In Situ Tar Sands Extraction Risks Contaminating Massive Aquifers

By Carolyn Campbell, AWA Conservation Specialist

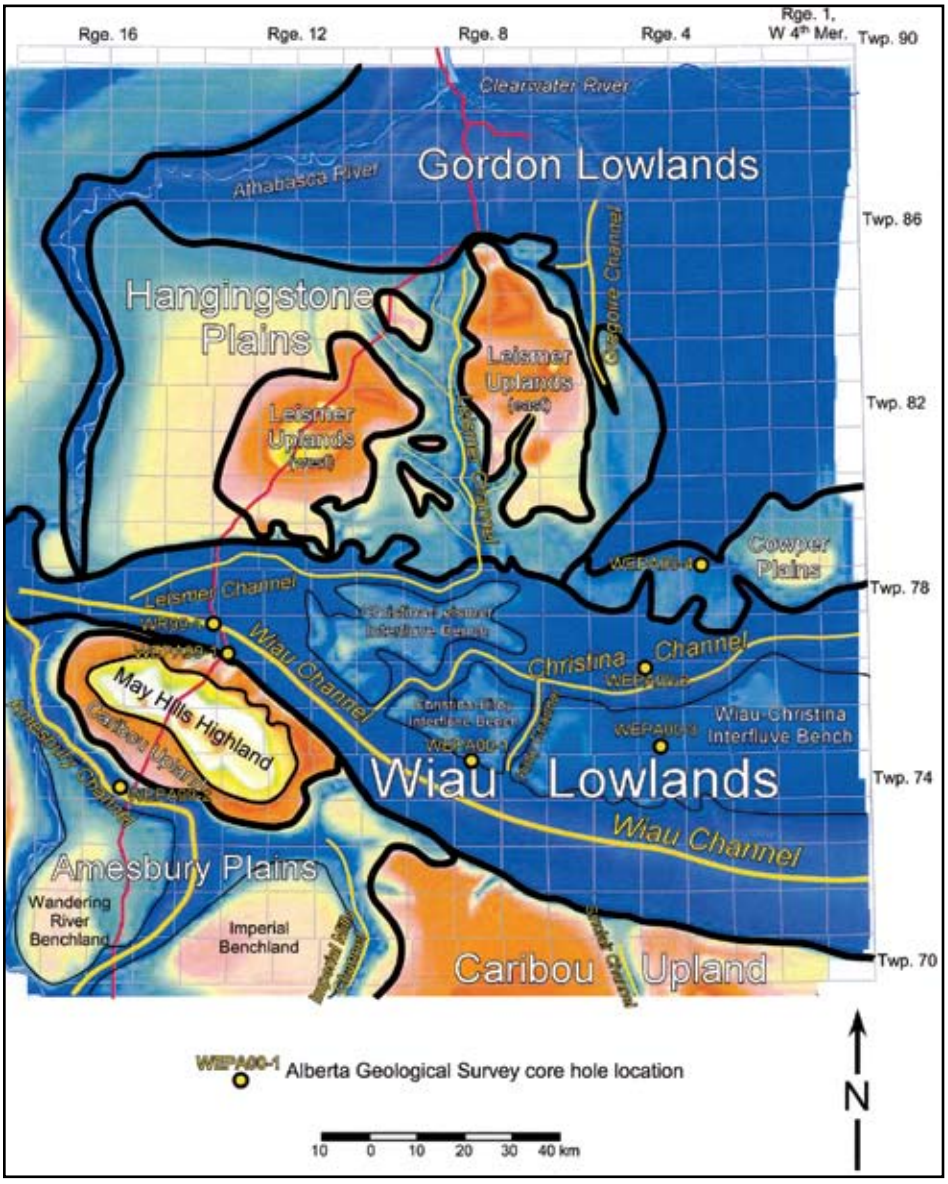
Recent research has revealed significant risks to huge underground freshwater channels from tar sands activity north of Lac La Biche and Cold Lake. In this region, the bitumen resource is deep enough that underground extraction (in situ) techniques, often involving high-pressure steam, are used instead of surface strip mining. Given that accidental steam blowouts have already occurred in the region, the potential for pollution of Canada's largest freshwater aquifer is very real. Increased monitoring requirements are necessary now to manage these risks, and new oil sands project approvals in the region should be halted until these risks can be better understood.

Few Albertans are aware of the scale of this underground freshwater resource, located in a wide swath running 40 km north of Lac La Biche and 30 km north of Cold Lake. This aquifer network is generally 200 to 300 metres below the surface. It consists of thick sand and gravel layers, called the Empress Formation, through which groundwater slowly flows at rates of perhaps a hundred metres per year. The aquifer layers sit on shale bedrock valleys that predate the last glacial period.

In a 2003 report, Alberta Geological Survey (AGS) presented the most comprehensive information available on the Empress Formation, based on oil and gas well data, water well drilling data, and a few of its own core samples. However, the picture is still incomplete, particularly with respect to mapping the aquifer channels' connections to other shallower aquifers.

The largest single aquifer in the network is the Wiau Channel. While generally 200 or more metres underground, it connects directly to the Athabasca River where the river carves its way through the surrounding land about 60 km north of Wandering River. The volume of water discharging into the Athabasca River from the channel is on average 7,700 m^3 per day, equivalent to 50,000 barrels per day. From the Wiau Channel's western limit at the Athabasca River, where it is 15 to 20 km wide, it has been mapped for 200 km east to the Saskatchewan border, where its width reaches 25 to 30 km. Farther east, its limits, and connections to other Saskatchewan aquifers are completely unknown. The Wiau Channel is connected to smaller channels at the same depth: the Christina, Leismer, and Amesbury Channels.

Water chemistry analysis and core samples suggest that in this region



Key features 200 m below ground from the pre-glacial (pre-Quaternary) period. Yellow lines indicate aquifer channel bottoms. Fort McMurray is located at the confluence of the Clearwater and Athabasca rivers (top). The Saskatchewan border aligns with the right side of the diagram, and Cold Lake and Lac La Biche are just south of this region.
SOURCE: ALBERTA GEOLOGICAL SURVEY, ESR 2002-03, FIG. 8 (MODIFIED)

On a Steam Assisted Gravity Drainage (SAGD) project site, a single well pad has many well pairs to steam and pressurize the bitumen so that it may be pumped to the surface.
PHOTO: J. HILDEBRAND

there are likely many stacked layers of "younger" aquifers – shallower water-conveying sandy layers deposited by subsequent glacial activity – above the Empress Formation channels. According to the AGS report, "[H]ydraulic pathways and connections can conceivably extend from near surface to the bedrock." As a result, human activity that affects shallower aquifer layers has the potential to affect the larger, deeper layers as well.

Based on analysis of the Wiau springs that flow from the Wiau Channel into the Athabasca River, as well as on groundwater monitoring wells at other points along the aquifer, the water quality in the underground channel is very good. Its pH is neutral compared to the somewhat more alkaline Athabasca River. The total dissolved solids (460 to 560 mg/L, depending on location) is only slightly higher than in the Athabasca River. Its temperature is about 6 degrees Celsius. One industry observer familiar with the aquifer has described it as "Perrier-quality water."

Under the geological layer containing these aquifers lies the McMurray Formation of bitumen about 400 metres below the surface, the target of oil sands extraction activity. By far the most common bitumen extraction technique in the area is the Steam Assisted Gravity Drainage (SAGD) method. With SAGD, two parallel wells are drilled down to the bitumen zone and then curve to a horizontal position one above the other. Quantities of steam are injected into the upper well, increasing both heat and pressure in that section of the bitumen formation. The McMurray formation is overlain with a layer of shale that will generally act as a cap to contain the pressure within the bitumen layer. The bitumen softens and flows, and is pumped to the surface via the lower production well.

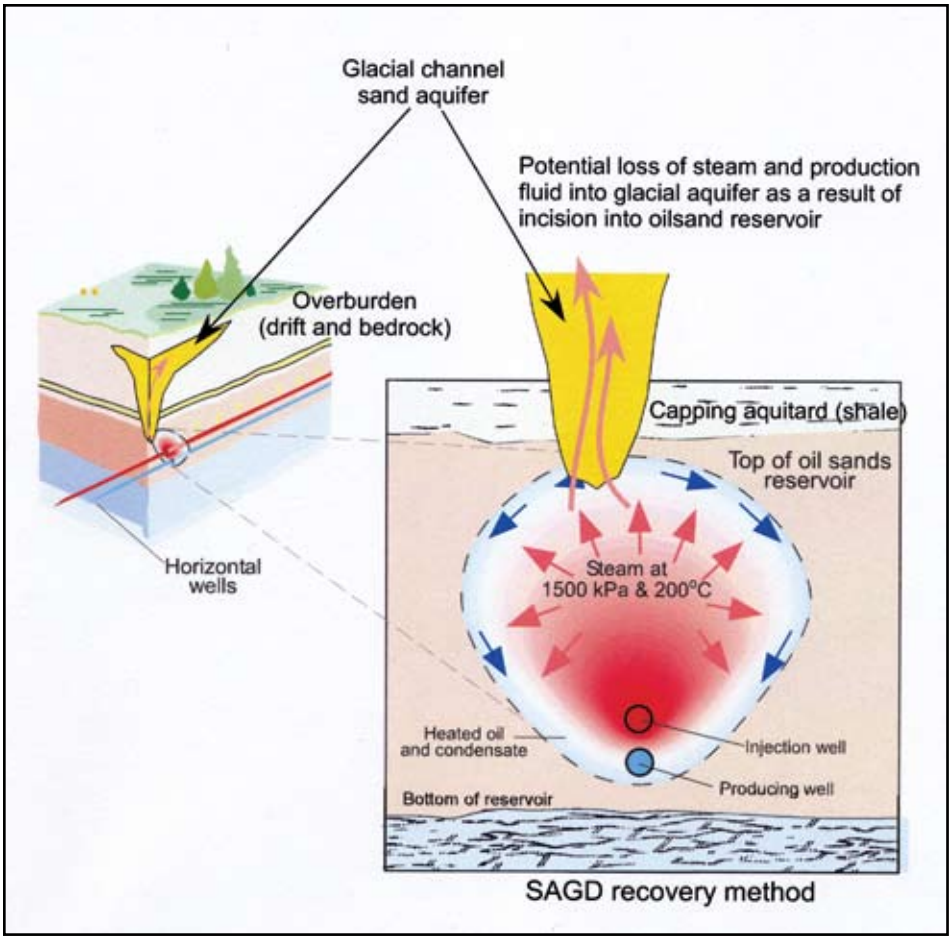
Several SAGD projects overlap with the aquifers, each with hundreds of planned well pairs. CNRL's Kirby Lake project is situated directly over the Wiau Channel, and parts of EnCana's Christina Lake operation, Devon's Jackfish project, and MEG Energy's Christina Lake project overlie the Christina Channel. Petrobank (which uses a technique of fire combustion called Toe to Heel Air Injection, or THAI) and Statoil SAGD projects are in the vicinity of the Leismer Channel.

Rick Boucher is vice-president of the Métis Nation of Alberta Region One, whose territory lies above this aquifer network. He has become very concerned about potential risks to these freshwater aquifer channels from SAGD: "It's just a matter of time before an accident causes injury or death, and pollution of this massive underground freshwater system."

Boucher's concern stems from research by Wallace King, the environmental advisor to the Métis Nation of Alberta Region One. King is a career geologist in the oil patch and has identified several ways that the soft pressurized bitumen could contact the aquifer layers. The steam injection cycles cause recurring expansion and contraction in the bitumen layer, placing stress on the layers overhead. Any gaps or breaks in the shale cap will cause the pressurized bitumen to flow upwards into areas of lower pressure, including into the permeable aquifers. In the Christina Lake vicinity, the Christina Channel aquifer actually penetrates below the hard shale layer into a more permeable sandstone layer above the McMurray Formation. Thus there is potential for direct connection between bitumen and the fresh groundwater, as illustrated in the diagram shown from the AGS's own report.

Another pathway that could connect the flowing bitumen to the aquifers is via the many abandoned wells in the area. Over the years, hundreds of exploratory and evaluation wells have been drilled through each of these aquifers and then through the shale cap layer into the McMurray Formation underneath. Regulatory requirements are for wells to be cased below aquifer depth and for cement plugs to be placed in old wells to seal them. However, King has identified many wells in this region with insufficient casing depth. Moreover, studies of well closures have revealed that a surprisingly high percentage of the seals degenerate and no longer plug the wells. King followed up his concerns with one of the companies operating in the area, who assured him that they were checking and resealing old wells on their leases. But he is still concerned about the gaps in the shale cap layer from wells that are not resealed.

Another risk is due to a particular geological instability of this region. Below the McMurray Formation is a deeper salt formation known as the Devonian evaporate or Devonian salt formation. Deeper groundwater in contact with this formation is causing it gradually to dissolve and collapse; the "front" of the collapsing zone is right below the Christina Channel portion of this aquifer network. Like a multi-storey building whose ground floor slowly caves in, the dissolving salt level introduces shifts and instability to the upper layers, including the shale cap layer above the McMurray



Potential connection between the aquifers and steam-pressurized bitumen from SAGD operations SOURCE: ALBERTA GEOLOGICAL SURVEY, ESR 2002-03, FIG. 52 (MODIFIED)

Formation. So even though companies operating here thoroughly mapped and monitored the formations prior to production start up, shifts can occur that make bitumen penetration into the aquifer layer possible.

Proof of this possibility occurred in May 2006 when a steam explosion occurred through a capping layer at a SAGD operation. This was in a different region, 60 km north of Fort McMurray, where the top of the bitumen layer is 60 to 70 metres below surface. Total E&P Canada, at its Joslyn operation, blew steam right up to ground level, spewing rocks and dirt over a 300 metre-wide circular swath created in the forest. The eruption lasted five minutes, no one was injured, and an operator shut down the well. In an incident report to the Energy and Utilities Board, Total explained that injection pressure was too high, creating a fracture at the depth of the injector, and that this anomaly was detected before the steam release. In future, they pledged to stop injection in a well if any anomaly was detected and reduce injection and circulation maximum pressures.

An accidental steam release at EnCana's Christina Lake project was fortunately blocked by the surrounding bitumen and sand. According to a June 2008 *Oilsands Review* article profiling the challenges of monitoring steam chambers, the steam was passing through a plastic monitoring well, which melted. EnCana's technical personnel interviewed for the article also stated that extensive monitoring of the steam chamber in the preproduction phase is very expensive; therefore, only rudimentary monitoring is done during the operational life of the project.

These examples demonstrate the need for the Energy Resources Conservation Board to insist upon stronger in situ operational procedures. Increased monitoring of steam pressure chambers during production and more vigilance on well materials under steam pressure are necessary. The bigger issue is the presence of so much in situ activity when the extent of these aquifers, their connections to other formations, and the sealing quality of the many historic wells is unknown. AWA recommends that new in situ operations not be approved until these risks can be better defined and reduced.

"Red Rock Canyon" 30x40 inches, acrylic ©B. ZHENG