EROSION MONITORING ON MOUNTAIN FOOTHILLS WASTE DUMPS

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"Reclamation in the Eastern Slopes of Alberta"

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R.G. Chopiuk, P.Eng., Manager, Mining Division
S.E. Thornton, P. Eng., Project Engineer

Coal Mining Research Company
One Oil Patch Drive
P.O. Bag No. 1400
DEVON, Alberta
T0C 1E0

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This study was carried out for Alberta Environment, Land Conservation and Reclamation Council, representing the Reclamation Research Technical Advisory Committee (RRTAC). Work was conducted under the authority of Dr. Paul Ziemkiewicz, Project Manager and Certification Officer, of Alberta Energy and Natural Resources, Scientific and Engineering Services and Research Division. This paper presents highlights taken from the project report.

PREFACE

The Waste Dump Design for Erosion Control study was initiated in 1983. Several foothills/mountain coal mine waste dumps were selected for the purpose of evaluating the effects of final configuration on the amount of surface erosion occurring on those dump surfaces. A series of statistically-valid research plots was established on the reclaimed slopes, and a program to monitor the amount of material movement on the slopes was begun.

The objectives of the program were:

-- Primarily, to determine the influence of the length and steepness of reclaimed waste dump slopes on erosion;

-- Secondly, to determine the effect of time and vegetation cover on erosion, i.e. does the age of the material, since reclamation, affect the amount of material movement on the slopes.

-- Finally, to develop, if possible, a model that will predict the effects of those factors contributing to erosion that are within the control of the mine operator, namely slope configuration and nature of material used to cover the slopes.

Data on the movement of the slope surfaces were collected twice in 1983, three times in 1984, and three times in 1985. The total amount of elapsed time between the final measurements obtained in 1985 and the time monitoring began in 1983 was 24 to 26 months.

This paper presents a history and outline of the project as well as an overview of the results of the monitoring program.

SECTION 1: INTRODUCTION AND BACKGROUND

1.1 BACKGROUND

Most studies related to surface mine hydrology have centered on estimating sediment yield rates and volumes for entire regions and watersheds. Little emphasis has been placed on site-specific analysis of erosion. The commonly-used Universal Soil Loss Equation (USLE) pertains mainly to agricultural land, usually for slopes less than 20 degrees. Published data for slopes in the 20 to 30 degree range are very scarce, hence the need for information directly related to coal mine waste dumps.

Essentially no information was available on the soil erodibility factor of exposed spoil material. Also, no data on erosion existed for length-slope factors beyond 120 metres and 20 percent.

In order to obtain the information needed to evaluate the influence of reclaimed waste dumps on downslope environments such as streams and rivers, the scope of the study included examination of resloped dumps of different configurations and ages, and having different covers. Data gathered included precipitation readings and measurements of the surface of the slopes two to three times each year.

1.2 PROJECT HISTORY

The project followed work begun in 1982 by the Coal Mining Research Company (CMRC) for the Reclamation Research Technical Advisory Committee (RRTAC). That study defined the slopes that were being achieved through regrading of coal mine waste dumps in the foothills/mountain areas.

Plots were established at three mine sites in Alberta: Tent Mountain, located near Blairmore; Smoky River, near Grande Cache; and Cardinal River, south of Hinton. The monitoring of those plots began in August 1983, and continued until October 1985. The plots at Cardinal River were monitored only once in 1984. RRTAC and CMRC decided to discontinue monitoring at this site because of extensive damage done to the plots when hydro-seeder access roads were cut through the study area the previous fall.

1.3 OBJECTIVES

The erosion study was designed to examine the effects of the regraded configuration (i.e. slope angle, slope length), waste material characteristics, age since reclamation, amount of precipitation, and vegetative cover on the amount of surface erosion occurring on the resloped faces of the waste dumps.

1.4 EXPERIMENTAL DESIGN

Since the primary objective of the study was to examine the effect of waste dump configuration, several slopes were chosen to obtain different degrees of steepness. On any one particular slope having a specific angle (steepness), plots were arranged to monitor the influence of slope length. It was decided that the effects of erosion would be measured at four or five different distances from the crest of the slope. To be statistically valid, this arrangement of five plots along the length of the slope was repeated, or in statistical terms, replicated, five times.

Number of slope length treatments per replicate:

To determine the effect of slope length, the number of lengths (treatments) for each slope was chosen to be 5 for long slopes (100 m or more) and 4 for shorter slopes.

Number of replicates:

The choice of the number of replicates was based on an 80% chance of detecting a mean difference as small as 10% of the experimental mean at the 5% level of significance. In this study, it was desired to measure a maximum of 5 different slope lengths for each slope angle; therefore, by definition, the number of treatments, n, is 5.

The number of replicates, r, was determined by using the formula

$$r = 2\ (cv)^2/D^2\ (t_1 + t_2)^2$$

where cv = coefficient of variation,
and D = mean difference desired,
and t_1 and t_2 = tabular values from any "t" distribution table.

Calculations determined that "r" in this case would be 5. Each of the 5 replicates consists of 5 plots (length treatments) arranged as shown in Figure 1.

Transects:

Although not a statistical term, the word "transect" was chosen to refer to a line of plots at approximately the same distance from the crest of the slope (ie. the same slope length). As shown in Figure 2, each slope transect which was set on a slope contour line consisted of 5 plots. Distance between plots varied according to slope width.

Based on the above, the plots on each slope to be studied were arranged in either 5 replicates of 5 plots (treatments or lengths) per replicate or 5 replicates of 4 plots per replicate, giving a 5 x 5 or a 5 x 4 pattern.

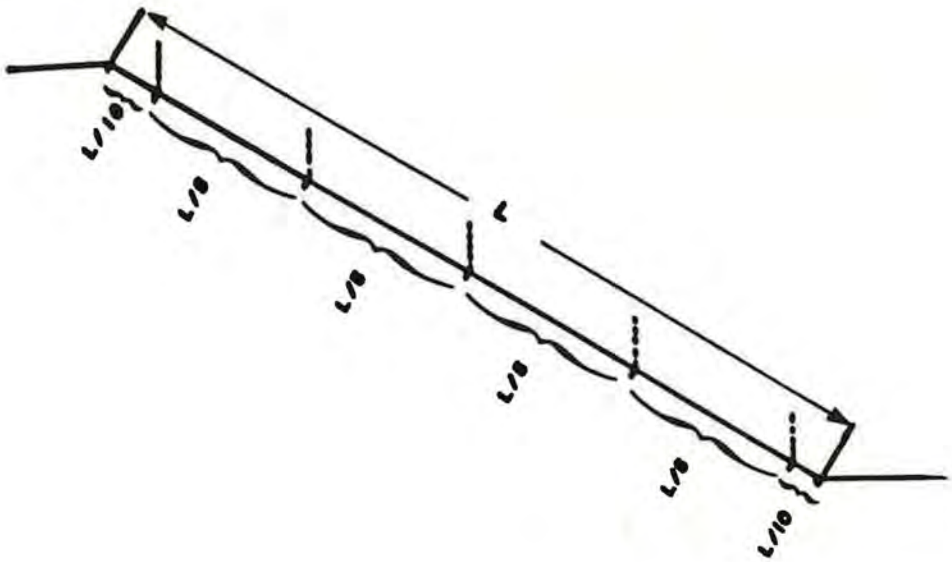


FIGURE 1 : EXPERIMENTAL PLOT ARRANGEMENT ON A RECLAIMED SLOPE

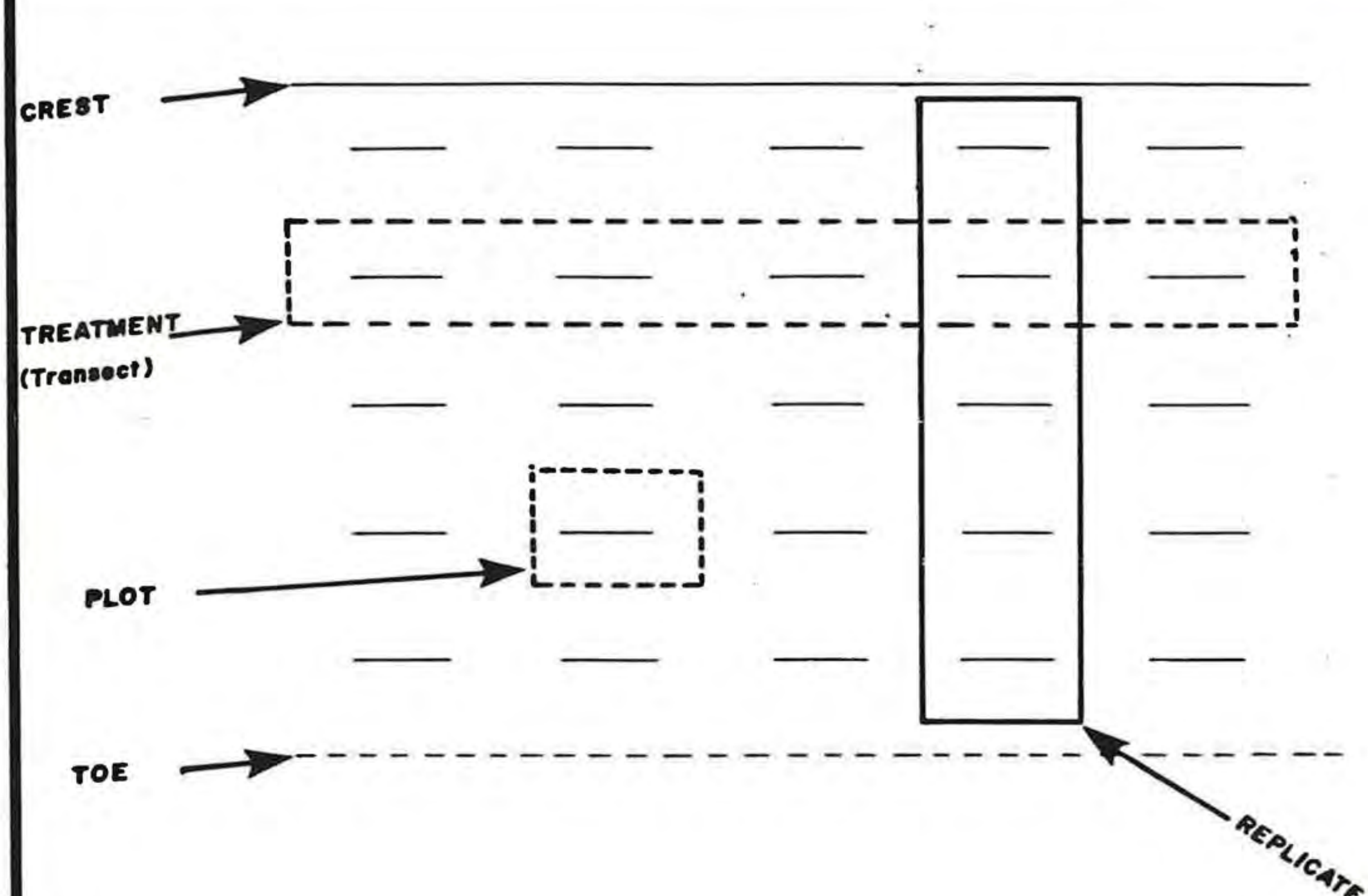


FIGURE 2 : REPLICATE DETAIL SHOWING PLOT LOCATIONS

1.5 EROSION PLOT DESIGN

Because erosion occurs sporadically, it is difficult to observe directly, and, therefore, the consequences of erosion must be examined. A plot design was established to measure the effects of erosion at a specific location on a slope.

Each plot was 2m long, defined by stakes at each end. An "erosion board" was positioned over a plot to obtain a detailed profile of the ground surface within the plot. The "board" consists of 21 rods mounted every 100mm across a 0.75m high by 2.2m long plywood sheet. The board was fastened to the plot stakes each time a reading was taken, guided by a notch and pin at one end to ensure consistent placement. When a plot was measured, the rods were allowed to contact the ground surface, and the vertical positions of the rods were noted.

The elevations of the stakes were surveyed every spring to ensure no stake movement had occurred and to provide a grid to which erosion board readings could be related.

In addition, plots within replicates 2 and 4 usually contained erosion pins (300mm long steel spikes with washers). The pins were spaced 400mm apart between the two plot stakes. Using a steel rule or tape, the distance was measured between the head of the spike and the washer which lies on the ground surface. The values of surface erosion obtained from pin readings were compared with those from the erosion board to evaluate both methods, and to serve as a check on accuracy.

1.6 LEVEL SURVEY

A detailed profile of each slope was obtained when the plots were first constructed. Control points were located on the slopes, adjacent to each transect, to verify the plot datum. This ensured that subsequent measurements were related to those of the previous year. In addition, control stations were located off the dumps on undisturbed ground to allow for any movement of the entire slope itself.

1.7 PRECIPITATION MEASUREMENTS

Non-recording rain gauges were situated at two locations on the Smoky River site and the Tent Mountain site. The gauges were read intermittently between site visits to Smoky River, and at the time of each visit to Tent Mountain. Precipitation during the time between the last reading in fall and the first in spring was estimated from Environment Canada records for each respective area.

SECTION 2: OBSERVATIONS

2.1 STUDY AREAS

Tables 1 and 2 provide brief descriptions of the slopes that were monitored throughout the course of the study.

Table 1
Tent Mountain Slopes

Slope No.	Length (m)	Angle (^{o})	Age (yrs)	Cover
1	150	38	1	-
2	200	25	1	-
3	30	26	1+	Grass
4	150	22	1	-
5	30	16	1	-

Table 2
Smoky River Slopes

Slope No.	Length (m)	Angle (^{o})	Age (yrs)	Cover
1	150	23-26	5+	Grass
2	100	20	1	Topsoil
3	40	33-36	3+	Topsoil
4	120	23	0	Topsoil

2.2 SOIL SAMPLING AND ANALYSIS

A limited plot-by-plot soil sampling and testing program was conducted. In total, 39 samples were collected from Smoky River slopes 2, 3 and 4 in June 1985.

The following analyses were conducted on the samples:

- -- material classification (visual)
- -- grain size analysis
- -- specific gravity
- -- field bulk density

Classifications of the materials are described below.

Slope 4

Weathered sandstone trace of silt, fine grained, low plastic fines, dry, loose, sandstone inclusion, dense, well cemented fine grained. Clay shale inclusion, grey, med plastic, hard. Dilatancy test: slow.

Slope 2

Weathered clay shale, pieces to 1½", med plastic, some silt, and a trace of fine sand, grey, fine roots.

2.3 PLOT MEASUREMENTS

Erosion board and erosion pin readings were conducted at the sites as follows:

- -- August 1983
- -- September/October 1983
- -- June 1984
- -- August 1984

-- October 1984
-- June 1985
-- August 1985
-- October 1985

An additional effort to try and explain the occurrence of large amounts of apparent deposition was undertaken in 1985. This involved the painting of narrow lines on the ground surface between the plot stakes when the first set of measurements was taken in the year. During subsequent visits, these lines were examined for evidence of the movement of lumps of material, for actual deposition, as well as for erosion. Close-up photos of each plot were used to aid in the visual comparison of the plots from event to event. The results showed that material was moving down the slope on a few of the plots. Material with paint on it could be found as far as three feet from its original position. From the paint it was also possible to see those areas where material was breaking down.

In those areas where no paint was visible, it was not possible to determine whether the paint had been covered over or simply washed away without destroying the plot site.

A survey grid at the base of Slope 5 at Tent Mountain (TM5) was established to assist in measuring the amount of material that was being deposited there. This was accomplished using steel pins spaced at approximately 1m intervals over the deposition area. The pins were measured again in August 1985. It should be noted that slopes other than slope 5 contribute to the deposition which accumulates in the basin. The pins were installed to observe what was happening to the area in general, as opposed to attempting to measure deposition resulting from erosion of slope 5 in particular. The average depth of deposition was found to be 17 mm over an area of about 60 square metres. When the deposition volume of 1 m^3 is considered in light of the large contributing area, the conclusion is that surface erosion of the slopes is minimal.

Another factor which was thought to affect the amount of erosion at any particular location on a slope was the phenomenon of surface features. Surface features were identified and mapped to help explain the variability in plot erosion values which could have been due to the influence of certain features. For example, large cracks between transects on a slope can act as runoff intercepts. Diversion trenches cut diagonally across a slope face can redirect runoff and alter the lengths of uninterrupted surface. These and other significant surface features were mapped by walking over each slope and noting the position and nature of the items, keeping in mind their effects on erosion and runoff patterns.

2.4 PRECIPITATION MEASUREMENTS

The non-recording rain gauges were read each time a site was visited during 1983, 1984 and 1985. Two instances of wildlife entering the rain gauge enclosure and upsetting the gauge occurred at Tent Mountain. Precipitation values for those times when on-site gauge readings were not available, i.e. late fall and winter, were taken from the closest monitoring station maintained by Environment Canada.

SECTION 3: DISCUSSION AND CONCLUSIONS

3.1 GENERAL CONCLUSIONS

Over the two-year time period that erosion was measured, the total amount of erosion on most slopes was minimal. This minimal amount of erosion, therefore, made it difficult to establish models or trends of the influence of contributing factors on erosion itself.

In general, the most reliable and dramatic results were obtained from the one slope which was monitored as soon as reclamation was completed. The effects of specific variables on the amount of erosion are presented individually in the next subsections.

3.2 SIGNIFICANCE OF RESULTS

The t-tests demonstrated that a large number of the plots exhibit no significant change in ground surface elevation from event to event. Considering the amount of precipitation recorded during these times, this occurrence is understandable. Generally speaking, only about half of the plot means were significantly different between events. Of those which were significant, less than half indicated erosion. The exception to this was Slope 4 at Smoky River. The monitoring of this slope began immediately after the topsoil was spread. On all other slopes monitoring began several months after regrading was completed.

Analysis of the erosion outliers showed that an average of 10 to 15 rills or gullies were developing in the plots on each slope at Smoky River and Tent Mountain. These gullies were determined to be as deep as 100mm in several instances. The outliers indicating deposition are attributed to material moving into depressions or lumps rolling onto the plot profile.

3.3 EFFECT OF COVER

As expected, the slopes which were covered with dense grasses (slope 1 at Smoky River and slope 3 at Tent Mountain) showed no signs of erosion whatever. The other slopes were developing strong stands of cover, to the point of making erosion board readings difficult. It is expected that thick mats of vegetation will soon prevent any sheet erosion from occurring at all.

3.4 EFFECT OF AGE

The influence of time since regrading was found to be as expected: that the amount of erosion decreases with time, due to initial loss of fine particles and to the formation of a weathered surface as well as increased vegetative cover.

Also as expected, the greatest amounts of erosion were found on slopes which were newly regraded. Results obtained from slope 4 at Smoky River were much more significant compared with other slopes which were older by at least one winter. Monitoring of Smoky River 4 began immediately after reclamation was completed.

The older slopes at Smoky River and Tent Mountain also exhibited similar results, i.e., erosion decreasing with age, although not as dramatically as with new slopes. The average annual amounts of erosion which were measured on each slope are shown in Figures 3 to 8. In most instances, however, the average surface erosion is minimal, eg. 0 to 5 mm.

3.5 EFFECT OF PRECIPITATION

The amount of erosion was found to be directly proportional to precipitation for newly-graded surfaces. Older slopes did not exhibit those results consistently. The correlation for these was relatively poor as well.

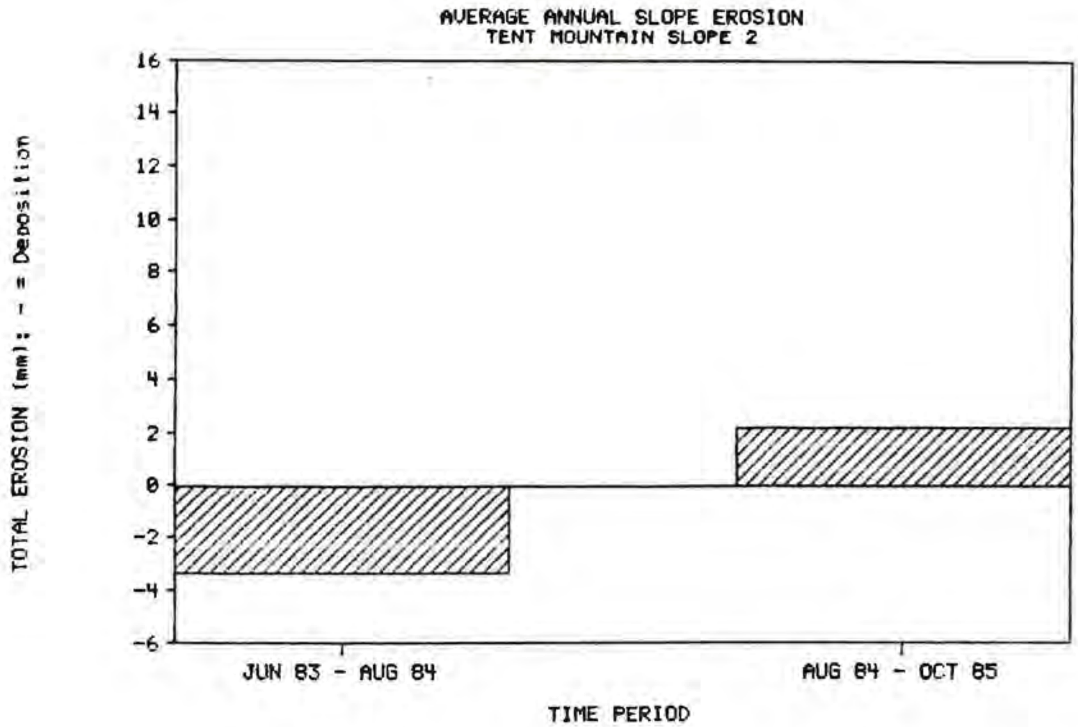


Figure 3

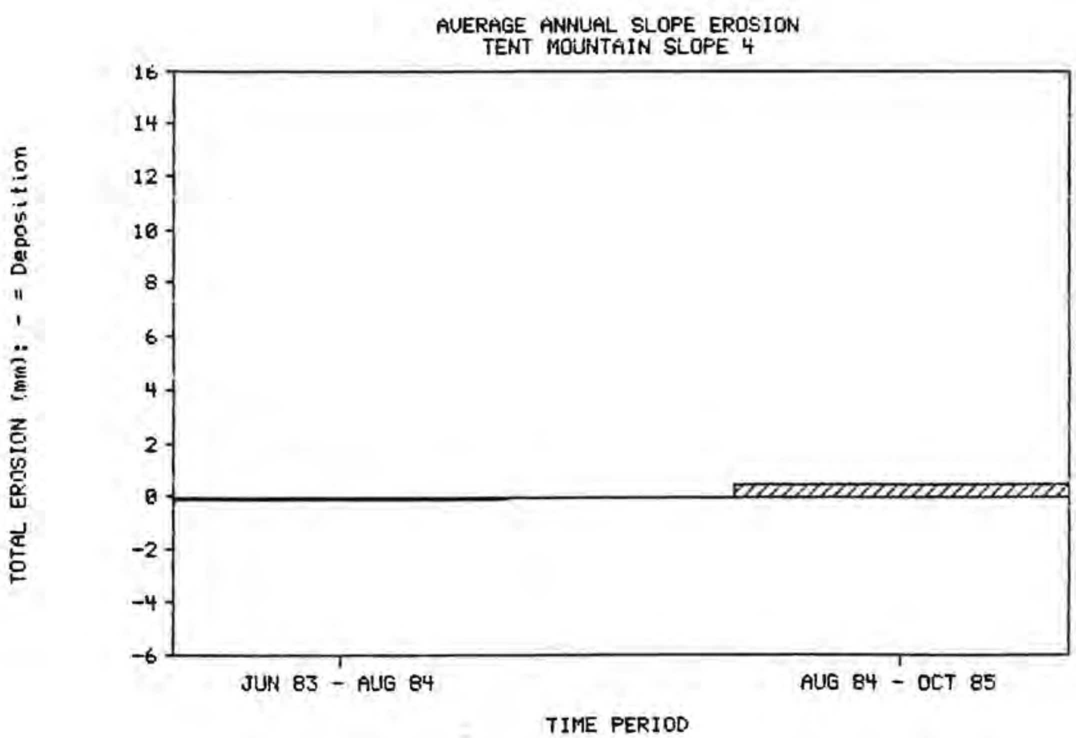
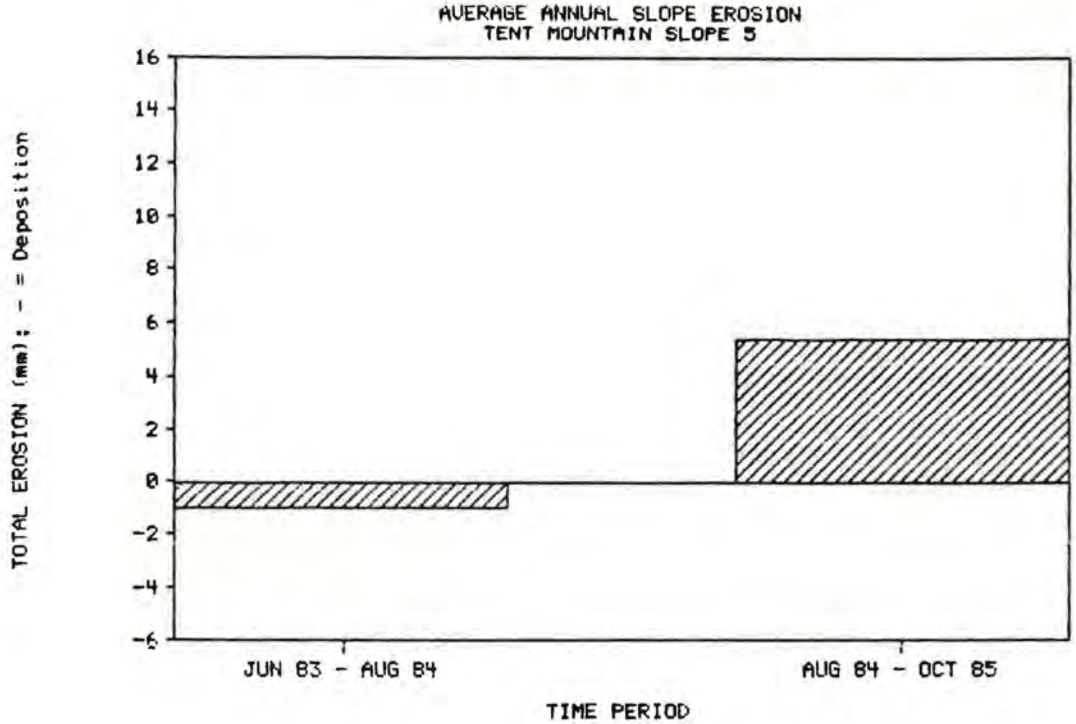


Figure 4



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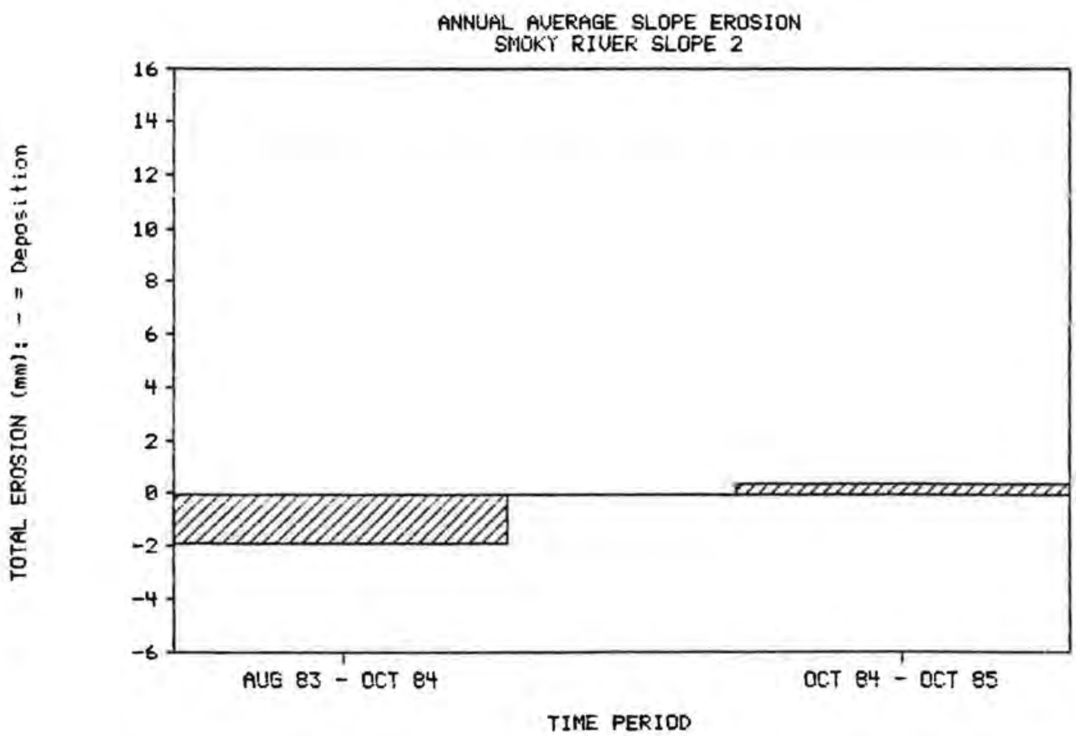

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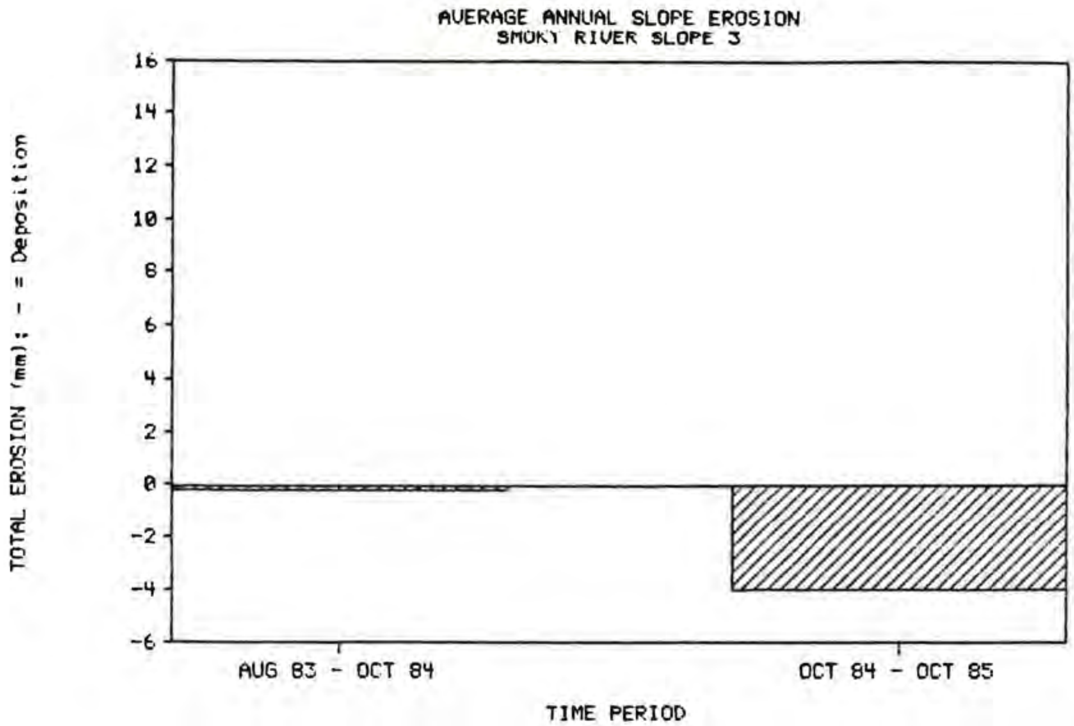

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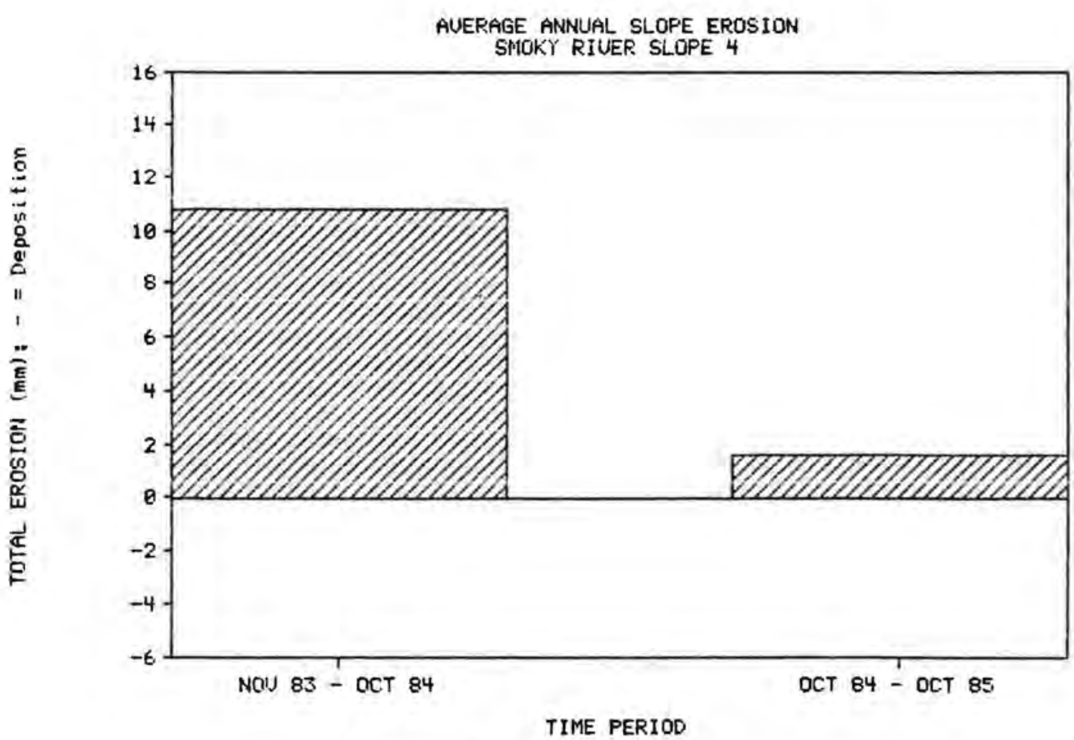

Figure 8

3.6 EFFECT OF SLOPE LENGTH

The results of correlations for erosion with slope length were not reliable other than for slope 4 at Smoky River. The linear regression analysis predicts an increase of 4 mm of erosion with every 100 m of slope length for this location.

3.7 EFFECT OF SLOPE ANGLE

The effect of the steepness of the slope was found to be poorly correlated. Results showed positive and negative effects of slope angle on the amount of erosion, with questionable reliability.

3.8 EFFECT OF MATERIAL CHARACTERISTICS

Laboratory analyses of the samples collected from the slopes at Smoky River were not as helpful as was initially hoped. There appears to be some relationship between density and erosion for slope 4 as shown in Figure 9, where erosion decreases with an increase in density of the soil. When the analysis from slopes 2 and 3 are included, no well defined relationship is apparent, as portrayed in Figure 10.

The grain size analyses showed no appreciable differences between plot samples. The same was true for the specific gravity tests.

3.9 SUMMARY OF RESULTS

A general observation of all the results, based on two annual periods of erosion measurement on the slopes, is that there appears to be no need for a great deal of concern about waste dump erosion. Other than for a small initial amount of surface deflation immediately after regrading is complete, no significant amount of material seems to leave the slopes. From knowledge of the nature of the materials involved (i.e., extremely course-grained "topsoil" overlying blocky, angular waste rock) one concludes that even measurable erosion is most likely redistributed over the slope itself (as

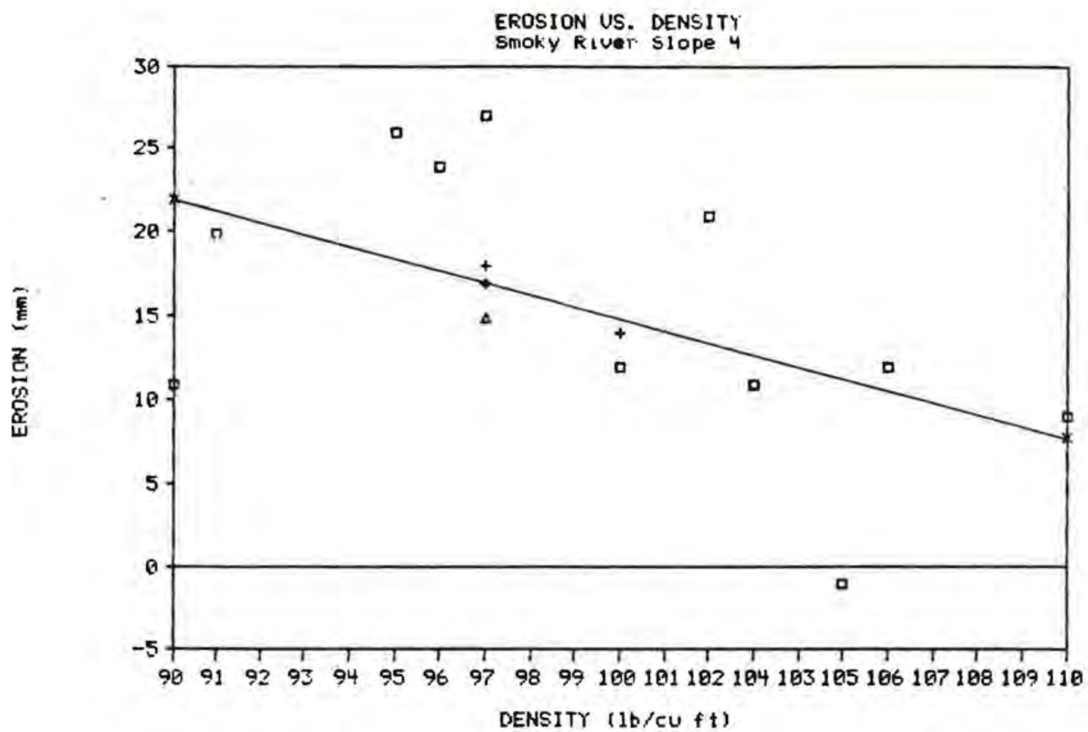

Figure 9

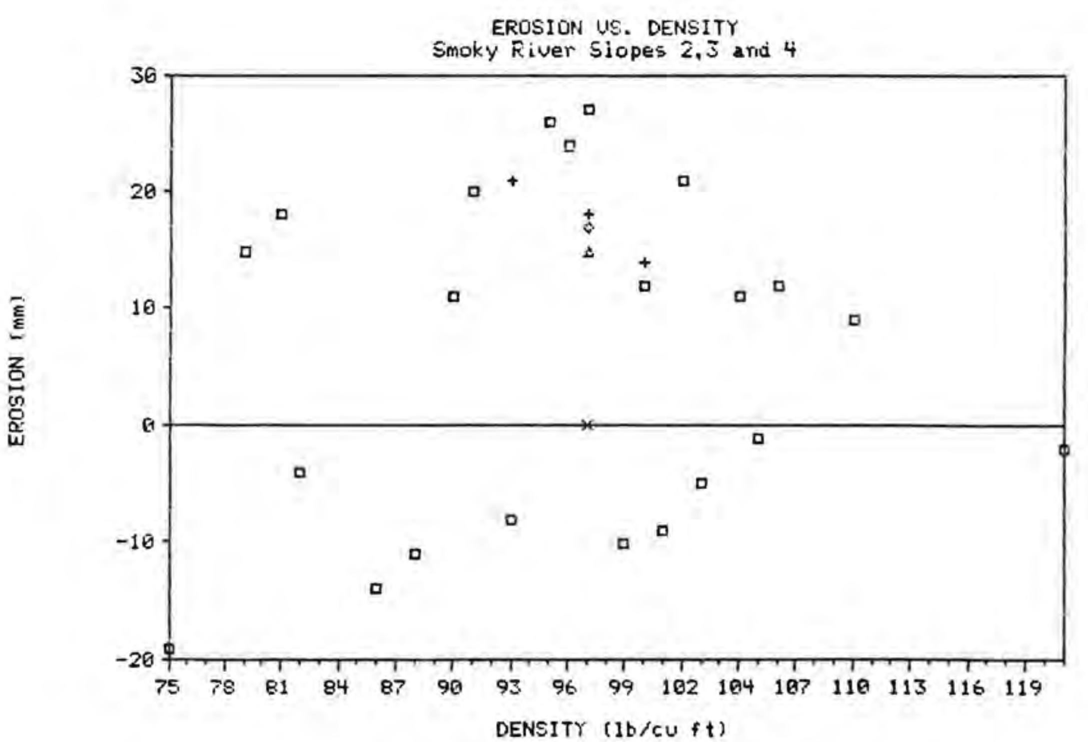

Figure 10

evidenced by numerous deposition results of plot measurements). One year after resloping, measured erosion becomes almost insignificant as fine particals have been deposited in voids in the waste rock.

Within the limits of the waste dump design parameters studied, there appears to be no reason to establish design criteria from the standpoint of erosion control. There was also no evidence to support the need for erosion intercepts (dozer cuts located diagonally across the slope face), supported by the results from the long, undisturbed slope 2 at Tent Mountain.

3.10 REPRESENTATIVE PHOTOGRAPHS

A few photos, representative of the numerous taken, are provided to help relate some of the previous information to actual site conditions.

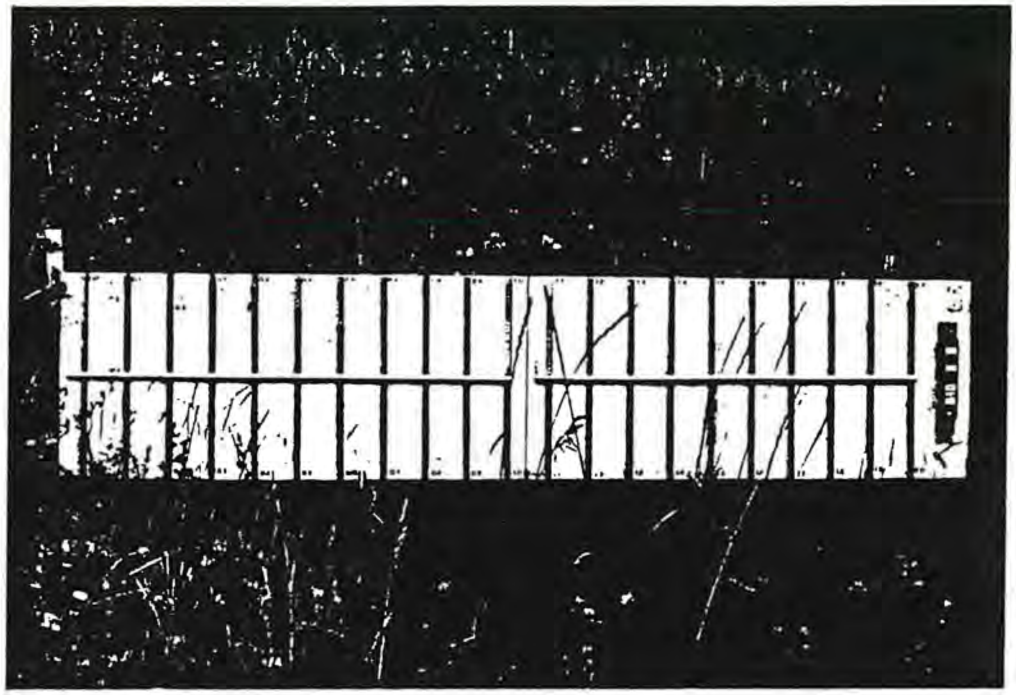

Figure 11. Erosion Board

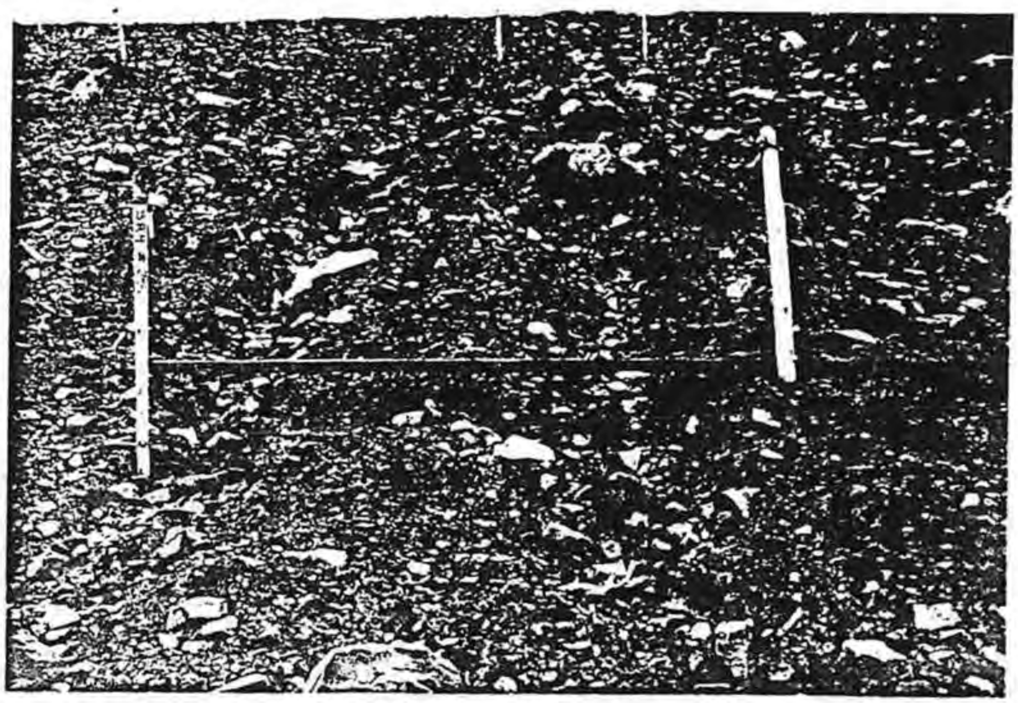

Figure 12. Plot 25, slope 4, Smoky River

Figure 13. Slumping at base of slope 2, Tent Mountain

Figure 14. Plot 7, slope 4, Smoky River

Figure 15. Deposition plot, base of slope 5, Tent Mountain

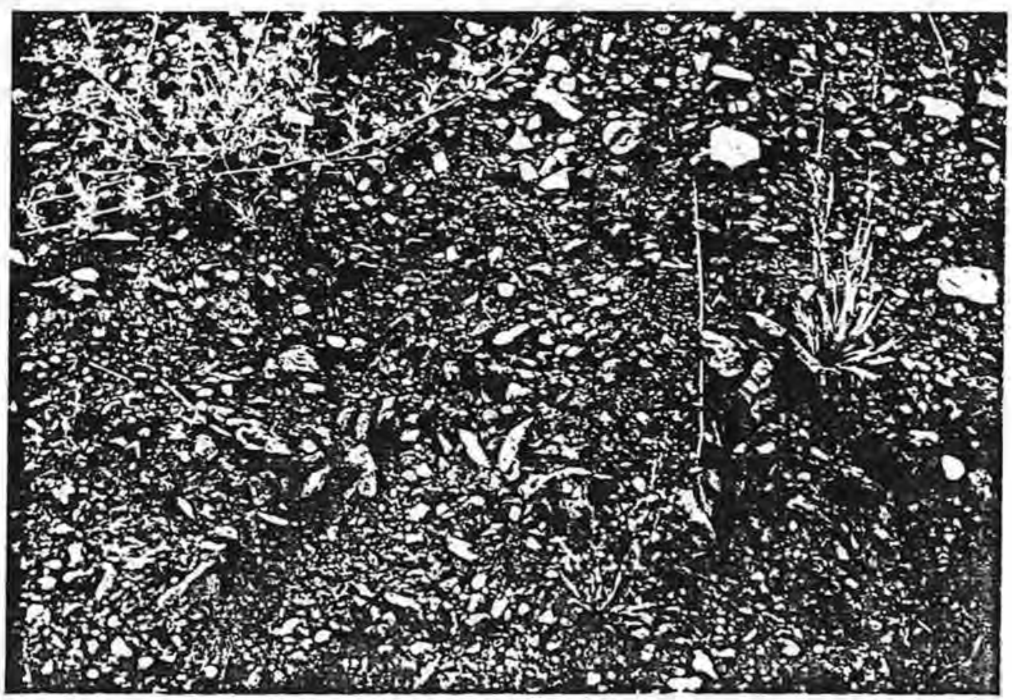

Figure 16. Plot 18, slope 5, Tent Mountain

PROCEEDINGS

ALBERTA RECLAMATION CONFERENCES

1985
Planning and Certification of Land Reclamation
April 16-17, 1985
Edmonton Inn, Edmonton

1986
Reclamation in the Eastern Slopes of Alberta
September 25-26, 1986
Overlander Lodge, Hinton

C.B. Powter
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1985: Planning and Certification of Land Reclamation, April 16-17, 1985, Edmonton Inn, Edmonton

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Most of the work, however, was done by the speakers who prepared the papers and delivered the talks to us and we offer them a strong vote of thanks.

Last, but not least, thanks to the two hotels for excellent accomodations and facilities.

For more information on the Alberta Chapter of the Canadian Land Reclamation Association please write to CLRA, Box 682, Guelph, Ontario, Canada N1H 6L3.

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NOTE: N/A means the paper was not submitted. We suggest you contact the speakers directly for more information.