cavity backfilled before revegetation is attempted.

3. GOALS OF WASTE HANDLING

The overall goal of waste handling is to optimize the process so it can be handled with a minimum of effort and leave the waste in an environmentally acceptable state.

Components of the waste handling team are shown on Figure 2. Dependency on the overall goals is apparent.

The purpose of the retaining dyke is to hold or retain material in the central pond as long as it requires external support.

4. SOME UNUSUAL ASPECTS OF OIL SAND TAILINGS

4.1 Effect of Size

Conventional tailings structures are relatively small in comparison with their surroundings. As a result the consequence of failure is an accepted risk.

In comparison, oil sand tailings are so vast that they dominate the landscape. Failure that permits sudden release of material from the dykes would choke the surrounding area with highly erodible sand. Failure that permits release of the tailings fines would have a more severe, far-reaching effect down the adjacent waterway. It is doubtful if the normal risk would be acceptable for these types of failure.

All earth structures will ultimately erode and the material contained in them released to the surrounding terrain. In view of the large quantities of material present in oil sand tailings, and the potential for its release to dominate the surrounding area, consideration must be given to controlling long-term erosion of the facility.

4.2 Perpetuation of the Central Pond

Clay in the tailings pond slowly drops out of suspension and accumulates on the floor of the pond. The sedimented material loads previously sedimented material and causes it to compress and develop strength that is proportional to the effective overburden stress. The amount of potential settlement is large. Figure 3 shows that settlement in excess of 50% of the initial height of tailings fines can be expected in normal oil sand tailings ponds. The space created can be used to increase storage capacity of the tailings pond if settlement occurs while operations are ongoing. If it occurs later, the ground surface will settle and keep a permanent lake on surface.

The rate of consolidation of fine materials is governed by material properties, by site geometry (length of the drainage path through consolidating material), and by consolidation theory (3). Predicted time for consolidation of oil sand fines is shown in Figure 4. With a short drainage path, consolidation can be accomplished in a few years, while operations are still underway. With a long drainage path, however, consolidation will probably take thousands of years. Present methods of handling oil sand waste create very long drainage paths (150 feet +) so the consolidation precess will be very slow.

From the above considerations, we can expect fines in today's oil sand waste facilities to consolidate very slowly. As consolidation takes place the ground surface will settle and perpetuate a lake at surface.

4.3 Required Life of the Retaining Structure

The tailings dyke must support the interior tailings fines until they consolidate and develop sufficient strength that they can support themselves without external support. With present methods of oil sand tailings construction, it will probably be thousands of years before the fines stabilize. The retaining dykes must remain functional for that length of time!

Designing retaining structures made of highly erodible fine sand that must remain operational for as long as the pyramids have been in existence is something new. Existing design guidelines for tailings are based on relatively short term soil mechanics considerations. Evaluation of long term stability requires a review of geological erosion processes and an assessment of how they could affect retaining structures.

5. EROSION PROCESSES AND STABILITY

5.1 Short Term Stability

Short term stability aspects are covered by designing in accordance with soil mechanics principles. Features include densifying sand in the dyke to give it increased strength, selecting an overall geometry that is known to be stable and controlling internal pore pressures to ensure that stability is maintained.

Liquifaction of the dyke is prevented by placing materials in a dense state that resists liquifaction. The interior fines are, of course, already in a liquid state.

Protection against surface erosion by wind and water is provided by surface vegetation.

5.2 Long Term Stability

Erosion processes that assume importance for the long term are natural geological processes that are active on the landscape today. The main processes are erosion by running water and by wind. These are described below.

5.2.1 Surface Runoff

The dykes are constructed of uniform fine sand that is easily eroded by running water. Erosion by runoff from normal precipitation falling on the dyke slopes can probably be resisted by surface vegetation. However if the vegetative cover is ever broken, runoff will be channelled and downcutting will be difficult to stop once started. Energy barriers and erosion control devices should be built into the slope to prevent downcutting.

5.2.2 Overflow from Surface Ponds

The surface of the tailings area represents a sizeable drainage basin. Lakes that form there contain a lot of stored energy that would cause rapid downcutting and breach the dyke if overflow ever occurred.

Design for long term stability should include steps to minimize the volume of water that can collect at the surface and that controls drainage from the upland area.

5.2.3 Toe Erosion

Design of retaining structures located near major rivers must consider the long term potential for erosion at the edge of the river. Where extremely long term protection is needed, it would probably be advisable to locate retaining structures well back from the river. Alternatively, heavy rip rap and long term maintenance programs will be required.

5.2.4 Wind Erosion

Wind is an effective eroding agent of exposed uniform dry sand. Active sand dune areas north of Fort McMurray cover several square miles and demonstrate the potential for wind erosion. There, large sand dunes are migrating over and destroying protective vegetation - a process that is very difficult to stop once it is started.

Normal surface vegetation will prevent wind erosion, but active erosion can be expected to start at any break in the vegetative cover. Growth of the eroding area is a legitimate concern. Channels cut by running water are ideal locations for wind erosion to start. Consideration should be given to including strips of cohesive soil in the dyke profile to halt wind erosion.

Dust bowl conditions are common on the abandoned surface of tailings dams. Protective vegetative cover will be needed to prevent this from happening on upland areas.

6. CONSIDERATIONS FOR BUILT-IN STABILITY

6.1 Location

One of the first considerations affecting the overall vulnerability and stability of a tailings facility is its location.

Locations adjacent to major rivers are less desirable because:

(1) there is a higher environmental risk from a structure located immediately adjacent to a major river,

(2) erosion processes are more active in major river valleys, so more consideration will have to be given to resisting erosive forces there, and

(3) local relief - and hence energy from runoff water - is greater for structures near major river channels than it is for those "buried" in mined out upland areas.

6.2 Outlet for the Tailings Drainage Basin

An outlet channel should be provided so drainage from the tailings pond area can be directed away from the dykes and controlled discharge can occur. Large settlements that might take place from post construction consolidation should be taken into account when planning this facility.

The most appropriate outlet would be over an inland course that has a long section with a gentle gradient over stable ground.

6.3 Minimize Volume of Water in Waste Pond Areas

As noted earlier, ponds in the upland area contain considerable stored energy that can cut through the retaining dyke if flow ever occurs in that direction. For this reason long-term planning should include methods of eliminating upland lakes. Methods are indicated in Section 6.7.

6.4 Vegetative Cover

Thick vegetative cover is needed to protect the surface from erosive forces.

Sandy dyke soils tend to be well drained, so are not likely to support vegetative cover of the type desired. Consideration should be given to providing fertile soil and water that will enhance vegetative growth. The next section indicates one method of accomplishing this.

6.5 Buffer Strips of Cohesive Soil

Present designs produce a dyke that is essentially all made of sand. Buried strips of cohesive soil illustrated in Figure 5 offer a number of advantages that could justify the cost of providing them. Advantages include:

(1) cohesive layers would check downcutting by flowing water on surface,

(2) cohesive layers would check wind erosion,

(3) cohesive strips are apt to induce a perched water table that will support better surface vegetation, and

(4) cohesive soil that contains a variety of minerals is more likely to support dense vegetation than quartz tailings sand.

This design feature would not be necessary in structures that only have to cope with short term conditions. It is worth considering however, where long term service is needed.

6.6 Energy Barriers

Surface erosion channels are difficult to halt once started. Built-in energy barriers such as periodic rows of rip rap can prevent channels from developing over the full height of the dyke slope. Energy barriers of this type provide a natural method of maintaining the slope.

6.7 Accelerated Consolidation of Tailings Fines

Methods of accelerating consolidation of tailings fines have been reported elsewhere (4). With minor changes to operations during placement of the tailings waste, it appears feasible to accelerate consolidation so it will be complete in a few years, instead of taking thousands of years. Advantages of this include:

(1) the ground will be stabilized within an identifiable control period,

(2) up to 50% increase in storage capacity for tailings fines will result,

(3) tailings fines will develop strength and become self-supporting at the same rate as consolidation occurs. This will reduce the service requirement for the tailings dyke from long term (thousands of years) to a life span that is much more predictable, and

(4) when consolidation is complete surface settlement will stop. If this occurs early enough, it will be possible to reduce and perhaps even eliminate surface lakes.

Increased storage capacity, increased stability, and shorter life requirements for the retaining dykes are obvious advantages arising from accelerated consolidation.

7. CLOSURE

Waste facilities resulting from oil sand processing dwarf previous waste facilities. Peculiar problems arise from the size of the installations.

A review of the way in which materials behave in oil sand tailings facilities indicates that materials will not stabilize for a very long time - perhaps thousands of years. Retaining structures will have to provide support for that period of time.

Existing guidelines for the design and construction of tailings structures are based on short term considerations only. There is no precedent for such long term support. To assess factors influencing long term stability natural geological erosion processes have to be taken into account. Major processes influencing highly erodible oil sand tailings facilities include:

- erosion from surface runoff
- overflow from surface ponds
- wind erosion, and
- toe erosion by rivers and streams.

Consideration of the effect of natural erosion processes reveals stabilizing steps that can be integrated into tailings planning and construction. Major factors are discussed in the preceeding report. Considerations include:

(1) location,
(2) providing an outlet for the surface drainage basin,
(3) minimizing the volume of water in upland areas,
(4) providing dense vegetative cover,
(5) incorporating buffer strips of cohesive soil in the dyke,
(6) providing surface energy barriers, and
(7) accelerating consolidation of the tailings fines.

Many of the above factors are not required in tailings facilities that will only have a short life. However, they offer definite advantages to facilities that will be required to last a long time. Accelerating consolidation appears particularly advantageous and may reduce present operating costs.

REFERENCES

1. Alpin, C.L. and Argall, G.O. Jr., Editors, Tailings Disposal Today, Proceedings of the first International Tailings Symposium, Tuscon, Arizona, 1972

2. Tentative Design Guide for Mine Waste Embankments in Canada; Mines Branch Technical Bulletin TB145, March, 1972

3. Terzaghi, K; Peck, R.B. (1948), Soil Mechanics in Engineering Practice, Wiley

4. Devenny, D.W. (1975); Subsidence Problems at Oil Sand Mines, Proc. 10th Canadian Rock Mechanics Symposium, Queen's University, Kingston, Ontario.

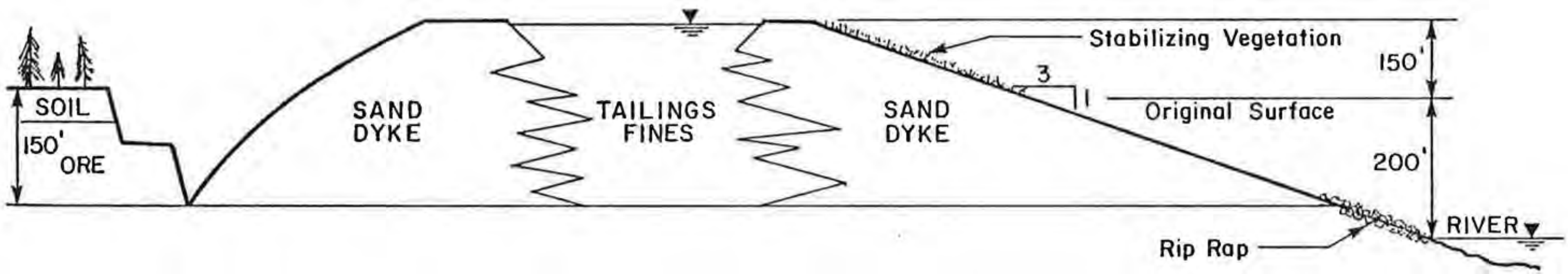

FIGURE 1 . CROSS SECTION OF A TAILINGS STORAGE DAM

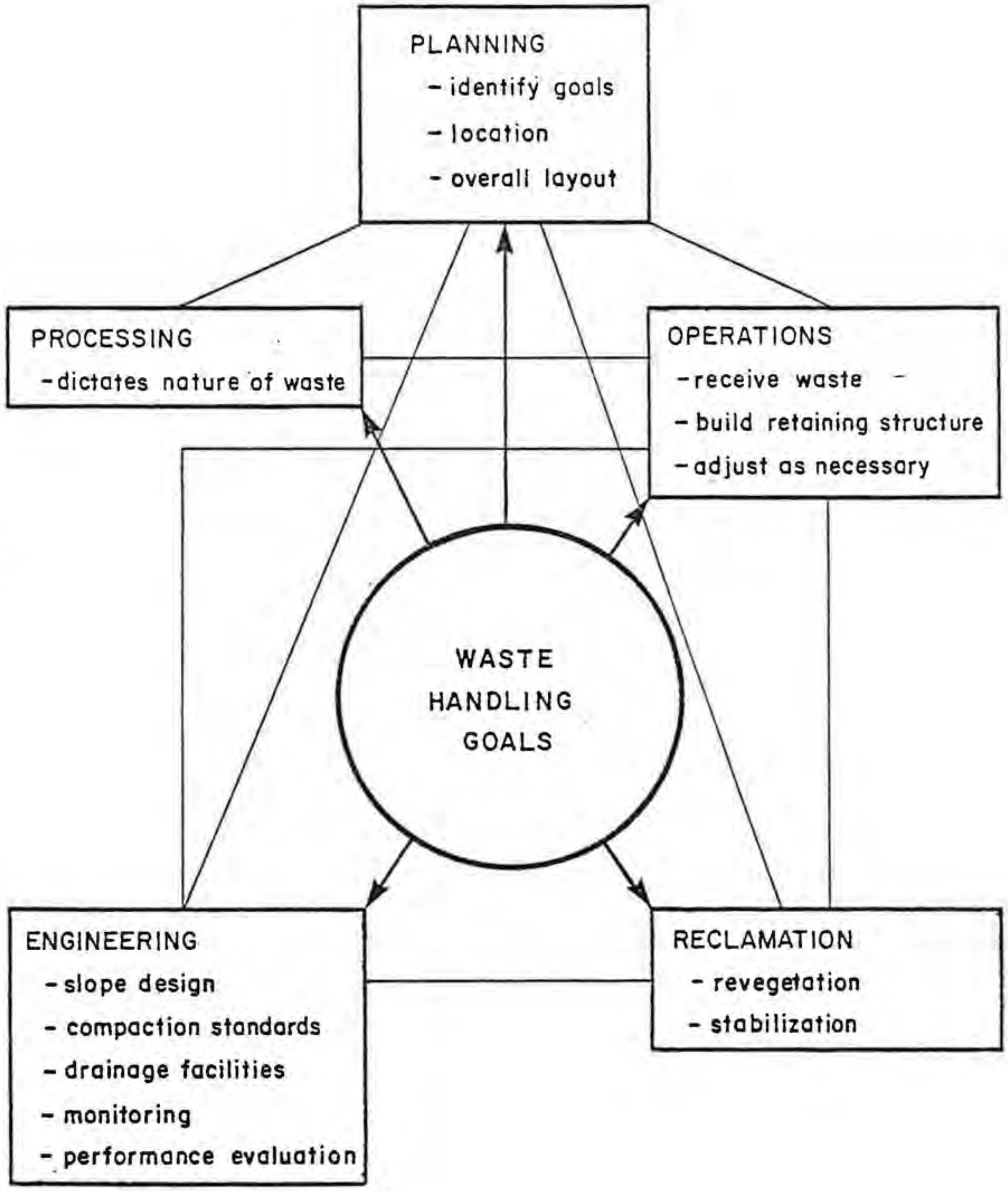

FIGURE 2 DISCIPLINES INVOLVED IN WASTE HANDLING SHOWING INTERDEPENDENCE AND CONTROL FROM OVERALL GOALS

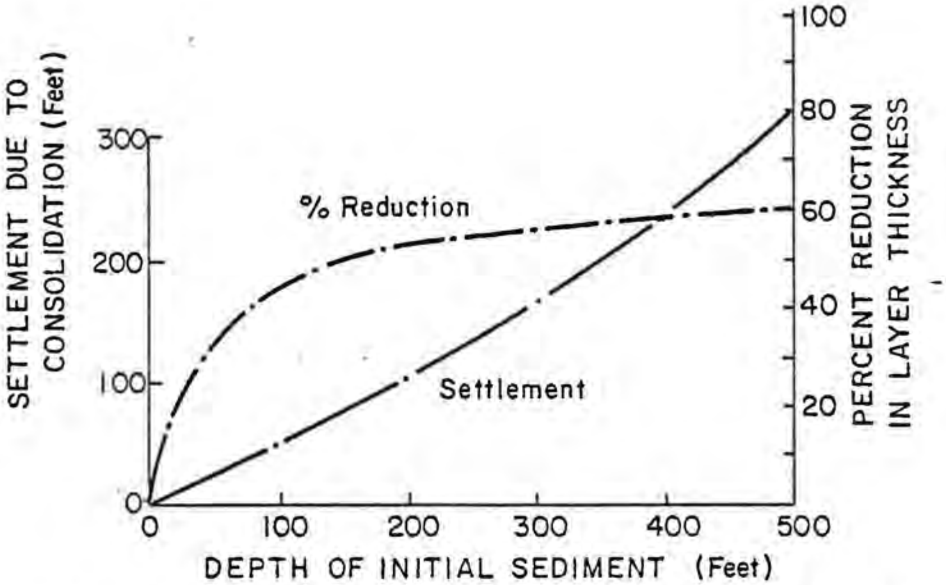

FIGURE 3 PREDICTED SETTLEMENT DUE TO CONSOLIDATION OF TAILINGS FINES

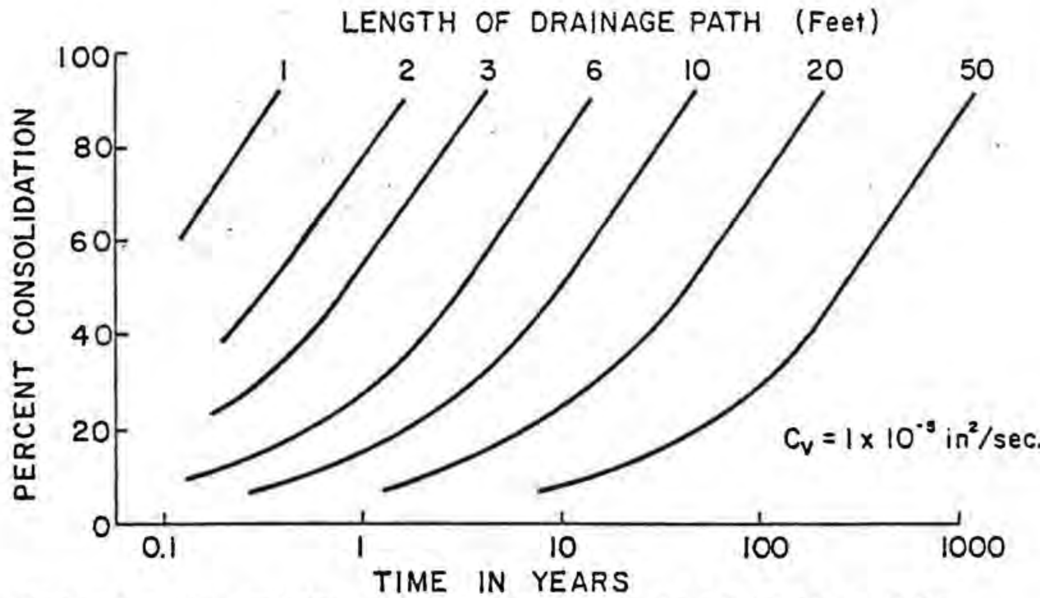

FIGURE 4 TIME RATE OF CONSOLIDATION FOR VARIOUS LENGTHS OF DRAINAGE PATH

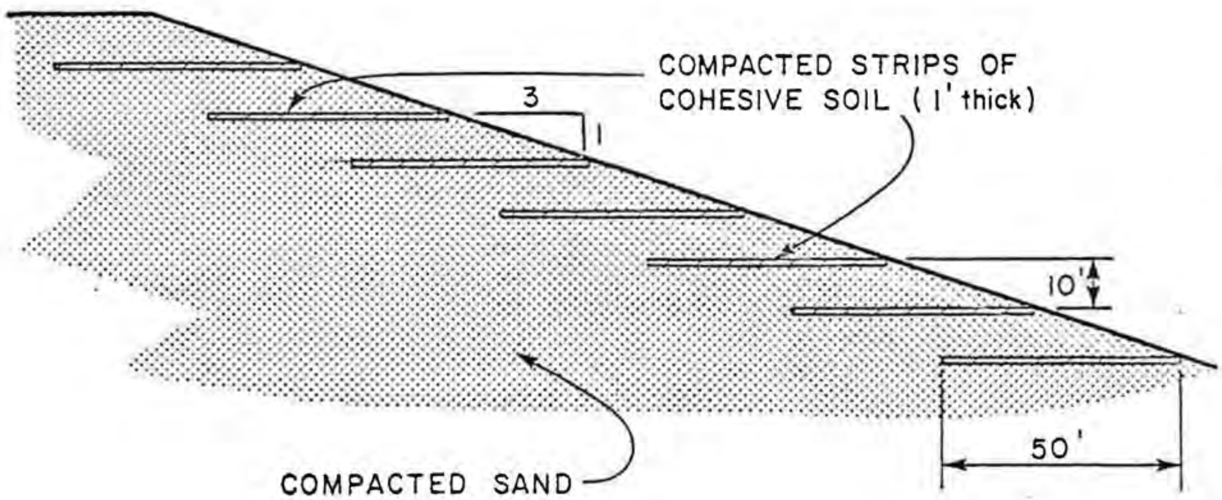

FIGURE 5 COHESIVE STRIPS IN SAND TAILINGS DYKE

PROCEEDINGS

OF

THE SECOND ANNUAL GENERAL MEETING

OF THE

CANADIAN LAND RECLAMATION ASSOCIATION

August 17, 18, 19 & 20 —1977 Edmonton, Alberta

(Sponsored by the Faculty of Extension, University of Alberta)

P R O G R A M

Canadian Land Reclamation Association

Second Annual General Meeting

August 17, 18, 19, 20, 1977

Edmonton, Alberta

Wednesday, August 17 (Optional Field Trips)

Field Trip No. 1 (Athabasca Tar Sands)

Leader: Philip Lulman (Syncrude Canada Ltd.)

Fee: $100.00 (covers bus and air transportation, lunch, and field trip information pamphlets)

Schedule: 7:30 am.- delegates board bus at Parking Lot T, located immediately south of the Lister Hall Student Residence complex. Air transportation from Edmonton Industrial Airport to Fort McMurray and return. Guided bus tour of surface mining and reclamation operations on Syncrude Canada Ltd. and Great Canadian Oil Sands Ltd. leases.
6:30 p.m.- delegates arrive back at Parking Lot T, University of Alberta campus.

Field Trip No. 2 (Aspen Parkland; Forestburg Coal Mine Reclamation)

Leader: George Robbins (Luscar Ltd.)

Fee: $25.00 (covers bus transportation, lunch, and field trip information pamphlets)

Schedule: 8:00 a.m. - delegates board bus at Parking Lot T, located immediately south of the Lister Hall student residence complex. Guided bus tour southeast of Edmonton, stopping at various points of interest (oil spill reclamation field plots; Black Nugget Park [abandoned minesite]; trench plots on Dodds-Roundhill Coal Field; solonetzic soil deep ploughing site) on the way to the Luscar Ltd. Coal Mine at Forestburg.
6:30 p.m. - delegates arrive back at Parking Lot T, University of Alberta campus.

Thursday, August 18

Events: Opening of Formal Meeting; Presentation of Papers

Location: Multi-Media Room, located on second floor of Education Building, University of Alberta.

8:00 a.m. Authors of papers being presented on August 18 meet with paper presentation chairmen and audio-visual co-ordinator (Douglas Patching)

9:00 a.m. Meeting Opened by Dr. Jack Winch (President of the C.L.R.A.; Head of the Department of Crop Science, University of Guelph). Comments by Dr. Winch.

9:15 a.m. Welcome to delegates on behalf of the Government of Alberta by the Hon. Mr. Dallas Schmidt, (Associate Minister Responsible for Lands, Alberta Department of Energy and Natural Resources)

9:25 a.m. Commencement of Paper Presentations. Morning session chaired by Mr. Henry Thiessen (Chairman of the Land Surface Conservation and Reclamation Council and Assistant Deputy Minister, Alberta Department of Environment).

9:30 a.m. Paper 1. Combined Overburden Revegetation and Wastewater Disposal in the Southern Alberta Foothills by H.F. Thimm, G.J. Clark and G. Baker (presented by Harald Thimm of Chemex Reclamation and Sump Disposal Services Ltd., Calgary, Alberta).

10:00 a.m. Paper 2. Brine Spillage in the Oil Industry; The Natural Recovery of an Area Affected by a Salt Water Spill near Swan Hills, Alberta by M.J. Rowell and J.M. Crepin (presented by Michael Rowell of Norwest Soils Research Ltd., Edmonton, Alberta)

10:30 a.m. Coffee Recess

11:00 a.m. Paper 3. The Interaction of Groundwater and Surface Materials in Mine Reclamation by Philip L. Hall of Groundwater Consultants Group Ltd., Edmonton, Alberta.

11:30 a.m. Paper 4. Subsurface Water Chemistry in Mined Land Reclamation; Key to Development of a Productive Post-Mining Landscape by S.R. Moran and J.A. Cherry (presented by Stephen Moran of the Research Council of Alberta, Edmonton, Alberta).

12:00 noon Lunch Recess

1:25 p.m.	Continuation of Paper Presentations. Afternoon session chaired by Mr. Philip Lulman (member of C.L.R.A. executive; reclamation research ecologist with Syncrude Canada Ltd.).
1:30 p.m.	Paper 5. Coal Mine Spoils and Their Revegetation Patterns in Central Alberta by A.E.A. Schumacher, R. Hermesh and A.L. Bedwany (presented by Alex Schumacher of Montreal Engineering Company Ltd., Calgary, Alberta).
2:00 p.m.	Paper 6. Surface Reclamation Situations and Practices on Coal Exploration and Surface Mine Sites at Sparwood, B.C. by R.J. Berdusco and A.W. Milligan (presented by Roger Berdusco of Kaiser Resources Ltd., Sparwood, B.C.).
2:30 p.m.	Paper 7. Agronomic Properties and Reclamation Possibilities for Surface Materials on Syncrude Lease #17 by H.M. Etter and G.L. Lesko (presented by Harold Etter of Thurber Consultants Ltd., Victoria, B.C.).
3:00 p.m.	Paper 8. The Use of Peat, Fertilizers and Mine Overburden to Stabilize Steep Tailings Sand Slopes by Michael J. Rowell of Norwest Soils Research Ltd., Edmonton, Alberta.
3:30 p.m.	Coffee Recess
4:00 p.m.	Paper 9. Oil Sands Tailings; Integrated Planning to Provide Long-Term Stabilization by David W. Devenny of E.B.A. Engineering Consultants Ltd., Edmonton, Alberta.
4:30 p.m.	Paper 10. Bioengineering. The Use of Plant Biomass to Stabilize and Reclaim Highly Disturbed Sites by H. Schiechtel and K. (Nick) Horstmann (presented by Margit Kuttler).
5:00 p.m.	End of August 18 Sessions.

Friday, August 19

Events: Presentation of Papers; C.L.R.A. Annual General Business Meeting; C.L.R.A. Annual Dinner.

Locations: Paper presentations and C.L.R.A. Annual General Business Meeting in Multi-Media Room, located on second floor of Education Building, University of Alberta.
- Annual Dinner held in Banquet Room located on second floor of Lister Hall.

8:00 a.m. Authors of Papers being presented on August 19 meet with paper presentation chairmen and audio-visual co-ordinator (Douglas Patching).

8:30 a.m. Showing of Film Rye on the Rocks. This film depicts reclamation situations at Copper Cliff, Ontario and is being shown for the purpose of introducing delegates to the site of the 1978 C.L.R.A. meeting (Sudbury, Ontario).

8:55 a.m. Continuation of Paper Presentations. Morning session chaired by Dr. J.V. Thirgood (Vice-President of C.L.R.A.; member of Forestry Faculty, University of British Columbia).

9:00 a.m. Paper 11. Reclamation of Coal Refuse Material on an Abandoned Mine Site at Staunton, Illinois by M.L. Wilkey and S.D. Zellmer (presented by Michael Wilkey of the Argonne National Laboratory, Argonne, Illinois).

9:30 a.m. Paper 12. A Case Study of Materials and Techniques Used in the Rehabilitation of a Pit and a Quarry in Southern Ontario by Sherry E. Yundt of the Ontario Ministry of Natural Resources, Toronto, Ontario).

10:00 a.m. Coffee Recess.

10:30 a.m. Paper 13. Amelioration and Revegetation of Smelter-Contaminated Soils in the Coeur D'Alene Mining District of Northern Idaho by D.B. Carter, H. Loewenstein and F.H. Pitkin (presented by Daniel Carter of Technicolor Graphic Services Inc., Sioux Falls, South Dakota).

11:00 a.m. Paper 14. The Influence of Uranium Mine Tailings on Tree Growth at Elliot Lake, Ontario by David R. Murray of the Elliot Lake Laboratory, Elliot Lake, Ontario.

11:30 a.m.	Paper 15. Weathering Coal Mine Waste. Assessing Potential Side Effects at Luscar, Alberta by D.W. Devenny and D.E. Ryder (presented by David Devenny of E.B.A. Engineering Consultants Ltd., Edmonton, Alberta).
12:00 noon	Lunch Recess.
1:25 p.m.	Continuation of Paper Presentations. Afternoon session chaired by Dr. John Railton, (Manager, Environmental Planning, Calgary Power Ltd., Calgary, Alberta).
1:30 p.m.	Paper 16. The Distribution of Nutrients and Organic Matter in Native Mountain Grasslands and Reclaimed Coalmined Areas in Southeastern B.C. by Paul F. Ziemkiewicz of the Faculty of Forestry, University of B.C., Vancouver, British Columbia.
2:00 p.m.	Paper 17. Systems Inventory of Surficial Disturbance, Peace River Coal Block, B.C. by D.M. (Murray) Galbraith of the British Columbia Ministry of Mines and Petroleum Resources, Victoria, British Columbia.
2:30 p.m.	Paper 18. The Selection and Utilization of Native Grasses for Reclamation in the Rocky Mountains of Alberta by D. Walker, R.S. Sadasivaiah and J. Weijer (presented by David Walker of the Department of Genetics, University of Alberta, Edmonton, Alberta).
3:00 p.m.	Coffee Recess; Distribution of Proceedings.
3:30 p.m.	Commencement of 1977 General Business Meeting of the Canadian Land Reclamation Association. Meeting chaired by Dr. J.V. Winch, C.L.R.A. President.
7:30 p.m.	Commencement of C.L.R.A. Annual Dinner in Banquet Room, second floor of Lister Hall.

Guest Speaker:	William T. Plass, Principal Plant Ecologist, U.S.D.A. Forest Service, Northeastern Forest Experiment Station, Princeton, West Virginia.
Topic of Speech:	Challenges in Co-operative Reclamation Research.

Note: Following the Annual Dinner and Mr. Plass's speech, delegates may retire to the adjacent Gold Room. A bartender will be on service until midnight.