AGRICULTURAL CAPABILITY OF SURFACE-MINED LAND IN EAST-CENTRAL ALBERTA[1]

by

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Abstract. Between 1979 and 1988, The Plains Hydrology and Reclamation Project (PHRP) studied the impacts of surface coal mining in the plains of Alberta on the agricultural capability and hydrology of reclaimed landscapes. The agricultural capability of reconstructed soil landscapes is generally equivalent to, although less variable than, that of unmined landscapes. Physical and chemical properties of well-drained reconstructed soils are improved through downward leaching of sodium and a decrease in bulk density. Surface wetness and soil salinity result in degradation of capability in small areas of reclaimed sites. The most important hydrologic impact of surface mining is removal of the shallow aquifers that provide the majority of agricultural water supplies. In some areas, replacement water supplies are available from beneath the base of mining. Chemical quality of groundwater in mine spoil is significantly degraded relative to that in pre-existing coal aquifers. Surface mining has essentially no impact on water quality outside of mined areas.

Additional Key Words: Hydrology, reconstructed soils.

Introduction

Between 1979 and 1988, the Plains Hydrology and Reclamation Project (PHRP) investigated interactions of groundwater, soils, and geology and successful reclamation of surface coal mines in the plains of Alberta. The overall goal of PHRP was: (1) to predict the long-term success and the hydrologic impacts of current reclamation practices, and (2) to develop reclamation technology that will allow necessary modification of current practice to assure long-term success and mitigation of deleterious environmental consequences.

The first phase of the study, which was completed in 1984, included characterization and instrumentation of two study sites: the Battle River area, which included Diplomat, Vesta and Paintearth Mines, and the Wabamun area, which

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included the Highvale and Whitewood Mines (Figure 1). The PHRP study areas are located in the two major coal zones currently being developed in Alberta. The results of the first phase of study led to the focussing of the second phase of the project on: (1) potential salinization of reconstructed soils from shallow groundwater, (2) deterioration of capability for agriculture as a result of differential subsidence, and (3) potential changes in the chemical and physical characteristics of reconstructed soils.

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Agricultural Capability of Reclaimed Landscapes

Maintenance of the capability of reclaimed landscapes for agriculture is one of the most important concerns about surface mining of caol in the plains of Alberta. Dryland agriculture is the dominant land use both before and subsequent to surface mining in most of the plains region of Alberta. Modern reclamation practice in Alberta generally involves grading spoil into long smooth surfaces that are flat or gently sloping. The overall topographic configuration of mined areas is generally slightly elevated relative to adjacent unmined areas because of the swelling or bulking of the replaced spoil. This "bulking factor" causes the reclaimed landscape to be elevated above the surrounding unmined landscape wherever the thickness of the pre-mining overburden is more than about four times that of the removed coal. The topography of the reclaimed area generally reflects a smoothed version of the premining topography with broad low areas where the premining overburden was thinner and locally elevated areas where overburden was thicker. Deep, steep-sided depressions are absent except as final cuts and in areas of older mining adjacent to current operations. From 1.0 to 1.5 m of "subsoil" is placed on the graded spoil using scrapers. About 15 cm of topsoil is then spread over the subsoil.

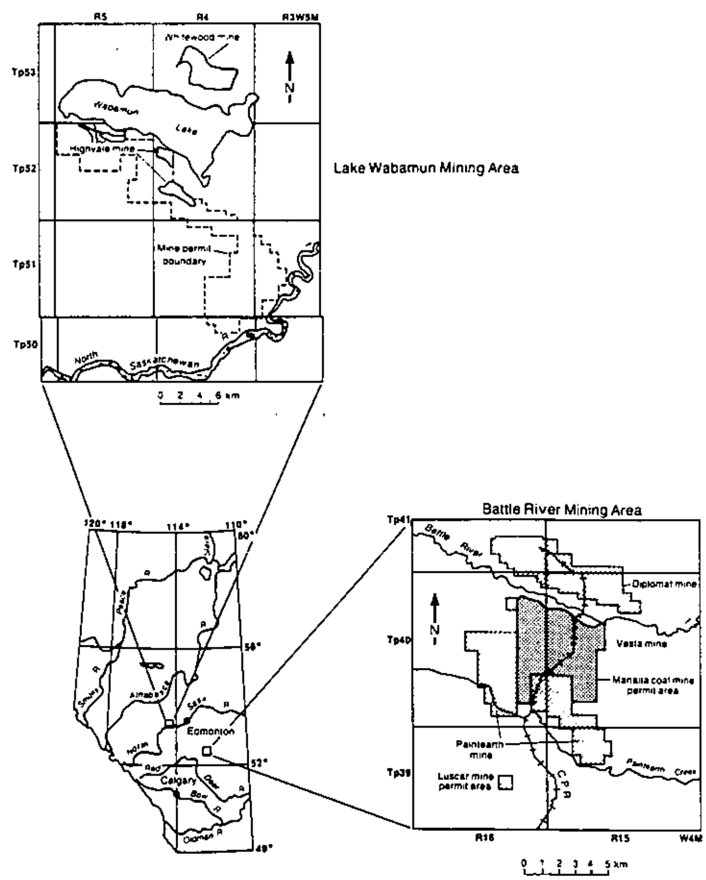

Figure 1. Location of Battle River and Wabamun study areas of the Plains Hydrology and Reclamation Project.

Initial Post-Reclamation Capability Compares Favorably with Capability Prior to Mining

The pre-mining landscape consists of a complex mosaic of soils, which reflect differences in parent material and landscape setting. At the Battle River mining area, for example, 129 individual soil units, representing combinations of as many as five phases of each of 20 soil series in 12 slope classes, were mapped by Macyk and Maclean (1987). Within a limited area, where the same parent material occurs in the same topographic setting, the soil is the same and the physical and chemical properties are quite uniform. Abrupt changes in chemical and physical properties occur within short distances as one passes laterally from one soil to another. These soil units ranged from Capability Class 1, soils that have no significant limitations to agriculture, to Class 6, soils that are not capable of producing perennial forage crops, either naturally or with improvement (Macyk and Maclean, 1987, p. 26-32).

Surface mining alters the scale over which variability in physical and chemical properties of soil occurs within the landscape. As described in the previous paragraph, the premining landscape is characterized by relatively homogeneous conditions on a local scale, but considerable variability over larger areas. Reconstructed soils, on the other hand, are heterogeneous on a local scale, but relatively homogeneous over larger areas (Macyk, 1986, p. 40-41). Mining mixes the soil zone to produce a reconstructed soil mantle of uniform thickness. Much greater variability in chemical and physical properties exists within the reconstructed soil profile and within distances of a few metres than in the unmined landscape. Mixing results in the blurring of the abrupt changes between different soil types that characterized the unmined landscape, resulting in a reconstructed soil mantle that is more uniform in its characteristics over larger areas than is the unmined landscape.

The capability of reconstructed soils for agriculture is generally a reflection of the pre-mining capability. Just as the properties of the reconstructed soil are an average of those of the pre-mining soil, so the capability of reconstructed soils reflect a mix of the pre-mining capability. The agricultural capability of reconstructed landscapes is more uniform than, and is generally not as good as the best nor as poor as the lowest, capability in the pre-mining landscape.

Once the reclaimed site begins to resaturate, water moving on and beneath the soil surface initiates physical and chemical changes that alter the initial capability of the landscape to support agricultural operations. Some of these changes improve the capability, whereas others result in degradation of the capability.

Leaching of Salts Improves The Capability of Reconstructed Soils

The salinity and sodium content of reconstructed soils in well drained sites has been observed to decrease in upland sites studied in the Battle River area between 1984 and 1987 (Moran and others, 1987). This trend was observed in the topsoil at seven of nine locations. The pattern was somewhat more complex in the subsoil, with salinity and sodium concentration decreasing at some depths and increasing at others. The overall pattern is consistent with downward flushing of salts with no evidence that sodium is moving upward from the spoil into the subsoil. Moran and others (1987) concluded that the capability of the reclaimed landscape is improving over time.

Decreasing Density of Reconstructed Soils Improves Capability of Reclaimed Landscapes

Discrete layers of more densely compacted material, which are formed by dozers during grading and scrapers during placement of subsoil and soil, form barriers to infiltrating water and to root penetration. Where these compacted layers or pans persist for extended periods they can significantly decrease the capability of the post-mining landscape. In some areas of the United States, compaction is seen as a major problem for reclamation (Smout, 1987, p. 124-125; McCormack, 1987, p. 23-25; Jansen and Hooks, 1988). Our studies indicate that density is progressively decreasing over time at most sites, which is interpreted to reflect frost action and increasing root penetration by forage crops (Moran and others, 1987). On this basis we conclude that the physical characteristics of reconstructed soils, and therefore the capability, are improving with time.

Differential Subsidence Decreases Capability of Reclaimed Landscapes

Differential subsidence forms depressions that are aligned between the original spoil ridges and appears to be an inevitable consequence of dragline mining (Dusseault, and others, 1985). Newly placed and graded cast overburden, which is considerably less dense than the pre-mining overburden, has a loose structure with an initial secondary porosity of about 25% of the total volume. As water comes into contact with the spoil material, the structure of individual fragments collapses and the spoil quickly loses strength (Dusseault, and others, 1988). Through this process, the entire spoil mass compacts, resulting in subsidence of the land surface (Dusseault, and others, 1985). The majority of the subsidence occurs in the capillary fringe above the rising water table as the spoil resaturates. In addition to area-wide subsidence, which results in general lowering of the land surface, differential subsidence results in formation of numerous oval depressions about 10 m by 20 m and as much as 0.5 m deep. These depressions, which typically occupy from five to ten percent of the reclaimed surface, increase infiltration and accelerate differential subsidence by ponding water during spring melt and heavy summer rain storms.

Ephemeral Ponding Decreases Capability of Reclaimed Landscapes

Ephemeral ponding of water in depressions that form by differential subsidence of spoil decreases capability of a reclaimed landscape for agriculture in two ways. (1) Ponding in the spring disrupts seeding, and during the summer it drowns crops. The ponding produced by spoil subsidence differs from the ponding that characterizes adjacent unmined landscapes in the number, size, and orientation of the ponded depressions. The reclaimed landscape contains numerous small depressions that are distributed in parallel lines across the entire quarter section, whereas the unmined undulating to rolling glacial terrain generally contains a small number of larger depressions per quarter. As a result, ephemeral ponding on reclaimed surfaces potentially results in greater disruption of field patterns, and in wet years, makes farming operations less efficient than on unmined land. (2) Evaporation from the saturated soil around perched ponds in reclaimed landscapes has the potential to produce sodic, saline soils. Hydraulic conductivity of sodic, bedrock-derived spoil is at least two orders of magnitude lower than that of the drift-derived subsoil. As a result, water ponded in subsidence depressions is perched above the permanent water table in the spoil (Figure 2). Evaporation from the saturated soil surface and transporation from plants around the edge of these depressions induces flow outward from the pond and upward from the upper surface of the spoil. Salt and sodium levels in the soil surrounding these depressions are expected to increase over time to levels that are detrimental to vegetation so that capability of these areas is permanently decreased.

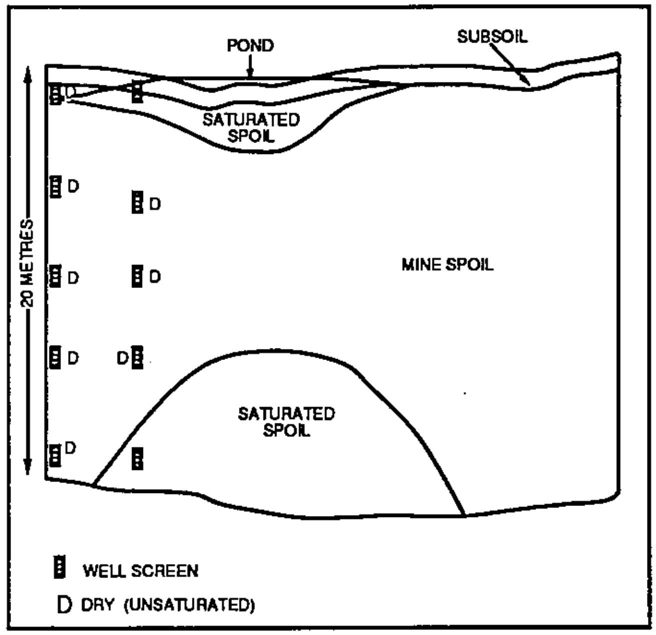

Figure 2. Hydrologic setting of a pond perched above the water table in a subsidence depression at Vesta Mine.

Ponding in subsidence depressions can be minimized through modifications of materials placement and grading within existing operations. By grading as much of the reclaimed landscape as feasible into open slopes with integrated drainage, ponding can be minimized. Pauls and others (in prep) report that slopes in the range of 1.5 to 3% along the long axis of these depressions are sufficient to drain about 90% of the water that is ponded on existing reclaimed surfaces.

<u>Salinization Degrades Capability of Reclaimed Landscape in Poorly Drained Lowland Sites</u>

Soil salinity has been observed to form within a few years in lowland settings in reclaimed landscapes, where extensive ponding of surface water develops. This type of setting occurs where thin overburden results in the reclaimed surface being at or below the premining grade. Deep depressions formed by final cuts in these settings become the site of permanent ponds, which result in rapid resaturation of the spoil. Groundwater levels rise to the vicinity of the land surface over extensive areas within one or two decades. Soil salinity develops through evaporation where the water table is within one to two metres of the surface. Salts migrate both outward from the spoil beneath the ponds and downward from adjacent upland areas (Moran and others, 1986).

Potential negative effects on agricultural capability in lowland settings can be minimized by appropriate land use. Where attempts are made to grow crops in lowland settings in reclaimed areas, the agricultural capability is expected to be progressively degraded as the salinity becomes worse. Optimum productivity of lowland settings can be maintained, however, by using these areas for forage or pasture.

Surface Mining Lowers Agricultural Water Supply Capability

In areas underlain by surface mineable coal, agricultural water supplies are routinely obtained from wells completed above the coal. Surface mining removes these shallow aquifers. In some areas, replacement water supplies will be available from aquifers beneath the base of disturbance. Although the chemistry of groundwater in mine spoil is significantly degraded relative to that in the pre-existing coal aquifers, surface mining should have essentially no deleterious effects on the water quality outside of the mined areas. Evidence suggests that spoil-derived groundwater will not discharge into surface streams at a sufficiently rapid rate to sensibly alter the water chemistry. Evidence for migration of spoil-derived groundwater into unmined aquifers has been observed only in a single isolated case, where a relatively rare combination of overburden stratigraphy and topographic configuration of spoil existed.

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