PLAINS HYDROLOGY AND RECLAMATION PROJECT: RESULTS OF 5-YEAR'S OF STUDY

by

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ABSTRACT

The Plains Hydrology and Reclamation Project, an interdisciplinary study of rock-water interactions in reclaimed landscapes, completed five years of research in 1984. The geology, soils, hydrology, and hydrogeochemistry of two sites in the plains region of Alberta have been intensively studied both in unmined and reclaimed settings. Although project studies are continuing, several significant findings have emerged.

Large amounts of soluble salt are liberated in mined landscapes, primarily from pre-existing secondary salt in the soil zone but to a lesser extend from weathering of fresh overburden. Solution of this salt results in spoil water 3 to 7 times more saline than premining groundwater. Chemical equilibrium constraints related to the abundance of calcium preclude solution of all the available salt thereby preventing extremely high salinity but extending the period of time over which water of elevated salinity is present. Prediction of salinity and chemical composition of post-mining groundwater has become possible with considerable accuracy using aqueous extract data from overburden in conjunction with the chemical equilibrium model PHREEQE.

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Spoil contaminated groundwater has been found in aquifers as much as 1.5 km from reclaimed areas. The only other significant offsite effect anticipated is the potential for soil salinization or saline seep development in favourable settings.

No evidence of soil salinization as a result of groundwater discharge has been found in reclaimed areas. Studies are continuing to assess the potential for salinization from surface ponding in depressions created by differential subsidence of the spoil and from shallow water table conditions. Management of post reclamation surface hydrology to minimize groundwater recharge appears the most promising approach to long-term prevention of salinization.

INTRODUCTION

As Alberta confronts the need for expanded development of coal resources in the coming decades, major concerns about the environmental impacts of mining and reclamation of mined areas remain unanswered. Most of the land that is underlain by minable coal in the plains area of the province is in agricultural production. Groundwater, which is commonly derived from coal beds, supplies nearly all the water needs of the region.

Reclamation research in Alberta and other parts of North America has concentrated largely on establishing soils and vegetation on graded overburden materials. Little work has focused on the long-term productivity of these reclaimed landscapes or on the long-term impacts of mining on water resources. Existing research and field experience in working mines suggest that in most places revegetation of graded, topsoil covered mine spoil is feasible. It is not clear whether salts liberated within the mine spoil will migrate into the replaced soil and degrade it or whether these salts will produce seriously degraded groundwater quality.

The objective of the Plains Hydrology and Reclamation Project is to develop a predictive framework that will permit projection of success for reclamation and impact of mining on water resources on a long term basis. Differences in physical and chemical properties of the pre-mining soils, overburden, and subsurface water will be used as keys to project postmining conditions. The predictive framework is to be based on an understanding of processes acting within the landscape so that in the future, mine sites that are not totally analogous to those that have been studied can be evaluated as well.

The project involves a holistic approach to reclamation by integration of studies of geology, hydrogeology, and soils, not only in a proposed mining area, but also in the adjoining unmined areas. This approach will permit the assessment of impacts and long term performance, not only in the mined areas, but also in the surrounding area.

During the first year of the proposed five year study, instrumentation to collect basic data on the geology, subsurface water, and soils of the Battle River mining area (Figure 1) was installed. Mapping of the soil and geology and a program of testhole drilling were also included in the initial phase of pre-mining site characterization. In spite of a late start during the first year, most of the instrumentation that was planned was installed but virtually no data could be collected.

During the second year (1980-81) approximately 90 percent of the instrumentation needed to characterize the Battle River site was completed. Monitoring programs that were begun in the very late stages of 1979-80 were continued throughout 1980-81. A considerable body of data on properties of overburden materials and chemistry and movement of subsurface water was accumulated by the end of 1980-81. In addition, experimental studies were initiated to describe the total salt yielding properties of various types of overburden materials under a range of conditions of water content and oxygen access.

During 1981-82, experimental studies on physical and chemical weathering of overburden materials at the Battle River site were carried out. Various physical and chemical properties of the overburden, such as grain size and mineralogy, were determined and were related to weathering characteristics.

Field studies were essentially completed to define hydrologic conditions at the Battle River site. Unanticipated complexities in flow patterns in spoil at Diplomat Mine, combined with problems with experimental techniques used to measure infiltration in spoil required further work on spoil hydrology at that site. Significant progress was made in the computer modeling of mine affected groundwater-flow systems (Schwartz et al., 1982). Study of post-mining groundwater supply potential was nearly completed and generalizable conclusions began. Preliminary synthesis of project data into a two component predictive model was possible. A group of hydrologic parameters that will permit projection of post-mining water-table configuration was identified and evaluation of their interactions had advanced well. The chemical component of the model had not advanced as far but the basic elements were identified.

During 1982-83, evaluation of a second site, the Highvale site (Figure 1), began with the installation of hydrologic monitoring instrumentation. Major effort focused on evaluation of hydrogeology and chemistry of mine spoil at both the Highvale and the Whitewood Mine. In addition, the existing network of wells installed by TransAlta Utilities to monitor groundwater in the unmined area adjacent to the Highvale Mine was expanded. A series of sites to monitor water movement in the unsaturated zone was installed. Initial study of the weathering characteristics of overburden was begun.

At the Battle River site new instrumentation was installed to refine our understanding of spoil hydrology and the flow of groundwater from the spoil into adjacent aquifers. Infiltration tests were successfully completed in the spoil and improved techniques of analysis greatly increased the amount of data that was derived from these and preceding tests. These data combined with groundwater data improved our understanding of groundwater recharge in the area. Overburden weathering studies were completed and a preliminary procedure to relate weathering data to groundwater chemistry in spoil was developed. Groundwater-flow modeling provided some significant insight into the spoil resaturation process (Schwartz and Crowe, 1984). Settlement of interridge areas following grading appears to facilitate infiltration of surface water, which promotes further settlement.

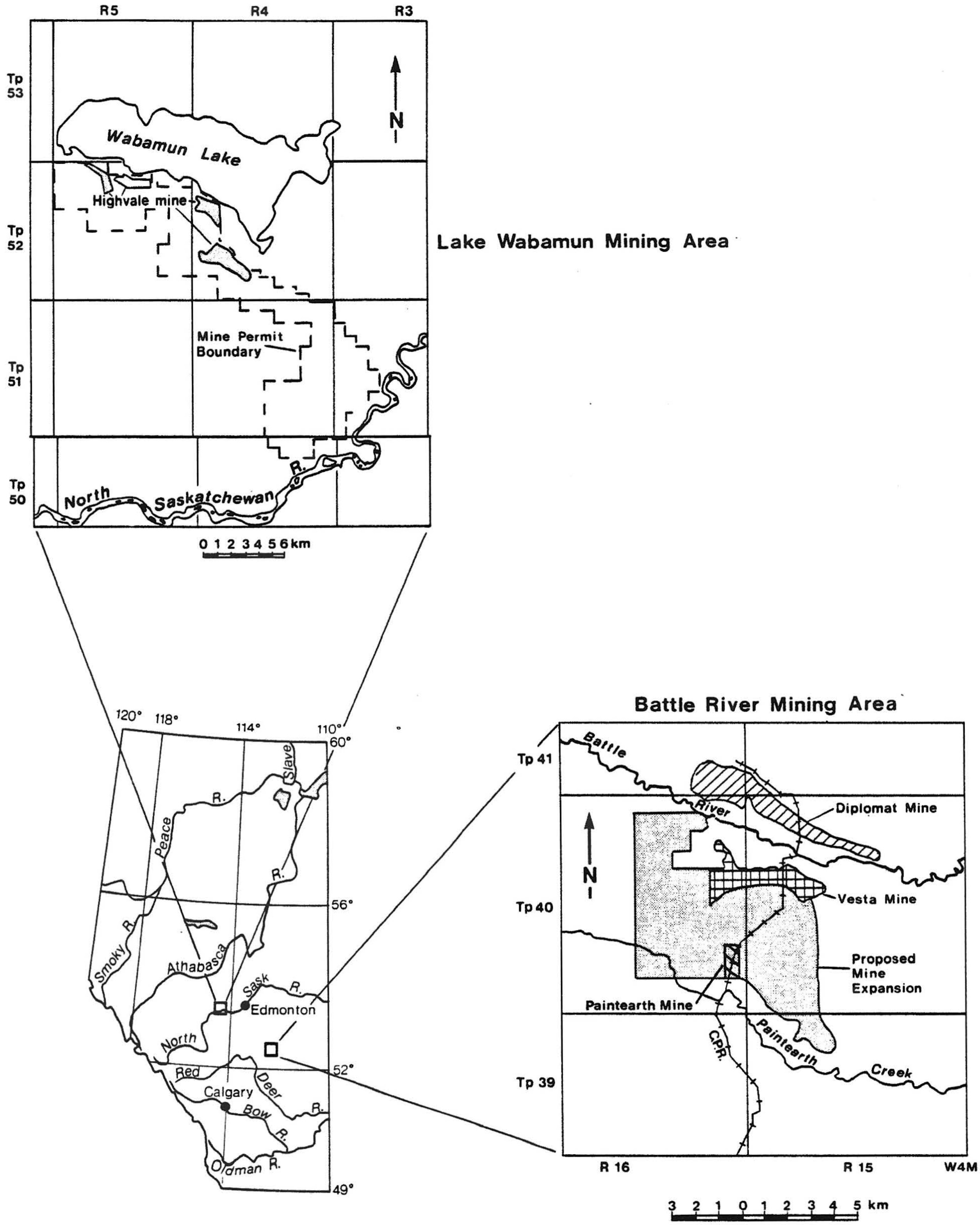

Figure 1. Location of PHRP study sites in the Battle River Mining Area and Lake Wabamun Mining Area, central Alberta

The fifth year of the study (1983-84) served as a period of refinement of the predictive framework developed at the Battle River site. At the Highvale Mine site instrumentation was completed and field scale experiments installed at both sites to test the validity of the overall predictive framework on salt yield of the overburden.

SUMMARY OF PROJECT RESULTS AND STATUS

The project is subdivided into two major objectives, which contain 5 and 3 subobjectives respectively. The following discussion is organized on the basis of these subobjectives.

OBJECTIVE A

To evaluate potential for reclamation of lands to be surface mined. The focus here is on features of landscape that make it productive in a broad sense not restricted to revegetation.

SUBOBJECTIVE A-1

To assess and evaluate the potential for long-term degradation of reclaimed "soils" through salt buildup.

The evaluation of long-term potential for salinization of reclaimed soils has involved (1) studies of the production of salt and (2) the transport of salt by groundwater. One of the major concerns that we had at the initiation of the study was that weathering of overburden materials, especially minerals containing sulfur in a reduced form, would lead to the long-term production of sulfate salts. Our research has established that, although considerable new salt can be released as a result of weathering of overburden materials, the processes are rapid and essentially complete soon after final regrading of the spoil surface (Wallick, 1983; Wallick et al., 1983). Although large amounts of salt are available from this weathering process and from salts already present in the overburden, especially in the lower part of the original soil zone, the release of this salt is limited by physical factors such as access to water and hydraulic conductivity of the spoil and by chemical saturation constraints. Regardless of the source of the salt, we find that groundwater in mine spoil is saturated with respect to calcite, dolomite, and gypsum (Trudell et al., 1983; Trudell and Moran, 1983). The factor that appears most critical in limiting salinity of spoil water is the availability of calcium over and above the level that can be consumed by ion exchange reactions.

We have found that the salt yielding properties of unmined overburden materials can be used as the basis for predicting the chemical makeup of groundwater in reclaimed mine spoil (Trudell et al. 1983; Trudell et al. 1984a; Trudell et al., 1984b). The predictive model allows the soluble salts in hypothetical 'spoil' material to dissolve in water based on a water: sediment ratio corresponding to field conditions. The aqueous geochemical model PHREEQE (Parkhurst et al., 1980) is utilized to account for mineral solubility limits particularly of calcite, dolomite and gypsum, partial pressures of CO_2 that are elevated relative to atmospheric levels, as well as ion exchange. The predictive model has been calibrated against observed spoil groundwater chemistry at Diplomat and Vesta Mines in the Battle River Mining area, Highvale Mine in The Lake Wabamun mining area, and has been used to predict groundwater chemistry at Paintearth mine in the Battle River Mining area. In another similar part of the study, an increase in spoil groundwater total dissolved solids from 4400 to 5400 mg/l as a result of flyash disposal was found to be predictable using an aqueous geochemical model (Cheel and Trudell, in press). Work is continuing to refine the methods developed for predicting quantitatively the chemistry of groundwater in mine spoil.

We have found no evidence of salt being transported to the spoil surface by groundwater discharge (Trudell and Moran, 1982), nor have we found any evidence of perching of water at the interface between replaced soil and spoil (Howard and Moran, 1983). The main mechanisms of potential soil salinization appears to be upward transport of water and salt by capillary rise from the water-table where it is sufficiently close to the surface. A second potentially significant factor in soil salinization is the formation of water holding depressions by differential subsidence of spoil (Dusseault and Soderberg, 1982; Dusseault et al., 1983).

On the basis of the preceeding discussion we conclude that significant progress has been made toward resolving subobjective A-1 but considerable work remains to be done. Weathering of spoil has been shown not to be a critical process and groundwater discharge has been shown not to be a major factor in soil salinization in mine spoil. It should be noted that discharge of more saline groundwater in favourable topographic settings adjacent to reclaimed areas can be enhanced and lead to increased soil salinization outside the area that has been mined (Trudell and Moran, 1984). Although work during the final year of phase 1 began study of capillary transport of salt, further work is needed to quantify those factors governing upward transport of salt as well as the factors determining the transient and final position of the water-table.

<u>Subobjective A-2</u>

To assess and evaluate the effectiveness of topographic modification and selective placement of materials to mitigate deleterious impacts on chemical quality of groundwater.

Study of potential selective placement of overburden was predicated on the assumption that significant differences would be found between overburden materials in terms of their susceptibility to weathering release of high levels of salt. Although the salt production potential of overburden material has been found to vary by a factor of more than 10, even at the low end of the range sufficient salt is available to produce severely degraded chemical quality in the groundwater that resaturates the spoil. For this reason, our concern has focused more strongly on using topographic configuration to control post-mining hydrology and thereby control the impact of the degraded groundwater on the landscape.

Progress toward the second aspect of this subobjective has focused on the role of ponds in the post-mining landscape. Ponds appear to influence the rate at which spoil resaturates. In areas of approximately the same age, the resaturation of spoil is significantly more advanced where ponds are present than where they are absent. The height of the water table in spoil appears to be strongly controlled by the presence of ponds. Where ponds are present in spoil at Vesta mine, the water table in the spoil is several metres above the pre-mining level. It is not yet clear whether this is solely a result of the ponds or whether the elevated topography of the spoil alone would produce a steady-state water table at the same level. Considerably greater work is required to quantify the various aspects of ponds and other landscape features as they influence final water-table configuration in reclaimed landscapes.

Subobjective A-3

To assess the availability of water supply in or beneath cast overburden to support post-mining land use. Includes both quantity and quality considerations.

In most potential mine areas in the plains area of Alberta, farming is the principal land use. In most of the province, the water supply needs of these farms are met by individual wells located very close to the point of use for the water. We have evaluated the potential for developing a similar type of water supply following reclamation at both the Battle River (Trudell, et al., in press,b) and Highvale sites (Trudell, in press,a; Trudell and Faught, in press).

Mining in the Battle River area will remove the Paintearth and Battle River Coal Beds, the two most productive aquifers currently supplying local water supply demands (Trudell and Li, 1981; Trudell et al., in press,a). In the eastern part of the mine area, approximately east of Highway 855, the "Deep Sandstone", a sandstone bed located about 60 m beneath the Battle River Bed, is capable of producing adequate amounts of water with sufficiently high chemical quality to meet individual farm domestic and stock watering needs. In the western part of the mine area, water in the "Deep Sandstone" is of degraded quality and is too saline for human consumption and only marginally acceptable for stock watering. No groundwater supply that would not require treatment was found in the western part of the proposed mining area although four sandstone units beneath the Battle River Bed were evaluated. No coarse-grained sediment that could be developed to support a distribution system was found in the fill of the Battle River or Paintearth Creek. The mine spoil itself is too impermeable to produce enough water and the chemical quality of the water in the spoil is unacceptable for human or livestock consumption (Trudell and Moran, 1983; Trudell and Faught, in prep.).

Domestic water supply requirements in the Highvale Project Area are currently met by production from aquifers in or above the Ardley Coal zone. These aquifers will be disrupted by mining, and the resulting groundwater within spoil is not suitable for exploitation because of both low yield and poor water quality. The only potential post-mining groundwater source in the Highvale Area is from sandstone bodies that form an aquifer within the upper Horseshoe Canyon Formation, situated stratigraphically below the Ardley Coal Zone. These sandstone bodies are laterally very discontinous, and where present, generally of inadequate transmissivity to meet domestic water supply needs. On the basis of 14 test sites, this aquifer is suitable for exploitation only in the area of Section 21-52-5-W5. Over the rest of the site it is not likely that significant zones of adequate transmissivity will be found, although small, local sandstone bodies might be identified by additional test drilling.

Subobjective A-4

To evaluate productivity potential of post-mining landscapes and the significance of changes in productivity as a result of mining.

The original subobjective of determining the effect of surface mining on soil productivity was modified to focus on capability for agriculture rather than productivity.

The objective of reclamation of surface mines in the plains region of Alberta in almost all cases is to produce a landscape that has a capability for agricultural production that is at least equivalent to that which existed prior to mining. The Canadian Land Inventory (CLI) system (Canada Land Inventory, 1965) of rating capability for agriculture has been used to provide a basis to evaluate existing capability in the pre-mining setting from information obtained in a soil survey of the study area (Macyk and MacLean, 1983). A new classification for reclaimed landscapes has been developed on a conceptual basis identical to the CLI (Macyk, 1984a; Macyk, 1984b).

Capability for agriculture has been chosen as the basis for evaluating the product of reclamation rather than productivity primarily because capability considers intrinsic properties of the landscape. Productivity, on the other hand, addresses a parameter that is very much subject to alteration by management practices. In simple terms, a given level of productivity can be achieved from either good land with minimal management input or poorer land with greater management input. The significance of this is that in the latter case, removal of the management inputs results in immediate deterioration of productivity. Therefore, using productivity as a measure of performance of reclamation does not allow separation of the relative contributions of the land itself and the management inputs. Put in economic terms, it is clearly the intent of reclamation legislation in Alberta that the cost of assuring agricultural productivity in the post-mining landscape is to be borne as a capital investment in the land rather than as an operating cost by the farmer. Capability provides a superior measure of adherence to that intent than does productivity.

Work is continuing to evaluate the productivity of reclaimed lands relative to unmined lands within individual capability classes subjected to the same management inputs.

Subobjective A-5

To assess and evaluate limitations to post-mining land use posed by physical instability of cast overburden.

The settlement of the surface of reclaimed landscapes has been shown to be a significant process affecting the utilization of the landscapes for agriculture. Although current operational procedures at the mines under study accommodates the early settlement by regrading of the surface approximately one year after initial grading, our studies suggest that this practice is unlikely to solve the problem. Resaturation of the spoil has been shown to be a significant factor in producing compaction and therefore settlement (Dusseault et al., 1984b). Further rise of the water-table in the spoil after this second grading, which seems almost a certainty except in very rare cases, would thus reinitiate differential subsiding of the surface. Depressions produced by this type of settlement have the potential to alter post-reclamation drainage patterns and increase infiltration and recharge by increasing surface retention of water (Dusseault et al., 1984a). Periodic ponding in these depressions is a potential mechanism to transport salts from subsoils to the soil surface. Other techniques, such as regrading with scrapers rather than dozers are being attempted to minimize subsidence. Our studies are continuing to evaluate the effectiveness of these techniques.

OBJECTIVE B

To evaluate the long-term impact of mining and reclamation on water quantity and quality.

Subobjective B-1

To assess and evaluate the long-term deterioration of quality of groundwater in cast overburden and surface water fed from mine spoil as a result of the generation of weathering products.

Evaluation of hydrologic impacts of salinized groundwater from mine spoil have focused on potential degradation of surface water and groundwater supplies. We have shown that potential for contamination of such surface water bodies as the Battle River and Paintearth Creek is very low and no further work is believed needed in this direction (Trudell, in prep.). However, we have found significantly degraded water migrating laterally from reclaimed mine areas at Vesta Mine into two adjacent unmined aquifers (Trudell and Moran, 1984; Trudell, in press,b).

The groundwater in the reclaimed mine spoil at Vesta Mine is of $Na^{+}-SO_4^{=}$ composition with a mean TDS of 7000 mg/l, and individual values ranging from 4,000 to 14,000 mg/l. In the unmined coal adjacent to the mine the spoil-affected groundwater has a TDS of 2500 to 3200 mg/l, compared to natural values of 900 to 1700 mg/l. Sulfate concentrations increase from less than 50 mg/l in the natural groundwater to more than 1000 mg/l in the plume.

There is a corresponding shift in composition from $Na^{+}-HCO_3^{-}$ (natural) to $Na^{+}-SO_4^{=}$, HCO_3^{-} (contaminated). The plume of contaminated water is approximately 2 km long and 1 km wide, and is driven by hydraulic head within the reclaimed spoil that is three to five metres higher than that in the unmined coal.

This head is associated with deep ponds in the reclaimed landscape that recharge the base of the spoil. The direction of spoil groundwater migration is opposite to the pre-mining flow direction, and is controlled by the major axis of horizontal permeability in the coal. There is little or no migration in the direction of the minor axis of permeability in the coal, despite the presence of a regional groundwater drain, a major meltwater channel, in that direction.

The plume of spoil groundwater in a thin (1 to 4 m) surficial sand aquifer adjacent to the mine has a salinity as high as 15,000 mg/l TDS, compared to the natural ranges of from 600 to 2,600 mg/l. Sulfate concentrations in the plume, at 2000 to 10,000 mg/l, are well above natural levels of less than 1200 mg/l. There is a corresponding compositional shift from the natural Ca^{2+}, $Mg^{2+}-HCO_3^{-}$ or Ca^{2+}, $Mg^{2+}-HCO_3^{-}$, $SO_4^{=}$ to the contaminated Na^{+}, $Ca^{2+}-SO_4^{=}$ or Ca^{2+}, $Na^{+}-SO_4^{=}$. The plume of contaminated water is approximately 2 km long and 2 km wide. The direction of migration is to the southwest, toward an ephemeral stream channel that is underlain by glacio-fluvial sand. The hydraulic potential for the migration of this plume is provided by a water table within the spoil that is 2 to 3 m above that in the sand. The high water table in the spoil is related to a reclaimed land surface that is in places 10 metres above the undisturbed level, and to shallow ponds located high in the reclaimed landscape.

Further work is required to assess the geologic and hydrologic controls on such contamination of aquifers adjacent to mining operations. This process has the potential to generate saline seep type salinity in stratigraphically and topographically favourable sites adjacent to mined areas.

Subobjective B-2

To assess and evaluate infiltration, groundwater recharge, and groundwater-surface water interactions within cast overburden.

The purpose of this portion of the study is to measure and compare infiltration characteristics, soil water movement patterns, and recharge in mined and unmined settings. This was accomplished primarily through the installation of instruments to measure soil moisture and groundwater levels at selected sites in two study areas of different geologic and hydrologic setting (Howard, et al., in prep.).

Infiltration into soils in the reclaimed settings was higher than that observed in bedrock- derived soils in the unmined setting, but lower than that observed for till-derived soils in the unmined setting. Upslope depressional areas allowed larger quantities of infiltration than non-depressional areas. In reclaimed landscapes, small depressions tend to become ponded during snowmelt, and subsequent infiltration can move several metres into the soil. In the Battle River Study Area infiltration rates were higher at the Diplomat Mine than those observed at the Vesta Mine. In the Highvale Study Area, the rate of infiltration appears to be related to the sodium adsorption ratio.

Recharge occurs primarily in response to snowmelt and precipitation in the late spring and summer, especially to heavy rainfall periods such as those of June, 1983; a lesser response to snowmelt is observed. Infiltration into non-ponded areas accounts for a larger proportion of the total recharge than had previously been recognized; our data suggest that approximately half to three-quarters of the total recharge comes from upland areas, however further work is required to verify this conclusion. The remaining contribution is from leakage below permanently-ponded areas. In the Battle River area, recharge is occurring at a greater rate on reclaimed land than on unmined land; in the Highvale area, however, higher rates are observed in unmined land than in mined land. Recharge rates at Diplomat Mine are 1.85 time those at Vesta, 2.26 times those in the unmined areas, and 8.97 times those at Pit 01 at Highvale.

The major difference in infiltration and groundwater recharge processes in reclaimed landscapes relative to unmined landscapes appears to be deeper penetration of infiltrating water in reclaimed landscapes as a consequence of removal of natural stratification. A major enigma remains however. All three study sites have been resaturated and an apparently stable groundwater regime has been established far more quickly than should be the case given the rate at which recharge processes are currently operating. It is our suspicion that the combination of fracturing of the spoil mass and ponding of water in low areas and in subsidence depressions allows for extremely rapid influx of water into the spoil mass at rates perhaps 10 to 100 times as fast as in the unmined landscape. The presence of the water then causes the spoil to slake and compact sealing off the cracks and fissures and slowing the rate of influx of water to the value that we currently observe. If this is an important process in resaturation of spoil, it has significant implications for many aspects of stabilizing of reclaimed landscapes, ranging from surface subsidence, to cessation of overburden weathering, to the establishment of a stable post-mining groundwater regime in the spoil. Further work is required to assess this early resaturation process and its relationship to the ultimate hydrologic regime in reclaimed lands.

Subobjective B-3

To characterize the groundwater chemistry generated within cast overburden.

The chemistry of groundwater in mine spoil at the three study sites has been sufficiently characterized to provide a basis for other related studies (Trudell and Faught, in prep.). The only element of work that is continuing is the periodic sampling of a small number of wells to evaluate changes in chemistry over time.

Subobjective B-4

To assess and evaluate surface water hydrology, runoff, erosion, and sediment yield from mined land.

No work has been undertaken to evaluate erosion and sediment production of reclaimed landscapes during the first phase of study. This will become a component of evaluation of various landscape alternatives that are being studied in the next phase of study.

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REFERENCES

Canada Land Inventory. 1965. Soil Capability Classification for Agriculture. The Canada Land Inventory Report No. 2. Environment Canada, Ottawa. 16 pp.

Cheel, D. B. and M. R. Trudell. (in press). Groundwater Chemistry Associated with In-pit Disposal of Coal Ash: Predictive Geochemical Modeling Based on Laboratory Leaching Experiment: Alberta Land Conservation and Reclamation Council Report #RRTAC 84- .

Dusseault, M. B., J. D. Scott, H. Soderberg, and S. Moran. 1984a. Swelling clays and post-reclamation mine subsidence in Alberta. In Proceedings: 5th International Conference on Expansive Soils, Adelaide, Australia.

Dusseault, M. B., J. D. Scott, G. Zinter and S. R. Moran, 1984b. Simulation of spoil pile subsidence. In Proceedings: Fourth Australia-New Zealand Conference on Geomechanics, Perth, Western Australia. May 14-18, 1984.

Dusseault, M. B., and H. Soderberg. 1982. Geomechanical Investigation of Post Reclamation Subsidence of Prairie Strip Mine Spoil; In Ziemkiewicz, P., Proceedings of the Alberta Reclamation Conference, April, 1982, Edmonton Alberta: Canadian Land Reclamation Association, Pub. 82-1, p. 149-166.

Dusseault, M. B., S. R. Moran, J. D. Scott and H. Soderberg. 1983. Post-reclamation Subsidence of Strip Mine Cast Back Overburden: In Proceedings of the 36th Canadian Geotechnical Conference, Geotechnical Research and its Application to Canadian Resource Development, Vancouver, 1983, p.5.5.1 to 5.5.7.

Howard, A. and S. R. Moran. 1983. Soil Moisture Movement Studies on Reclaimed and Unmined Land, Battle River Area, Alberta (Preliminary results 1983): p. 273-301; In Fedkenhuer, A. W. (ed) Proceedings: Second Annual Alberta Reclamation Conference, Edmonton, Feb. 23-34, 1983: Canadian Land Reclamation Association, CLRA/AC 83-1.

Howard, A., M. R. Trudell, S. R. Moran, B. Monroe, G. J. Sterenberg. (in prep.). Infiltration and Recharge in Mined and Unmined Settings in East-central Alberta. Alberta Land Conservation and Reclamation Council Report #RRTAC 84- .

Macyk, T. M., and A. H. Maclean. 1983. Soil Survey of the Plains Hydrology and Reclamation Program - Battle River Project Area. Soils Department, Alberta Research Council.

Macyk, T. M. 1984a. An Agricultural Capability Rating System for Reconstructed Soils: Alberta Land Conservation and Reclamation Council Report #RRTAC 84- .

Macyk, T. M. 1984b. An Agricultural Rating System for Reconstructed Soils. In Proceedings: Ninth Annual Meeting, Canadian Land Reclamation Association, Aug. 21-24, 1984. Calgary, Alberta.

Parkhurst, D. L., D. C. Thorstenson and L. N. P. Plummer. 1980. PHREEQE - A Computer Program for Geochemical Calculations. United States Geological Survey. Water Resources Investigations 80-96. NTIS Report No. USGS/WRD/WR1-80/018.

Schwartz, F. W. and A. S. Crowe. 1984. Simulation of Changes in Ground Water Levels Associated with Strip Mining. Bull. Geol. Soc. Assoc. (in press).

Schwartz, F. W., A. S. Crowe, and S. R. Moran. 1982. Model Studies on the Impact of Mining on Groundwater Flow Systems; In Proceedings of the 2nd National Hydrogeological Conference, Winnipeg, Feb. 4-5, 1982, p. 70-80.

Trudell, M. R. (in prep.). Impacts of Surface Mining on Chemical Quality of Surface Water: Alberta Land Conservation and Reclamation Council Report #RRTAC 84- .

Trudell, M. R. (in press,a). Post-mining Groundwater Supply Potential of the Highvale Mine Site: Alberta Land Conservation and Reclamation Council Report #RRTAC 84- .

Trudell, M. R. (in press,b). Potential Contamination of Shallow aquifers by Surface Mining of Coal: Alberta Land Conservation and Reclamation Council Report #RRTAC 84- .

Trudell, M. R., D. Cheel, and S. R. Moran. 1984a. Post-mining Groundwater Chemistry and the Effects of In-Pit Coal Ash Disposal: Predictive Geochemical Modeling Based on Laboratory Leaching Experiments. In Proceedings: Ninth Annual Meeting, Canadian Land Reclamation Association, Aug. 21-24, 1984. Calgary, Alberta.

Trudell, M. R., and R. L. Faught. (in press). Hydrogeology and groundwater chemistry of the Highvale Mining area: Alberta Land Conservation and Reclamation Council Report #RRTAC 84- .

Trudell, M. R., and R. L. Faught. (in prep.). Chemistry of Groundwater in Mine Spoil: Alberta Land Conservation and Reclamation Council Report #RRTAC 84- .

Trudell, M. R., R. L. Faught and S. R. Moran. (in press,a). Hydrogeology and Groundwater Chemistry of The Battle River Mining Area: Alberta Land Conservation and Reclamation Council Report #RRTAC 84- .

Trudell, M. R., and R. C. Li. 1981. Post-mining Water Supply at a Site in the Plains of Alberta. (Abstract), Geological Association of Canada, Joint Annual Meeting, May 11-13, 1981, Calgary, Alberta. pA-56. Abstracts Volume 6.

Trudell, M. R., A. Maslowski, E. Wallick, and S. R. Moran. 1983. Prediction of Groundwater Chemistry in Reclaimed Landscapes, In Fedkenheuer, A. W. (ed) Proceedings: Second Alberta Reclamation Conference, Edmonton, Alberta, February 1983. Alberta Chapter, Canadian Land Reclamation Association, Pub. #CLRA/AC 83-1, pp. 238-251.

Trudell, M. R. and S. R. Moran. 1982. Spoil Hydrogeology and Hydrochemistry at the Battle River Site in the Plains of Alberta: In Graves, D. H. and DeVore, R. W., (eds.), Proceedings of the 1982 Symposium on Surface Mining Hydrology, Sedimentology and Reclamation, Lexington, Kentucky, December, 1982: University of Kentucky Office of Engineering Services Bulletin 129, p. 289-297.

Trudell, M. R., and S. R. Moran. 1983. Chemistry of Groundwater in Coal Mine Spoil, Central Alberta. (Abstract), The 66th Canadian Chemical Conference, Chemical Institute of Canada, Calgary, Alberta, June 5-8, 1983.

Trudell, M. R., and S. R. Moran. 1984. Off-site Migration of Spoil Groundwater, East Central Alberta. (Abstract). 13th Annual Rocky Mountain Groundwater Conference, Great Falls, Montana, April 8-11, 1984. Montana Bureau of Mines and Geology Special Publication 91.

Trudell, M. R., S. R. Moran, E. I. Wallick, and A. Maslowski Schutze. 1984b. Prediction of Post-Mining Groundwater Chemistry in Reclaimed Coal Mine Spoil, Central Alberta. (Abstract). Geological Association of Canada Annual Meeting, London, Ontario, May 14-16, 1984. Abstracts Volume 9, p. 112.

Trudell, M. R., G. J. Sterenberg and S. R. Moran. (in press,b). Post-mining Groundwater Supply at the Battle River Site, East-central Alberta: Alberta Land Conservation and Reclamation Council Report #RRTAC 84- .

Wallick, E. I. 1983. Gas composition in the unsaturated zone as an index of geochemical equilibrium in reclaimed landscapes: p. 225-237; In

Fedkenhuer, A. W. (ed). Proceedings: Second Annual Alberta Reclamation Conference, Edmonton, Feb. 23-24, 1983: Canadian Land Reclamation Association, CLRA/AC 83-1.

Wallick, E. I., M. Trudell, S. R. Moran, H. R. Krouse, A. Shakur. 1983. Chemical and Carbon Isotopic Composition of Gas in the Unsaturated Zone as an Index of Geochemical Activity in Reclaimed Mined Lands, Alberta, Canada: poster presentation at International Symposium on Isotope Hydrology in Water Resources Development, I.A.E.A. -SM-270, Vienna, Austria, 12-16 Sept., 1983.

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NINTH ANNUAL MEETING CANADIAN LAND RECLAMATION ASSOCIATION

RECLAMATION IN MOUNTAINS, FOOTHILLS AND PLAINS: DOING IT RIGHT!

AUGUST 21-24, 1984
Calgary, Alberta, Canada

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