CANADIAN ADVISORY COMMITTEE ON ROCK MECHANICS

Report of the Sub-Committee

on

STABILITY OF WASTE EMBANKMENTS

by

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FOREWORD

This report, prepared by a Subcommittee of the Canadian Advisory Committee on Rock Mechanics, reviews the status of knowledge on the stability of waste dumps and the like structures and suggests research to close the gap in the knowledge of the subject. While not dealing with land pollution directly, the report discusses the broad design criteria required to ensure maximum safety in regard to waste dumps, ore piles, and tailings dams. This report is published in the interests of dissemination of scientific knowledge and to encourage further discussion of this important subject.

John Convey
Director

AVANT-PROPOS

Le présent rapport, rédigé par un sous-comité du Comité consultatif canadien de la mécanique des roches, passe en revue les connaissances actuelles sur la stabilité des terrils et autres dépôts de résidus et recommande certaines recherches en vue de combler les lacunes d'information en cette matière. Bien qu'il ne traite pas directement de la pollution du sol, le rapport étudie les critères techniques généraux devant assurer la sécurité des terrils, des dépôts de minerai et des barrages de retenue des stériles. Le rapport vise à diffuser les connaissances scientifiques et à encourager l'échange d'idées sur cet important sujet.

John Convey
Directeur

TERMS OF REFERENCE

The general terms of reference assigned to the Subcommittee on Waste Disposal by Dr. D.F. Coates, Chairman of the Canadian Advisory Committee on Rock Mechanics were "to determine the research requirements for routine design of waste dumps, tailings ponds, control devices for acid water and other systems for handling the disposal of mine wastes (letter to C.O. Brawner dated June 12, 1968). The Committee was advised that these terms of reference were to serve as a preliminary guide and that the committee could modify these terms of reference if this was considered advisable.

The committee considered that it was desirable that engineering and operating aspects relating to waste piles as well as research should be included within the terms of reference. It was also considered that the stability of tailings dams, waste dumps and ore storage piles was of primary and generally equal concern. Secondary problems such as pollution, snow avalanches, hydraulic design considerations were considered beyond the scope of this investigation.

The general form of the committee's report was selected as follows:

(a) To define the problems of stability of tailings dams, waste dumps and ore piles.

(b) To determine existing controls and legislation in Canada.

(c) To develop recommendations for design guides, education, legislation and research in Canada.

The views of the members are personal considerations and are not intended to represent company or government policy.

COMMITTEE MEMBERSHIP

Committee membership was selected to encompass broad experience in the mining industry. In order to facilitate periodic meetings with the maximum turnout of membership committee members were selected who reside in British Columbia but who have extensive experience in Canada. The names of the committee members are as follows, with the specialty area of experience given in brackets.

C.O. Brawner, Golder, Brawner & Associates Ltd., Vancouver. (Soil and Rock Mechanics, Foundations and Stability Engineering).

K. Davies, Cominco Ltd., Kimberley. (Base Metals)

L. Dwarkin, Kaiser Resources Ltd., Fernie. (Coal)

G. Godfrey, Rio Algom Mining Ltd., Vancouver. (Uranium)

R. Harris, Cassiar Asbestos Ltd., Cassiar. (Asbestos)

K. McRorie, Wright Engineers Ltd., Vancouver. (Iron Ore)

W. Robinson, B.C. Dept. of Mines, Vancouver. (Government)

PROCEDURE

Three meetings were held by the subcommittee. The first on November 12th, 1968, the second March 3rd, 1969 and the final meeting on August 15th, 1969. These meetings were all held in Vancouver.

Following the first meeting, letters were forwarded to Deputy Ministers of all provincial Departments of Mines to determine whether any guidelines, regulations or legislation existed which specifically deal with design, construction control or stability evaluation of waste piles in Canada.

To assist the committee in determining the overall problem a literature research was made. The Chief Librarian of the Department of Mines prepared a basic bibliography to which committee members have made additions. This bibliography is enclosed as Appendix A of this report.

At the first subcommittee meeting it was agreed that a questionnaire sent to all mining companies in Canada might provide significant information regarding tailings dams, waste dumps and ore piles in Canada, that a general outline of stability problems could be obtained and that advice from the mining companies regarding the need for guidelines might be indicated. The preliminary outline of the questionnaire was prepared at this meeting. The detailed outline of the questionnaire was developed and finalized at the second meeting. The questionnaire and summary of answers is included in this report as Appendix B. One hundred and fifty questionnaires were sent out and 66 answers were received. Mining engineers were advised that answers would be treated as confidential. Accordingly, all answers were numbered and the list of mining companies who answered the questionnaire has been provided to the subcommittee members and Dr. Coates only.

The final committee meeting dealt with the general review of the questionnaires received, development of the form that the final report should take and detailed discussion and decision on the recommendations to be included in the report.

SUMMARY OF LEGISLATION IN CANADA

A letter was forwarded to the Deputy Ministers of all provincial Departments of Mines in Canada to determine whether provincial governments have established guides or controls for the design and construction of tailings dams, waste dumps and ore piles. In addition, information was also requested regarding each department's opinion or policy regarding the adequacy of the present controls or guides regarding these structures, the possible need for more clearly defined controls and the potential means of developing and implementing these controls. Answers were received from all provincial governments except Prince Edward Island which at the present time does not have a mining industry. Answers to this letter are summarized below.

British Columbia

At the time that the letter was received in December, 1968, specific guides or controls for the design and construction of tailings dams and waste dumps had not been established.

In the spring of 1969 the Mines Regulations Act was amended and Section 7 now provides the Minister and the Inspector with specific authority to implement remedies of any defect which in the opinion of the Inspector endangers the safety or health of any person in or about the mine or the safety of the public. In addition, if it is the opinion of the Inspector that delay in remedying such matters would be dangerous he may order the closing of the mine or any part thereof. The Inspector may also order the mine to be worked so as not to interfere with any public work, highway, railway, pipeline, or other mine or endanger the safety of the public and may require at the expense of the owner, agent or manager a suitable engineering report assessing the conditions at a mine for the purpose of this sub-section of the act.

Alberta

No specific guidelines or procedures exist in the province of Alberta at the present time. Some regulations exist regarding tailings and waste materials in the Coal Mines Regulations Act and the Quarries Regulation Act but none of these deal with stability or construction control.

Saskatchewan

No regulations or controls for the design, construction or stability of tailings dams and waste dumps exist in the province of Saskatchewan. We were advised however that a committee was appointed recently to investigate the subject and to draft regulations that will establish guidelines and to define the methods by which regulations are to be administered.

Manitoba

The mines branch does not have specific regulations governing the design and construction of tailings dams or waste dumps. However, an application is required for the development of the mine and each application is handled as a separate entity and all phases from the selection of the site to the final designs are considered by the Mines Branch.

Ontario

The Ontario Water Resources Commission of the Division of Industrial Waste has developed guidelines which set out the information required and criteria used to evaluate embankment retention systems used to impound solid waste materials. An application for impoundment must be presented to the Ontario Water Resources Commission and that application must provide detailed information on the method of design and construction proposed. The design and construction must be acceptable and the application approved before construction commences.

No regulations exist at the present time regarding guidelines or controls for the construction of waste dumps or ore piles in the province.

Quebec

No specific guidelines for the development of tailings dams and waste dumps exist in the province of Quebec. Three separate acts exist, however; the Mining Act, Water Courses Act and Water Board Act which require that drawings showing site location and proposed construction works for mining projects shall be transmitted to the Minister for review and approval. In addition, it is required that each operator shall keep an up to date plan showing the boundaries of his land, water courses, roads and railroads, electric transmission lines, shafts and adits, buildings and other installations, deposits of tailings and rock outcrops, etc. The inspectors, engineers or geologists of the Department shall have free access to such plans at all times.

New Brunswick

No guidelines or regulations exist in the province of New Brunswick regarding the design and construction of tailings dams and waste dumps. However, we were advised that some regulations are being considered.

Nova Scotia

No regulations exist at the present time regarding guidelines or regulations concerning the design and construction of tailings dams or waste dumps. It was indicated that controls are necessary and the suggestion was made that the best method of enforcement is probably a deposit large enough to cover possible damages, forfeitable if regulations are not strictly adhered to.

Newfoundland and Labrador

No regulations presently exist regarding design and construction control for tailings dams or waste dumps in the province.

Summary

The only province in Canada which at the present time has developed guidelines for the design and construction control of waste dams is Ontario. This guide is of a general nature and illustrates the type of information which should be obtained to evaluate stability. Detailed techniques of site investigation, design, construction control, maintenance and inspection are not provided.

The provinces of Manitoba, Ontario and Quebec now require that engineering drawings be submitted to the Department of Mines for review by that Department prior to the commencement of construction. The province of British Columbia gives explicit authority to mines inspectors to require modification to the mining program or existing conditions to improve stability. In addition, he may close the mine down if he considers the mine conditions are dangerous or demand a specialist engineering report.

It is not common practice for the provincial mining departments to have qualified stability specialists such as soil mechanics engineers on their staffs to review design and construction of tailings dams, waste dumps and ore piles.

BIBLIOGRAPHICAL LITERATURE

Numerous articles are now available in the literature which describe the general conditions of stability and stability analysis and the general requirements of construction for tailings dams, waste dumps and ore piles. A list of this information is included in Appendix A.

Existing Guides

The bibliographical search has located three Guides or Codes of Practice.

1. U.S. Atomic Energy Committee Guide - "The A.E.C. Licensing Guide - Information and Criteria Pertinent to Evaluation of Embankment Retention Systems".

   This guide was compiled as an aid in the preparation of application for resource material licenses in which embankment retention systems are employed to prevent or control the release of radio activity in concentrations exceeding those permitted to be released. Since the characteristics of embankment systems may vary significantly from one location to another the criteria are very general.

   This A.E.C. guide outlines factors which must be evaluated for the design and construction of tailings dams. It does not outline design methods or techniques of analysis. A copy of this guide is included in Appendix C of this report.

2. Ontario Water Resources Commission Guide.

This guide is very similar to the A.E.C. Licensing guide and has obviously been patterned on that guide but modified somewhat for Ontario conditions and for material other than uranium wastes. This guide was reviewed by the Mining Association of Canada in June 1967. Criticism generally involved suggestions that the guide should be more general than it is now. Greater emphasis is placed upon economy of constructing the waste pile system than the overall safety aspects of the system. The Ontario guide is included in Appendix C.

3. National Coal Board of Britain, Code of Practice for Spoil Heaps and Lagoons, first draft, December 1968.

As a result of the Aberfan failure on October 21, 1966 a very detailed investigation has been carried out on behalf of the National Coal Board by the Aberfan Tribunal. One of the recommendations of this tribunal was that a code of practice be developed for the design, construction and maintenance of all existing spoil heaps and lagoons and for all such structures that are proposed in the future. The first interim draft of the Code of Practice is approximately 200 pages in length. Only one copy of this code of practice was obtainable. It has been forwarded separately to the Chairman of the Canadian Advisory Committee on Rock Mechanics. To indicate the detail of this guide, the

Table of Contents is included in the Appendix C.

In order to illustrate and emphasize the significance of failures of earth or rock embankments constructed during mining operations the committee considers it important that a summary of the more significant findings and recommendations of the Aberfan Tribunal should be summarized in this report. The committee recognizes that the recommendations may be influenced by extreme public reaction. However, the requirement of safety in mining cannot be over-emphasized. Important recommendations are summarized in the following text.

a) One of the primary lessons to be learned from the Aberfan failure is the evaluation of the proposed tipping sites in the future.

b) The problem of burning and its influence on stability must always be considered in relation to coal mining dumps.

c) A public suggestion was that all tailings should be stored underground. The National Coal Board advises that while the underground storing of the general run of mine rubbish is in broad terms technically feasible it is unsuitable for universal adoption because it would make the cost of coal mining completely uneconomical.*

* The same interpretation would probably be applied to other fields of mining operations.

Although the depositing of waste dumps in disused mine shafts provides a partial solution, in general we see no present alternative to the creation of tips on the surface.

d) The disaster teaches us several lessons relative to tips in general. The first is that they should all be regarded as potentially dangerous. The second is that they should all be treated as engineering structures and that, accordingly, the procedures of preliminary site investigation and subsequent construction control customary to the branch of civil engineering should be applied.

e) A third broad lesson relates to the National Coal Board administration. It urgently needs a complete overhaul in the system of intercommunication both vertically and horizontally between the various departments on levels of the board.*

f) Mr. Tasker Watkins, Q.C. for the Tribunal criticized the apparent failure to circulate through the south-west division of the National Coal Board, news of the novel initiatives and experiments.**

* The committee feels that intercommunication within the mining company, between mining companies and governmental agencies should be reviewed to determine if the present system of communication is adequate.

** The committee considers that a review of present experience and new developments should be brought to the attention of all concerned in the mining industry as soon as possible.

g) Experts of the Treasury Solicitor assisting the Tribunal begin their recommendations by insisting that all colliery tips be treated as engineering structures. They therefore suggest that the site investigation for a new tipping area or for the extension of an existing tip complex should be under the direction of a civil engineer experienced in soil mechanics.

This approach is of fundamental importance. Specifically, it is recommended that the following be performed:

i) Maps prepared by the geological survey should first be studied.

ii) A site investigation by using borings, soil testing and observations of groundwater level should be carried out by a civil engineer in consultation with a geologist and mining engineer where necessary.

iii) On the basis of this data, engineering design should be made by the civil engineer for the tip, including where necessary, drainage and compaction.

iv) While the tipping process is continuing, the stability aspects should be under the control of a civil engineer.

v) When tipping has been completed, inspection by a civil engineer should continue thereafter and routine measurements and observations made and recorded.

vi) The basic information so obtained should be placed on permanent record and be available to the local authority or to any person reasonably requiring it.

h) Professor Bishop of Imperial College, London, recommended that a National Safety Committee be set up by the appropriate Minister to report particularly on the standards of safety to be called for in circumstances varying from large tips near inhabited property to small tips in remote areas.

i) The Tribunal recommends that the appropriate Minister should consider appointing a committee to advise him in the exercise of his responsibility for the safety, and inspection of all tips whether or not they are connected with mines or quarries. This should include tips belonging to industries not concerned with mining such as electric authorities and steel works and <u>should also include abandoned tips</u>.

j) The National Coal Board should arrange courses of instruction in soil heap management.

k) Sir Andrew Bryan recommended to the National Coal Board for consideration of the National Tip Safety Committee that a "Code of Practice" be developed giving guidance on (a) features and factors that may give rise to or reveal instability in a tip, and (b) standards of safety called for in particular locations and circumstances.

l) Mr. Wardell recommended that if any local planning or community authority be dissatisfied about the stability of an existing or proposed tip after consideration of all available information the matter should be submitted to the Minister of Power with a request for a special investigation and report.

m) Mr. Lyden James on behalf of the National Union of Mine Workers made the following recommendations on future education and training.

i) Present managers and surveyors should as soon as possible receive training in groundwater conditions and the rudiments of soil mechanics so as to be able to appreciate the significance of the reports of, and opinions expressed by, the experts in these subjects.

ii) The statutory qualifications for managers and surveyors should in future include awareness of the elements of soil mechanics and hydrogeology, in addition to the geology which is already contained in the syllabus.

iii) The unit engineers and charge hands should be instructed in the significance of tip deformation and of the appearance and disappearance of water courses. In addition the charge hands should be trained to record at frequent intervals on a form or simple questionnaire dealing with such matters as toe movement, crest sinking, cracks and breaks. These records should be kept at the unit office and inspected regularly by the manager and mechanical engineer. They should also be produced by the civil engineer charged with tip responsibility and to Her Majesty's Inspectors of Mines on the occasion of each visit to the tip.

n) Statutory provision should be made for regular inspections of all tips by persons competent to judge their stability and safety and for the due recording of the nature, extent and result of such inspection. In addition all tips should be subject to regular inspection by Her Majesty's Inspector of Mines and Quarries whose resultant detailed reports should be made freely available to the local authorities concerned. A statutory obligation should be imposed upon the owners and managers of mines to maintain and keep at the mine office an up to date plan of the surface area of the undertakings, including the tipping area, and contours of it once the tip exceeds a height to be prescribed. The starting of a new tip and/or an extension of the existing tip complex should be prohibited unless preceded by an adequate site investigation and in accordance with the normal civil engineering code of practice with the proposed new code referred to earlier and the submission to and approval by Her Majesty's Inspectorate of Mines in charge of the tipping plan. New sites and tips should not be started until the report as to the suitability of the tipping scheme has been submitted to and approved by the planning authority.

o) Following are some of the matters upon which it is suggested guidance should be given in the Code of Practice:

i) Choice and exploration of a site for new tips with special reference to the effect of the nature of sub soil, slope of ground, presence of water and proximity to places of work or other facilities.

ii) Characteristics of the various methods of tipping and their possible effect on the stability of tips.

iii) Matters to be considered when the nature of the material to be tipped varies in quality and quantity.

iv) Factors affecting the determination of the safe height of the tip.

v) Possible degree of instability arising from tipping fresh debris.

vi) Signs and symptoms of instability in the tip.

vii) Methods of improving the factor of safety in tips.

viii) The possible effects of underground workings under the tip site on the stability of the tip.

ix) The system of inspection that is required in different circumstances.

SUMMARY OF EXPERIENCE WITH WASTE EMBANKMENTS WITH EMPHASIS ON CANADIAN CONDITIONS

Numberous failures of tailings dams and waste dumps have occurred throughout the world on mining projects. Typical of the more serious of these failures are the following:

Tailings Dams

1. Barahone, Chile (1928). A tailings dyke up to 200 ft. high failed during a severe earthquake releasing 9 million tons of liquefied tailings into the valley below causing great loss of life and extensive property damage.
2. Louisville, Kentucky (1963). Chemical waste banks 100 ft. high failed in an industrially developed area during heavy rain causing extensive damage to adjacent property but no loss of life.
3. El Cobra, Chile (1965). Ten tailings dams liquefied as a result of an earthquake and over 250 people were killed as a result of tailings flowing down the valley near the community of El Cobra.

Waste Dumps

1. Aberfan, Wales (1965). The failure of a waste coal tip caused by heavy rains resulted in the loss of life of over 100 school children.
2. Kaiser Coal, Canada (1968). A portion of a waste dump failed and flowed across the Southern Trans-provincial Highway killing two persons in a motor vehicle.

A general summary of experience in Canada was obtained from the answers received to the committee's questionnaire. Most of the information which was obtained was of a general nature describing site conditions, design details, climatic conditions, material gradations, etc. This information will be useful if or when a very detailed evaluation of the stability problem is desired. For the purpose of this committee the most significant information relates to the number of stability problems that have been described and the types of failures that had occurred. The questionnaire and answers are included in Appendix B of this report. For the purpose of evaluating the significance of stability, 55 of the 66 answers received, answered the question "Have you had stability problems of tailings dams?" Twenty of the 55 or 36 per cent indicated they have had stability problems in the past.

The type of failures included complete dyke failure, foundation failure, slope failure, excess seepage through the toe, excess surface erosion, thermal cracks releasing dirty effluent, tailings overflowing the dyke on top of snow and ice.

Thirty-one of the 66 questionnaires received answered the question, "Have you had any problems with stability of waste dumps or ore piles?" Six of the 31 or 19 per cent indicated they have had failures. These included foundation failures, slope failures, flow slides or slumps on top of snow layers.

It is the committee's belief that a large enough sample of experience has been obtained as a result of the questionnaire to accept the statistics that about 35 per cent of existing tailings dams and 20 per cent of existing waste dumps in Canada have undergone some degree of failure over the past years. Combined with the situation that many mining current developments in Canada involve open pit operations with great volumes and quantities of tailings and waste material the scale of height, shear forces, water pressures, etc. increases the overall potential danger of failure of those structures. This requires that detailed consideration to specialized stability studies be made.

A further very significant factor indicated from the questionnaire was that soil and foundation investigations were only performed for 13 of 56 or 26 per cent of the tailings dams reported and for 7 of 31 or 23 per cent of the waste dumps reported.

One of the most important questions answered in the questionnaire was "Do you believe there is a need for published guidelines?" Of the 50 mining engineers that answered this question 47 indicated yes, two indicated no, and one expressed no opinion. The committee considers that 94 per cent favourable answers is an overwhelming endorsement for the development of guidelines relating to the design, construction control and inspection of tailings dams and waste dumps.

The last section of the questionnaire dealt with typical factors which it was believed should be included in the guidelines in addition to those which were listed in the questionnaire. These included the following:

1. There is a need for evaluation of the stability of dumps

involving mixed material.

2. There is need to assess the long term stability of waste dumps, particularly following completion of mining operations.
3. Consideration is required on the effect of frost action on stability.
4. The development of instrumentation is necessary to monitor slope stability and warn of impending instability.
5. Research is required dealing with construction of tailings dams and waste dumps on permafrost.

DEFINITION OF THE PROBLEM

Based on the answers to the questionnaire it appears that approximately 35 per cent of tailings dams and 20 per cent of waste dumps in Canada have suffered some degree of instability. In addition to this, 94 per cent of the mining engineers questioned indicated it is desirable to establish definite guidelines for the design and construction of tailings dams and waste dumps. With the great increase of mining activity in Canada and particularly the great increase in open pit mining involving extremely large volumes of tailings and waste material, the magnitude and seriousness of potential failures increases significantly. It is the contention of the committee that a potential problem does exist and that urgent action is required to control the problem.

The committee suggests that the problem results from a combination of many factors, some of which are as follows:

1. Tailings dykes and waste dumps will remain for many centuries and as a result they should be considered as engineering structures and be designed accordingly. This design must emphasize long term stability.
2. Stability engineering in the past has normally been a civil engineering subject. Few mining engineers who are responsible for stability, including company and government inspection engineers, have had training in this specialist field.
3. Some universities that offer courses in mining engineering do not at the present time include a course in soil

mechanics and stability in their curriculum.

4. There are no detailed 'design guides' or 'codes of practice' which specifically deal with stability which are available to mining engineers at the present time.

5. Government regulations to ensure stable design of waste dumps and tailings dykes are minimal.

6. The present economics of mining invariably emphasize production and as a result costs relating to tailings dykes and waste dumps tend to be minimized.

7. Many old dykes and dumps presently exist in Canada and the stability of many of these is unknown.

8. Many mining operations in Canada are too small to afford staff engineers with specialized stability experience.

9. A shortage of mining engineers in Canada exists.

10. Numerous unfavourable side effects may occur, many of which are not often understood or recognized. Typical of these include:

    i) Safety of people and equipment operating on dumps.

    ii) Great distances that failures may travel.

    iii) Damming and blockage of water channels with subsequent flooding.

    iv) Raising downstream water levels due to seepage which reduces stability.

DISCUSSION AND RECOMMENDATIONS

There are over 170 mining operations in Canada and many new projects are commencing each year. In view of the failures that have taken place, the great increase in the size of projects in recent years, the potential danger that exists to life if failures occur, the lack of experience and specialized knowledge regarding stability among the mining profession and the general limitation of government controls, the committee recommends that a four stage program be considered at an early date to effectively minimize stability problems in Canada relating to tailings dams, waste dumps and ore piles, and to ensure that failures such as occurred at El Cobre and Aberfan do not occur in Canada.

This program includes the following:

1. Development of a detailed design guide.
2. Establishment of an educational program.
3. The development of uniform reasonable governmental controls.
4. The development of research programs to assist in obtaining answers to technical questions relating to stability.

Each of these is discussed in the following text.

1. Design Guide

The committee recommends that a 'design guide' be developed for use by mining engineers and government officials charged with the responsibility of operation and inspection of mining projects. The prime purpose of the 'design guide' should be to outline the general aspects relating to stability, the more common types of problems which may develop and investigations necessary to evaluate each of these problems. It is recommended that a portion of the 'design guide' be explicitly detailed to outline site investigation details, design requirements and specifications, techniques of construction, procedures of inspection and the approach to evaluate stability of existing facilities.

A two part design guide is recommended: Part A which outlines the general problems of stability and the general approach to evaluating the problems. The Ontario Water Resources Commission guideline could be used as a basis for this section. Part B which outlines detailed investigation, design, construction, maintenance and inspection is recommended which is based on the proposed British 'Code of Practice for Spoil Heaps and Lagoons' modified to meet Canadian conditions and requirements.

One of the major purposes of the design guide is to provide a uniform approach to the investigation, design, construction, maintenance and inspection of waste embankments for the mining industry in Canada.

Several possiblities are available for the development of these guidelines. These are as follows:

a) Members of the National Research Council Soil Mechanics Section are technically qualified in the theory of stability. However, they have limited experience in the specific applications of stability encountered in the mining industry.

b) A University project by a post graduate student. This could also satisfy a theoretical approach to the problem but the committee considers that practical experience relating to site stability would be lacking.

c) The Federal Mines Research Branch is competent to develop the guide having both the theoretical ability and practical contact with the mining industry. One disadvantage is that the mining industry will probably question the possibility of bias for this approach.

d) The fourth possiblity considered is to commission a consulting engineer or engineers to prepare the design guide. It is the committee's opinion that this approach will provide a comprehensive and unbiased design guide.

The committee recommends that consideration be given to commissioning a consulting engineer or engineers with a specialist background in stability as well as a knowledge of practical mining economics and problems to develop a design guide of practice which outlines the general considerations of stability as Part A and detailed considerations of investigation, design, construction and inspection recommendations as Part B.

If this is approved it is recommended that the preliminary draft of the design guide be submitted for review to the Subcommittee on Waste Embankments for review prior to the preparation of the final draft. It is also recommended that interim advice and review by the committee be available to the consultant.

2. Education

It was pointed out by the Aberfan Tribunal that the majority of mining engineers do not have training in the specialized field of stability relating to waste embankments as constructed in the mining industry. It is the opinion of the committee that it is practically and economically feasible to develop at an early date an educational program to improve the technical ability of mining engineers in this field. The committee recommends the establishment of a program along the following general outline.

a) Establish a lecture series on stability either through University extension courses or through the various Canadian Institute of Mining branches throughout Canada for senior mining officials. This set of lectures must recognize that these personnel have been away from University for many years. Therefore the lectures must be practical in nature, outlining the general problem and referring to theory only where a basic concept is absolutely necessary. In order to provide continuity of such a lecture program it is suggested for consideration that a single lecturer or a lecture team be established to travel all across Canada.

The basic purpose of this approach is to bring to the attention of senior mining personnel the general magnitude of the problem, the general approach to the problem and the methods of dealing with the problem at the management level. It is not the intention to train these personnel in the detailed theoretical techniques related to the problem.

b) There are still some Universities that do not include in their Mining Engineering curriculum courses on soil mechanics or stability that relate to the mining industry. The committee specifically recommends that all universities in Canada which offer courses in Mining Engineering be requested to give a course in soil mechanics and stability with particular emphasis relating to site investigations, design, construction, maintenance and inspection of tailings dams, waste dumps and orepiles.

c) Information is being published in Canada and elsewhere relating to stability that many mine officials are not aware of. It is recommended that some committee or department be charged with the responsiblity of ensuring that significant new developments, case histories and research relating to this problem be transmitted to senior operating officials of mining companies in Canada.

3. Controls

It is the opinion of the committee that some control at the governmental level should be established to ensure that mining companies throughout Canada take the necessary precautions to ensure long term stability of waste embankments constructed by mining companies throughout Canada. It is most important that the controls recognize the variability of each mining operation, including the location of that operation relative to facilities which may be damaged or in which loss of life may be involved. There are several approaches that may be followed regarding the establishment of controls. These range from minimum control requiring a permit prior to any construction or extension of any development on one hand to detailed government regulations requiring adherence to a code of practice such as is being proposed by the National Coal Board in England. The minimum control program which is recommended by the committee is as follows:

Prior to the commencement of the development or construction of any new mining property a permit must be obtained from the provincial department of mines approving the construction of the waste embankment. The application for this permit must include sufficient engineering detail to describe the proposed development so that the project can be reviewed and any aspects of stability that may be of concern can be evaluated. A permit should also be required for modifications or addition to work approved under an initial permit.

A review of the design details would then be required by the Department of Mines of the specific province. In the larger provinces where extensive mining is performed it is suggested that these Departments of Mines hire specialists trained in soil mechanics and stability to assist in evaluation of the proposed design or that the department be in the position to require that the mining company submit an engineering report by a consulting engineer specialist in the field of soil mechanics, who would indicate if the proposed design, in his opinion, is stable.

It is further recommended that all waste dumps, tailings dams or piles be inspected at least once during the year by a representative of the Department of Mines who is experienced in the field of soil mechanics and stability.

The committee also recommends that each mining company be required to file annually with the Department of Mines, a review of the work that has been performed during the past year and the status of the existing project.

In addition it is recommended that mining companies be required to maintain an up to date set of drawings including all engineering details and dimensions which would be pertinent to stability and that these be available for inspection by the Department of Mines Inspector at all times.

If the proposal of the design guide is approved it is recommended that all mining companies be provided with this guide and that consideration be given to amending existing mining acts to note the existence of this design guide.

4. Research

Limited research is now being performed which relates specifically to site investigations, design, construction, maintenance and inspection of tailings dams, waste or ore piles in Canada.

The committee recommends that consideration be given to the establishment of a general cooperative research program involving mining companies, provincial Departments of Mines, the federal Department of Mines and Universities.

Prior to the establishment of a detailed research program with designated selection of topics, the committee recommends that mining companies and the Department of Mines be consulted to determine what practical problems relating to stability require most urgent evaluation. At the same time it is recommended that an evaluation be made to determine the most effective, practical and economic means to develop the research program. The prime requirement of the program is to find solutions to practical mining problems. To provide guidance to the Advisory Committee on Rock Mechanics the committee offers the following preliminary recommendations for research.

Typical Research Projects

1. Determination of the engineering properties and characteristics of tailings materials produced from the various types of mining operations such as base metal, gold, iron ore, coal, uranium, etc.
2. Evaluation of the significance of seismic acceleration forces due to blasting and earthquakes on the stability of waste embankments.
3. Evaluation of various methods of design and construction of waste embankments.

4. Evaluation of the possibility of developing dry disposal systems.
5. Evaluation of the possiblity of stabilizing mine tailings.
6. Development of design and construction criteria of waste embankments on permafrost.

Method of Research Program

It is believed that one effective means of developing a research program will be to combine facilities and financial resources of the federal and provincial Departments of Mines and the mining companies.

One of the basic requirements is for funds to be available for such a program. A proposal that the committee suggests be reviewed is to determine whether the smaller mining companies who do not have the financial resources to perform their own research programs may be willing to subscribe funds in the order of $1,000 to $10,000 annually, depending on the size of the mining operation, to support a selective practical research program in which the contributing mining company has an opportunity to designate a specific problem for research. The Royal School of Mines, London, England, Rock Mechanics section has very successfully developed this general type of program.

Where the project is of a highly practical nature the program must be set up in such a way to allow for field instrumentation and field travel and make maximum use of pertinent facilities which the company may have available.

The committee emphasizes that the need for a practical research program is believed to be more important at this time than pure research and theoretically oriented programs which are normally performed by the Universities.

It is further emphasized that the development of a research program should include assessment of research priorities, establishment of means to obtain funds from mining companies, and federal and provincial governments. In addition, assignment of specific research projects to consulting engineering firms should be considered where results are desired at an early date.

SUMMARY

A sub-committee to report on stability of Waste Embankments was established by the Canadian Advisory Committee on Rock Mechanics. The findings and recommendations of this committee are summarized as follows:

A. Findings

1. A review of bibliographical literature indicates many serious failures of waste embankments have occurred throughout the world, including some in Canada.
2. Based on the results of a questionnaire, approximately 35 per cent of tailings dams and 20 per cent of waste embankments constructed by mining companies in Canada have suffered some degree of instability.
3. Stability investigations were only performed for 26 per cent of the tailings dams and 23 per cent of the waste dumps reported.
4. Present mining regulations in Canada generally do not require a detailed evaluation of stability prior to construction.
5. Ninety four per cent of the mining engineers who submitted completed questionnaires indicated that it is desirable to establish definite guidelines for the design and construction of waste embankments.

B. Recommendations

In view of the recent major failures of waste embankments,

the recent increase in Canada of major mining developments, the lack of mining regulations in Canada and the limited background of mining engineers in stability engineering the sub-committee believes that a potential serious problem does exist and that urgent action is required to control the problem.

The sub-committee recommends the following program be undertaken:

1. Develop a Design Guide for the investigation, design and construction of waste embankments. This should include two parts: Part A to outline the general approach and Part B to outline the detailed requirements.

2. Encourage education programs through universities (both in extension and undergraduate courses) and through the Canadian Institute of Mining and Metallurgy (possibly with a specialized symposium at their annual general meeting or with a special lecture program arranged by the Canadian Advisory Committee on Rock Mechanics), which deal with the basic considerations of stability.

   Recommend to the grants-in-aid sub-committee of the National Advisory Committee on Mining and Metallurgy that project proposals on the subject of stability of waste embankments be favourably considered.

   Develop an information distribution program which will ensure that the latest literature on stability relating to mining is available to all mining engineers.

3. Inform provincial governments (possibly by direct communication to the Deputy Ministers of Mines or possibly through the Minister of Energy, Mines and Resources attending the Mines Ministers Conference) of the current practices in connection

with construction of waste embankments, of the value of specialists trained in stability engineering in appraising design and of the value of periodic inspections of major waste structures.

4. Encourage existing mining research programs in Canada to expand to include practical research relating to site investigations, design, construction, maintenance and inspection of waste embankments (possibly by communicating the findings of the sub-committee to the Mining Association of Canada for it to initiate and sponsor such research). Typical projects are outlined in the report.

5. Consideration should be given to obtaining more funds for research in this area (possibly by the Mining Association of Canada, by the Canadian Advisory Committee on Rock Mechanics or by a university department or institute) by approaching mining companies for annual subscription together with their designations of a practical research project that it wished to have investigated.

APPENDIX A

BIBLIOGRAPHY

on

TAILINGS DAMS, WASTE DUMPS AND RELATED STRUCTURES

BIBLIOGRAPHY

TAILING DAMS, WASTE DUMPS AND RELATED STRUCTURES

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APPENDIX B

QUESTIONNAIRE AND ANSWERS

ON

STABILITY OF

TAILINGS DAMS AND WASTE DUMPS

QUESTIONNAIRE

STABILITY OF TAILINGS DAMS AND WASTE DUMPS

CANADIAN ADVISORY COMMITTEE ON ROCK MECHANICS SUB COMMITTEE ON TAILINGS DAMS AND WASTE DUMPS

Name of Mine ______________________________

Location ______________________________

Type of Mine (Open Pit or Underground) ______________

Materials Mined (e.g. copper, uranium, coal) ______________

Do you have tailings dams? Yes_____ No_____

Waste or tailings dumps or ore piles? Yes_____ No_____

A. TAILINGS DAMS OR DYKES

1. General

Method of depositing tailings ______________________

Dimensions of Tailings Dams

Height (present)__________ Proposed ______________

Length ______________ Top Width ______________

Area of Tailings Pond_____ Rate of Deposition __________

Average Slope Angle (downstream) ______________

(upstream) ______________

Freeboard ______________________________

Surface Drainage Control (describe) ______________

____

Distance to Mine ______________________________

Are tailings used for any purpose? ______________

Gradation of Tailings

% Passing # 10 screen ______________

% Passing # 35 screen ______________

% Passing #100 screen ______________

% Passing #200 screen ______________

% Passing #325 screen ______________

Gradation curve attached - Yes ______ No ______

Average annual rainfall _______ Average annual snowfall _______

Average temperature extremes ______________

Are any facilities located below the dam or dump that would be endangered if a slide occurred? Yes ______ No ______

Type of facilities ______________________________

Do you reclaim water from your tailings dam? Yes ______ No ______

Decant tower ______ Floating pumphouse ______ Other ______

If not, how do you dispose of the water? ______________________________

____

2. Design

Was a subsurface soil and groundwater investigation performed prior to design of the tailings dam? Yes ______ No ______. How was this information used in the design? ______________________________

____

Does the dam occupy a stream channel? Yes ______ No ______

How is this water controlled? ______________________________

Were earthquake forces considered in the design? Yes ______ No ______

Embankment Soil - Type ______________________________

Source ______________________________

Was provision made for seepage control through or under the dam?

Yes ______ No ______ If so, how? Impervious core __________

Granular Underdrains __________ Filter Toe ______________

Pressure Relief Wells __________ Other ________________

If a plan or section is available please enclose.

3. Construction

Describe method of construction ______________________________

Was compaction, moisture content or gradation control used? Yes ______

No ______. Were settlements or pore water pressures measured during

construction? Yes ______ No ______. By what method(s) ____________

____

Rate of construction (vertical height) __________________________

Has provision for surface erosion been incorporated? Yes ______ No ___

If so, how? ____

____

4. Stability

Have you had any problems with stability of tailings dams or dykes?

Yes ______ No ______.

Type of problem: Slope failure ______ Dam failure and release of

tailings ____

Foundation failure ______ Excess seepage ______ Surface erosion _____

____

Other (specify) ____

B. WASTE DUMPS AND ORE PILES

1. General

Approximate dimensions of dumps or ore piles.

Height ________ Length ________

Volume ________ Side Slopes _____

Slope of original ground (degrees)____

Type of Rock or Ore ________________________

Approx. gradation % above 4" ________________

% passing 1/4" ________________

% passing #200 screen ________________

2. Design and Construction

Was the waste dump foundation investigated to evaluate stability?

Yes _____ No _____. If so, how? ________________________

Was provision made for subsurface drainage under the dumps? Yes____

No ______. If so, how? ________________________

Method of placing waste or ore ________________________

3. Stability

Have you had any problems with stability of waste dumps or ore piles?

Yes _____ No _____.

Type of problem: Slump failure _____ Flow failure _____ Failure on buried snow layers _____ Failure of underlying soil _____ Failure due to vibration (earthquake or blasting)_____ Other ______________

____

Are the dumps inspected for evidence of movement? Yes_____ No _____

How frequently ________________________

____

C. DESIGN GUIDES

Do you believe there is a need for the development of Guidelines which outline Design and Construction criteria for tailings dams, waste dumps and ore piles? Yes ________ No ________.

Typical factors which should be covered by the criteria are as follows. Please note others that you consider important.

Foundation Stability

Bearing capacity of soil

Settlement of foundation

Pore water pressures

Seepage and piping

Others (please specify) ____

____

Slope Stability

Pore water and seepage pressure

Inadequate soil density

Liquafaction (seismic forces)

Tailings as dam material

Others (specify) ____

____

Surface Stability

Water and wind erosion

Others (specify) ____

____

Below Dam Stability

Raising groundwater level

Others (specify) ______________________________

____

Hydraulic Design

Diversion of creeks

Seepage around culverts, decant tower, etc.

Others (specify) ______________________________

____

D. COMMENTS

Please comment on aspects of stability that have not been included in this questionnaire, emphasize special problems that exist in your area or provide advice that you believe will assist the sub committee. (Use extra paper if necessary)

____

____

____

____

____

Date ____________ Signed ______________________________

____

____

Please return to:

C. O. Brawner,

Subcommittee on Tailings Dams and Waste Dumps,

% Golder, Brawner & Associates Limited,

224 West 8th Avenue,

Vancouver, B. C.

SUMMARY - QUESTIONAIRE ON WASTE EMBANKMENTS

Mine	1	2	3	4	5	6
Location	Ontario	B.C.	B.C.	Quebec	Quebec	Ontario
Type of Mine	Underground	Underground	Fertilizer Plant	Open Pit	Underground	Open Pit
Materials Mined	Gold	Lead, Zinc, Iron	-	Iron	Copper Lead, Zinc	Iron Ore
Tailings Dam(s)	Yes	Yes	Yes	Yes	Yes	Yes
Waste dumps or ore piles	No	Yes	No	Yes	No	Yes
A. TAILINGS DAMS (General)						
Method of deposition	6" pipe, retained by spigots	Launders on trestles	Pipelines	Hydraulic	Direct discharge 6" pipe	Hydraulic Slurry
Present Height	40'	40'	-	50'	12'	50 - 60'
Proposed Height		40'	80' +	60'		70'
Length	Circular dyke	10,000 - 18,000 ft.	2100 ft (2)	10,800'	70'	4450 Circum.
Top Width		12' - 12'	20 ft	30'	15'	35' min.
Area of Tailings Ponds			200 Acres	40 Acres	1 mile square	15.1 Acres
Rate of Deposition	350 T/day	3050 T/day	1500 T/day	1,350,000 T/yr.	700 T/day	250,000 T/yr
Upstream Slope	5°	8%	1.5:1	15%	35°	35°
Downstream Slope	30° - 45°	Ave. 30°	2:1	0.4%	35°	30°
Freeboard		Variable	.5'	5' - 20'	2'	12'
Surface Drainage Control	Decant Towers	Penstock to ditch	30" decant lines		Adjustable Wier	Overflow culvert
Distance to Mine	1¼ Miles	4 Miles	6000'	1900'	1 mile	1600'
Tailings used for any purpose	Coarse for undg'd fill	Not at present	NO	Some for roads	Coarse for undg'd fill	Not at present
Tailings Gradation % passing #35 screen		100%	99%	35.4% 99.7%		91.8%
#100 screen	66.5%	90%	96.5%	12.3% 77.2%		74.4%
#200 screen	42.7%	80%	87%	6.0% 33.5%	73%	60.1%
#325 screen		65%	78%	3.5% 16.0%	58%	50.8%
Average yearly rainfall.	24"	24"	25"	25"	30"	22.4"
Average yearly snowfall	123"	150"	160"	81"	100"	7'-0"
Average temp. extremes	-40° - 90° F	-45° - 93° F	-45° - 95° F	-25° - 90° F	-30° - 90° F	-40° - 80° F
Would a failure of dam cause damage to facilities?	No	Yes	Yes	Yes	No	No
Type of facilities		Railway & road	School, Rail, Road	Road, office, Power		
Do you reclaim water from tailings dam?	No	No	No	Yes	No	Yes
Decant tower		Yes				
Floating pumphouse						Yes
Other				Siphon		
If not how do you dispose of water?	To creek + evap.		Decant line to creek		Drains, Stream, Lake	
TAILINGS DAMS (DESIGN)						
Was a soil investigation performed for design	No	No	Yes	No	No	No
How was information used in design?			Yes			
Does dam occupy stream channel?	No	No	Yes	No	Yes	No
How is this matter controlled?			Decant system		As surface drainage	
National Building Code Earthquake Zone						
Were earthquake forces considered in design	No	No	Yes	No	No	No
Embankment soil type	Gravel - mine waste	Coarse tailings	Compacted clay, gravel	Tails over rock core	Crushed rock & sand	
Embankment soil source	Gravel pit - mine	Settled tailings	Site		Mine waste	
Was provision made for seepage control under or through dam	No	No	Yes	Yes	No	Yes
How			Impervious face	Impervious core		Impervious core
TAILINGS DAMS (CONSTRUCTION)						
Describe method of construction	Coarse fraction for walls by spigots	Tailings from launder on trestles	Compacted layers	Spigotting of tails	Tails occupy natural basin	Base stripped under core Gravel & rock on top
Was compaction, gradation control used?	No	Yes	Yes	Yes	No	Yes
Was settlement or pore water pressure measured?	No	No	No	No	No	No
Rate of construction	1 ft/yr.		1 ft./day	10 ft./yr.		10'/yr.
Was provision for surface erosion incorporated	Yes	No	No	Yes	No	No
How	Trees & Grass			1-2' coarse rock layer		
TAILINGS DAMS (STABILITY)						
Have you had stability problems?	Yes	Yes	No	No	No	Yes
Type of problem?	Seepage thru toe	[illegible]				Excess seepage surface erosion
B. WASTE DUMPS AND ORE PILES						
Height	None	325'		To 120'	None	150' - 250'
Length		980'		4000 - 2500'		2000'
Volume		5,000,000 Tons				30,000,000 cu/yds
Side slopes		18° - 33°		1:1.5		37½° (repose)
Slope of Original Ground		10°		Flat		Flat
Type of Rock or Ore		Siliceous waste rock		Granite		Ashrock, gravel [illegible]
Approx. Gradation % above 4"		Nil		85%		85%
% passing ¼"		Nil		< 5%		< 5%
% passing #200 screen		Nil		< 1%		< 1%
WASTE DUMPS (DESIGN AND CONSTRUCTION)						
Was waste dump foundation stability investigated?		No		Yes		No
How				Soundings		Rock exposed
Was provision made for surface drainage under dumps		No		No		No
How						
Method of placing waste or ore		Conveyor & stacker		Backdumping + Push cat		
WASTE DUMPS (STABILITY)						
Any problems with stability of waste dumps or ore piles?		No		Yes		Yes
Type of problem				Flow failure		Foundation failure (clay)
Are dumps inspected for evidence of movement		Yes		Yes		Yes
Frequency		Daily - visually		Visually daily		Variable
C. DESIGN GUIDES						
Do you believe there is a need for Published Guidelines for design and construction of tailings dams and waste dumps in Canada.		Yes		Yes		Yes
Typical Factors to evaluate						
Foundations Stability						
Bearing capacity of soil						
settlement of foundation						
Pore water pressures						
Seepage and piping						
Other				Soil over bedrock		
Slope Stability						
Pore water and seepage pressure				Yes		
Inadequate soil density						
Liquafaction (including earthquakes)				Yes		
Tailings as dam material				Yes		
Other						
Surface Stability						
Water and wind erosion						
Other						
Below Dam Stability						
Raising groundwater level						
Other						
Hydraulic Design						
Diversion of creeks						
Seepage around culvert, decant towers, etc.						
Other						
D. COMMENTS				Need evaluation of mixed material dumps - fluid clay dumped on waste rock		

Mine	7	8	9	9 (a)	10	11	12	13	14
Location	Sask.	Quebec	B.C.	B.C.	Quebec	Manitoba	Ontario	Quebec	Quebec
Type of Mine	Underground	Underground	Open Pit	Open Pit	Open Pit	Both, mainly underground	Underground	Underground	Underground
Materials Mined	Potash	Copper - Zinc	Molybdenum	Molybdenum	Asbestos	Nickel, Copper	Nickel - Copper	Copper, Zinc	Copper, Zinc
Tailings Dam(s)	Yes	Yes	Yes	Yes	Tailings dump	Yes	Yes	Yes	No
Waste dumps or ore piles	No	No	Yes	Yes	Yes	Yes	No	No	No
A. TAILINGS DAMS (General)									
Method of deposition	Perimeter spill from pipe	Spigot from pipe	Spigotting	Spigotting & cycloning	Belt conveyors	Open discharge inside cycloned dams	Gravity	Spigot line around	Discharge into lake
Present Height	30'	0 - 50'	70'	100'	170'	30'	0 - 40'	25'	
Proposed Height	50'	60'	170'	300'		40'	40'	40 - 50'	
Length	2700'	900'	5000 - 6700'	Proposed 6300'	2000'	10,000'	800'	7800'	
Top Width	900'	2 - 5'	20'	20'	800'	·10'	16'	2 - 3'	
Area of Tailings Ponds	50 Acres	102 Acres	483 Acres	400 Acres		3 sq. miles	2.8 Acres		
Rate of Deposition	3000 T/day	130,000 T/yr.	9000 T/day	17,000 T/day	3500 T/day	3600 T/day	400 T/day		1000 T/day
Upstream Slope	2°	15°	20:1	20:1	1°	15° - 20°	35° - 40°		
Downstream Slope	45°	40°	2:1	3:1	29°	8° - 10°	35° - 40°	35°	
Freeboard		6'	12'	12'		3 - 5'	3'		
Surface Drainage Control	Central overflow well	Located on high land	Drainage ditch around			[illegible]	Nil		
Distance to Mine	2000'	300 - 3300'	8000'	7500'	800'	8000 - 10,000'	100'	1050'	3 miles
Tailings used for any purpose	Not at present	Coarse for undg'd fill	NO	NO	No	No	Underground fill	No	Coarse used for backfill
Tailings Gradation % passing #35 screen	40°		#48 - 90%	#48 - 90%	25%	97%	97.2%	100%	Slimes 100%
#100 screen	16°	86.9%	62%	62%	14.5%	75%	70.9%	95%	100% 86%
#200 screen	6°	63.0%	42%	42%	8.5%	66%	33%	85%	99% 71%
#325 screen		46.4%	33%	33%		42%	5%	70%	96% 60%
Average yearly rainfall.	13.9"	18"	11.1"	11.1"	32.1"	18"			25"
Average yearly snowfall	43"	55"	102.9"	102.9"	125"	36"	'		80"
Average temp. extremes	-40° - 100° F	-10° - 70° F	-30° - 88° F	-30° - 88° F	0° - 80° F	-50° - 75° F	-50° - 100° F		0° - 70° F
Would a failure of dam cause damage to facilities?	NO	No	No	No	No	No	No	No	
Type of facilities									
Do you reclaim water from tailings dam?	Reclaim brine	No	Yes	Yes	No	No	No	No	No
Decant tower									
Floating pumphouse			Yes	Yes					
Other	Pumped from ponds	3 decant towers							
If not how do you dispose of water?						overflow over weirs	Evap., Percolation	Decant Tower	Channel to river
TAILINGS DAMS (DESIGN)									
Was a soil investigation performed for design	Yes - Partly	No	Yes	Yes	No	No	No	Yes	
How was information used in design?	[illegible] percolation		Foundation stability	Foundation stability				Checked muskeg depth	
Does dam occupy stream channel?	No	Yes	Yes	Yes	No	No	No	No	
How is this matter controlled?		Decant Tower	Pumped to mill	Pumped to mill					
National Building Code Earthquake Zone			2	2					
Were earthquake forces considered in design	No	No	Yes	Yes		No	No	No	
Embankment soil type	Tailings	Tailings over few ft. soil	Sandy till & clay	Rock fill, filter coarse tails		Mine waste + coarse tails	Mine waste rock	Clay	
Embankment soil source	Tailings		Site	Site				Site	
Was provision made for seepage control under or through dam	Partly	No	Yes	Yes		Yes	No	No	
How	Seepage catch basin		Filter toe	Filter toe		Filter toe			
TAILINGS DAMS (CONSTRUCTION)									
Describe method of construction	Cat spreads coarse top-tailings fraction	Cat pushed soil coarse tails spread	Constructed filter toe then coarse tailings	Constructed filter toe filter layer then tailings		Cycloned tailing pl'd over coarse mine rk	Dumped waste rock	Tailings placed over clay dredlined, to form orig. dam	
Was compaction, gradation control used?	No	No	Yes	Yes		No	No	No	
Was settlement or pore water pressure measured?	No	No	No	No		No	No	No	
Rate of construction	6'/yr	3'/yr.	6'/yr	6'/yr		3'/yr		4'/yr	
Was provision for surface erosion incorporated	No	No - but starting				No	No	No	
How		Vegetation							
TAILINGS DAMS (STABILITY)									
Have you had stability problems?	Yes	Yes	Yes	No	Yes	No - minor	No	Yes	
Type of problem?	[illegible]	Dam failure [illegible] excess seepage surface erosion	Excess seepage		Slope failure	Surface erosion		Foundation failure	
B. WASTE DUMPS AND ORE PILES									
Height	None	None		90'	170' (3 dumps)	30 - 35'			
Length				4600'	1400'	200 - 400'			
Volume				12,000,000 cu/yds	4,000,000 cu/yds	up to 4,547,000 cu/yds			
Side slopes				34°	34°	45°			
Slope of Original Ground				Flat - 20°	4°	Flat to rolling			
Type of Rock or Ore				Quartz, Monzonite	Clay & blast rock	Diorite - andesite			
Approx. Gradation % above 4"				80%		95%			
% passing ¼"				2%		5%			
% passing #200 screen				1%		Nil			
WASTE DUMPS (DESIGN AND CONSTRUCTION)									
Was waste dump foundation stability investigated?				No	No	No			
How									
Was provision made for surface drainage under dumps				Yes	No	No			
How				Large boulders as base					
Method of placing waste or ore				End dumping	End dumping				
WASTE DUMPS (STABILITY)									
Any problems with stability of waste dumps or ore piles?				No	No	No			
Type of problem									
Are dumps inspected for evidence of movement				Yes	Yes	No			
Frequency				Monthly	Daily				
C. DESIGN GUIDES									
Do you believe there is a need for Published Guidelines for design and construction of tailings dams and waste dumps in Canada.	No opinion	Yes		Yes		Yes	Yes	Yes	Yes
Typical Factors to evaluate									
Foundations Stability									
Bearing capacity of soil						Yes			
settlement of foundation						Yes			
Pore water pressures									
Seepage and piping									
Other									
Slope Stability									
Pore water and seepage pressure									
Inadequate soil density									
Liquafaction (including earthquakes)									
Tailings as dam material									
Other						Public access			
Surface Stability									
Water and wind erosion									
Other									Ice movement & Pressure
Below Dam Stability									
Raising groundwater level									
Other						underground stab'y			
Hydraulic Design									
Diversion of creeks									
Seepage around culvert, decant towers, etc.									
Other									
D. COMMENTS		Long term stability after completion of mining necessary. Erosion control necessary							

SUMMARY - QUESTIONAIRE ON WASTE EMBANKMENTS

Mine	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Location	N.W.T.	Ontario	QUEBEC	Ontario	N.W.T.	Ontario	N. B.	Ontario	Manitoba	Newfoundland	Ontario	Manitoba	Yukon	B.C.	Ontario
Type of Mine	Underground	Underground	Underground	Open pit	Underground	Underground	Underground (Open Pit	Underground + Open Pit	Underground	Underground	Underground	Open Pit	Open Pit	Open Pit	Underground
Materials Mined	Gold	Uranium	Silver + Gold	Taconite	Gold	Gold	Lead, Zn, Copper, Silver	Siderite Iron Ore	Copper - Zinc	Copper, lead, zinc	Nickel - Copper	Iron Ore	Asbestos	Copper	Copper - Gold
Tailings Dam(s)	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Waste dumps or ore piles	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	
A. TAILINGS DAMS (General)															
Method of deposition	4" diam. pipe	Open pipe + spigots	Pumped + piped	Natural Settling	Discharge to small lake	To hydraulic fill and natural basin	Spigotting and end spill	Pipe into settling pond	Pumps + pipe lines	Impounded hydraulically	pipeline	Hydraulic		Wood Stave pipe	Pipe around pond perimeter
Present Height	0-10'	50'	15-58' (8 dams)	50'			30'	52'	8-50'	7'		80'		65'	0-60'
Proposed Height		50-60'		50'			40'	50'				50'		110'	18,000'
Length	500'	5000'	1100 - 2200	1300'			2200'	1500'	9600'	1500'		4000'		750'	
Top Width		20'		80'			15' Final	35'	10 - 40'	20'		60'		20'	16'
Area of Tailings Ponds	14 Acres	130 Acres	26 Acres	560 Acres				15 Acres	680 Acres	3,000,000 sq. ft.		40,000 T./day			45,000 T/mo.
Rate of Deposition	250 T/day	5½'/Year	1080 T/day	7000 T/day				75,000 T/Yr.	5300 T/day	850 T./day					
Upstream Slope		60° (?)		22°			0.5%	35°	Variable?	0.5%		45°-60° (?)			5°
Downstream Slope		60° (?)		35°				35°		2%		15°			45°
Freeboard		4 - 8'		2'			1'	3-4'	4-8'	4'		35'		5'	2-5'
Surface Drainage Control	Semi-Arid not req'd	[illegible]	Natural				Concrete weir	Drained thru crib	Control dam-setting	2 Sluiceways in dam				Water Reclaimed	Weir Outlets
Distance to Mine	0-3000'	½-1 Mile	5400'	1.5 Miles	1-2 Miles		3000'	2000'	2000'	2000'	½-2 miles	½ mile		¼ mile	1 mile
Tailings used for any purpose	Airstrip	Coarse for Dam	Hydraulic backfill	Road surfacing	55% for underg'd fill		No	No	Mine backfill	No	backfill	Roads constr. backfill		No	
Tailings Gradation % passing #35 screen		100%	100%	76.7%		83.8%			100%	100%		94%			
#100 screen				67.6%	98%	71.3%		90.5°	96.8%	91.1%		62%		20%	
#200 screen	60%	47.2%	50.4%	61.4%	85%	65.6%		82.5°	81.1%	71.9%		35.5%		60%	
#325 screen				47.3%	70%	49.8%		66.4°	83.4%	55.8%		19.5%			91%
Average yearly rainfall.	5"	30-32"	23-45"	32.8" Total	10-12" Total	10"	8.5"	20"	12"	29"	24"	20"	12"	20"	
Average yearly snowfall	3'	4'	111"			21"	55.5"	100"	58"	112"	78"	160"	24"	24" n ground	
Average temp. extremes	-53° - 75° F.	-40° TO 95°F.		-60° to 100° F.	-50 to 80°F	-37° to 90°F	15° to 65°F (av.)	-40 to 79° F	-45° to 80° F	-10° to 80° F	0.3° to 77.6°F	-40° to 75°F	-55° to 78° F	-40° to 95° F	
Would a failure of dam cause damage to facilities?	No	Yes	No	No			No	Yes	No	No	Yes	No	No	No	No
Type of facilities		Roads						Plant water supply			East mine #1 shaft				
Do you reclaim water from tailings dam?	No	No	No	No		No	No	No	No	No	No	No		Yes	
Decant tower			Yes								Yes				
Floating pumphouse														Yes	
Other		To water course		Decant											
If not how do you dispose of water?				Decant overflow ditch		Natural drainage	To watershed	Overflow thru crib	Settling ponds-creek	Into natural drainage	decant to natural drainage	Divert into lake			Decant water
TAILINGS DAMS (DESIGN)															
Was a soil investigation performed for design	No	No	No	Yes			No	No	No	No	No	No		No	Not known
How was information used in design?				Foundation stability											
Does dam occupy stream channel?	No	Yes	No	Yes			No	No	No	Yes	Yes + No	Yes		Yes Bay of lake	No
How is this matter controlled?		Weir level		Diverted				Settling pond		2 Sluiceways in dam	Dam upstream of pond				
National Building Code Earthquake Zone															
Were earthquake forces considered in design	No	No	No	No			No	No	No	No	No	No		No	Not known
Embankment soil type	Tailings	Coarse tailings	Waste rock + tailings	Silt, Sand, Gravel + [illegible]			Gravel + fine sand	crushed rock	Pyrite [illegible] slag	Mine waste + coarse tails	Gravel + tailings			Glacial fill + lake sediment	Coarse tailings
Embankment soil source			Underground	Borrow Pits			Local	Mine waste	Cycloned tailings		Local			Local	Mill
Was provision made for seepage control under or through dam	No	Yes	No - Yes	No			Yes	No	No	No	No	No		No	No
How		Rock filter toe	Pressure relief wells				Impervious core								
TAILINGS DAMS (CONSTRUCTION)															
Describe method of construction	Poured into a hollow	Cyclone for Coarse	Rock dam with tails	Constructed in layers			Scrapers with compaction	Spread coarse tails	Dewatered lake		Bulldozer + truck	Cyclone discharge		Pit run waste	Tailings built on perimeter
Was compaction, gradation control used?	No	Yes	No	Yes			Yes	No	No		No			No	No
Was settlement or pore water pressure measured?	No	No	No	No			No	No	No		No			No	No
Rate of construction		8 feet lifts	As required	As required				2'/yr.						2'/mo.	As required
Was provision for surface erosion incorporated	No	No	No	Yes			Yes	No	No		No			Yes	Yes
How				Rock face										Rock dam	Vegetation
TAILINGS DAMS (STABIILITY)															
Have you had stability problems?	No	Yes	No	No			No	Yes	No		No	No		Yes	Yes
Type of problem?		DAM FAILURE - DUE TO WATER FROM CONCRETE FLUME						Initial dam failed						Foundation failure	Dam failure surface erosion
B. WASTE DUMPS AND ORE PILES															
Height				80'			75'	100'				80'	40-200'	50'	
Length				1000'			800' x 800'	700'				200'	350'	500'	
Volume				1,000,000 cu yd.			1,800,000 cu yds	30,000,000 cu yds.				48000 cu yds	17,136,000 cu ft.	200,000 cu yd.	
Side slopes				38°			45°	45°				50°	48°	38°	
Slope of Original Ground				Flat			flat	15°				0°	17°	8°	
Type of Rock or Ore				Andesite			Schist + Iron foundation	Cherts Iron + fluff				Iron Ore Pellets	Serpentine	Volcanics - porphyry	
Approx. Gradation % above 4"				96.5%			75%	89%					Nil	94%	
% passing ¼"				3.0%			20%	10%				½" φ	60%	5%	
% passing #200 screen				.5%			5%	1%					10%	1%	
WASTE DUMPS (DESIGN AND CONSTRUCTION)															
Was waste dump foundation stability investigated?				No			No	No				Yes	No	No	
How												Drill program			
Was provision made for surface drainage under dumps				No			No	Yes				No	No	None req'd	
How								Coarse rock base							
Method of placing waste or ore				Trucks + dozers			Trucks + Tractors	Dump truck				Boom stacker + Conveyor	Cantilevered conveyor	Dump by truck	
WASTE DUMPS (STABILITY)															
Any problems with stability of waste dumps or ore piles?				Yes			Yes	No				No	No	No	
Type of problem				[illegible]			[illegible]						Minor slope flows		
Are dumps inspected for evidence of movement				Yes			Yes	No				No	Yes	No	
Frequency				Daily by tractor operators			Twice Yearly						Daily		
C. DESIGN GUIDES															
Do you believe there is a need for Published Guidelines for design and construction of tailings dams and waste dumps in Canada.	Yes	Yes		Yes			Yes	Yes		Yes		Yes	Yes	Yes	Yes
Typical Factors to evaluate															
Foundations Stability															
Bearing capacity of soil				Yes											
settlement of foundation															
Pore water pressures															
Seepage and piping															
Other								Glaciated sloping bedrock covered by fine soil				Consequences of failure			
Slope Stability															
Pore water and seepage pressure				Yes											
Inadequate soil density															
Liquafaction (including earthquakes)															
Tailings as dam material				Yes											
Other		Seepage and erosion										Consequences of failure			
Surface Stability															
Water and wind erosion				Yes											
Other														Research on reclamation	
Below Dam Stability															
Raising groundwater level															
Other															
Hydraulic Design															
Diversion of creeks															
Seepage around culvert, decant towers, etc.															
Other														Methods of sealing rock dams	
D. COMMENTS	Recommends gov't should provide better regulations for dumps and tailings	Keep water volume low as possible													Frost action Suitability of lower micron sizes as dam material

SUMMARY - QUESTIONAIRE ON WASTE EMBANKMENTS

Mine	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Location	Newfoundland	Que.	Ont.	Que.	Sask.	Ont.	B.C.	Yukon	Que.	Ont.	B.C.	Sask.	N.W.T.	Que.	Ont.
Type of Mine	Underground	Underground + open pit	Underground	Underground	Underground	Open Pit	Underground	Open Pit	Open Pit	Open Pit	Open Pit + Undg'd	Underground	Underground	Open Pit + Undg'd	Underground
Materials Mined	Fluorspare	Copper - Zinc	Gold	Copper - Gold	Potash	Nepheline - Syenite	Silver, Lead, Zinc	Copper	Asbestos	Magnetite	Magnetite + Copper	Copper	Gold	Copper + Moly	Gold - Copper
Tailings Dam(s)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes		Yes	Yes	Yes	No
Waste dumps or ore piles	Yes		No	Yes	No		Yes	Yes	Yes	Yes	Yes		Yes	Yes	No
A. TAILINGS DAMS (General)															
Method of deposition		Filling lake	Wooden Pipe	Gravity flow to pond	Pumped as slurry	Pumped as slurry	Pipeline - Pond	Tailings - Pipeline	Dry Tailings dump	Pumped thru pipe		Piped to lake	Pumped to tails pond	Pipes, spilling & spigots	
Present Height			30-40'	10-20'-65'	20'	20'	10'	45'	400'	62'		15'	30'	47 - 100'	
Proposed Height					30'		15'	85'	460'	62'		15'	40'	140 - 180'	
Length			1800-3500'	700 - 3900'	22,327'	570'	2,000'	2700'	1200'	2100'		400'	2200'	4000 - 7000'	
Top Width				16 - 50	12'		10'	50'	10'	80'		10'	15 - 20'	10 - 12'	
Area of Tailings Ponds		494 Acres	191 Acres	100-225 Acres	426 Acres	184 Acres	10 Acres	39.2 Acres		67 Acres		4000 x 600'	82 Acres	538-1067 Acres	
Rate of Deposition		7'/Year	1300 T/day	520,000 T/Year		200 T/day	1'/year	2400 T/day	500 T/hour	4x10⁶ cu.ft/yr		800 T/day	510 T/day	4,000,000 T/yr	
Upstream Slope			20:3500	45°	2:1	15°		10:1	35°	Almost horizontal		10°	35° - 40°	1°	
Downstream Slope				45°	2:1	40°	Shallow	3:1		Almost horizontal		45°	35° - 40°	35 - 40°	
Freeboard			5-9'	4 - 7½	5'	2'	2'	3'		11'		6'	1 - 4'	4'	
Surface Drainage Control			Perimeter ditches	Creeks diverted	Bypass ditches	Culvert effluent control	Seepage thru gravel bed	Seepage thru dam + reclaim		Decant system		Decant		Decant & Pipes under tails	
Distance to Mine		2.75 Miles	900' - Mill	700'	1297' - Concentrator	½ Mile	1 Mile	1700'	5000'	2200'		600'	2800'	26,000'	
Tailings used for any purpose		40% for backfill	No	35% for backfill	No	No	No	No	Roads	No		No	No	No	
Tailings Gradation % passing #35 screen			100%	100%	40%	84.4%			6.5%	94%					
#100 screen		100%	82%	80%	20%	22.5%		78%		78%		85%		78%	
#200 screen		96%	62%	60%	15%	6.7%	65%	55%		63%		61%	100%	60%	64%
#325 screen		93%	50%	40%	—			40%		48%			98.5%		
Average yearly rainfall.		35"	82" (1968)	26"	11"	25"	10"	5.5"	30"	28"	35"	11.9"	9"	21"	
Average yearly snowfall		120"	102" (1968)	140"	37"	70"	4 - 6'	45.5"	100"	51"	16'	55.7"	36"	178"	
Average temp. extremes		-50° to 90° F	-45° - 85° F	-55° - 95° F	-40° - 90° F	-35° - 90° F	-45° - 110° F		-30° - 90° F		10° - 85° F	-30° - 70° F	-55° - 90° F	-33° - 91° F	-50° - 100° F
Would a failure of dam cause damage to facilities?		No	No	No	No	No	No	No	No	Yes		No	No	Yes	
Type of facilities										R.R. & Pipeline				Salmon River	
Do you reclaim water from tailings dam?		No	No	No	Yes	No	No	Yes (85%)		Yes		No	No	No	
Decant tower			Decant tower					Decant Tower		Decant Tower					
Floating pumphouse															
Other															
If not how do you dispose of water?		Overflow to river	Decant tower	Weir overflow & decant tower				Partial sub-surface drainage				Decant			
TAILINGS DAMS (DESIGN)															
Was a soil investigation performed for design			No	No	Yes	No	No	No	No	Yes		No	No	No	
How was information used in design?					Seepage control					Topog. studied to remove slimes					
Does dam occupy stream channel?		Yes	No	No	Yes	No	No	Yes		Partially		Yes	No	Yes	
How is this matter controlled?					Bypass ditch	Decanted thru culvert		Not significant		Diverted		Decant		Decant & Drains	
National Building Code Earthquake Zone				1	1										
Were earthquake forces considered in design			No	No	Yes	No	No	No	No	No		No	No	No	
Embankment soil type			Course waste + tails	Clayey Gravel	Silt & silty clay	Tailings	Gravel Clay	Gravel & Sand		Limestone		Waste rock-clay tails	Mine waste & clay	Till & Tailings	
Embankment soil source				Local Pits	Local area		Local	Local		Stripping material		Local	Local	Local	
Was provision made for seepage control under or through dam			No	Partly	Yes	Yes	No	No		Yes		Yes	No	Yes	
How				Impervious core	Impervious core filter toe	Filter Toe				Clay lining		Impervious Core		Perforated Pipe	
TAILINGS DAMS (CONSTRUCTION)															
Describe method of construction			Waste rock + tails	Used impervious soil	Scrapers & compaction	Course rock, fine rock & tailings	Bulldozed dam	Gravel sand & rock		Rock core, clay facing			Materials spread + dozer	Dragline & dozer	
Was compaction, gradation control used?			No	Yes	Yes	No	No	Yes		Yes		No	No	No	
Was settlement or pore water pressure measured?			No	No	No	No	No	No		No		No	No	No	
Rate of construction			1'/Year	3 - 5'/lift		3'/2 months		10' Yearly		62" in 14 Years			18" - 24"/lift	6'/lift	
Was provision for surface erosion incorporated			Yes	Yes	Yes	No	No	No		Yes			No	Yes	
How			Course rock face	Course rock face	Waste rock face					Reforestation				Steps & vegetation	
TAILINGS DAMS (STABILITY)															
Have you had stability problems?		No	No	No	No	No	No	No	No	No		Yes	Yes	Yes	
Type of problem?			Surface water erosion			Some Seepage		Considerable seepage				Excess seepage placed rock filter	Dam erosion by ice, foundation failure, excess seepage, permafrost	Slope failure, seepage	
B. WASTE DUMPS AND ORE PILES															
Height				70'			50'	25 - 100'	200'	100'	150'		25'	120 - 150'	
Length				400'			300		1600'	6000'	2500'		800'	2500'	
Volume	50,000 Tons			204,000 cu.yds			200,000 T.	To 2,000,000 cu.yds	50,000,000 T	22,000,000 cu.yds	10,000,000 T		140,000 cu.yds.	16,000,000 T	
Side slopes				40°			40 - 45°	40°	38°	38°	36°		35 - 40°	35 - 37°	
Slope of Original Ground	Flat			Flat			20°	0 - 6°	Flat	Flat	28 - 30°		Flat	2 - 3°	
Type of Rock or Ore	Fluorspare			Mine waste rock			Quartz diorite	Diorite, limestone, skarn	Serpentine, Peridotite	Limestone, trap rock	volcanic, limestone, skarn		Andesite	copper, iron oxide, limestone	
Approx. Gradation % above 4"	Nil			98%			50%	85%	75%	90%	65%		80%	80%	
% passing ¼"	30%			1½%			10%	10%	5%	10%	10%		5%	10%	
% passing #200 screen	Nil			½%			1%	5%	2%						
WASTE DUMPS (DESIGN AND CONSTRUCTION)															
Was waste dump foundation stability investigated?	No			Yes			No	No	No	Yes	Yes		No	No	
How				Evaluated load on underground workings						Topog. studied, shallow rock	Drilling + visual				
Was provision made for surface drainage under dumps	No			No			No	No	No	No	Yes		No	No	
How											Trenches				
Method of placing waste or ore	Trucks + Bulldozer			Truck + Tractor			Bulldozed from dump	Dumping		Trucks dumping	Trucks dumping		Trucks + dozer	Trucks dumping	
WASTE DUMPS (STABILITY)															
Any problems with stability of waste dumps or ore piles?	No			No			No	No	No	No	No		No	No	
Type of problem								Frozen overhang						Minor slumping due to snow	
Are dumps inspected for evidence of movement	No			Yes			Yes	Yes	No	Yes	Yes		No	No	
Frequency				Occasionally			Monthly	Daily		Daily	Daily				
C. DESIGN GUIDES															
Do you believe there is a need for Published Guidelines for design and construction of tailings dams and waste dumps in Canada.				Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes particularly tailings dams	
Typical Factors to evaluate															
Foundations Stability											Yes		Yes	Yes	Yes
Bearing capacity of soil											Yes		Yes		
settlement of foundation											Yes				
Pore water pressures											Yes		Yes		
Seepage and piping															
Other						Preload for settlement				Watch stream pollution			Dams on permafrost		
Slope Stability											Yes				
Pore water and seepage pressure															
Inadequate soil density															
Liquafaction (including earthquakes)										Evaluate	Yes		Yes		
Tailings as dam material														Chemical reaction	
Other						Control erosion with rock									
Surface Stability															
Water and wind erosion															
Other															
Below Dam Stability															
Raising groundwater level															
Other															
Hydraulic Design										Evaluate					
Diversion of creeks													Yes		
Seepage around culvert, decant towers, etc.														Capacity for flash flood	
Other															
D. COMMENTS					Consider stability and evaluate monitoring Program to warn of instability									Emphasize - collect all local data, decant + drainage design, tailings line design	

SUMMARY - QUESTIONAIRE ON WASTE EMBANKMENTS

Mine	45	46	47	48	49	50	51	52
Location	Yukon	B.C	Quebec	Quebec	B.C	Saskatchewan	Newfoundland	Quebec
Type of Mine	Underground	Underground	Underground	Open Pit	Open Pit	Underground	Open Pit	Underground
Materials Mined	Gold + Silver	Lead, Zinc	Copper, Zinc	Asbestos	Copper	Uranium	Iron Ore	Gold
Tailings Dam(s)	Yes	Yes	Yes	No	Yes	No	No	Yes
Waste dumps or ore piles	Yes	Yes	No	Yes	Yes	Yes	Yes	No
A. TAILINGS DAMS (General)								
Method of deposition	Settling	Pump, pipe, spigot, launder	Hydraulicad		Behind waste rock dam	To lake	Into lake	Pipe line
Present Height	10-20'		70'		120'			20'-40'
Proposed Height			90'		160'			
Length	350'	5400'	490'		350'			4 miles
Top Width	10'		60-70'		50'			15'
Area of Tailings Ponds		48 Acres	15 Acres		70,000 yd²			1 squ. mile
Rate of Deposition	250 T./day		6' yr.		2½'/mo.		29000T/day	6"/yr.
Upstream Slope	45°		7°		36°			45°
Downstream Slope	45°		37°		36°			45°
Freeboard	6'		10'		5'			
Surface Drainage Control			Decant towers		Used in milling			
Distance to Mine	7 miles		1700 Ft.		3000'		19000'	1000'
Tailings used for any purpose	No		No		No		No	No
Tailings Gradation % passing #35 screen		95%	97%				40%	100%
#100 screen	90%	80%	83%		75%		20%	90%
#200 screen	65%	40%	80%		43%		15%	70%
#325 screen	40%	15%	40%		40%	93%	13%	55%
Average yearly rainfall.	8-10"	23"	15"		18"	12"	30"	25"
Average yearly snowfall	10'	100"	60"		4'	24"	170"	125"
Average temp. extremes	-30° to 68° F.	-10° - 95° F.	-40° to 90° F.		-15° to 80°F	-40° to 75° F.	-46° to 85° F.	-20° to 90° F.
Would a failure of dam cause damage to facilities?	No	Yes	No		Yes		No	No
Type of facilities		River			Main Highway			
Do you reclaim water from tailings dam?	No	Yes	No		Yes			No
Decant tower		Decant towers	Decant towers				Natural drainage	Gravity
Floating pumphouse					Yes			
Other								
If not how do you dispose of water?	Decant Tower							
TAILINGS DAMS (DESIGN)								
Was a soil investigation performed for design	No	Yes	Yes		Yes		No	No
How was information used in design?		Foundation stabilized	Sub soil stripped		Foundation bearing			
Does dam occupy stream channel?	No	No	Yes		Yes		No	No
How is this matter controlled?			Decant towers		Pumped to mill			
National Building Code Earthquake Zone	2							
Were earthquake forces considered in design	No	No	No		No		No	No
Embankment soil type	Gravel + clay		Rock, clay core + tails		Clay		Tailings	Gravel + Soil
Embankment soil source	Local		Local		Local			Local gravel pit
Was provision made for seepage control under or through dam	No	Yes	Yes		Yes		No	No
How		Filter toe	Seeps thru tails		Soil removed to rock			
TAILINGS DAMS (CONSTRUCTION)								
Describe method of construction	Bulldozing	Buldoze gravel	Cycloning covered by waste		Rock fill then clay compacted			Filled spread + compacted with cats
Was compaction, gradation control used?	No	No	Yes		Yes			No
Was settlement or pore water pressure measured?	No	No	No		No			No
Rate of construction	5-15'/year							
Was provision for surface erosion incorporated	No	Yes	Yes		Yes			No
How		Cultivated Vegetation	Rip rapped face		Dam spillway			
TAILINGS DAMS (STABILITY)								
Have you had stability problems?	No (7 mo operation)	Yes	No		Not with new dam			Yes
Type of problem?		Toe failure - Loaded and flattened			old dam failed			Tailings overflowing dam in winter on snow
B. WASTE DUMPS AND ORE PILES								
Height	50'	25'		150'	59'		70'	
Length	60'	5400'		4000'	1000'			
Volume		2,515,000 T		50,000,000 cu.yds.	1,500,000 T			
Side slopes	37°	1½:1		33°	36°		37°	
Slope of Original Ground	20°	Level		Flat	12°		12°	
Type of Rock or Ore	Granu. diorite	dolumite tails		Silt sand + mine rock	Scarn	Electronically sorted waste	Quartzite	
Approx. Gradation % above 4"	60%			25%	50%	100%	20%	
% passing ¼"	5%	100%		40%	20%		60%	
% passing #200 screen		40%		25%	10%		20%	
WASTE DUMPS (DESIGN AND CONSTRUCTION)								
Was waste dump foundation stability investigated?	No	Yes		No	No	No	No	
How		Soil sampling			On bedrock			
Was provision made for surface drainage under dumps	No	Yes		No	Yes	No	Yes	
How		Filter toe			Drain box + pipeline		Culverts	
Method of placing waste or ore	Dump from mine cars			Trucks dumping	Tipping + pushing	Truck	Trucked + pushed	
WASTE DUMPS (STABILITY)								
Any problems with stability of waste dumps or ore piles?	No	Yes		Some	No	No	No	
Type of problem		Toe failures		Slope flow failure				
Are dumps inspected for evidence of movement	Yes	Yes		Yes	No	Yes	Yes	
Frequency	Intermittently	Daily		Regularly		Casual inspection daily	Every 6 months	
C. DESIGN GUIDES								
Do you believe there is a need for Published Guidelines for design and construction of tailings dams and waste dumps in Canada.	Yes	Yes	Yes	No - Each company should look after its own stability problems	Yes	Yes		Yes
Typical Factors to evaluate								
Foundations Stability								
Bearing capacity of soil			✓			✓		
settlement of foundation			✓			✓		
Pore water pressures			✓			✓		
Seepage and piping			✓			✓		
Other	Permafrost					Seismal Activity		
Slope Stability								
Pore water and seepage pressure			✓			✓		
Inadequate soil density			✓			✓		
Liquafaction (including earthquakes)			✓			✓		
Tailings as dam material			✓			✓		
Other						Permafrost		
Surface Stability								
Water and wind erosion			✓			✓		
Other	Verbatum if used as road							
Below Dam Stability								
Raising groundwater level						✓		
Other						Mine Subsidence		
Hydraulic Design								
Diversion of creeks						✓		
Seepage around culvert, decant towers, etc.						✓		
Other								
D. COMMENTS								Wind dispersion of drg. tails a problem

Mine	53	54	55	56	57	58	59
Location	Ontario	Saskatchewan	Ontario	Ontario	Ontario	Quebec	Ontario
Type of Mine	Open Pit	Underground	Underground	Underground	Underground	Underground	Underground
Materials Mined	Iron Ore	Lead + Zinc	Gold	Gold	Gold	Copper	Copper Nickel
Tailings Dam(s)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Waste dumps or ore piles	Yes	No	Yes	Yes	No	No	No
A. TAILINGS DAMS (General)							
Method of deposition	Pumped + decanted	Hydraulic	Piped + Decanted	Pumping + spigotting	Spigotting	Pipe line	Pump
Present Height	40'-80'	8'	15'-30'	6-55' (7)	30'	13-23'	
Proposed Height				25-55'	60'	21-31'	
Length	3900'	280'	200'-545'	1000 - 2400'	1800'	9600'	
Top Width	70'	10'	12'-15'	-	20'	15'	
Area of Tailings Ponds	270 Acres	31 Acres	40 Acres	285 Acres	2,000,000 squ. ft.	211 Acres	
Rate of Deposition	2500'/day	250 T/day	300T/day	1100 T/day	500T/day	1.7' yr.	600 T./day
Upstream Slope		45°	45°		5°	0.5-1%	15°
Downstream Slope	1°	45°	45°	1½-1	30°	50-55°	30°
Freeboard	5'	1'	4'			3'	
Surface Drainage Control	Mill use	None		Decant to weir to creek	Weirs, pipes + siphons		Culvert pipe
Distance to Mine	¼ mile	5400'	5000'	1000-5000'	1000'	3000'	
Tailings used for any purpose	Road surfaces	Dyke	No	Some for mine fill	No	No	No
Tailings Gradation % passing #35 screen	85.4%	100%		100%		100%	100%
#100 screen	76.2%	94.6%		98%	100.0%	76%	86.4%
#200 screen	64.2%	73.2%	100%	80%	81.5%	57%	60.0%
#325 screen	43.8%	56.8%	93.1%	60%	60.1%	42%	
Average yearly rainfall.	23.8"	12"	21"	17"		20"	
Average yearly snowfall	78"	60"	24'	123"		132.5"	
Average temp. extremes	-47° to 97° F.	-50° to 100° F.	-44° to 67°F	-40 to 90° F.	-40° to 90°F	-50 to 90°F	-35° to 80°F
Would a failure of dam cause damage to facilities?	Yes	No	No	Yes	Yes	No	No
Type of facilities	Plant + tailings			Highway + railway	Lake for fishing	None	
Do you reclaim water from tailings dam?	Yes	No	No	No	No	No	No
Decant tower	Floating decant tower	Overflow to lake	Overflow to lake	Decant to creek	Decant tower	Decant tower	
Floating pumphouse							
Other							
If not how do you dispose of water?							
TAILINGS DAMS (DESIGN)							
Was a soil investigation performed for design	No	No	No	No	No	No	Yes
How was information used in design?							Sampled soil used for dam
Does dam occupy stream channel?	No	Yes	No	No	No	Yes	No
How is this matter controlled?						Bypass Constructed	
National Building Code Earthquake Zone							
Were earthquake forces considered in design	No	No	No	No	No	No	No
Embankment soil type	Gravel + tailings	Clay	Waste rock + gravel	Tailings	Waste rock + tailings	Crushed rock-gravel	Clay + gravel
Embankment soil source	Local	Local	Local			Local	local
Was provision made for seepage control under or through dam	No	No	No	No	No	No	Yes
How							Impervious core
TAILINGS DAMS (CONSTRUCTION)							
Describe method of construction	Compacted gravel over rock	Pushed by cat	Truck + Dozer	Classified tailings	Waste rock + tailings	Crushed rock added as required	
Was compaction, gradation control used?	Yes	No	No	Yes	Yes	No	No
Was settlement or pore water pressure measured?	No	No	No	No	No	No	No
Rate of construction					1.5'/yr.	1-2'/yr.	
Was provision for surface erosion incorporated	Yes	No	Yes	Yes	Yes	No	
How	Riprap		Vegetation	Wood chips on slope	Coarse tails + Vegetation		
TAILINGS DAMS (STABILITY)							
Have you had stability problems?	No	No	No	Yes	Yes	No	No
Type of problem?				Slope failure	Ice dams + overflow		
B. WASTE DUMPS AND ORE PILES							
Height	50-100'			25'			
Length	1000'			200'x400'			
Volume	4,600,000 cu.yd			1,000,000 cu.yd			
Side slopes	2:1			2:1			
Slope of Original Ground				Level			
Type of Rock or Ore	Tuff diabase, granite			Coarse Waste			
Approx. Gradation % above 4"	54%			50%			
% passing ¼"	5%			20%			
% passing #200 screen	1%			5%			
WASTE DUMPS (DESIGN AND CONSTRUCTION)							
Was waste dump foundation stability investigated?	Yes			No			
How	Visual						
Was provision made for surface drainage under dumps	No			No			
How							
Method of placing waste or ore	dumped by truck			By truck			
WASTE DUMPS (STABILITY)							
Any problems with stability of waste dumps or ore piles?	No			No			
Type of problem							
Are dumps inspected for evidence of movement	Yes			Yes			
Frequency	Yearly			Weekly			
C. DESIGN GUIDES							
Do you believe there is a need for Published Guidelines for design and construction of tailings dams and waste dumps in Canada.	Yes	Yes	Yes	Yes	Yes	Yes	—
Typical Factors to evaluate							
Foundations Stability							
Bearing capacity of soil							
settlement of foundation							
Pore water pressures							
Seepage and piping							
Other							
Slope Stability							
Pore water and seepage pressure							
Inadequate soil density							
Liquafaction (including earthquakes)							
Tailings as dam material							
Other							
Surface Stability							
Water and wind erosion							
Other							
Below Dam Stability							
Raising groundwater level							
Other							
Hydraulic Design							
Diversion of creeks							
Seepage around culvert, decant towers, etc.							
Other					Design for max. rainfall inflow		
D. COMMENTS					Design decant towers with 2 pipes in case one should fail		

SUMMARY - QUESTIONAIRE ON WASTE EMBANKMENTS

Mine	60	61	62	63	64	65	66
Location	Quebec	Quebec	Ontario	Quebec	Ontario	New Brunswick	
Type of Mine	Underground	Underground	Underground	Underground	Underground	Underground	Underground
Materials Mined	Copper Gold	Asbestos	Uranium	Copper, Gold, Pyrite	Copper, lead, Zinc, Silver	Lead, zinc, copper	Gold
Tailings Dam(s)	Yes	No	Yes	Yes	Yes	Yes	Yes
Waste dumps or ore piles		Yes	No	No	No	Yes	
A. TAILINGS DAMS (General)							
Method of deposition	Pumped between rock causeways		Gravity thru tailings line	Hydraulic Pipe	Spigotts in tailings	Pipe discharge	Pipeline
Present Height	25'-30'		32'	35½'	50'	40'	20'
Proposed Height			170'		100'	80'	30'
Length	8000'		1000'	520'	6000'	820'-2000'	400'
Top Width	10'-15'		16'	20'		18'	10'
Area of Tailings Ponds	88 Acres			44 Acres	70 Acres		75 Acres
Rate of Deposition	600,000 T/year			1265 T/day	800,000 T/year	70,000 T./mo.	350 T/day
Upstream Slope	3°-4°		34°		10°	2:1	45°
Downstream Slope			34°	35°	45°	2:1	45°
Freeboard	1'-2'		4'	8'	20'-50'	3'	6'
Surface Drainage Control	Decant tower		None	Weir on outlet	Decant tower	Concrete weir	
Distance to Mine	500'		4500'	4 miles	1 mile	6000'	4600'
Tailings used for any purpose	Coarse for mine fill		No	Some mine backfill	Mine Backfill	No	No
Tailings Gradation % passing #35 screen	90.5%		100%		95%		
#100 screen	58.8%		85%	100%	80%		100%
#200 screen	30.6%		60%	85%	56%	35%	99%
#325 screen				65%	40%	85%	
Average yearly rainfall.	26"		23.9"	25"	25"	26.7%	
Average yearly snowfall	126"		23.4"	70"	100"	148"	
Average temp. extremes	-40° to 75°F.	-20° to 90°F.	-30° to 85°F.	-45° to 90°F.		-20° to 85°F	
Would a failure of dam cause damage to facilities?	No		No	No	No	No	No
Type of facilities							
Do you reclaim water from tailings dam?	No		No	No	No	No	No
Decant tower							
Floating pumphouse							
Other							
If not how do you dispose of water?	Decant tower		Treated with BaCl to settling to natural watershed	Rock out	Decant tower	Overflow to stream	Natural drainage
TAILINGS DAMS (DESIGN)							
Was a soil investigation performed for design	No		No	Yes	No	No	No
How was information used in design?				Design weir + Dam			
Does dam occupy stream channel?	No		Yes	Yes	Yes	Yes	Yes
How is this matter controlled?			Part of tails effluent	Weir	Decant tower	Stream flows over tails	Use channel as lake [illegible]
National Building Code Earthquake Zone							
Were earthquake forces considered in design	No		No	No		No	No
Embankment soil type	Waste rock		Sand + Gravel	Clay core, waste rock	Sand	Glacial till clay, sand	Clay, Glacial boulders
Embankment soil source	Mine		Pit	Local	Tailings	Borrow Pits	Local
Was provision made for seepage control under or through dam	No		No	No	No	Yes	No
How						Separate lane, toe drains	
TAILINGS DAMS (CONSTRUCTION)							
Describe method of construction	Truck + dozer		Trucks + Dozer	Truck + Dozer	Sand bank spigotted tails	Trucked, compacted	Waste rock by truck
Was compaction, gradation control used?	No		Yes	Yes		Yes	No
Was settlement or pore water pressure measured?	No		No	Yes	No	No	No
Rate of construction	2'/mo.		5'-8' lifts		6'/year	3'/year	As required
Was provision for surface erosion incorporated	No		Yes	Yes	No	Yes	Yes
How			Filter canvas barricade	Rock rip rap		Oversize on slope	Waste rock
TAILINGS DAMS (STABILITY)							
Have you had stability problems?	No		No	No	No	No	No
Type of problem?	Minor seepage						
B. WASTE DUMPS AND ORE PILES							
Height		40'				60'-75'	
Length		¾ mile				500'-640'	
Volume						to 214,000 cu. yd.	
Side slopes		40°±				47°-50°	
Slope of Original Ground		Flat				1½°	
Type of Rock or Ore						Gossan + waste	
Approx. Gradation % above 4"		10%				60%	
% passing ¼"		90%					
% passing #200 screen		60%					
WASTE DUMPS (DESIGN AND CONSTRUCTION)							
Was waste dump foundation stability investigated?		No				No	
How							
Was provision made for surface drainage under dumps		No				No	
How							
Method of placing waste or ore		Dumped from rail cars					
WASTE DUMPS (STABILITY)							
Any problems with stability of waste dumps or ore piles?		No				No	
Type of problem							
Are dumps inspected for evidence of movement		Yes				No	
Frequency		Monthly					
C. DESIGN GUIDES							
Do you believe there is a need for Published Guidelines for design and construction of tailings dams and waste dumps in Canada.	Yes		Yes	Yes	Yes	Yes	Yes
Typical Factors to evaluate							
Foundations Stability							
Bearing capacity of soil							
settlement of foundation							
Pore water pressures							
Seepage and piping							
Other							
Slope Stability							
Pore water and seepage pressure							
Inadequate soil density							
Liquafaction (including earthquakes)							
Tailings as dam material							
Other							
Surface Stability							
Water and wind erosion							
Other							
Below Dam Stability							
Raising groundwater level							
Other							
Hydraulic Design							
Diversion of creeks							
Seepage around culvert, decant towers, etc.							
Other							
D. COMMENTS				In favor of guidelines but against rigid regulations			

APPENDIX C

DESIGN GUIDES

(a) U.S. Atomic Energy Commission

(b) Ontario Water Resources Commission

(c) Table of Contents - National Coal Board "Code of Practice"

A E C   L I C E N S I N G   G U I D E

I N F O R M A T I O N   A N D   C R I T E R I A
P E R T I N E N T   T O   E V A L U A T I O N   O F
E M B A N K M E N T   R E T E N T I O N   S Y S T E M S

U. S. ATOMIC ENERGY COMMISSION

SOURCE AND SPECIAL NUCLEAR MATERIALS BRANCH

DIVISION OF MATERIALS LICENSING

WASHINGTON, D C. 20545

N O T E

This guide has been complied as an aid in the preparation of applications for source material licenses in which embankment retention systems are employed to prevent or control the release of radioactivity in concentrations exceeding those permitted to be released in 10 CFR 20. This guide is not intended as an interpretation of Commission regulations within the meaning of Section 40.6 of Title 10, Code of Federal Regulations, Part 40. Nothing contained in this guide may be construed as having the force and effect of United States Atomic Energy Commission regulations, nor as indicating that applications for appropriate licensing by the Commission which follow the recommendations of this document necessarily will be approved; nor as relieving any licensee from the requirements of Title 10, Code of Federal Regulations, Parts 20 and 40 or other pertinent regulations.

1. INTRODUCTION

The processing of unrefined source material, particularly the milling of uranium ore, results in the production of large volumes of liquid and solid wastes both of which usually contain concentrations of radioactive material in excess of those which may be released into unrestricted areas under the provisions of Section 20.106, Part 20, Title 10, Code of Federal Regulations, "Standards for Protection Against Radiation". Also, the wastes usually contain chemicals such as acids, alkalies, salts and organics, which could have an adverse effect on the environment if indiscriminately released. It is therefore necessary to contain such wastes so as to prevent or control their release to the environment. Containment may be accomplished by the construction of embankment retention systems. An additional advantage of containment is that it provides storage of solids for possible future reprocessing for other materials and permits the reclamation of liquids for reuse in ore processing.

The size and construction of these retention systems vary with the production capacity of the processing mill, the amount of liquid waste produced, the topography of the area in which the mill is located, and the amount of land available to the mill; for example, these systems may vary in size from a few acres to over 100 acres. Generally, the location of a retention system is selected to take maximum advantage of the natural contour of the area in which it is located, but it is usually necessary at some point to construct an earth and/or tailings embankment to contain the liquid waste. Earth embankments may be constructed for the purpose of retaining only liquid waste or for retaining both solid and liquid waste. In the latter case, the liquid and solid wastes are usually discharged to one area within the system so that the coarse solids continually build up in essentially the same area and the fine solids or slimes and liquids flow toward and are retained by an earth embankment.

Where tailings are used to build or increase the height of embankments, usually one of two techniques is employed - gravity or cyclone separation. When gravity separation is employed, tailings are transported to the retention system as a slurry and discharged near the inside edge of an initial earth embankment. The coarse solids settle out near the initial embankment and the fine solids or slimes and liquids drain to and are retained at the center or rear of the system. When the coarse solid tailings or liquids rise to within a few feet of the top of the embankment, the system is extended or raised by the use of a drag line and/or earth moving equipment. From time to time the embankment may be further raised in the same manner whenever required. In the case of cyclone separation, tailings are also transported to the retention system as a slurry and separated by truck or trestle mounted cyclone separators. Truck mounted cyclones move slowly along the top of the embankment and extend the height of the embankment by depositing the coarse fraction of the tailings along the top and the slimes and liquids well within the retention systems. Trestle mounted cyclones perform the same operations but must be periodically moved along the embankment.

It is important that these embankment retention systems be constructed and maintained in accordance with sound engineering principles in view of their purpose to prevent or control the release of radioactive materials and chemicals to the environment. The Commission has developed criteria for the construction and maintenance of these earth and tailings embankments to be used in connection with the evaluation of the structural integrity and other safety features of these systems prior to the issuance of source material licenses and license renewals.

It is the purpose of this guide to specify information which the Commission will require in connection with the licensing of source material activities involving embankment retention systems. This information pertains primarily to the integrity of the retention system and is in addition to other information normally required by the Commission in support of applications for licenses authorizing milling activities, such as information on local meteorological conditions, geological and hydrological data, effluent survey programs, etc. The purpose of the guide is also to identify the criteria for the construction and maintenance of embankment retention systems that will be used by the Commission in evaluating such systems. The criteria are necessarily general in nature since the characteristics of embankment systems may vary significantly from one location to another. Therefore, conformance with these criteria shall not be considered as relieving an applicant or licensee of his responsibility for assuring that his system is adequate from a structural integrity and radiological safety standpoint.

The Commission may request additional information beyond that specified from applicants or licensees if such information is necessary to provide reasonable assurance that the applicant or licensee has established an adequate system. (See § 40.31(b) of 10 CFR 40.) Such requests may be avoided by a thorough study of Commission regulations and this guide prior to submitting information to the Commission.

An applicant or licensee may incorporate by reference information contained in applications, statements and reports previously filed with the Commission's Division of Materials Licensing, provided that such references are clear and specific. (See § 40.31(e) of 10 CFR 40.) In order to be clear and specific, the aforementioned references must indicate by date, page and paragraph what information the applicant wishes to reference and how such information is applicable to the license application.

2. AUTHORITY

The Atomic Energy Act of 1954, as amended, charges the United States Atomic Energy Commission with, among other things, responsibility for regulating the receipt, possession and use and transfer of source material. The Commission is authorized to establish by rule, regulation or order such standards and instructions to govern the receipt, possession and use of source material as it may deem necessary or desirable to protect health or to minimize danger to life or property.

In the performance of its regulatory functions, the Commission has promulgated the regulations contained in Title 10 of the Code of Federal Regulations. The following regulations are particularly pertinent to the subject of this guide:

1. Part 20, "Standards for Protection Against Radiation".

2. Part 40, "Licensing of Source Material".

Amendments to the regulations are published from time to time in the Federal Register. Current copies of Commission regulations may be obtained from the Division of Materials Licensing, U. S. Atomic Energy Commission, Washington, D. C. 20545, or from any of the following U. S. Atomic Energy Commission Division of Compliance Regional Offices:

Director, Region I
Division of Compliance USAEC
376 Hudson Street
New York, New York 10014

Director, Region II
Division of Compliance, USAEC
50 Seventh Street, Northeast
Atlanta, Georgia 20323

Director, Region III
Division of Compliance, USAEC
Suite 410 Oak Brook Professional Building
Oak Brook, Illinois 60523

Director, Region IV
Division of Compliance, USAEC
10395 W. Colfax
Denver, Colorado 80215

Director, Region V
Division of Compliance, USAEC
2111 Bancroft Way
Berkeley, California 94704

3. <u>INFORMATION REQUIRED</u>

In addition to the information required by Section 40.31, 10 CFR 40, applications for specific source material licenses which involve the use of embankment retention systems for holding wastes containing radioactive material in concentrations greater than those permitted to be released pursuant to Section 20.106, 10 CFR 20, shall contain the following information as applicable:

A. Drawings showing the layout in plan; typical cross-sections of all embankments showing proposed design, and if applicable, anticipated future extensions; and other pertinent design details. Embankment design should include information on heights, top width, side slopes, freeboard, seepage control, and protection of embankment surfaces as well as foundation design.

B. A design analysis of the integrity of the proposed system including, as applicable, the results of soil tests, geologic exploration, nature of foundation materials, stability investigations and characteristics of fill material as well as a description of the construction methods and specifications.

C. An evaluation and discussion of conditions that might lead to accidental release of the waste, the probable environmental effects of such release, and proposed program of inspection and maintenance to prevent such an accidental occurrence.

4. EMBANKMENT RETENTION SYSTEM CRITERIA

The Commission will take the following factors into consideration in evaluating for approval the information submitted pursuant to Section 3 of this guide:

A. Location

(1) The site should be subject to the control of the licensee so as to permit entry only of authorized personnel thereto.

(2) The site should not occupy the channel of any permanent watercourse unless a provision has been made for permanent diversion of such water course around the site.

(3) The site should be permanently protected against run-off when necessary, from the surrounding drainage area by the provision of diversion channels to prevent such run-off from entering or washing out the embankments.

(4) A minimum distance of 200 feet should be maintained between the embankments and any permanent flowing watercourse at flood stage to minimize percolation effects unless information is submitted for satisfying a closer location.

B. Design

(1) Foundations - Foundations should be investigated to determine that they have suitable strength and permeability characteristics for the embankment proposed, including anticipated future extensions. A foundation of rock or graded sand and gravel is normally considered to have satisfactory strength for small embankments (under 25 feet in height). Foundations of alluvial deposits, which have not been consolidated under appreciable loads, and those of fine and uniform sands or of plastic clays must be given careful investigation and treatment to insure safety of the embankment.

(2) Embankments

(a) Construction material - The embankment material used in the construction of earth embankments may be natural soil, usually borrow soil found nearby, suitable for the construction of such sustems. Coarse tailings material may be used to extend an earth embankment during construction of a tailings embankment provided design and construction methods specified in this guide are followed.

(b) Top width - The minimum top width of an embankment should be eight feet. As the height of the embankment increases the top width should be increased as specified in Table I below. It may be necessary to further increase the top width if the embankment material is susceptible to erosion or sloughing.

TABLE I - RECOMMENDED MINIMUM TOP WIDTH FOR EMBANKMENTS

Height of Embankment (feet)	Minimum Top Width (feet)
8 to 12	10
13 to 20	12
21 to 30	15
Over 30	20

(c) Side slopes - In most cases the type of material that is readily available for embankment systems will require that side slopes on the upstream face (i.e., in contact with the liquid) have a slope ratio between 4 to 1 and 2 1/2 to 1 and on the downstream face of the embankment between 3 to 1 and 2 to 1. Table II below contains recommended maximum slopes for embankments constructed of various materials. (For further details of these and other commonly used soil materials, reference is made to the chart, "Unified Soil Classification, Including Identification and Description", adopted by Corps of Engineers and Bureau of Reclamation, January 1952).

TABLE II - RECOMMENDED HORIZONTAL TO VERTICAL SIDE SLOPE RATIOS FOR EMBANKMENTS

Embankment Materials	Upstream Face	Downstream Face
Homogeneous Sandy Clay	2-1/2 to 1	2 to 1
Coarse Sand with compacted clay or structural core wall	3 to 1	2-1/2 to 1
Sand-gravel mixture with compacted clay or structural core wall	3 to 1	2 to 1
Homogeneous Silty Clay	4 to 1	3 to 1
Homogeneous Sandy Loess	3 to 1	3 to 1
Coarse Tailings (dry)	2-1/2 to 1	2 to 1

Where coarse tailings material is used to increase the height of an initial earth embankment, the Commission will consider the material as purely frictional with an angle of internal friction of 33 degrees (i.e., a natural slope of approximately 1-1/2 to 1). This will mean that the downstream face of the embankment should have a total slope ratio of approximately 2 to 1. Berms may be employed in the construction of the embankment to satisfy this side slope ratio, provided the berms are at least eight feet in width, the height of each embankment section does not exceed 18 feet, and the slope of each tailings embankment section is at least the natural slope of the material.

The recommended slopes in the above table may have to be flattened when necessary to spread the load so that the maximum unit stress induced in the foundation will be less than the shear strength of the foundation material or when full knowledge is not available on shear strength and seepage flow.

(d) Freeboard - The freeboard height of the embankment above the maximum liquid level should not be less than three feet. Consideration should be given to future compaction and settlement of the embankment and to frost penetration which would materially effect the possible freezing and cracking of the embankment above water level.

(3) Seepage Control - Suitable methods should be employed to minimize the effect of seepage on the embankment and its foundation. Methods of controlling seepage include toe drains, filter layers, impervious cut-offs or blankets, and corewalls. Seepage along the contact surface between the foundation and the embankment should be minimized

by removal of all organic material such as sod and top soil and where appropriate the installation of a "key" trench.

(4) Protection of Embankment Surfaces - Embankment surfaces should be protected against erosion by the use of such means as vegetation, berms, logs, or riprap. The method of protection used must be based upon the susceptibility to erosion.

(5) Protection Against Environmental Release - Where deemed necessary, provisions such as the use of additional surrounding embankments or sumps should be made for capturing or holding liquid waste resulting from seepage through the embankment or unexpectedly released by failure of the primary embankments.

Unprotected surfaces on the top or within the retention system, such as inadequate crust formation, should be provided with an effective means of dust control, such as a sprinkler system for periodically wetting down these surfaces, a form of cement, asphalt or other binder for a more permanent sealer of the surfaces, or vegetation if found feasible.

C. Construction Methods

Construction of the earth embankment should be started only after clearing and grubbing operations are completed and the foundation has been properly prepared. Embankment material should be free of sod, roots, stones over six inches in diameter, and other material should not be placed in embankments and embankments should not be constructed on frozen foundations. The placing and spreading of embankment material should be started at the lowest part of the section under construction and the embankment carried up in horizontal layers not exceeding eight inches in thickness. Insofar as possible, these layers should be of uniform elevation and extend over the entire area of the fill. The distribution and gradation of materials throughout the embankment should be such that there are no lenses,pockets or streaks created, and the moisture content of the materials should be proportioned for maximum degree of compaction. Proper compaction of the embankment material should be achieved by the use of equipment designed for this purpose, usually a sheepsfoot roller. The travel of excavating equipment is generally not considered an adequate method for obtaining compaction. If the sheepsfoot roller is used, it should be weighted to give a unit pressure of not less than 200 pounds per square inch of the total surface area of the feet simultaneously in contact with the embankment. Usually six passes of the roller over each individual layer of material are sufficient to obtain good compaction. For relatively low embankments, under 25 feet in height, the adequacy of compaction may be determined by observation of the roller in action. For embankments over 25 feet in height, field control over compaction should be more precise and the embankment should be rolled until some predetermined degree of compaction is obtained, usually 90 to 95 percent of maximum density as determined by appropriate compaction tests.

Tailings embankments should be started with an initial outer earth embankment as described previously and may be raised when necessary by using coarse tailings material. The tailings, usually in the form of a slurry, should be deposited within the system in such a way that coarse sands settle out first near the embankment, while the fines or slimes are carried away toward the liquid pond area where the liquid is retained. Observations should be made and records kept of the deposition of tailings as well as sampling of the tailings near the embankment to determine its properties for use in building up the embankment. In order to gain the maximum shear strength from this material, it should have as low a moisture content as possible during embankment extension and all subsequent seepage flow should be minimized. Proper construction methods should be observed as specified above.

D. Maintenance and Inspection

A program of maintenance and inspection should be established to detect and repair environmental and other effects which might tend to lessen the integrity of the embankment system.

THE

ONTARIO WATER RESOURCES

COMMISSION

INFORMATION REQUIRED AND CRITERIA USED TO EVALUATE EMBANKMENT RETENTION SYSTEMS DESIGNED TO IMPOUND SOLID WASTE MATERIALS DISCHARGED AS SLURRIES

N O T E

This guide has been prepared as an aid in the preparation of applications for approval of industrial waste treatment and disposal systems in which embankment or impoundment is used to prevent or control the discharge of suspended solids.

This is not intended as an interpretation of Commission policy within the meaning of Section 27 and 50 of the OWRC Act, nor as indicating that applications which follow the recommendations of this guide necessarily will be approved.

INTRODUCTION

The processing of unrefined ores, particularly the milling of gold, uranium and base metal ores, produces large quantities of liquid and solid wastes (tailings) which contain concentrations of suspended solids and toxic ions in excess of OWRC objectives for discharge to surface waters in Ontario. It is therefore necessary to impound these wastes, such that their discharge to surface waters is controlled or prevented. Impoundment is usually accomplished by the construction of dyked retention systems with a controlled decant to a surface water. The advantage of this system, apart from pollution control, is that solids are retained for reprocessing, and, in cases where an abundant water supply is not available, the decant can be re-used in the mill circuit.

The size and construction of these retention systems will vary with the production capacity of the mill, the volume of liquid waste produced, the topography of the area and the availability of land for a disposal site. Generally, the location of a retention system is chosen to take advantage of the natural contour of the area, but it is usually necessary to construct an earth and/or tailings dyke at some point to contain the liquid or solid wastes, or both. In the latter case, the liquid and solids are usually discharged to one area within the system so that coarse solids build up in essentially the same area, and the fine solids or slimes and liquids flow toward the centre of the tailings pond area. Tailings embankments are usually constructed by discharging a tailings slurry near the inside edge of the initial earth embankment. The coarse solids rapidly settle out near the initial embankment and the fine solids drain to the centre of the system. When tailings accumulate to within a few feet of the top of the embankment, the system is extended by depositing coarse solids on the top of the embankment.

It is important that these embankment retention systems be constructed and maintained in accordance with sound engineering principles in view of their purpose to prevent or control the release of objectionable constituents to the receiving stream environment. The Commission has proposed criteria for the construction and maintenance of these earth and tailings embankments, which are principally derived from the requirements of the United States Atomic Energy Commission for the licensing of disposal systems for uranium ore processing wastes.

It is the purpose of this guide to specify in detail the information which the Commission will require in connection with the issuance of certificates of approval for industrial waste treatment works specifically related to tailings disposal areas, and to identify the criteria for their construction and maintenance that will be used in evaluating such systems. The criteria are necessarily general in nature since the characteristics of embankment systems may vary significantly from one location to another. However, these criteria should not be considered as relieving an applicant of his responsibility for ensuring that his system is adequate from a structural and pollution control standpoint.

The Commission may request additional information from applicants if such information is necessary to provide reasonable assurance that the applicant has established an adequate system. Such requests may be avoided by a thorough study of Commission objectives and this guide prior to submission.

An applicant may incorporate, by reference, information contained in applications, statements and reports previously filed with the Commission's Division of Industrial Wastes, provided that such references are clear and specific.

INFORMATION REQUIRED

In addition to the information required by Section 31 of the OWRC Act, as outlined in the application form, the following information should also be included:

(a) Drawings showing the layout in plan; typical cross-sections of all embankments showing proposed design, and if applicable, anticipated future extensions; and other pertinent design details. Embankment design should include information on heights, top width, side slopes, freeboard, seepage control, and protection of embankment surfaces as well as foundation design.

(b) A design analysis of the integrity of the proposed system including, as applicable, the results of soil tests, geologic exploration, nature of foundation materials, stability investigations and characteristics of fill material as well as a description of the construction methods and specifications.

(c) An evaluation and discussion of conditions that might lead to accidental release of the waste, the probable environmental effects of such release, and proposed program of inspection and maintenance to prevent such an accidental occurrence.

EMBANKMENT RETENTION SYSTEM CRITERIA

The Commission will take the following factors into consideration in evaluating for approval, the information submitted by an applicant:

A. Location

1. The site should be subject to the complete control of the applicant so as to permit entry only of authorized personnel thereto.

2. The site should not occupy the channel of any permanent watercourse unless a provision has been made for permanent diversion of such watercourse around the site.

3. The site should be permanently protected against runoff from the surrounding drainage area by the provision of diversion channels to prevent such runoff from entering or washing out the embankments.

4. A minimum distance of 200 feet should be maintained between the embankments and any permanent flowing watercourse at flood stage to minimize percolation effects, unless information is submitted for satisfying a closer location.

B. Design

1. Foundations - Foundations should be investigated to determine that they have suitable strength and permeability characteristics for the embankment proposed, including anticipated future extensions. A foundation of rock or graded sand and gravel is normally considered to have satisfactory strength for small embankments (under 25 feet in height). Foundations of alluvial deposits, which have not been consolidated under appreciable loads, and those of fine and uniform sands, or of plastic clays, must be given careful investigation and treatment to ensure safety of the embankment.

2. Embankments

(a) Construction material - The embankment material used in the construction of earth embankments may be natural soil, usually barrow soil found nearby, suitable for the construction of such systems. Coarse tailings material may be used to extend an earth embankment provided design and construction methods specified in this guide are followed.

(b) Top width - The minimum top width of an embankment should be eight feet. As the height of the embankment increases, the top width should be increased as specified in Table I below. It may be necessary to further increase the top width if the embankment material is susceptible to erosion or sloughing.

TABLE I

RECOMMENDED MINIMUM TOP WIDTH FOR EMBANKMENTS

Height of Embankment (feet)	Minimum Top Width (feet)
8 to 12	10
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(c) Side Slopes - In most cases, the type of material that is readily available for embankment systems will require that side slopes on the upstream face (i.e. in contact with the liquid) have a slope ratio between 4 to 1 and 2-1/2 to 1, and on the downstream face of the embankment between 3 to 1 and 2 to 1. Table II below contains recommended maximum slopes for embankments constructed of various materials.

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C. Construction Methods

Construction of the embankment should be started only after clearing and grubbing operations are completed and the foundation has been properly prepared. Embankment material should be free of sod, roots, stones over six inches in diameter, and other material which might interfere with proper compaction. Frozen material should not be placed in embankments and embankments should not be constructed on frozen foundations. The placing and spreading of embankment material should be started at the lowest part of the section under construction and the embankment carried up in horizontal layers not exceeding eight inches in thickness. Insofar as possible, these layers should be of uniform elevation and extend over the entire area of the fill. The distribution and gradation of materials throughout the embankment should be such that there are no lenses, pockets or streaks created, and the moisture content of the materials should be proportioned for maximum degree of compaction. Proper compaction of the embankment material should be achieved by the use of equipment designed for this purpose, usually a sheepsfoot roller. The travel of excavating equipment is generally not considered an adequate method for obtaining compaction. If the sheepsfoot roller is used, it should be weighted to give a unit pressure of not less than 200 pounds per square inch of the total surface area of the feet simultaneously in contact with the embankment. Usually six passes of the roller over each individual layer of material are sufficient to obtain good compaction. For relatively low embankments, under 25 feet in height, the adequacy of compaction may be determined by observation of the roller in action. For embankments over 25 feet in height, field control over compaction should be more precise and the embankment should be rolled until some predetermined degree of compaction is obtained, usually 90 to 95 per cent of maximum density as determined by appropriate compaction tests.

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D. Maintenance and Inspection

A program of maintenance and inspection should be established to detect and repair environmental and other effects which might tend to lessen the integrity of the embankment system.

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