PRELIMINARY REPORT

A STUDY OF THE NATURAL REVEGETATION OF PLACER MINING DISTURBANCES IN THE KLONDIKE AREA, YUKON TERRITORY.

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ABSTRACT

The purpose of this study is to identify and describe those spatial and temporal factors which influence successional trends of naturally revegetating mining disturbances. Vegetation communities ranging from 2 to 80 years in age are described on 67 sites disturbed by placer mining. Principal components analysis, a gradient analysis technique, is used to transform site environment variables into single component scores. Regression analysis is then used to isolate the determinants of vegetation patterns. The influence of site environmental conditions account for 48.8 % of the variation in total vegetation cover, 8.2 % of the variation is explained by site age, and 43.0 % by other residual factors. These residuals may include the influence of adjacent vegetated areas, soil movement as a result of erosion, climatic variability, sampling error, and chance. Once confounding effects of site age and residual factors are partitioned, vegetation cover and site conditions are significantly correllated. Soil moisture, soil macropore space and slope angle comprise the major environmental influences. This information is used to identify the condition present mine sites may be left in when abandoned, in order to promote optimal natural revegetation.

INTRODUCTION

Placer mining has taken place in the Klondike continously since 1896. Excavation of lower slopes and creek bottoms for mining purposes has resulted in extensive areas of disturbed land. Different mining techniques used in particular situations are reflected in the wide range of site conditions contained within these disturbed lands. In addition, despite the fact that mining equipment and methods have changed, site conditions produced today are similar to those produced by mining in the past.

To date, the mining industry has not been required to manage disturbed lands. Consequently, these areas have been left for nature to stabilize and revegetate. Current vegetation occuring on disturbed land represents a range of natural recolonization and establishment. Variation, in both the amount and type of vegetation on disturbed land in northern areas has been observed by Hernandez (1973), Hardy and Associates (1978), Naldrett (1982), Holmes (1982), and Durst (1982). Some mined lands support vegetation communities with characteristics similar to that of adjacent unmined areas, whereas other disturbances maintain vegetation quite distinct from that of the surrounding area.

Environmental features which have been disturbed by mining activity are also components of other environmental resources presently considered valuable by the people of Yukon and Canada (Fox, Eyre and Mair 1983 ,Placer Guidelines Review Committee 1983). Specifically, three types of resources or resource uses are being affected by mining: fishing, terrestrial wildlife, and recreation. In order to maintain features of the environment in a condition such that these other resource values may be realized, mined-land management is necessary. Revegetation of surface-mined land is perhaps one of the most critical components of any land management procedure (Banks, Nickel, and Blome 1981). In this respect vegetation helps:

1) Stabilize soil, thus slowing erosion and sediment discharge.

2) Enhance wildlife habitat, and

3) Improve the aesthetic quality of a site, thus making it more attractive for recreation.

This study is concerned with identifying and describing spatial and temporal factors which may influence the successional trends of naturally revegetating mining disturbances. It will concentrate on describing the nature of present regrowth in the Klondike, and provide an assessment of factors which may have led to its present composition and distribution. Specifically, the study will determine the extent to which total vegetation cover, along a successional gradient, is determined by site characteristics.

The analysis and results presented in this preliminary report address relationships between vegetation cover and environmental factors of mined land. The amount of vegetation cover on disturbed land is generally considered to be a measure of the ability of that land to resist soil erosion (Rutter 1967). Cover reduces the impact of rainfall on soil, increases adsorption, checks the speed of flowing water, and binds the soil (Agric. Canada 1961).

The results of this study will aid in the prediction of natural revegetation patterns on present day disturbances. In addition, an understanding of conditions amenable to natural revegetation will aid in determining the extent to which revegetation management is required in order that other resource values may be recognized. This report will suggest environmental management practices which involve the use of ecological information pertaining to the sensitivity and/or the resiliency of a disturbed ecosystem. This form of environmental management has been recognized by others (Hollings 1978, Beanlands 1983).

Revegetation characteristics of individual species are discussed in a Masters thesis by Brady (1984).

LITERATURE REVIEW

Considerable research has been completed in the field of applied mined-land revegetation in the North (Johnson and VanCleve 1976; Peterson and Peterson 1977). However, few studies are concerned with the natural revegetation of lands disturbed by mining. Errington (1975) and Meidinger (1979) in British Columbia, and Hernandez (1973) in the Northwest Territories, have studied natural revegetation on abandoned roads and mining disturbances. Hardy Associates (1980) in Yukon, and Rutherford and Meyer (1981), Durst (1981) and Holmes (1982) in Alaska, recently completed studies about natural revegetation on dredge tailings and associated disturbances. These studies are generally descriptive in nature. The variation in vegetation composition and abundance (percent cover) between the disturbed sites was not related to the combined effects of;

1) Site conditions (slope, texture, etc.),

2) Site age (revegetation period), and

3) Unexplained or residual factors (chance, seed source, climate, etc.).

An understanding of the proportion of influence that each of these factors may have on disturbed land will aid in the identification of optimal conditions for revegetation of present-day mining sites. Specifically, the degree of manipulation of site factors, such as slope angle, material compaction, percentage of fine material, and water supply which will promote vegetation, can be quantified.

STUDY AREA

The study area is located within the Klondike Plateau portion of the Western Yukon Plateau (Bostock 1948). This region is characterized by narrow, deeply disected "V" shaped valleys often associated with unglaciated terrain. The plateau is developed mainly on Paleozoic metamorphic rocks with extensive areas of Tertiary age basalts, shales and sandstones. Some valleys contain high level gravel benches over bedrock terraces and varying depths of creek gravels over the valley floors (McConnel 1906). Most of the area lies below 1000 m in elevation and the study sites range between 400-600 m above sea level. The disturbed areas are located within the Bonanza, Klondike, Hunker, Sulphur and Gold Run drainage basins, on alluvial plains and terraces.

The climate of the Klondike is subarctic continental, characterized by long cold winters and short hot summers. Mean annual temperature is -5 C, with extremes of -28 C in January and 15 C in July (Environment Canada 1982). Temperatures are extreme, and frost may occur in any month. The average frost-free period is 92 days with 910 degree-days over 9 C (1941-70). Mean annual precipitation ranges from 306 to 350 mm over much of the low elevation terrain which includes the mined areas of interest. Average rainfall between June and August is 141 mm, with maximum rainfall occuring in late summer (Env. Can. 1982).

The study area lies within the discontinuous permafrost zone. In general, vegetated valley flats and north facing slopes have permafrost. Frozen ground is usually lacking on south facing slopes, under valley floors of large streams, and in recent alluvium. Most mining activity has occured in permafrost areas.

The Klondike Plateau is covered by Boreal forest . Commonly, lower slopes contain black spruce (<u>Picea mariana</u>) and white spruce (<u>Picea glauca</u>) in pure stands or mixed with aspen (<u>Populus tremuloides</u>), balsam poplar (<u>Populus balsamifera</u>), and paper birch (<u>Betula papyrifera ssp. Humils</u>). In areas of permafrost and/or poor drainage the primary association consists of black spruce, with a shrub layer of labrador tea (<u>Ledum palustre</u>), and a thick mat of feather moss, sphagnum and lichen. Willows (<u>Salix sp.</u>) and ericaceous shrubs are commonly abundant in the understory on most sites. Within the Klondike , it is important to note that during the extensive mining activities of the early 1900's, nearly all the forests were cut for lumber and fuel. The present vegetation is a result of regrowth from that period.

FIELD METHODS

Soil, vegetation, and site conditions were examined at 67 sites disturbed by mining activity between 1898 and 1981. Field work was completed during the summer of 1983. Sites were located within the lower slopes and valley bottoms of the heavily disturbed drainages near Dawson City, Yukon territory. They were selected to illustrate a range of revegetation occuring over a wide variety of environmental conditions and age since disturbance. The locations and ages of mining areas sampled were identified by utilizing four sources of information. These included the Dawson Mining Recorder ledgers, Yukon Archives, various local publications and a heavy reliance on information provided by a few of the more experienced miners in the area. The estimated age since disturbance on sites older than 40 years since abandonment, is considered to be accurate to within five years.

Sample areas within the disturbed sites were selected to represent the dominant revegetation pattern occuring over the largest portion of the site. Approximately ten sample points were randomly located within each sample area. Vegetation and soil information was then recorded. Estimates of total vegetation cover, tree density and dominance, cover by species and strata, surface stoniness, litter cover, and exposed bare areas are examples of data collected at each site. The largest trees in the sample areas were identified and increment cores taken for age determination. In addition, observations were made on the vigour of the major recolonizing species and comments were recorded about microtopographical influence and species propogation. A brief description was also made of vegetation on adjacent unmined areas.

Estimates of soil texture and percentage by volume of fine material (< 2 mm diam.), coarse material (> 2 mm diam.) and macropore space were visually estimated from 10 small (15 cm in depth) pits which were dug at each site. A major soil pit (up to 1 m in depth) was excavated at a point determined to be representative of the general soil condition of each sample area. The soil profile was described and comments pertaining to soil development were recorded. Material samples from the top 15 cm of three of the small pits were taken for physical and chemical analysis. A detailed description was then made of site conditions. Slope angle and configuration, aspect, topographic position, parent materials and modifying processes (washed gravel) were recorded for each sample area.

RESULTS AND DISCUSSION

Soil drainage, % fine material, macropore void space, and slope angle are environmental variables which best explain the conditions of each of the 67 sample areas. Figure 1 illustrates the scalar ranges of these environmental variables.

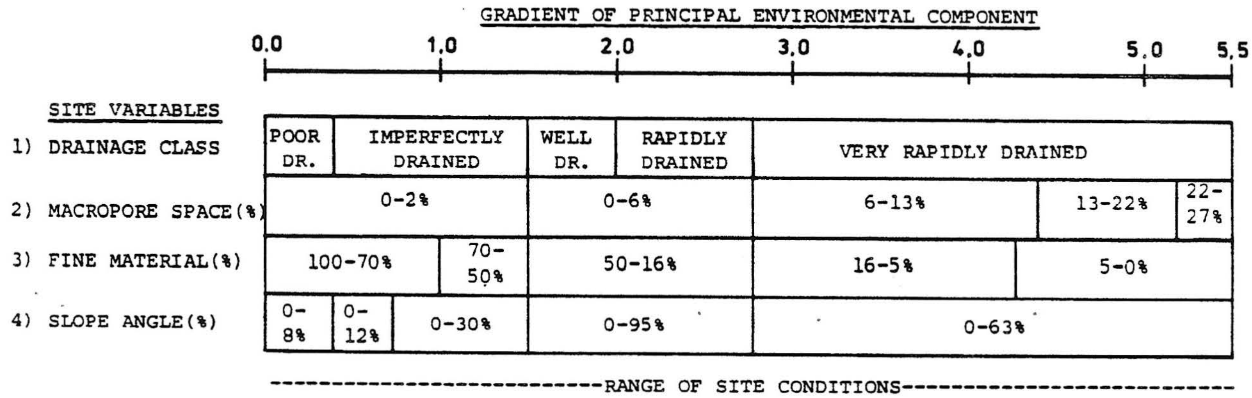


Figure 1. Scalar ranges of four environmental variables representing the site environmental gradient.

The Environmental gradient presented in figure 1 summarizes major trends in substrate composition and moisture supply. Gradient boundaries were identified using an ordination technique refered to as Principal Components Analysis (Pimentel 1979). The upper half of the gradient (92.8 - 5.50) represents very well drained soil conditions, characterized by a range of 0 - 16 % fine material, 0 - 63 % slope angles and 8 - 27 % soil macropore space. Soils in this drainage class have very low available water storage capacity (usually less than 2.5 cm) within the control section, and are usually coarse textured, or shallow, or both (CanSIS 1982). Water source is primarily precipitation. The lowest portion of the gradient (0.0 - 2.5), classed as poorly drained, is characterized by ranges of 70 - 100 % fine soil material, 0 - 8 % slope angles and 0 - 2 % soil macropore spaces. Water is removed from the soil sufficiently slowly, in relation to supply, such that the soil remains moist for a significant part of the growing season (CanSIS 1982).

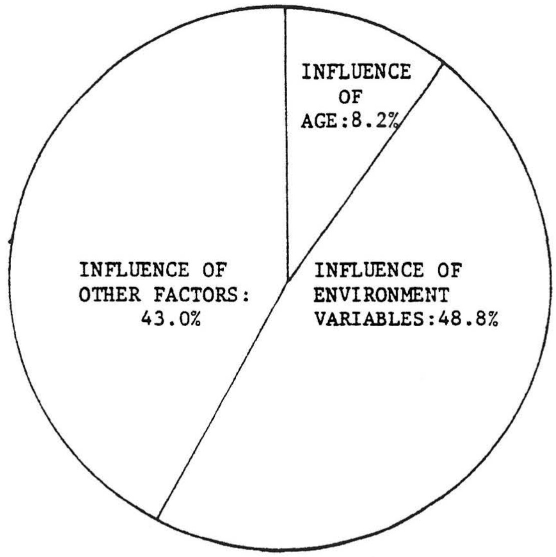
Subsurface flow or groundwater flow, or both, in addition to precipitation, are the main water sources in poorly drained areas. These soils may exhibit a wide range of available water supply, texture and depth. Thus, the wide range of some of the scalar values (eg. 0 - 63 % slope angles) may be a result of variability in water supply to each sample area.

Partitioning Determinants of Vegetative Cover

Linear regression analysis was performed using total vascular cover values, against age since disturbance of each sample area. The regression coefficient indicates that 8.2 % of the total variation in vegetation cover is due to the influence of site age. This low correlation appears reasonable, considering the variability between sample areas. For example, several mined areas, abandoned two years previous to the study (1981), contain up to 80 % vegetation cover. Conversely, some areas dredged up to 70 years ago were observed to have less than 5 % ground cover. The small variation related to site age, may partially be explained by the extremely wide range of man made conditions produced by mining activity. For example, settling ponds often contain 100 % fine material (silt loam), whereas dredge tailings may contain no fine material and up to 27 % macropore void-space. Ninety one percent of the variation in vegetation cover is accounted for by factors other than age of site. Thus, site conditions and adjacent vegetated areas have a much greater influence on vegetation growth than does the time period since abandonment.

A second regression was performed to further partition the determinants of vegetation cover into effects due to site conditions and those due to unmeasured residual variables on and off the site. The second regression line, representing the influence of site conditions, accounts for 48.8 % of the variation in vegetation abundance. The remaining 43 % of variation represents the influence of all factors affecting vegetation growth that were not measured at each sample area. As such, it represents that portion of the data that remains unexplained following the identification of the influence of site condition and age. Figure 2 illustrates the proportion of influence of each of the three determinants on vegetation cover over the disturbed sites.

Figure 2. The proportion of influence of spatial and temporal factors on vegetation abundance is partitioned into: 1) site age, 2) site conditions, 3) unidentified residual factors.



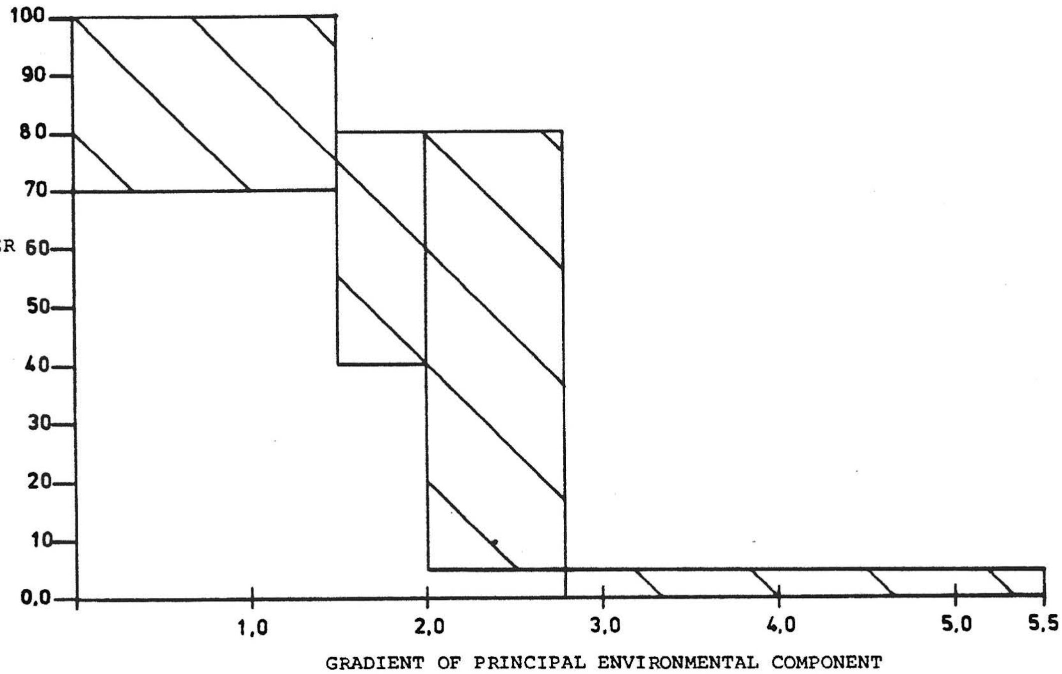
Residual factors may represent variables such as climate, soil nutrients, sampling error, and the effects of soil erosion. In general, soil movement may inhibit plant propogation. However, due to low rainfall in the Klondike (320 mm/year) and the coarse textured soils exposed by mining, little evidence of erosion was observed on uphill sites, except where degrading permafrost provides a continual source of water. However, considerable bank erosion was observed in valley bottoms where stream levels fluctuate continually. The resultant unstable substrate conditions do not provide a medium for revegetation .

In addition to on-site conditions, the influence of adjacent vegetated areas surrounding the disturbances must be considered. These areas provide a source of seed for the revegetating sites. However, there is some variability in the capacity of adjacent areas to provide both quality and quantity of seed. Wind direction, tree age and seed production, dispersal periods of seed, and dispersal distance are factors influencing seed availability from adjacent areas to disturbed sites (Zasada 1971). They require consideration when assessing the revegetation potential of any site.

Although aspects of seed source availability are factors to be considered, it is important to note that as a result of the frequent fire regime and extreme seasonal temperatures characteristic to the North, many plant species have developded wide tolerance ranges to environmental conditions and in general, are capable of rapid recolonization in many disturbed areas (Viereck, 1983). Preliminary field observations indicate that the influence of adjacent vegetated areas are most prominent on mesic-type sites and mainly evident in understory species composition. Most tree species were found in any site condition, and their cover and density values did not appear to be affected by the proximity of adjacent stands.

Vegetation - Environment Relationships

Figure 3 illustrates the relationship between vegetation cover and environmental conditions of mined land in the Klondike. The influences of both site age and unidentified residual factors (adjacent vegetated areas, soil nutrients, climate, etc.) have been removed so as not to confound this relationship.



SITE VARIABLES					
1) DRAINAGE CLASS	POOR DR.	IMPERFECTLY DRAINED	WELL DR.	RAPIDLY DRAINED	VERY RAPIDLY DRAINED
2) MACROPORE SPACE(%)	0-2%	0-6%	6-13%	13-22%	22-27%
3) FINE MATERIAL(%)	100-70%	70-50%	50-16%	16-5%	5-0%
4) SLOPE ANGLE(%)	0-8%	0-12%	0-30%	0-95%	0-63%

---------------------------RANGE OF SITE CONDITIONS---------------------------

Figure 3. A graph illustrating the relationship between vegetation cover and the range of site conditions (gradient of principal environmental variables) found on land distubed by mining in the Klondike. Hatched areas represent the range of both vegetation cover and site conditions.

The ranges of vegetation cover associated with portions of the site condition gradient illustrate the variation in vegetation response to the mined sites. For example, comparatively narrow ranges of cover values are found at the extremes of the gradient, while wider ranges occur in the central portion. This suggests that vegetation response is more predictable at extremes of the gradient of site conditions.

70-100 % cover values are most often found in moist areas which are characterized by substrate conditions of; poor drainage, 0-2 % macropore space, 70-100 % fine material and slope angles of less than 8 %. Conversely, 0-5 % cover values are found in dry areas characterized by; very rapidly drained substrate conditions with 6-27 % macropore space, 0-16 % fine material and slope angles of up to 63 %. Medium sites however, contain a wider range of site conditions, and vegetation response is highly variable. It is within these intermediate areas where adjacent vegetated areas may have the most influence on vegetative composition. Interactions between colonizing plant species become increasingly complex as site age increases. Eventually, vegetation begins to modify the site, producing a more favorable medium for growth.

Very dry sites support few plant species. These include; lichens (Cladina , Stereocaulon), mosses (Polytrichum), small shrubs (Rubus , Salix), and trees (Betula , Populus). The degree to which these species may alter their environment is limited. Similarly, moist sites support a limited number of species. These include plants capable of rapid colonization and growth. Willows (Salix sp.), alders (Alnus sp.), grasses (Calamagrostis sp.) and horsetails (Equisetum sp.) are commonly found in wetter areas. Detailed species - environment descriptions are provided in a report by Brady (1984).

SUMMARY

Substrate conditions of the disturbed sites are best characterized by differences in; soil drainage, the volume of soil macropore space, and slope angle. These variables reflect a gradient of both soil water holding capacity, and moisture supply. The influence of site conditions accounts for 48.8 % of the variation in vegetation cover on the mined sites. Another 8.2 % of this variation is a function of site age, and 43.0 % is accounted for by other unmeasured factors. These may include; 1) the ability of the adjacent vegetated areas to supply viable seed, 2) the stability of substrate material as a result of wind or water erosion, 3) the chemical composition of the substrate, 4) climate, and 5) chance.

Revegetation trends appear to be more predictable at the extremes of the gradient representing mined site conditions (figure 3). With site age partitioned, 70-100 % vegetative cover was found over moist sites and 0-5 % cover over the driest sites. Intermediate sites were observed to exhibit a wide range of cover values; between 5 and 80 %.

The study area includes all major streams in the Klondike, extending south to the Indian River. Observations were also made in the Clear Creek area east of Dawson. Revegetation conditions here appeared similar to those found in the Klondike. However, further east towards Mayo, an increase in precipitation rates may alter the natural revegetation potential from that of the Klondike. Further observations are required to determine the geographical extent to which the results of this study may be extrapolated.

MANAGEMENT INTERPRETATIONS

Based on the information derived from the preceeding analysis, the following management considerations are suggested. These refer to the conditions which present mining operations should be left in, to promote optimal natural revegetation.

A) SITE AGE CONSIDERATIONS

1) Site age has little influence on the amount of vegetation on disturbed land in the Klondike. However, older sites with little vegetative cover are generally coarse textured. They do not appear to contribute to soil loss and water quality problems. Revegetation of these coarse textured sites will require specific treatment to meet desired land-use goals.

B) SITE CONDITION CONSIDERATIONS

1) Improvement in substrate moisture holding capacity may increase the revegetation potential of placer mined land. This can be accomplished by compacting coarse material, reducing macropore void-space to 5 % , preferably lower. Also, slope surfaces should be kept to a minimum angle, preferably less than 30 %, and fine material content (% fine sand, silt and clay) should be 50 %, or greater.

2) Revegetation of disturbed land is also dependent upon the amount of moisture supplied by precipitation, or more importantly (due to low rainfall rates), subsurface seepage and groundwater. Improved moisture supply may be promoted by controlled flooding of coarse textured material in valley bottoms. This procedure promotes siltation and accumulation of fine material, which will improve substrate moisture holding capacity. In addition, mounds of coarse material may be levelled and recontoured to reduce the depth to water supply for plant roots.

C) OTHER CONSIDERATIONS

1) Generally, adjacent vegetated areas are capable of providing seed to mined land in the Klondike. Thus, active seeding and fertilizing programs are not necessarily required for revegetation of these areas. This study has illustrated that mined land can be abandoned in conditions that promote high levels of natural revegetation. This degree of vegetation resiliency is unique to northern areas and cannot be related to that of southern Canada. It is believed that the increse in fire frequency associated with northern areas is the reason for this phenomenon. Carleton and Maycock (1978), in a study on the effects of fire, observed that deforested sites in northern regions become reforested more rapidly and extensively than than those in southern forest regions. Shafi and Yarranton (1973) suggest that evolutionary pressures in a repeatedly disturbed environment have resulted in species adapted for rapid growth and reproduction. Considering these differences in natural revegetation potential, vegetation management of mined land in the Klondike should not necessarily be based on criteria used for southern mining situations.

2) Soil movement may reduce revegetation potential of disturbed sites. Two types of soil instability problems were observed to inhibit plant propagation and growth:

I) Degrading permafrost in excavations can provide excessive moisture on slopes, and promote sliding of soil material. Where permanetly frozen ground has been disturbed, slope angles should be reduced to enable moisture to penetrate the surface. Adequate drainage pathways may also be required to drain water from the thawed material.

II) Fluctuating stream levels appear to contribute to instability problems in valley bottoms where spoil material has not been recontoured and sufficient channel stabilization established. Stream bank erosion often inhibits vegetation establishment and may contribute sediment to the stream. In contrast, on uphill sites sheet and gully erosion does not appear to cause significant substrate instability problems. Low precipitation rates, in combination with the well drained alluvial material associated with the mining areas little surface overland flow of water.

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