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Hydrological modelling of reconstructed watersheds using system dynamics

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Mining of oil sands in semi-arid Northern Alberta, Canada causes large-scale landscape disturbance, which subsequently requires extensive reclamation work to re-establish the surface and subsurface hydrology. The reconstructed watersheds examined in this paper are located at the Syncrude Canada Limited mine site, 40 km North of Fort McMurray, Alberta, Canada. The three experimental reconstructed watersheds, with thicknesses of 1.0 m, 0.50 m and 0.35 m comprising a thin layer of peat (15-20 cm) over varying thicknesses of secondary (till) soil, have been constructed to cover saline sodic overburden and to provide sufficient moisture storage for vegetation while minimizing surface runoff and deep percolation to the underlying shale overburden. In order to capture the hydrological behavior, and to assess the sustainability of the reclaimed watersheds and trace its evolution over time, a suitable modeling exercise is needed. In this paper, a model is developed using the system dynamics approach to simulate the hydrologic processes in the three experimental reconstructed watersheds and to assess their ability to provide the various watershed functions. The model simulates each watershed for vertical and lateral water movement, surface runoff and evapotranspiration. Actual evapotranspiration, which plays an important role in the hydrology of the Canadian semi-arid regions, is simulated using an indexed soil moisture method. The movement of water within the various soil layers of the cover is based on parametric relationships in conjunction with conceptual infiltration models. The feedback relationships among the various dynamic hydrologic processes in the watershed are captured in the developed system dynamics watershed (SDW) model. Since one of the primary objectives of a reconstructed watershed is to maintain the natural flora and fauna, it is important to recognize that soil moisture plays an im-

portant role in assessing the performance of the reconstructed watersheds. Therefore, soil moisture becomes an influential factor for quantifying the health of the reconstructed watershed. The developed model has been calibrated and validated with data for two years (2001-2002), upholding the sensitive relationship between soil moisture and runoff. The model was subsequently used to simulate the three sub-watersheds for five years, with changing the calibrated model parameters to use them as indicators of watershed evolution. The results of the study signify that all three sub-watersheds are still evolving. Failure to identify a unique parameter set for simulating the watershed response may support the hypothesis of watershed evolution. The results also demonstrate the successful application of the system dynamics approach and the developed model in simulating the hydrology of reconstructed watersheds and the potential for using this approach in assessing complex hydrologic system.