Proceedings of the 15th Annual British Columbia Mine Reclamation Symposium in Kamloops, BC, 1991.
The Technical and Research Committee on Reclamation

Le développement de directives opérationnelles concernant les sites de dépôt de résidus

par

Peter C. Lighthall et Blair S. Trenholme
Klohn Leonoff Ltd.

Les sites de dépôt de résidus, provenant des exploitations minières de la Colombie-Britannique, comptent parmi les plus grandes structures construites sur la terre. Ces sites doivent être construits en tenant compte de contraintes imposées par la sécurité des travailleurs et de la population, ainsi que par la protection et la réhabilitation de l'environnement.

Au cours de ces dernières années, plusieurs exploitations minières de la Colombie-Britannique ont subi des ruptures importantes au niveau de leurs sites de dépôt, impliquant des millions de mètres cubes de débris, des écoulements sur de grandes distances et des impacts majeurs sur l'environnement. Heureusement, aucune perte en vie humaine ne s'est produite.

Cette communication résume les conclusions d'une étude effectuée par Klohn Leonoff Ltd pour le ministère de l'Energie, des Mines et des Ressources pétrolières de la Colombie-Britannique, portant sur les pratiques industrielles dans ce domaine. L'étude définit l'état de la situation actuelle en matière de sites de dépôt de résidus et présente un ensemble de directives visant à assurer la construction et l'utilisation sécuritaire de ces sites. Ces directives se veulent suffisamment flexibles pour répondre aux besoins uniques et particuliers des différentes opérations minières.

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DEVELOPMENT OF GUIDELINES FOR OPERATION AND MONIROTING OF MINE DUMPS

Peter C. Lighthall and Blair S. Trenholme

Klohn Leonoff Ltd.
10200 Shellbridge Way
Richmond, British Columbia V6X 2W7

Mine dumps being developed in British Columbia are some of the world's largest man-made structures. A number of recent failures of these dumps has prompted the British Columbia Ministry of Energy, Mines and Petroleum Resources, in conjunction with other funding agencies, to commission a series of guidelines and studies to improve the safety and understanding of mine dumps. Klohn Leonoff Ltd. Prepared the Interim Guidelines for Operation and Monitoring of Mine Dumps.

These Interim Guidelines developed operation, monitoring, safety, inspection and reporting criteria for operation dumps. Procedures for mine closure are presented along with monitoring and maintenance requirements for completed dumps. The responsibility for personnel involved with mine dump operations is defined. An empirical procedure is proposed for setting the maximum rate of dump crest advance. Standard forms are introduced for Mine Dump Inspections and for Failure Reporting.

INTRODUCTION

Mine dumps being developed in British Columbia are among the world's largest man-made structures. Several British Columbia coal mines have experienced large dump failures in recent years. Some typical examples of these failures are:

In 1984 and 1985, a series of three massive failures occurred at a northeastern British Columbia coal mine involving between 1.5 million m^3 and 3 million m^3 of material each on dumps with slope heights of 240 m to 250 m. Runouts of the failed mass were in excess of 2 km beyond the dump toe. In one case, the failure was not adequately detected by monitoring and the personnel and equipment retreated only minutes before the slide occurred.

Between 1988 and 1991, several massive failures occurred at a southeastern British Columbia coal mine involving tens of millions of cubic metres of material on dump faces of over 350 m in height.

In 1990, a foundation failure of a relatively low dump occurred at a northeastern British Columbia coal mine. The failed dump and foundation flowed into the adjacent river and blocked flow for a period of some 24 hours.

Some of the above failures have caused environmental damage although no recent fatalities have occurred from dump failures.

In response to the failures which have occurred, the British Columbia Ministry of Energy, Mines and Petroleum Resources (MEMPR), in conjunction with other funding agencies, has commissioned development of a series of guidelines and studies to improve the safety and understanding of mine dumps. These are:

Investigation and Design of Mine Dumps - Interim Guidelines	(MEMPR, 199Ia)
Operation and Monitoring of Mine Dumps - Interim Guidelines	(MEMPR, 199Ib)
Methods of Monitoring Waste Dumps Located in Mountainous Terrain	(CANMET, 1991)
Runout Characteristics of Debris From Dump Failures in Mountainous Terrain	(CANMET 1992)

This series of documents is a major initiative which hopefully will be of great benefit to the industry.

Klohn Leonoff was engaged to undertake development of the Interim Guidelines for Operation and Monitoring of Mine Dumps for the British Columbia Mine Dump Committee, with funding provided by the Provincial Sustainable Environment Fund. The development of the Guidelines consisted of:

visits to MEMPR offices in Fernie, Prince George and Kamloops to interview District Inspectors and to review their files on mine dump operational procedures and dump performances;

visits to a number of key mines to interview engineering and operating personnel regarding their dump operating procedures and overall dump performance. Other mines were also included by carrying out telephone interviews;

developing a questionnaire that was mailed to all operating mines in British Columbia to obtain details of dump operations;

collecting mine dump operation manuals currently in use at all of the mines in British Columbia;

preparing draft guidelines and having them reviewed by a large number of representatives from operating mines, by consultants and by government officials; and

by maintaining close liaison with the British Columbia Mine Dump Committee throughout the guideline development process.

These guidelines are to be issued this year as an interim document for use by operators of mine dumps within the Province. It is the intention of the MEMPR to update these guidelines after sufficient time has passed to assess their applicability. It is expected that these guidelines will help to standardize mine dump operation throughout British Columbia and ultimately will form a basis for revision of the mining code (MEMPR 1990).

DUMP FAILURES – COAL MINES AND METAL MINES

Based on the site visits and questionnaire results, it is clear that coal mines in British Columbia have experienced significantly more and larger failures than the metal mines. This higher incidence of failure is possibly a result of finer grained dump materials and steeper, weaker foundations.

OBSERVATIONAL METHOD

Mine dumps are usually designed based on relatively limited information and , hence, some design parameters must be approximated or assumed. Consequently, the designer often must adopt a design which may have uncertainties. Given these uncertainties, the observational method (Terzaghi and Peck, 1948) is often the only practical approach for mine dump design and operation.

> "The procedure is as follows: Base the design on whatever information can be secured. Make a detailed inventory of all the possible differences between reality and the assumptions. Them compute, on the basis of the original assumptions, various quantities that can be measured in the field. For instance., if assumptions have been made regarding pressure in the water beneath a structure, compute the pressure at carious easily accessible points, measure it, and compare the results with the forecast. Or, if assumptions have been made regarding stress-deformation properties, compute displacements, measure them, and make a similar comparison. On the basis of the results of such measurements, gradually close the gaps in knowledge and, if necessary, modify the design during construction."

The observational approach is dependent upon the ability to modify the design and construction method or rate of dump development during construction. Mine dumps are well suited to this approach.

The observational approach relies heavily on adequate monitoring of appropriate conditions such as movement rates, material quality, piezometric conditions and development rate.

In order to avoid excessive restrictions on operational procedures while maintaining adequate safety against mine dump failures, it is recommended that the observational approach be followed.

PLANNING, TRAINING AND RESPONSIBILITY

Mine dump planning includes sequencing dump development, material removal and placement scheduling, material quality control and measures to control surface water, groundwater and snow. Planning must be an ongoing process and the level of planning should be increased for dumps experiencing difficulties.

Appropriate training of the personnel responsible for implementing the plans is essential for effective operations. A survey of British Columbia mines indicates a range of staff training from minimal to excellent. Proper training in all aspects of dump operations for all staff concerned from dump persons to mine manager will assist greatly in developing an understanding of the importance of each task which will thereby increase the likelihood of adherence to construction and inspection guidelines with benefits to efficiency and safety. The importance of instilling a basic understanding of general design concepts and safety hazards cannot be overemphasized. The guidelines present a summary of needs and perceived benefits of training and education for the various groups most closely associated with mine dump operations.

The guidelines provide details of responsibility for personnel at various levels relating to mine dump operations as summarized in Figure 1.

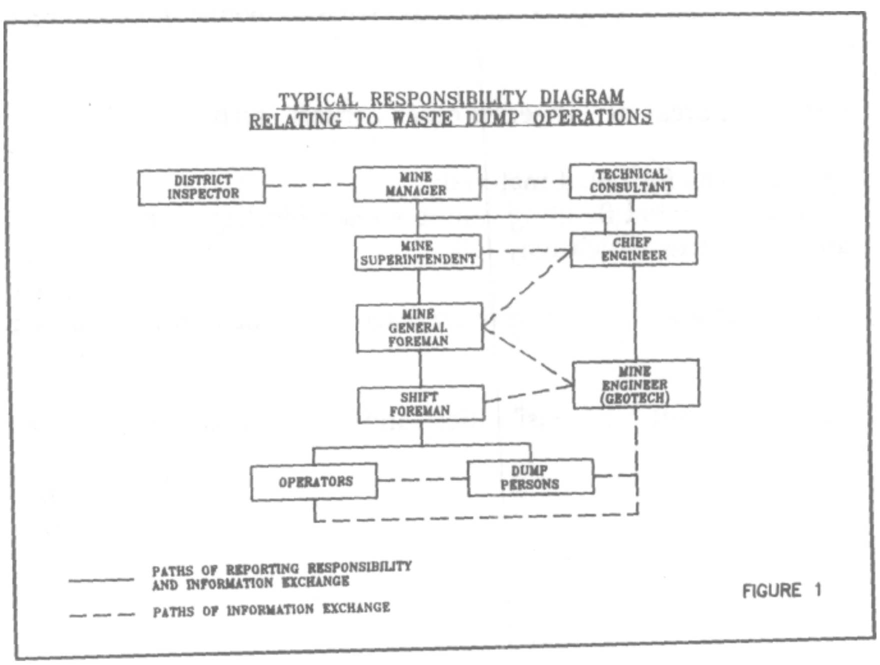

FIGURE 1

The mine manager is responsible for all aspects of dump operation. This responsibility will include adherence to specific procedures and design specifications as well assuming that accurate and meaningful records are kept of dump construction and performance. According to rules set out in the Code, the manager must adhere to certain reporting requirements pertaining to unusual or unsafe occurrences. Delegation of responsibility by the manager is necessary to carry out the operations of the mine.

MANUAL FOR DUMP OPERATION

Several of the British Columbia mines surveyed have prepared written manuals for mine dump operations covering such topics as dumping rules, truck and dozer procedures, dump person procedures and monitoring.

The guidelines require that each mine prepare a site-specific manual for its mine dump operations. Such a manual will give details of specific procedures suited to local conditions and be in compliance with the Code.

The guidelines for an individual mine should include a section on emergency preparedness and response related to mine dumps. For the site specific conditions of the mine and its individual dumps, the emergency preparedness plan should;

Define an emergency situation. This would include the obvious event of a major dump failure but may also include the following unusual or extreme events:

- slumping, bulging, cracking or other evidence of impending failure of the dump;
- sudden change or increase in seepage volumes from the dump or a cloudy water appearance in the seepage;
- large earthquake;
- severe storm (which may lead to failure of diversion structures); and
- blockage of creek r river by or relating to mine dump.

Particular attention must be given to inspection and, where necessary, repairing the dump and associated structures (drainage, stream diversion etc.) following unusual or extreme events;

identify potential areas of danger or other concern such as:

- runout areas for failed material;
- areas of potential flooding due to stream blockage; and
- dump surfaces which may fail.

define physical assets as well as human resources which may be located within danger areas; and

clearly mandate staff responsibilities and responses under defined emergency conditions.

DUMP OPERATION

The interim operational guidelines developed define general requirements for foundation preparation, drainage controls, dumping procedures, material quality control and degradation, verification of material properties and control of snow.

It is clear from studying case histories of mine dump failures in British Columbia that there is an important relationship between crest loading rates and stability. Because other factors are also involved, it is not always clear which factors are the most significant in causing failures. However, the relationship between dump height and rate of crest advance stands out.

Figure 2 is a plot of crest rate advance (m/day) versus maximum dumping height. A curve (labelled "lower bound of most failures") has been drawn such that most (all but three whose causes can be attributed to other extreme conditions) failed dumps fall above and most stable dumps fall below the line.

As a guideline for new mines or dumps with no performance history upon which to base dumping rate limits, the initial relationship of dumping rates and dump height should be governed by the second curve, labelled "guideline" on Figure 2. This curve has been offset a prudent amount from the lower bound curve to offer a degree of extra safety. As more data becomes available, it may be possible to revise the criteria for a particular dump based on its proven performance. The fact that some stable dumps plot above this guideline illustrates this point. However, had the dumps which did fail been restricted by this guideline, it is likely that some if not most of the failures could have been avoided.

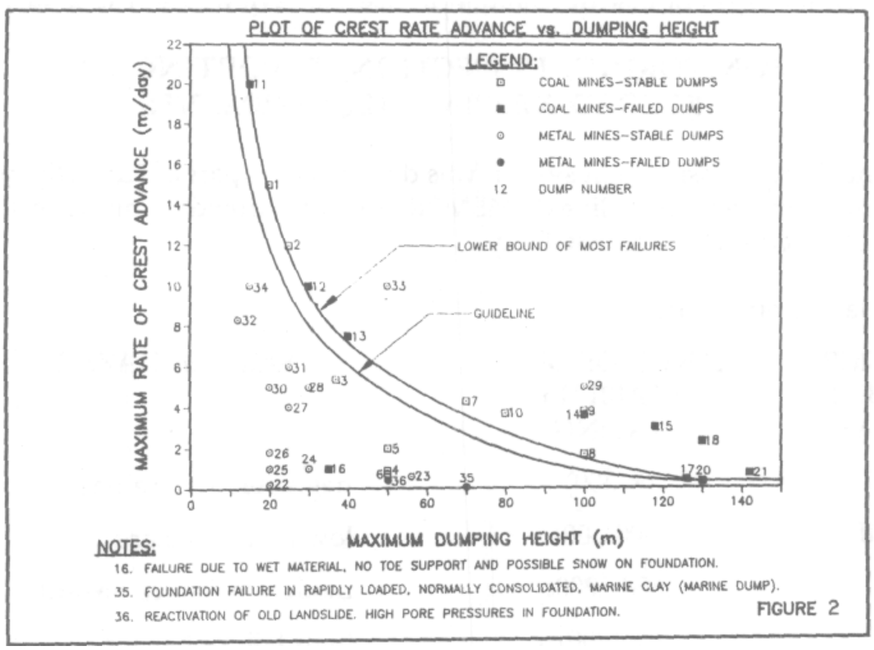

FIGURE 2

There may be special cases for which the guideline can not be practically applied. For these cases, a more rigorous inspection and monitoring program will be required than that for other dumps. These extra measures must be defined by an engineer with appropriate geotechnical experience after a review of the site conditions and all pertinent data.

Other conditions which appear to have a major effect on crest displacements and failure include time of year (e.g. spring thaw), piezometric levels, precipitation, material type, dump height, blast-induced or seismic vibration, foundation slope, and foundation material. As well as recording dumping rates and crest displacements, these other parameters should be noted as one or more of them may significantly affect stability.

DUMP MONITORING

Mine dump monitoring is carried out visually or with instrumentation to recognize signs of instability and quantify movement rates, total movement and water pressures. In British Columbia instrumented monitoring is carried out at many of the mine, particularly those with high dumps in mountainous terrain.

Monitoring is carried out for the following reasons:

- safety of personnel and equipment;
- understanding and predicting dump behaviour; and
- provide information for modifying current designs or for future dump designs.

The interim guidelines highlight the importance of visual inspection as the most practical and common monitoring method. On the other hand, wireline extensometers are the most commonly used form of instrumentation. The principal use is for crest movement monitoring. Other types of instrumentation in use are reviewed in the guidelines.

MONITORING, INSPECTION, REPORTING AND RECORD KEEPING REQUIREMENTS

A mine dump classification system was developed as part of "Investigation and Design of Mine Dumps – Interim Guidelines" (MEMPR, 1991) to provide a numerical dump stability rating (0-1800) based on risk of instability.

The classifications are:

DUMP STABILITY CLASS	RANGE OF DUMP STABILITY RATING	FAILURE HAZARD
I	(<300)	negligible failure hazard
II	(300-600)	low failure hazard
III	(600-1200)	moderate failure hazard
IV	(>1200)	high failure hazard

Based on this classification system, monitoring, inspection and reporting requirements were developed and are specified in the Guidelines are presented in Table 1.

TABLE 1 MONITORING, INSPECTION AND REPORTING REQUIREMENTS

DUMP STAB. CLASS	DUMP STAB. RATING	REQUIREMENTS				
		INSTRUMENT MONITORING	SHIFT REPORT	INSPECTION		REPORTING
				DESCRIPTION	FREQUENCY	
I	< 200	Visual inspection only unless unexpected movements detected	Yes	Shift foreman to inspect.	4 hours	Shift log reports.
				* Periodic detailed inspection by the engineer**.	Annual	Annual in-house report.
		Piezometers where applicable.				
II	200–500	Instrumentation required if movements other than consolidation settlement noted.	Yes	Shift foreman to inspect.	4 hours	Shift log reports.
				Inspection and interpretation of data by the engineer**, if instrumented.	Daily	Quarterly inspection.
		Piezometers where applicable.		* Periodic detailed inspection by the engineer**.	Quarterly	Annual in-house report.
III & IV	> 500	Instrumentation for movement monitoring required as specified by design consultant.	Yes	Shift foreman to inspect.	4 hours	Shift log reports.
				Inspection and interpretation of data by the engineer**.	Daily	Quarterly in-house report.
				* Periodic detailed inspection by the engineer**.	Monthly	Annual report by independent reviewer.
		Piezometers where applicable.		Inspection by independent reviewer	Annual	

*Periodic detailed inspection refers to inspection form described in Section 8.4.

Shift log report required by the Code.

Visual monitoring is required for all waste dumps.

**The engineer is defined as a permanent staff member, who is a professional engineer or other competent person with appropriate geotechnical experience who is responsible for understanding and implementing of technical aspects of waste dump design and operation.

Comprehensive and uniform procedures for periodic mine dump inspections and reporting of failures have to date been non-existent. To standardize the reporting and to ensure that complete and accurate records are kept, two reporting forms have been developed:

- Mine Dump Inspection Form – This four-page form will be specified for periodic regular inspection of mine dumps in accordance with the inspection frequencies specified in Table 1.

- Mine Dump Failure Report – This report provides a format for comprehensive reporting of mine dump failures.

SUMMARY

Interim Guidelines for Operating and Monitoring of Mine Dumps have been developed to standardize certain operating, monitoring and reporting procedures for British Columbia mines. It is hoped that these Guidelines will help to reduce the incidence of instability of mine dumps and hence to enhance safety and environmental protection and to minimize the economic impact that a large failure can have.

The new procedures introduced in the Guidelines include:

- defining the responsibility of personnel involved with mine dump operations;
- proposed empirical procedure for setting maximum rate of crest advance;
- defining monitoring, inspection and reporting requirements for mine dumps; and
- the introduction of forms for Mine Dump Periodic Inspection and Failure Reporting.

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