Foote, L. 2012. Threshold considerations and wetland reclamation in Alberta's mineable oil sands. *Ecology and Society* **17**(1): 35.
http://dx.doi.org/10.5751/ES-04673-170135

Synthesis, part of a Special Feature on Balancing Ecology and Community using Cumulative Effects Models

Threshold Considerations and Wetland Reclamation in Alberta's Mineable Oil Sands

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ABSTRACT. Oil sand extraction in Alberta, Canada is a multibillion dollar industry operating over 143 km² of open pit mining and 4600 km² of other bitumen strata in northern boreal forests. Oil production contributes to Canada-wide GDP, creates socio-cultural problems, provides energy exports and employment, and carries environmental risks regarding long-term reclamation uncertainties. Of particular concern are the implications for wetlands and water supply management. Mining of oil sands is very attractive because proven reserves of known quality occur in an accessible, politically stable environment with existing infrastructure and an estimated 5.5 billion extractable barrels to be mined over the next five decades. Extraction occurs under a set of limiting factors or thresholds including: limited social tolerance at local to international levels for externalities of oil sand production; water demands > availability; limited natural gas supplies for oil processing leading to proposals for hydroelectric dams and nuclear reactors to be constructed; difficulties in reclaiming sufficient habitat area to replace those lost. Replacement of the 85 km² of peat-forming wetlands forecast to be destroyed appears unlikely. Over 840 billion liters of toxic fluid byproducts are currently held in 170 km² of open reservoirs without any known process to purify this water in meaningful time frames even as some of it leaches into adjacent lands and rivers. Costs for wetland reclamation are high with estimates of $4 to $13 billion, or about 6% of the net profits generated from mining those sites. This raises a social equity question of how much reclamation is appropriate. Time frames for economic, political, and ecological actions are not well aligned. Local people on or near mine sites have had to change their area use for decades and have been affected by industrial development. Examining mining effects to estimate thresholds of biophysical realities, time scales, economic allocations, and social tolerance helps to contextualize the needs for decision making and relevant policy formation as a way of constructively reconciling production with governing safeguards to the environment and citizens.

Key Words: *environmental constraints; limits; oil sands; reclamation; thresholds; time frames*

They [our tools] do not suffice for the oldest task in human history: to live on a piece of land without spoiling it. (Leopold 1949)

INTRODUCTION

Rational decision making about energy use is one of the great problems of this century. Risks from energy production include climatic changes, cascading biological repercussions, and potentially irreversible losses of ecosystems and their functions. The costs and benefits of energy use have broad implications for public welfare, and have led to geopolitical maneuvering and social discord over allocation of access for resource extraction (Homer-Dixon 1991, Larsen et al. 2005, Dyer 2006, Pasqualetti 2009, Simieritsch et al. 2009). Oil sands extraction will span a period of the greatest growth of population and consumption of energy that the world will have experienced to this point, pointedly focusing global attention on the conflicting demands between the environment and energy security.

In this paper I use the intersection of Alberta's surface mineable oil sands and pre-existing wetlands as a case study to examine the many linked social, economic, and ecological outcomes associated with the extraction of petroleum for human use. I explore the question of whether environmental and social thresholds will be exceeded as well as challenges in changing course. Thresholds are points in a continuum that represent irreversible or noteworthy changes in the human-resource relationship that manifest in ecological, social, or economic regime changes. Because they often involve unprecedented responses of low predictability, thresholds tend to be detected in hindsight, after they have been exceeded. To avoid this situation, ecological and social thresholds can be established as a planning objective that involves specifying more moderate development limits to minimize risk. Planning thresholds provide a way that policies and social consensus can be improved as well as benchmarks for monitoring progress. As a planning tool, thresholds are amenable to adaptive management and prescriptions for improvements. By explicitly involving repercussions of mining in the decision process, threshold-driven management is a form of risk-based management.

The oil sands provide an excellent illustration of threshold concepts. There are two broad propositions in this paper. The first is that scientific knowledge and operational techniques are weak or lacking for addressing a suite of impending resource constraints and ecological thresholds. The current guiding policy for development of high value, nonrenewable resources, i.e., petroleum, has not adequately addressed many

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concerns about excessive harm and violation of thresholds of other natural resources, particularly wetlands. In particular, the standards for habitat replacement, water use, air pollution, and aerial deposition of contaminants in the oil sands are weak, difficult to obtain, and confusing. In addition, because they are source based the standards that do exist provide little useful or constructive guidance for establishing development limits and have not presented realistic challenges to industry operations (e.g., Kennett and Wenig 2005, Dyer et al. 2011). Standards used for mining approvals are not applied transparently or consistently resulting in poor accountability for mining approval decisions and contentious public hearing processes. Thus far, the Government of Alberta has approved 100% of the oil sand mine applications received (Rooney and Bayley 2011), yet insiders realize this is misleading; project proponents are in close consultation with provincial regulators from project initiation, and flawed initiatives never reach the application stage. On 28 January 2011 a seventh mine owned by Total Ltd. was approved for startup in 2017 with plans to operate for 20 years thereafter (CBC 2011). The continued approval of mines in the face of increasing public concern raises questions of whether there is an adequate policy framework in place for the evaluation and approval of projects relative to thresholds (Kennett and Wenig 2005).

The second proposition is that sustainability of oil sands mining can be beneficially viewed in terms of thresholds by comparing short-term societal benefits to longer term societal costs. As a way of understanding the interrelationship between environmental degradation and social thresholds Homer-Dixon (1991) identifies seven major environmental problems that contribute to social conflict including: greenhouse effects; deposition of toxic materials; deforestation, overuse, and pollution of water supplies; depletion of usable fish; degradation of agricultural lands; and ozone depletion. All except the last two are immediate concerns for oil sands development. Other concerns related to health of local communities and global social acceptance are less easily measured and may only become recognized after large swings occur in existing regimes.

The social backlash that continues to build in response to ongoing development of oil sands without satisfactory consideration of environmental degradation is a risk to energy producer’s continued operations. The paper is organized as follows. I first provide the local and global context and pressures for development of oil sands, even with the possibility of exceeding thresholds. I then outline the numerous resource and ecological constraints facing the sector, and uncertainties around irreversible changes. Finally, I outline potential social impacts from ecological degradation on local communities, particularly aboriginal communities. In the discussion section, impediments addressing thresholds are outlined. While this paper draws on a literature review, it is also informed by experts, i.e., university and industry operators, researchers, consultants, who have shared their research as well as considerations and prescriptions for reclamation.

The development context

The oil sands of northern Alberta are the largest, and potentially the most valuable hydrocarbon resource on earth. An estimated 173 billion barrels of recoverable oil exist in the ground as a thick, tar-like substance called bitumen (Government of Alberta 2012*a*). This mineral deposit is owned by the province of Alberta and leases are extended to private companies to mine and process the oil, a process that is expected to continue over the next 40 to 60 years. The value of this resource to the Alberta and Canadian economies is immense. Honarvar et al. (2011) estimate $2106 billion in GDP stimulation and 905,000 jobs created for Canada in the 2010-2035 period. Ebner (2005) describes the $1.4 trillion addition made by oil sands to the GDP of Canada during the 2000 to 2020 period with an average oil price of $40 per barrel.

Bitumen in the region is impregnated into shallow subterranean sands across an area of approximately 4750 km^2 (ERCB 2009). Approximately 20% of the oil sand deposits exist close enough to the surface to be extracted by surface mining. The remaining 80% will be extracted through steam-injection wells.

A number of factors make oil sands very attractive and are driving the development. These include:

1. Reliability of supply: there is a known volume and predictable delivery schedule.
2. Quality of product: though expensive to process, the quality of petroleum from bitumen mining is high and well known and extraction is not complicated by pressurized natural gas or highly toxic sour gases such as hydrogen sulfide.
3. Security of source location: the political system of Canada is well respected for its stability and long standing relationship with the adjacent and dominant U.S. market.
4. Ability to continue increasing production during a period of decreasing world supplies.
5. Relatively safe and simple transport of crude oil via pipeline to U.S. refineries as well as emerging opportunities to reach west coast ports for international distribution by tankers.

Other external market factors are also shifting attention to the oil sands. Petroleum demand from the world’s largest consumers of oil, U.S., China, and India, are rising. At the same time, many low cost supplies are in a collapsing phase (Pasqualetti 2009). For example, production from Mexico’s great offshore Cantarell oil field dropped from 2.1 million barrels per day (MBD) in 2006 (Collier 2006) to 0.75 MBD in 2009 (Campbell 2009). Venezuela exports have slumped for political reasons while production in North Sea fields and Indonesia are rapidly declining. As a result of decreasing supply options and increasing demands, global inventories are declining. In 2003 there was a 3.0 MBD global surplus in oil production and by 2008 that was down to zero (Energy Information Administration 2007).

Harder to access hydrocarbon deposits are more costly and may pose even greater environmental risks. For example, between April and 15 July 2010 an offshore British Petroleum drilling platform collapsed and released approximately 5 million barrels of light crude oil into the Gulf of Mexico. This event immediately slowed offshore drilling progress in U.S. and international waters that will exacerbate future shortfalls. Shale gas production through formation fracturing (fracking) processes has also been associated with risks of groundwater contamination and earthquakes (Parfitt 2010, Holland 2011).

Resource constraints: water, pollution, energy, and carbon emissions

A number of resource constraints and challenges must be addressed as oil sand production is scaled up.

Water

Future production rates may be more limited by water availability and tailings storage than by production technologies, access to markets, or availability of reserves. Water is an essential component of the oil sands separation process. Between two to four barrels of water are needed to process each barrel of oil. According to 2010 data, five industrial oil sands companies held licensed water use permits in the lower Athabasca River Basin totaling 180 gigaliters annually, most of which is allocated to the surface mining operations in the Fort McMurray oil sands (Adamowicz et al. 2010). Water demands are expected to increase under business as usual cases (CAPP 2011) and this increase comes at a time when climate change is anticipated to reduce river flows (Mannix et al. 2010).

Water used for surface mining is a liability because it must be stored in tailings ponds (Giesey et al. 2010) so it is in the industry’s interest to minimize water use. Water recycling helps to reduce demand on river sources but this concentrates contaminants in the tailing ponds. Tailing pond water volumes have increased over time and represent a major liability and risk to both energy companies and the public with approximately 1 billion cubic meters of tailings water stored on the combined oil sands as of 2009 (Simieritsch et al. 2009, Gosselin et al. 2010). Though technology is advancing rapidly to store produced water as shallow groundwater in clay and gypsum slurries, thickened tails, and polymer enriched sludges, tailings pond reclamation is an unproven technology. Companies do not yet have a cost-effective way to remediate the volumes of water produced and they may have to store it for decades to centuries (Del Rio et al. 2006).

Pollution thresholds

Pollution is used here to describe the production, concentration, and discharge of undesirable compounds as well as the placement of normally benign materials (salt) in an undesirable context. This is typically a consequence of industrial activity in the oil sands though smaller examples of natural geologic releases also occur. Many water quality problems remain to be addressed in postmining wetlands. Of the thousands of petroleum compounds found in natural crude oil, only a small fraction is actually water-soluble. Notable groups of these such as alcohols and naphthenates dissolve into the water used during the bitumen/water separation process. These soluble components as well as salts and some soluble/suspended heavy metals return to the tailings reservoirs with the waste water where they cause problems for insects (Barr 2009), fish (Tetreault et al. 2003), amphibians (Hersikorn 2009), and birds (Gentes et al. 2006). Initially the plans of oil companies were to use wetlands as scrubbers to improve processed water quality. However, this has not worked well for fully soluble components like naphthenics and salt, and these plans have been largely abandoned or marginalized. As a result settling basins are the primary method for suspended solid removal.

Trace amounts of petroleum compounds enter the Athabasca River naturally each year because of river down-cutting and annual river erosion. This natural contamination of the river is probably low compared to the two to eightfold increase in river loadings of petroleum associated directly with mining activities (Kelly et al. 2009). River and vegetation contamination near active mine sites is further compounded by aerial deposition from the mining, trucking, and upgrading ore (Kelly et al. 2009). Some leakage of contaminated water finds its way through containment dikes surrounding the greater than 170 km^2 of tailings ponds and Marsden (2007) relates a 1997 Suncor admission that approximately 1600 m^3 of contaminated water leaks into the Athabasca River daily from older tailing pond dikes. Ferguson et al. (2009) offer the optimistic appraisal that such leakage diminishes with time as fine clays plug the more porous flow paths in the dikes. However a legacy of contaminated pore water remains and regional groundwater is contaminated and will remain so for centuries. One great unknown is the degree to which downward migration of contaminated water occurs under the pressure of elevated tailings ponds.

It is difficult to establish acceptable thresholds for background and fluctuating levels of waterborne polycyclic aromatic compounds (PAC) in terms of environmental and human health. Kelly et al. (2009) found pollutant levels at key stream mouths on the Athabasca exceeded the levels known to cause death to fish embryos and affect endocrine function of adults.

This could be broadly taken as having exceeded an acceptable threshold of contamination at those specific locations, especially in waters fished downstream for household fish consumption. However possibly because of dilution and sequestration this same signal was not detectable downstream where the Athabasca entered Wood Buffalo National Park.

Energy and carbon

Substantial energy inputs are required to produce fuels from the tarry, sandy bitumen. Extraction of oil sands requires almost as much energy as is produced with an energy return on investment value of 1.5 whereas easily extracted Middle East oil may return 15 to 30 times the energy required to produce them (Rousse et al. 2009). Approximately 4% of all natural gas produced in the Western Sedimentary Basin of North America is used for oil sand processing but that amount could escalate by 2.5 times by 2015 (National Energy Board 2007). Use of natural gas for bitumen separation appears to be a cost-effective option; supplies are abundant, prices are low, and natural gas burns relatively cleanly and efficiently. However, local supplies are not infinite and natural gas has many competing markets domestically.

The hydroelectric potential of the major rivers in the region are being reinvestigated in anticipation of increased demands over the next 50 years from the energy sector production, both for oil sands and carbonates. In April 2010, British Columbia announced a major dam called Site C on the Peace River that would produce 4600 gigawatt hours of electricity annually (Hume 2010). The Alberta government has also considered a dam on the Peace River and the Northwest Territories is considering a major dam on the Slave River in Fort Smith, Northwest Territories. In each of these cases, oil sands are a major potential customer for energy sales.

Greenhouse gas emissions from oil sands pose a significant social and regulatory challenge for the industry (e.g., Chastko 2010). Energy requirements for processing bitumen have led to recommendations that nuclear power generation supplant natural gas as the primary energy source for oil sand processing (Halper 2011). They did not discuss uranium availability, waste disposal, malfunction risks, or public acceptability issues that are typically considered in environmental and social impact assessments prior to approval of nuclear power development.

Although this discussion centers on surface mining, an even larger volume of bitumen is liquefied beneath the surface through injection of steam and solvents in a process called steam-assisted gravity drainage (SAGD). The emissions from this technique are also significant: emissions from creating sufficient steam to produce the targeted daily volumes of 1 million barrels of oil are over 86,000 metric tons of CO_2 equivalents each day. Greenhouse gas emissions from the ultimate combustion of the oil will vastly exceed those from production however.

Wetlands and the potential for irreversible ecosystem loss

Wetland ecosystems get special consideration in the oil sands region because they dominate the landscape, occupying up to 65% of the active surface mining area (Raine et al. 2002). Wetlands are defined as areas that are substantially affected by water saturation or shallow inundation for periods of time sufficient to develop characteristic soil types, and/or specially adapted vegetation.

Wetlands contribute special ecological functions and values. They accumulate carbon and also slow water runoff resulting in longer time intervals for water infiltration and groundwater recharge. Wetlands also moderate storm water run-off, attenuating flood pulses for down-gradient receiving systems. The soils of most wetlands in the oil sands region are very active habitats for microbial communities. When contaminant levels are moderate, natural microbe communities can transform, sequester, bind, and isolate many undesirable materials from the water column, purifying water (Frederick 2011). Wetlands are also disproportionately valuable for wildlife, concentrating insect, fish, bird, and mammals in closely linked food chains. Wetlands provide aesthetic, recreational, cultural, and spiritual values for naturalists, hunters, and anglers.

A primary condition of mine permitting is the agreement to return disturbed wetlands on the mine sites to a socially acceptable condition. Ideally, conditions would be restored to those nearly identical to the premine state. However, peatlands, the primary class of wetland cover throughout the oil sands region, cannot feasibly be replaced because of insufficient available area, time requirements for peat development, gaps in reclamation knowledge, and expense. Peat accumulation is a complex nonlinear process (Clymo 1992) dependent on simultaneous accumulation and decomposition with a positive balance. Restoration of fen peatland conditions requires stable and calcium-rich groundwater of low salinity flowing into low gradient areas with a fairly stable climate and low fire frequency. Even with these exacting conditions, at 1 to 3 mm of peat accumulation per year, approximately one to three centuries would be needed to generate the 30 cm minimum of accumulated peat to technically qualify as a peatland.

Oil sands mining creates unique landscape replacement challenges, mostly related to new soil types, changes in land form, and severed hydrologic connections. In the short term, boreal forestland is largely replaced with large piles of sandy tailings and the fen wetlands are excavated disrupting water supplies. Fens are typically replaced with emergent lacustrine wetlands on salt-affected soils with low permeability. Because the bitumen resides on, and is overlain, by ancient marine sediments, salts are liberated by the hot water used to separate oil from sediment yielding salt concentrations of 4000 to 6000 microsiemens in the tailings. This is approximately 10%

seawater strength, too high for all common nonmarine wetland plants, fish, amphibians, and most insects, so the community diversity of plants and animals is reduced.

These challenges call for expensive and innovative management approaches to replace suitable growing conditions including: isolating damaging chemicals from the growing environment; elevating soil layers; installing under-drains to evacuate the saltiest water; and finding a tolerant subset of plants and animals that can persist in these novel conditions. Furthermore focusing only on replacement of landforms and soil conditions is insufficient. A broad consideration of the processes and requirements of entire ecological communities is required otherwise plant occupancy for crucial microbial, insect, and wildlife components will be missed.

Social thresholds

Local people of partial or full aboriginal heritage, predominantly Cree, Dene, and Métis, continue to live in the oil sands mining region and their occupancy predates oil sand discovery and development in the region. Local aboriginal communities maintain a complex relationship with oil sand development. Despite greatly increased employment opportunities with oil companies and some improvements in education and training, many communities have had limited success with government or industry in influencing the direction of land use planning and development and their impacts on wetlands, water quality, and wildlife habitat. Concerns about oil sands development include concerns about human health and water pollution; contamination of wild-gathered foods; and limited employment opportunities for Aboriginal youth near the oil sands (Droitsch and Simieritsch 2010).

There is strong evidence that First Nations view the landscape in a fundamentally different way than people with predominantly European backgrounds (Lewis 2010). A strong connection to the condition of the land is often brought forward by aboriginal communities for whom long-term reclamation and closure planning are of concern. Garibaldi (2009) contends that spirituality is inextricably linked to the concept of reclamation and that reclamation activities may be enhanced by clear linkages to land-connection desires of local people. It is significant then that reclamation may require excluding the public from mining sites for over 50 years, which would break the linkage of local communities to the land element for at least a generation or more and constitute a serious loss of connection with previously existing landscapes (Smith et al. 2002). It is unlikely that hunters, trappers, gatherers, and travelers in the region would retain detailed knowledge of exclusion zones for five decades. Isolation from the land contributes to increased First Nation concerns about maintaining identity through land-based traditional activities in the presence of oil sands development.

Tomich et al. (2004) provide a framework for understanding the socio-political dynamics of environmental issues by outlining seven stages of problem acceptance and action: (1) problem perception by pioneers, if judged correct, or crackpots, if judged wrong; (2) lobbying by action groups yet no action by authorities; (3) widening acceptance of problem existence and mounting pressure on authorities; (4) debates as to cause and effect and attribution of blame; (5) inventory and assessment of prevention and mitigation; (6) negotiation on prevention/mitigation steps; and (7) implementation of monitoring and enforcement of protections. These stages represent a sequence of social perceptions and responses relevant to oil sands mining. It could be argued that currently the oil sands are stalled at the fourth stage, i.e., debates as to cause and effect, in the cycle of social acceptance.

To most people, images from oil sand mines with large excavation pits, steaming upgraders, frothy brown lakes, and dusty large equipment digging open pits are disturbing (e.g., Latura 2011). The remote and inaccessible location of the mines in northern Alberta has meant that relatively few people viewed these settings and that for years there was relatively little public awareness or concern about what happened on these sites. Over the last decade, however, the public has become more aware of environmental challenges associated with oil sands development through feature magazine articles such as National Geographic (Kunzig 2009) and television specials highlighting carbon emissions and water shortages. Complaints of local First Nations communities activist groups such as Greenpeace refer to the mine areas as “tar sands” and publicly call for the end of mining (Greenpeace 2010) on the grounds of pollution, CO_2 releases, land use alteration, and cultural disruption (Chastko 2010).

In the spring of 2008, a highly symbolic and discrete event galvanized the public’s attention when 1600 migratory waterbirds, mostly ducks, became oil-soaked and died in the bitumen layer on a Syncrude tailings pond. Ducks die every year in Alberta, up to 100,000 can die naturally on a single lake from botulism outbreaks, and many biologists, the author included, are on record stating that the absolute number lost was not of significant concern to the continental population. However, the symbolic images of oiled birds dying in industrial ponds produced emotional reactions and public anger at Syncrude for poor prevention of a known problem. These exposures helped to elevate awareness and led to broad public acceptance of the problem and mounting pressure on authorities (stage 3 in the above cycle of acceptance).

Alberta is currently at the fourth, and arguably most difficult, stage of the acceptance cycle. Recent reviews of health impacts from the oil sands, and monitoring policies have generated extensive debate on cause and effect, which in many cases cannot be solved because of poor environmental monitoring in the region. Criticisms of Alberta’s monitoring of oil sands impacts continue to build and include inadequate funding and poor design of monitoring protocols (Auditor General of Canada 2010, Gosselin et al. 2010, Dillon et al. 2011, Main 2011).

In 2008 the Government of Alberta launched a Land Use Framework (LUF) to address significant cumulative effects challenges related to land use in the province including criticisms related to the continual approval of oil sands projects in the absence of limits and thresholds. One of the key strategies of the LUF was to develop regional plans that would identify outcomes and cumulative effects thresholds for land, air, and water that could be used to establish guidance and regulatory parameters to set limits and conditions on project approvals (Government of Alberta 2008). However to date no regional LUF plan has been adopted by Cabinet. In addition, the draft regional plan that has been developed for the Lower Athabasca Region where the oil sands mines exist does not identify thresholds. Instead the recommendations only provide guidance for setting thresholds in subsequent subregional planning exercises. In the meantime, the government has changed and the LUF and supporting legislation (the Alberta Land Stewardship Act) is undergoing political review. The stalling of the framework and direction for cumulative effects management suggest the province has not yet advanced to steps 5 to 7. Nonetheless there remains a need for inventory and assessment of prevention and mitigation strategies for ecosystem impacts, as well as the negotiation and implementation of cumulative effects thresholds.

Challenges in setting thresholds

Policy challenges

In spite of mounting local, national, and international pressures to demonstrate better environmental outcomes in the oil sands, there are several difficult challenges to setting development limits. These are demonstrated by the inability of the province to come up with a suitable wetland policy for the region.

Governments are generating policies and protective legislation for wetlands and other impacts related to oil sands development. Currently Canada's national wetland protection policy is primarily a set of principles. Alberta currently has no wetland policy for the forested area of the province. The 1993 interim policy that applies for the settled area of the province requires compensation for damages to wetlands. In 2005, the Alberta Water Council was directed by the Government of Alberta to establish a Wetland Policy Project Team to develop recommendations for a new wetland policy and corresponding implementation plan. In 2008 the team recommended a no-net-loss goal to maintain wetland area in Alberta such that the ecological, social, and economic benefits that wetlands provide are maintained (Alberta Water Council 2008). However, in the fall of 2010, the government rejected the council's recommendations over concerns raised by oil sands stakeholders over potential costs of the policy.

In the current policy the language of wetland loss, reclamation, replacement, regulation, and policy are often confusing and even misleading in ways that make evaluation and accountability harder to achieve (Clare et al. 2011). The words creation, restoration, reclamation, and remediation are often ill defined or conflated. Each has a specific and different meaning and given that even experts sometimes interchange them, it is clear why the public struggles to grasp the concepts of ecosystem repair.

Because restoration time frames measured in centuries do not match business cycles or bonding/liability agreements, reclamation agreements tend to default to short-term and hence less rigorous requirements for approval. The regulatory intent of wetland reclamation focuses on the duty of those altering or destroying a wetland to return the sites to a condition capable of producing ecological goods and services. Because in many cases it will be impossible to replicate the original feature within a meaningful time frame, the approval for reclamation is often held to a standard of "equivalent capability" where similar degrees of social, ecological, and commercial goods and/or services can be produced from the site. Those goods and services may be of different types; for example, a groundwater recharge wetland might be replaced with a productive commercial forest under the concept of equivalent capability. Consequently, most peatlands will be replaced by upland forest, pasture, or marsh type wetlands for quicker results. The absence of knowledge on wetland reclamation also means that regulatory requirements, formulated without clear end use targets, are criticized as being vague or over specified.

The concept of equivalent land capability is based on a regional forestry classification called the Land Capability Classification for Forest Ecosystems (Leskiw 2004) and it may not fully capture nonmarket ecological goods and services specific to wetlands such as groundwater recharge, nutrient processing, flood attenuation, aquatic pollution abatement, biodiversity, aesthetics, or cultural values. A wetland's relative importance is context-dependent; for example, as wetland area dwindles, the scarce remaining wetlands may spike in value for regional biodiversity, flood attenuation, or recreational opportunities.

Costs of reclamation

Reclamation, clean up, and mine closure are very expensive activities and oil companies in the oil sands region have invested hundreds of millions of dollars into reclamation thus far but several key questions remain:

- Is the investment sufficient to reclaim the area?
- Who decides when reclamation is achieved?
- How is this decision made and enforced into the future?

Reclamation costs are estimated to fall between $10,000 and $250,000 per ha depending on end conditions sought (G. McKenna, BCG Engineering, *personal communication*; and two anonymous oil sands reclamation specialists). Using simple calculations to estimate the costs of wetland replacement based conservatively on $50,000 per ha for each of the 85,500 ha of wetlands slated for loss from mining yields an estimate of $4.3 billion required for wetland reclamation at a 1:1 ratio. If regulations require 3:1 area ratios for reclamation, that is, 3 ha of wetlands replaced for each one lost, the costs jump to $12.9 billion. In all of these reclamation projects success is not guaranteed. Assuming that of the 4750,000 ha of oil sands area, of which 3% are mineable, each mined hectare produces approximately $2.6 million in company income (assuming $70/barrel oil price as of June 2010, $18/barrel production cost, and after a 25% provincial royalty has been removed), the 4,750,000 ha of oil sands area of which 3% are mineable puts the net value of recoverable oil from mines underlying wetlands at approximately $196 billion.[1] The $12.9 billion calculated in wetland reclamation costs equals about 6% of the net petroleum profits these simple numbers suggest are being extracted, a lower reclamation rate than many other extractive industries face.

Despite ongoing research in wetland creation and reclamation in the oil sands region, only a few vegetated wetlands > 4 ha in size have been recreated on postmining oil sand substrates, and no large scale wetland creation > 100 ha has been attempted. Problematically, the regulatory agencies, primarily Alberta Environment, have issued little clear and consistent reclamation guidance and few criteria by which to gauge reclamation success. Consequently, as of 2011, for a variety of reasons, none of the industries operating in the region has attempted to validate any of their wetlands as certifiably reclaimed.

One argument sometimes given for the low reinvestment rate in wetlands is that uncertainty about reclamation success and the open-ended nature of the regulatory demands can be unsettling to investors. Such economic liabilities translate directly into stock values and place tremendous pressures on regulatory bodies in government to relax regulations. As of 31 March 2010 oil sands operators had cumulatively invested approximately $916 million into repair bonds (Government of Alberta 2011) to help ensure reclamation would occur should companies default on mine reclamation requirements. This $916 million is held to cover wetland replacement, mine site repair, roads and pipeline reclamation, and take care of hundreds of km² of contaminated tailings ponds and major dike maintenance over many decades. Auditor general reports suggest that this is an inadequate bond for cleanup responsibilities and would leave a seriously degraded landscape or a major cost to government and tax payers (Auditor General of Alberta 2009).

The potential for companies to default on bonds needs to be addressed. Historically, bond defaults have occurred in other mining situations throughout remote, lightly populated regions of northern Canada where abandonment of industrial extraction sites without reclamation has been common, if not the norm. Birtwell et al. (2005) reported on 50 northern Canadian lakes that were either partially or entirely eliminated, or approved for elimination, during the 1985-2000 era as a result of diamond mining, placer mining, or oil sands operations. In all cases, these violated the letter and spirit of Canada's Fisheries Act, yet, because of data gaps, absence of validation, or compensation, there have been no examples of whole lake restoration to date.

Meaningful time

Reclamation, which validates the concept of sustainability, is also hampered by the disappearance of meaningful benchmarks. When mining alters the entire landscape it is difficult without a benchmark to select a comparison of what it might have looked like in its "natural" reference state and identify an appropriate replacement type. The lack of benchmarking introduces a process of forgetting or "cultural amnesia" in social science terms. Natural scientists refer to this as the "shifting baseline syndrome" (Pauly 1995) whereby each generation relates the present with a limited historical recollection. Today natural reference areas still exist in northern Alberta because oil sands mining is a recent development embedded in a large region of similar habitat. Many people alive today will recall the appearance and configuration of specific premine sites. Aerial photographs from the 1940s and 1950s show the untracked expanses that are now open excavation pits and these may corroborate the personal narratives of many that traversed, lived on, hunted, and fished these areas before mining. Such memories may not persist for another 50 years however when oil sands mining is put in the context of landscape changes expected to occur from the development of other nonconventional oil and gas sources underlying the region.

Time scales are particularly difficult to relate to in a meaningful way considering bitumen is a nonrenewable resource that has taken hundreds of millions of years to accumulate, and at current extraction rates, may be exhausted from this formation in approximately eight decades, approximately the life expectancy of an average North American human being today. With as few as 10 years of accumulated evidence, projections are being formulated to confirm that long-term reclamation targets will be achieved and this is dubious forecasting given the uncertainties at hand.

From a survey of closure plans for 57 mines in western North America, McKenna and Dawson (1997) identified the uncertainty around time frames for good performance of their reclaimed land to be a most problematic aspect. They identified 10 to 10,000 years as the range of time frames likely, but suggested a 200-year time frame for good reclamation site performance, a rough guideline emerging largely from uranium mines and mill sites. Peatlands will require centuries of natural peat accumulation under favorable climate to return to their premine function. Neither mining companies nor their insurers want obligations for centuries. Discount rates on investments and held bonds make long-term reclamation assurances very attractive but this does not increase their plausibility.

Time scales for quarterly business reports, media cycles, political election cycles, and government policy formulation are short, ranging from days to years. Such short-term decision frameworks have become the primary governing influence guiding reclamation criteria and regulation. Such criteria and regulations do not match well with biophysical time frames such as ecological succession, evolutionary processes, or geological and landform development, all of which operate in the centuries to multimillennial or even epochal time frames.

Companies and government representatives typically meet at the end of the productive mine life to renegotiate the terms of ongoing decommissioning and reclamation and to renegotiate the appropriate performance bond required (Government of Alberta 2012*b*). The long-term reclamation success will not be known until long after the final decommissioning agreement and bond renegotiation are settled. This creates a very difficult situation for policy setting.

Timing of knowledge is important too. Lindahl (2009:4) writes:

> *In reality, people tend to have access to different sources of information and may also differ with respect to skill of processing this information. The symmetry of information could vary from situation to situation, as it depends on how expensive it is to acquire information and on the rules of disseminating it. In a rivalry setting, agents may have incentive to use their own and others knowledge strategically, which could have consequences for individuals and overall welfare.*

To avoid as many reclamation responsibilities as possible, it may be rational in the short term for companies to not embrace recent but speculative wetland reclamation procedures, at least until after finalizing the mine closure agreements. Once reclamation techniques are proven they may be adopted by government regulators as standards of practice, and they may prove to be very expensive and hence a financial liability to companies.

CONCLUSION

Production of petroleum products comes not at a single calculable cost but as a series of complex interlinked and interactive costs that are borne by large sectors of society and indeed, the entire world population to some degree. Simple cost/benefit analyses fall woefully short of reflecting the trade-offs that must be considered in guiding where to pursue energy development and how to do so. Thresholds can provide definite decision points at which people, companies, or governments can choose to change their management strategies, or can provide boundaries beyond which all parties agree to cease or slow development. Examination of thresholds is instructive because embedded in establishing thresholds is the question of how to determine “Where is the stopping point?” or “At what point is different action merited?” Wetland impacts from oil sands mining illustrate the difficult social and scientific challenges in making these important trade-offs and developing thresholds.

The state of knowledge in wetland reclamation is meager in comparison to the needs to create, restore, reclaim, and compensate wetlands in the face of oil sands development. However the pressures to expand development are massive and accumulating from companies, government, and the public. This paper addresses a number of issues that taken in aggregate provide a larger breadth and dimension to the sustainability of oil sands development beyond the question of whether it is possible to simply compensate for some proportion of the physical damage done. Permanent solutions to reclamation problems may not be discovered for centuries, or ever, and the concept of a “disposable landscape” or a national sacrifice zone is troubling to many. There is legal precedent in the U.S. around brownfield sites, i.e., mine-scarred lands and hazardous pollutant sites, to place sites off-limits for decades awaiting technological fixes (U.S. Congress 1980). For example, the Rocky Flats Nuclear weapons facility in Golden, Colorado was made off-limits for 30 years during which time expensive decontamination work was undertaken.

Where thresholds are being approached, moderation of the pace or the manner of oil sand production may be required. Without specific targets, guidance, or alternatives, political restructuring and hardening of protections by government and industry may occur to allow mining to continue unabated despite growing public and international opposition. A broader consideration of environmental risks and social opposition will be needed to understand the profitability of operations because awareness of these effects is an increasingly large cost of conducting business.

Some undesirable thresholds may be avoided by increasing investments in reclamation efforts and processing efficiencies if knowledge can be developed to solve these novel problems. However if, in a very rational approach to oil sands production, trade-offs are useful to measure the costs and benefits of petroleum development as it is currently carried out, we must grapple with this very difficult question: how long can companies maintain the current social license to operate in the existing knowledge vacuum? Because it is not possible to satisfactorily predict postmining wetland reclamation in advance, I suggest that negotiated thresholds may help development move toward a more acceptable way of mining and reclaiming wetlands.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol17/iss1/art35/responses/

Acknowledgments:

I thank the three conscientious and well-informed anonymous reviewers whose suggestions and additional sources improved this article significantly.

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