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The tributaries of the Athabasca River, within the oil sands region of northern Alberta, Canada, cut through the McMurray Formation (MF); the geological strata that constitutes the “oil sands”. The minable MF is comprised of large proportions of bitumen containing silts and clays intermixed with sand. The erosion of the MF by the rivers represents a major source of natural hydrocarbons to the Athabasca River. Within basins, all too often the terrestrial sediment/erosional processes are not linked to the subsequent fluvial processes once delivery to the river has occurred. Such a truncation to the sediment continuum does not provide a comprehensive examination of sediment/contaminant transport.
To improve our process-based understanding of the sediment continuum (from hillslope to river depositional zone), we link a rainfall simulator with an annular flume (river flow simulation) to generate and assess the evolution of the physical (e.g., grain size, washoff rate), chemical [i.e. polycyclic aromatic hydrocarbons (PAHs)], and toxicological (i.e. fathead minnow assay) characteristics of the uniquely hydrophobic bitumen containing sediment. By linking the terrestrial hillslope with the aquatic environments, the aim of this research is to; 1) quantify the bitumen containing sediment characteristics (i.e. size, loadings, rates) within the washoff generated by rainfall simulation, 2) quantify the PAH and toxicological characteristics of the surface washoff delivered to the flume, 3) assess and compare variability in the physical , chemical and toxicological characteristics of surface washoff between plots of sediment collected from the Ells River (EL) and Steepbank (STB) River, and 4) assess the washoff sediment/contaminant dynamics (transport and deposition) within a simulated river environment. Towards this end, the washoff hydrophobic sediment (oil coated) was found to be very fine (d50 = 5 μm) for all plots. Given this small size in conjunction with buoyant properties and a lack of flocculation, once in suspension, the sediment will travel long distances (unless trapped in the bed matrix). The sediment contaminant load was greatest for the EL (high sediment concentrations), while the STB had the lowest contribution to river loads (particles were highly “stuck” to the hillslope due to high bitumen/oil concentration thus limiting erosion). If normalizing the PAH concentrations with the sediment mass delivered to the flume, however, the STB was one to two orders of magnitude higher than the EL (μg/g sediment). The EL river proved to be the most toxic to fathead minnow embryo survival due principally to high PAH concentrations and sediment loads. The Clearwater Formation above the MF proved to have no toxicological effect given the lack of bitumen. This work has shown the importance of assessing sediment/contaminant characteristics over the whole continuum in order to support basin wide management strategies for the protection of aquatic and human health.