Horn River Basin
Unconventional Shale Gas Play Atlas

JUNE 2014 | BC Oil and Gas Commission

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About the

BC Oil and Gas Commission

The BC Oil and Gas Commission (Commission) is the single-window regulatory agency with responsibilities for regulating oil and gas activities in British Columbia, including exploration, development, pipeline transportation and reclamation.

The Commission's core services include reviewing and assessing applications for industry activity, consulting with First Nations, cooperating with partner agencies, and ensuring industry complies with provincial legislation and all regulatory requirements. The public interest is protected by ensuring public safety, respecting those affected by oil and gas activities, conserving the environment, and ensuring equitable participation in production.

For additional information regarding this report please contact:

June Barker
Senior Petroleum Geologist
June.Barker@bcogc.ca
250-419-4400

Commission Mission

We regulate oil and gas activities for the benefit of British Columbians.

We achieve this by:
- Protecting public safety,
- Respecting those affected by oil and gas activities,
- Conserving the environment, and
- Supporting resource development.

Through the active engagement of our stakeholders and partners, we provide fair and timely decisions within our regulatory framework.

We support opportunities for employee growth, recognize individual and group contributions, demonstrate accountability at all levels, and instill pride and confidence in our organization.

We serve with a passion for excellence.

Vision

To be the leading oil and gas regulator in Canada.

Values

Respectful

Accountable

Effective

Efficient

Responsive

Transparent

Purpose of Report

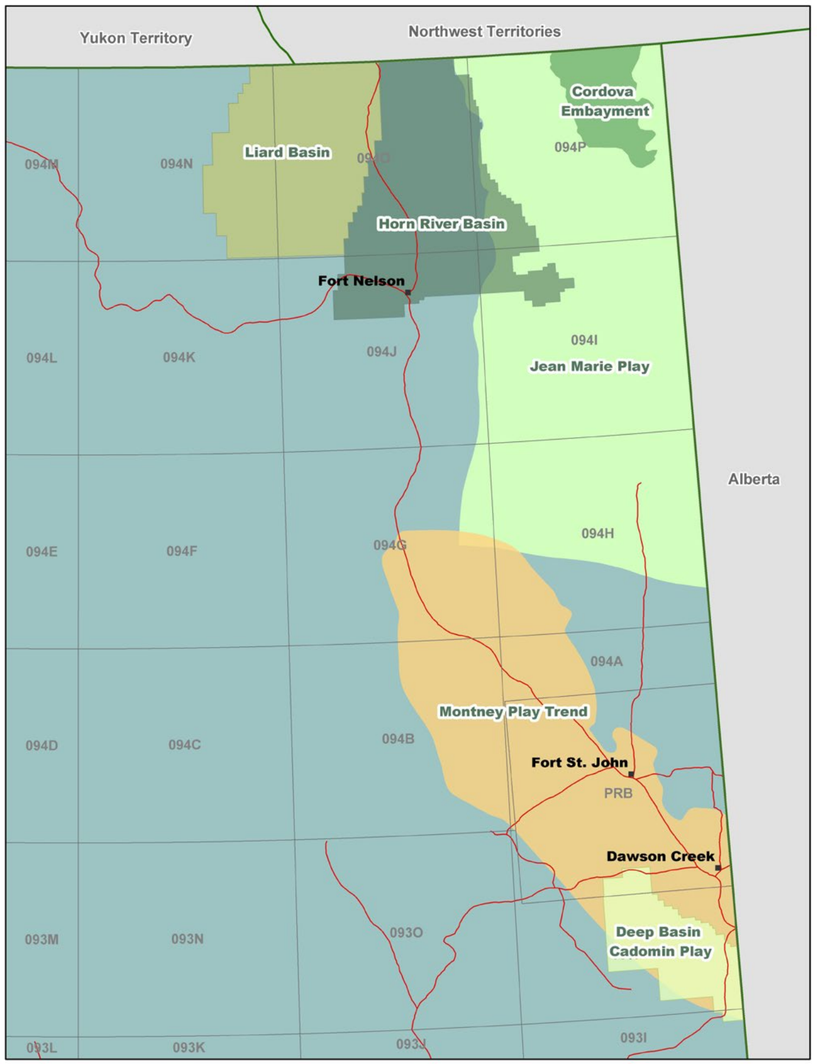
Horn River Basin Unconventional Shale Gas Play Atlas

The Commission's regulatory role includes understanding the impacts and distribution of the natural gas and petroleum resource base in the province.

This report includes regional mapping of the Muskwa, Otter Park and Evie Formations within the Horn River Basin (HRB).

The series of maps were derived from non-confidential well and core data to aid in the delineation and distribution of these formations within northeast British Columbia. Each map in this report links to a larger map available online at www.bcogc.ca.

Figure 1: Unconventional Gas Play Trends of NE British Columbia



Background
Unconventional Gas in the Horn River Basin

The Horn River Basin encompasses approximately 1.1 million hectares of land in northeastern British Columbia, north of Fort Nelson and south of the Northwest Territories border. Natural gas exploration and development occurring in the Horn River Basin over the past few years has been unconventional in nature. The advent of horizontal drilling combined with multi-stage hydraulic fracturing increased interest in unlocking the potential of shale gas. Prior to 2005, operators were targeting Devonian pinnacle reefs, with the basinal shales then considered a seal and source rock for gas. After 2005, operators began applying horizontal drilling and multi-stage hydraulic fracturing technology from the analogous Barnett shale in Texas to investigate economic recovery in the Horn River Basin.

Production in the Horn River Basin has been steadily increasing as shown in Figure 2. As of December 31, 2012, the Horn River Basin represented 28 per cent (11.1 tcf) of the province's remaining recoverable raw gas reserves. In 2012, 0.15 tcf was produced from the Muskwa-Otter Park and Evie Formations, accounting for 10 per cent of total production in the province. By December 2013, daily gas production reached 580 mmcf per calendar day from 203 producing wells.

As of December 2013, 291 horizontal and 78 vertical wells have been drilled across the Horn River Basin targeting shale gas. The play concept has extended several kilometres south and east of the pre-existing production as a result of 2012/13 drilling activity. A considerable quantity of well data, held confidential under the terms of Special Project Innovative Technology approvals, is now publicly available.

Figure 2: Horn River Basin Production History

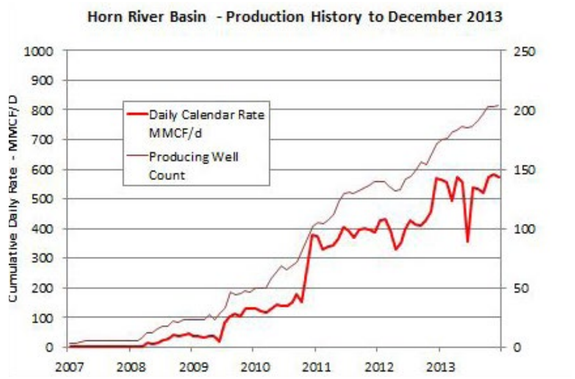


Figure 3: Daily Production Split for Northeast British Columbia (December 2013)

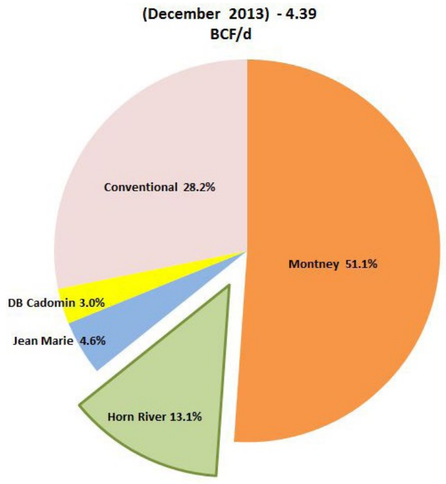
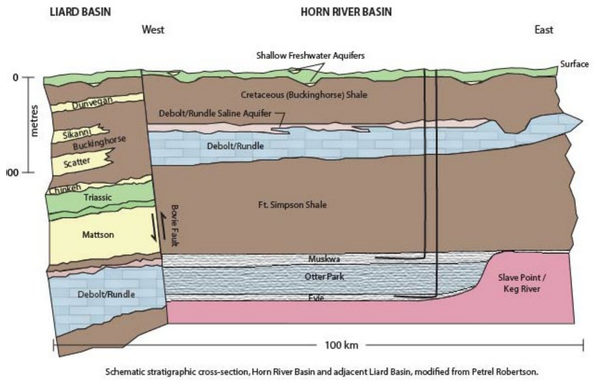


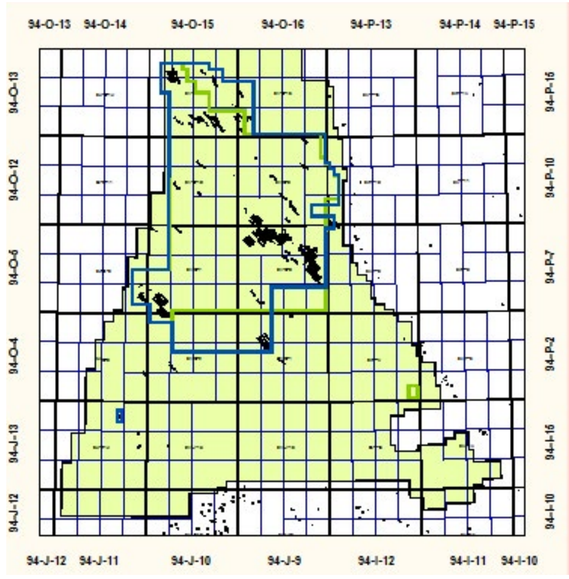
Figure 4: Horn River Basin Geology



Schematic stratigraphic cross-section, Horn River Basin and adjacent Liard Basin, modified from Petrel Robertson.

Figure 5: Horn River Basin Pool Designation Areas

Denotes wells drilled and the pool designation areas (PDAs) for the Muskwa-Otter Park (Blue outlines) and Evie (Green outlines).



Geology for Horn River Basin

The Horn River Basin is an unconventional shale play targeting dry gas from mid-Devonian aged over pressured shales of the Muskwa, Otter Park and Evie Formations. The Horn River Basin is confined to the west by the Bovie Lake Fault Zone and to the East and South by the time equivalent Devonian Carbonate Barrier Complex. Stratigraphically, the organic rich siliciclastic Muskwa, Otter Park and Evie shales of the Horn River group are overlain by the Fort Simpson shale and underlain by the Keg River platform carbonates.

The Evie Shale consists of dark grey to black, organic rich, pyritic, variably calcareous and siliceous shale. This shale exhibits relatively high gamma ray readings and high resistivity on well logs. The unit is at its thickest immediately west of the barrier reef complex, generally thinning westward towards the Bovie Lake Fault Structure.

The Otter Park Shale thickens considerably in the southeast corner of the Basin, characterized by increasingly argillaceous and calcareous facies. Limestone marls were deposited at the expense of shale. The unit thins to the north and west, exhibiting higher gamma ray readings.

The Muskwa Shale consists of grey to black, organic rich, pyritic, siliceous shale, and is also characterized by high gamma ray readings and high resistivity on well logs. A gradational contact exists between the overlying silt-rich shale of the Fort Simpson Formation. Generally, the Muskwa Formation thickens westward towards the Bovie Lake Structure. This shale thins and extends over the top of the barrier reef complex and continues eastward into Alberta, stratigraphically equivalent to the Duvernay Shale.

Muskwa and Otter Park formations were mapped in combination and analyzed as one interval. From a geomechanical perspective, the Muskwa and Otter Park Formations are considered as one flow unit after hydraulic fracturing with few barriers to fracture propagation. The Evie formation was evaluated and mapped as a separate unit. Mapping completed thus far has defined areas of reservoir variability within the Basin, particularly within the Otter Park Formation. Net Pay values mapped for each interval were derived from qualitative analysis of available open hole logs and should be considered estimates only. In general, gas pay is identified by increasing gamma ray, resistivity and density values and decreasing neutron response.

Reservoir Characteristics

A general range of reservoir parameters is provided in the following Table 1.

Due to the depth and corresponding high temperature and pressure of the Muskwa, Otter Park and Evie shale formations, the recoverable gas is sweet dry gas, >87 per cent methane, with trace amounts of ethane, (0.2 per cent) and heavier hydrocarbon components, C_3+, (<0.1 per cent). The majority of gas analyses show no H_2S, or very low levels, with slightly higher values in the Evie. CO_2 content in the recoverable gas averages 10 per cent in the Muskwa-Otter Park formations and 12 per cent in the Evie formation, and generally increases with depth in the Basin. The average values and range of components typically found in Horn River gas are summarized in Table 2.

Drilling And Completions

Advancements in horizontal well technology and hydraulic fracturing were key to unlocking the reserves in the HRB. Up to 16 horizontal wells per pad have been drilled, receiving multi-stage slickwater fracture programs with 18 fracture stages, 64,000 m^3 of water and 3,700 T of sand on average, based on stats for 130 wells completed between 2010-2012. Microseismic monitoring is used extensively in the HRB to identify faults, optimize fracture design and study fracture growth. To date, the overlying Ft. Simpson shale has been demonstrated to be a highly effective fracture barrier.

The horizontal leg of each well is commonly cemented with casing and a “perf and plug” technique used to initiate fractures, starting at the toe of the well and proceeding to the heel. Each hydraulic fracture stage is isolated with bridge plugs and receives multiple perforations prior to pumping the stage. Once all the stages are complete, the bridge plugs are drilled out and the fracture water is flowed back to surface. On average, 40 per cent of fracture water is flowed back to surface on clean up and production, with the majority recycled.

To date, the majority of wells in the HRB are completed through casing (95 per cent), with open hole completions conducted in five per cent of wells. The fracture fluid is predominately slickwater, with N2 gas, an energizer, used in a few wells.

Water Usage and Disposal

The eastern flank of the HRB contains favorable Mississippian strata (Debolt formation) for sourcing and disposing of water necessary for large scale hydraulic fracture operations. Mississippian sourced water in the Horn River area is non-potable (15,000 – 40,000 mg/l total dissolved solids) and significantly reduces the demand for usable water from other sources. This extensive deep subsurface Debolt regional aquifer essentially allows source/disposal recycling of fracture water.

Table 1: Horn River Shale Reservoir Parameters

RESERVOIR DATA	
Depth Range	1,900-3,100m
Gross Thickness	140-280m
TOC Range	1-5%
Porosity	3-6%
Water Saturation	25%
Pressure	20-53MPa
Pressure Regime	Normal-Over Pressure
Temperature	80-160ºC

Table 2: Horn River Gas Composition, Mole Percentage

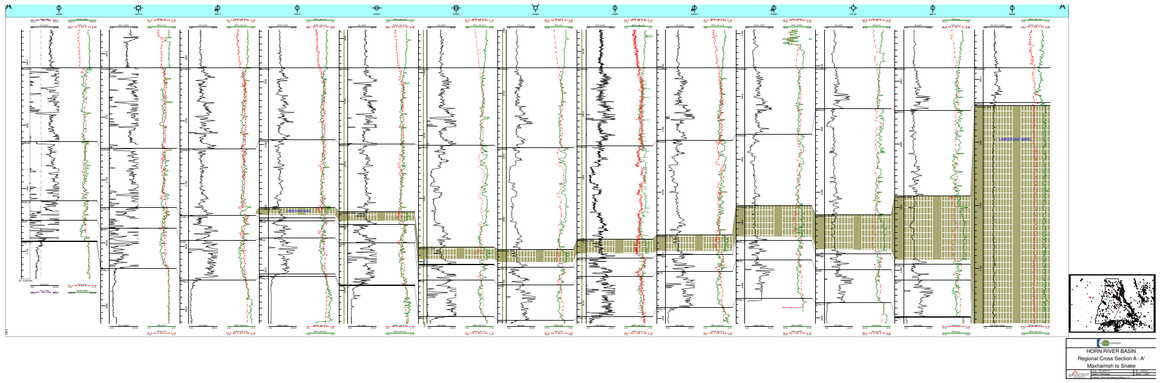
GAS COMPOSITION, Avg (Min-Max) %	Muskwa-Otter Park	Evie
Methane (C_1)	89 (71-95)	87 (75-98)
Ethane (C_2)	0.2 (0.01-3)	0.2 (0.01-7)
NGLs (C_{3+})	0.05 (0-4)	0.07 (0-4)
CO_2	10 (4-22)	12 (0-19)
H_2S	0 (0-0.1)	0.07 (0-0.1)

Table 3: Horn River Shale Drilling and Completions (2010-2012)

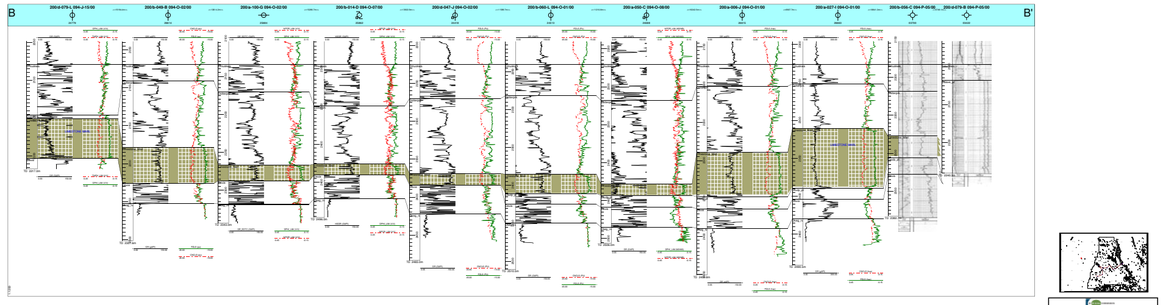
DRILLING DATA	
Wells/pad	Up to 16
Well Spacing	100 - 600m, avg 300m
HZ Length	Up to 3,100m, avg ~1,500m
Wellbore	Cased
COMPLETION DATA	
Frac Type	Perf and Plug
Frac Fluid	Slickwater
Frac Stages	Up to 31, avg 18
Pump Rate	8 - 16 m^3/min
Water/well	avg 64,000 m^3
Sand/well	avg 3,700 T

Regional Cross Sections

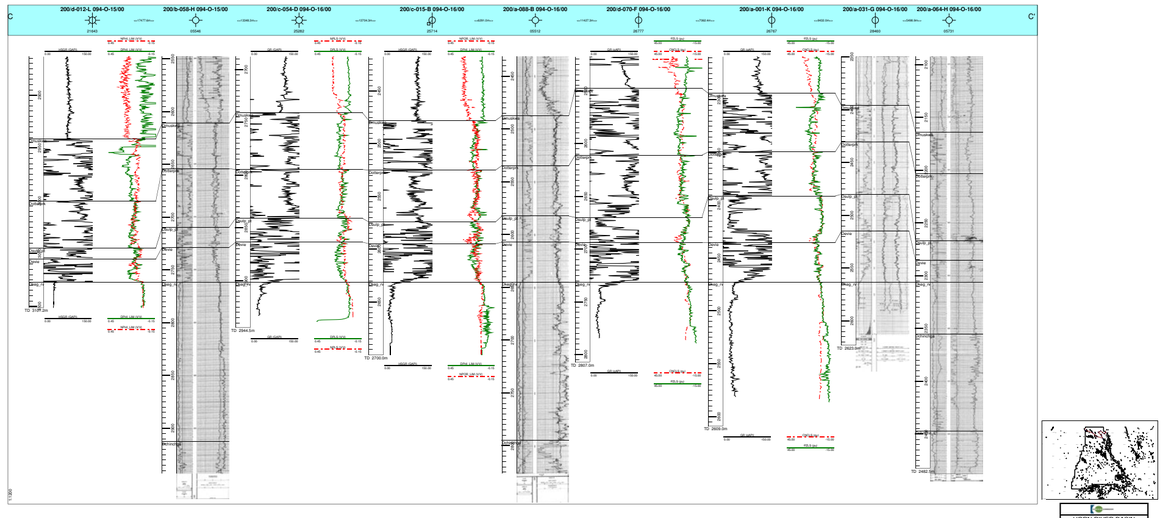
Regional Cross Section A - Maxhamish to Snake



Regional Cross Section B - Evie/Snake to Gunnell Creek



Regional Cross Section C - Maxhamish to Petitot



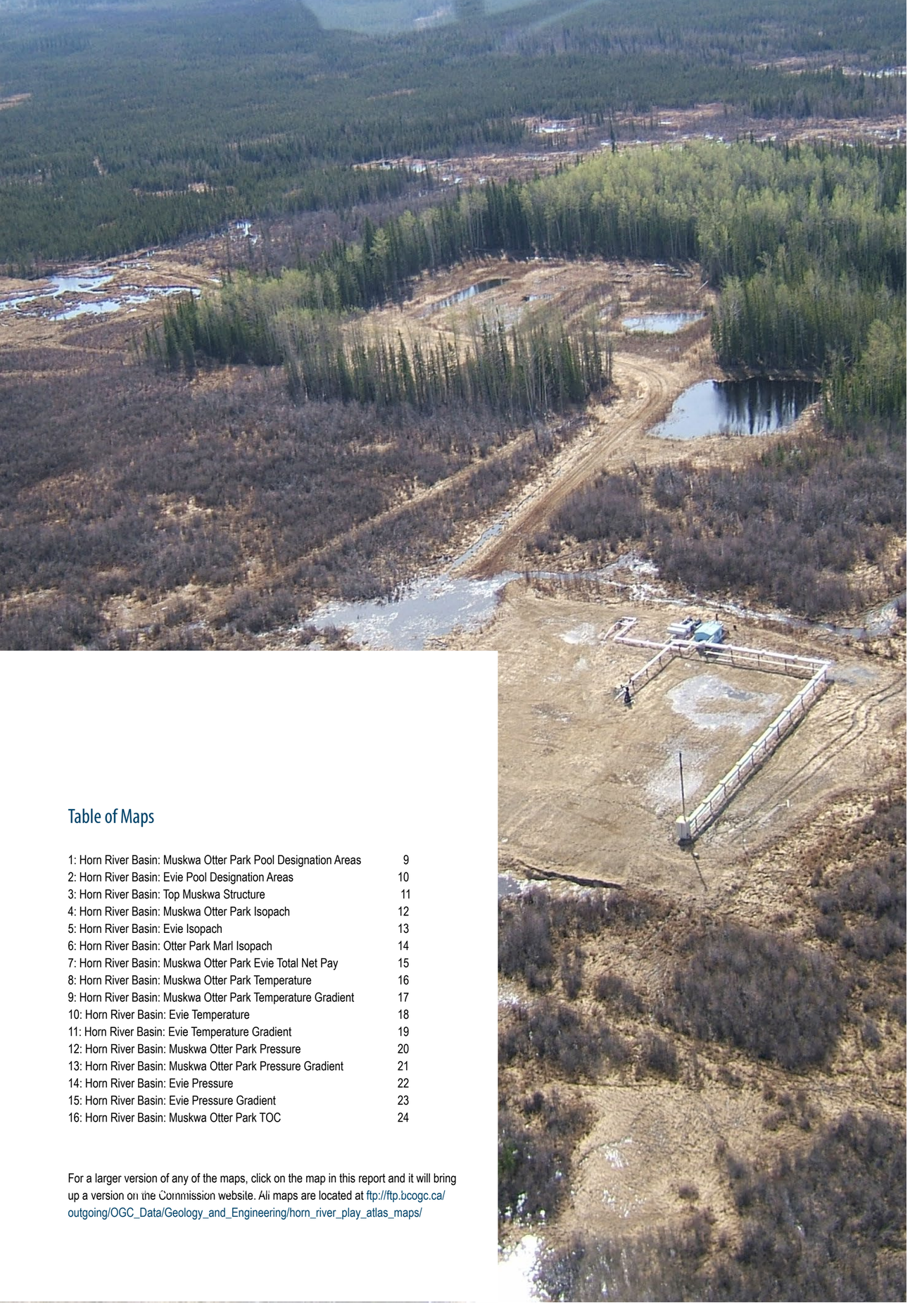
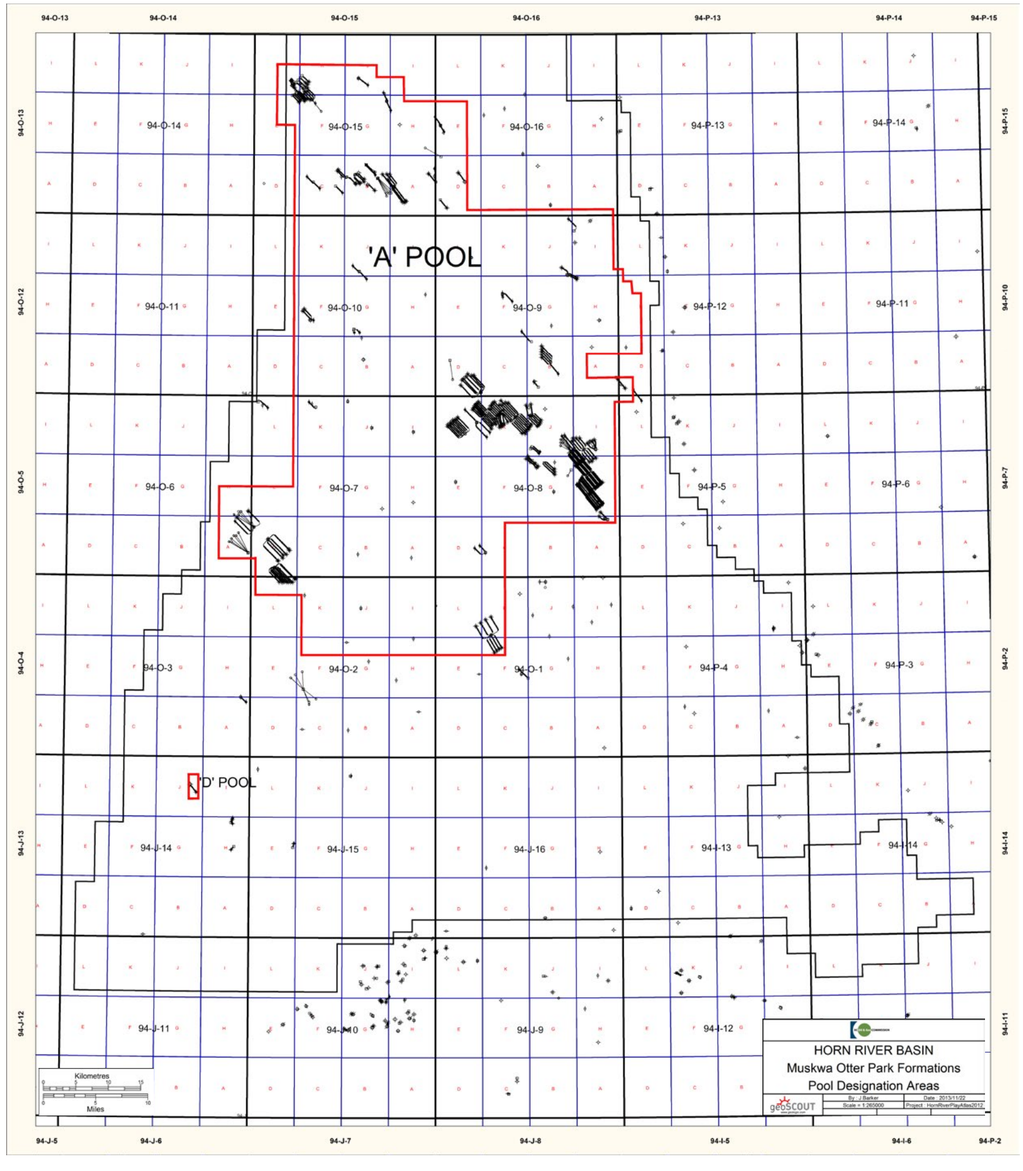


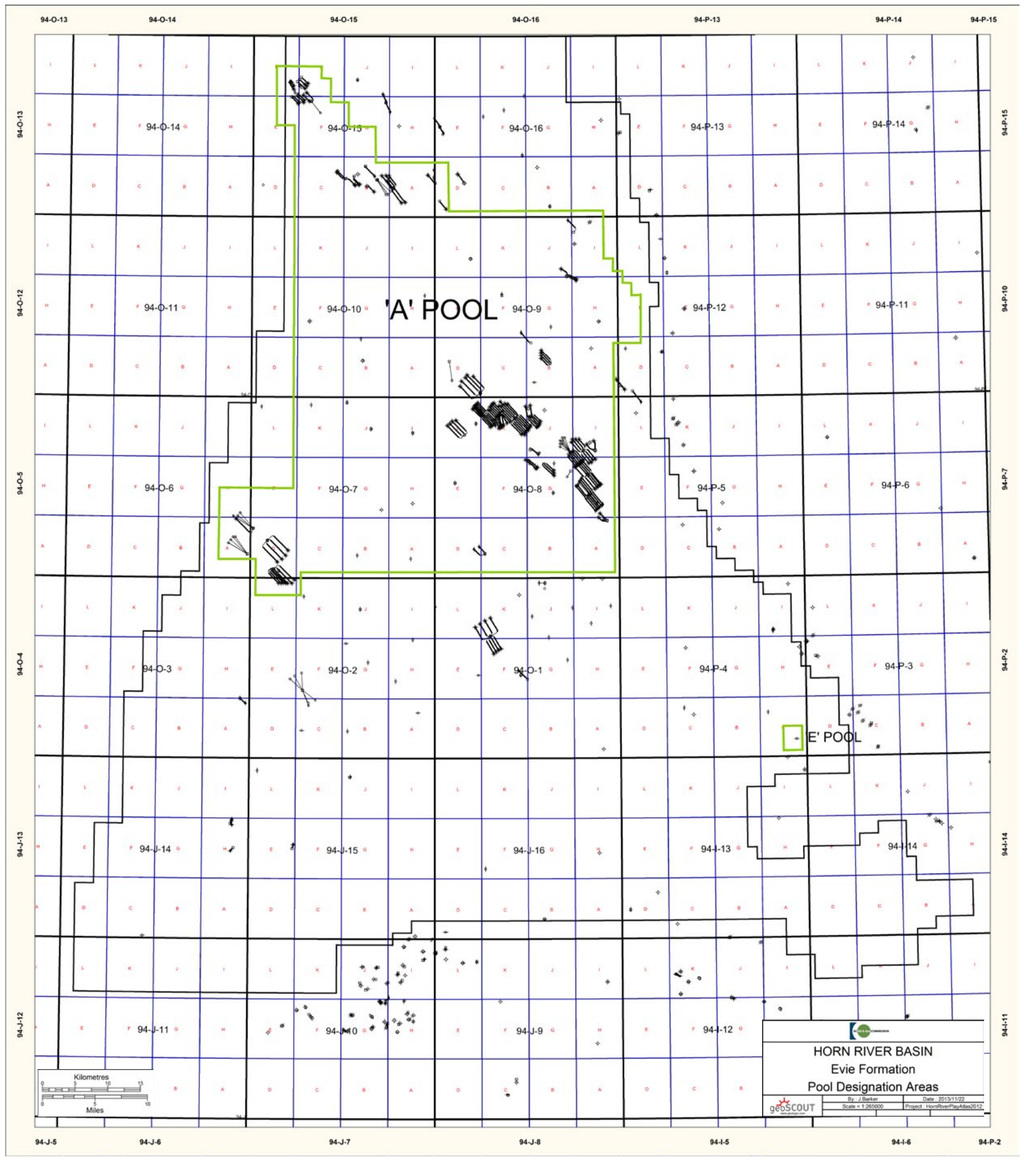
Table of Maps

For a larger version of any of the maps, click on the map in this report and it will bring up a version on the Commission website. All maps are located at ftp://ftp.bcogc.ca/outgoing/OGC_Data/Geology_and_Engineering/horn_river_play_atlas_maps/

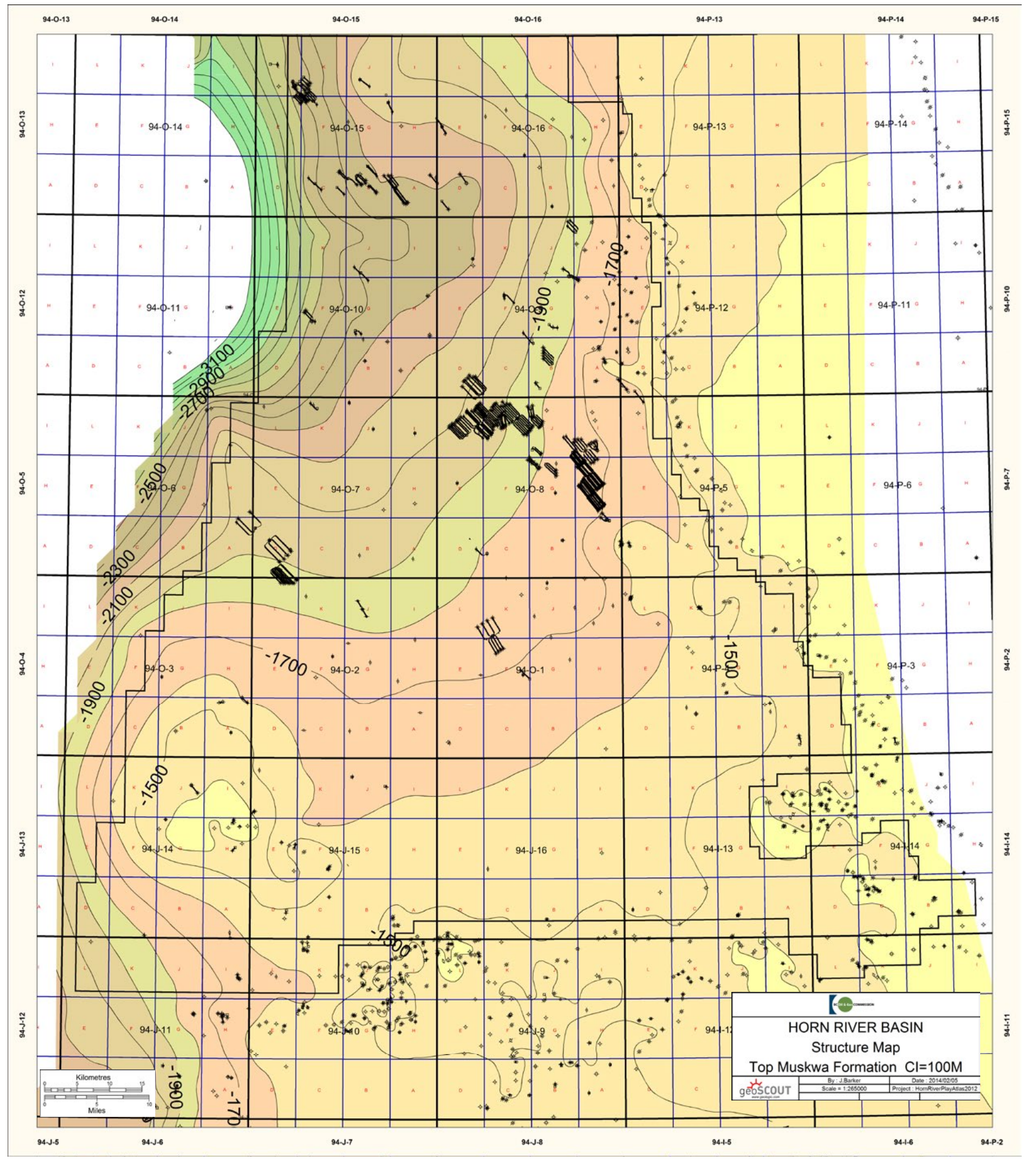
Map 1: Horn River Basin: Muskwa Otter Park Pool Designation Areas



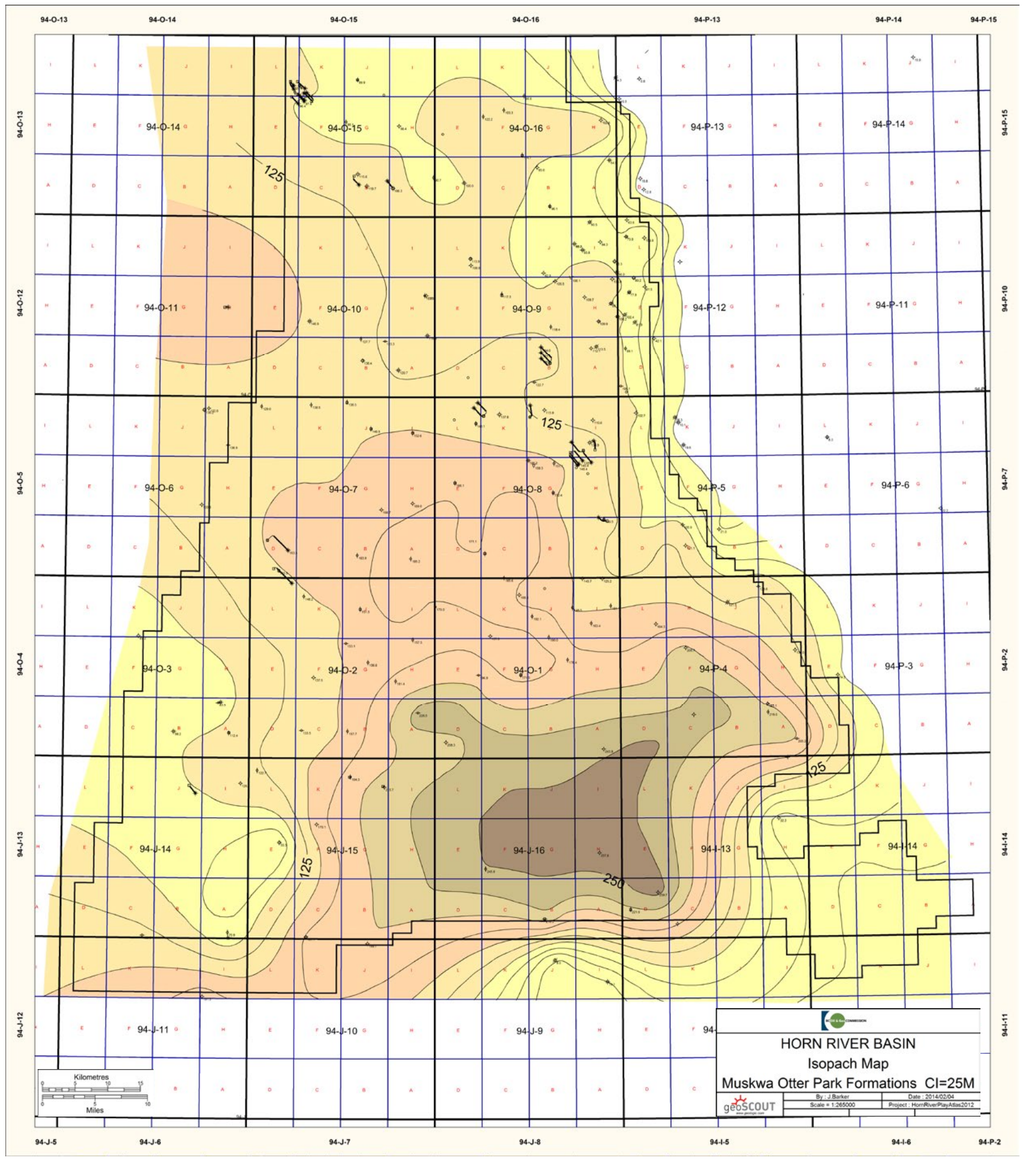
Map 2: Horn River Basin: Evie Pool Designation Areas



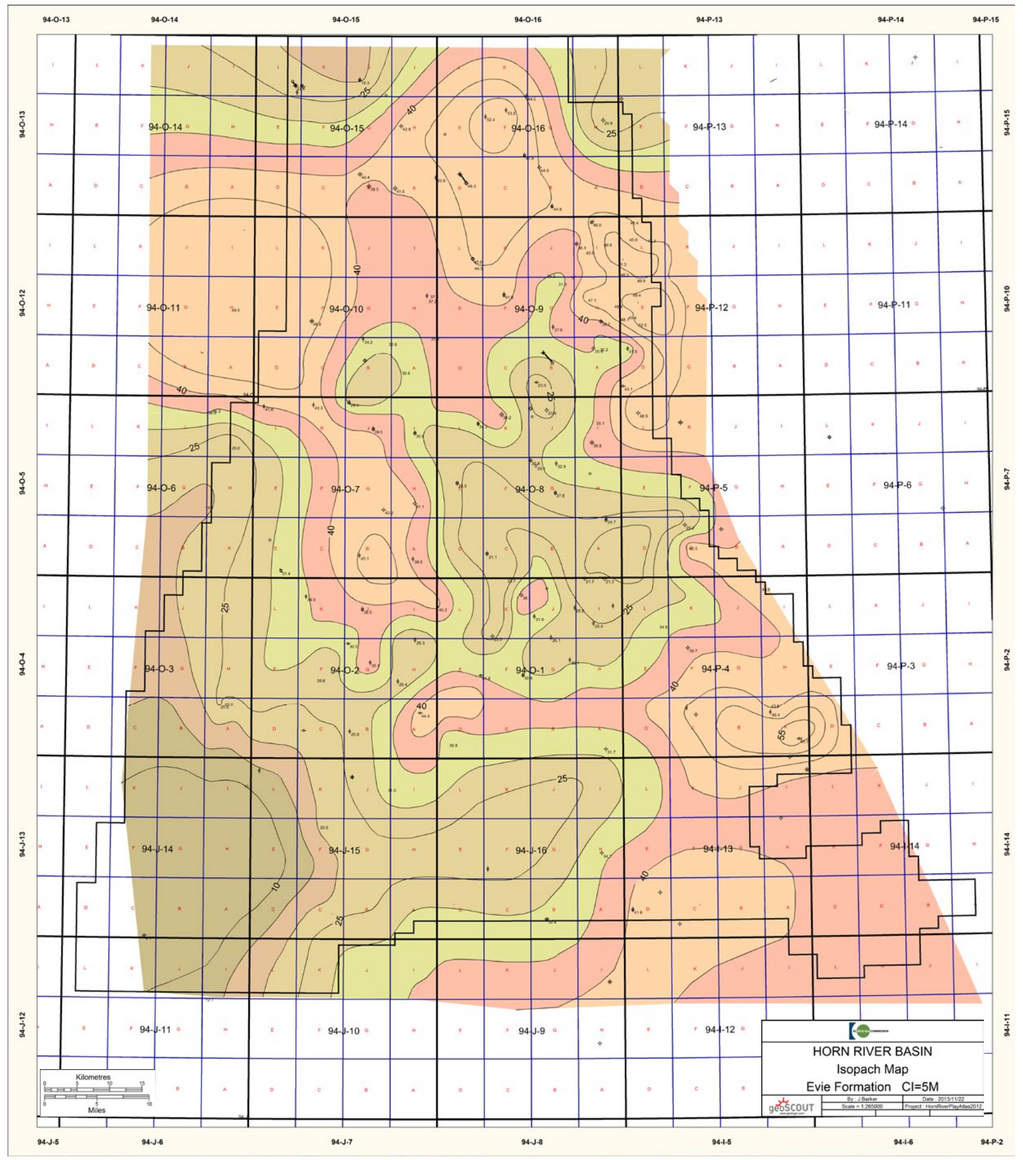
Map 3: Horn River Basin: Top Muskwa Structure



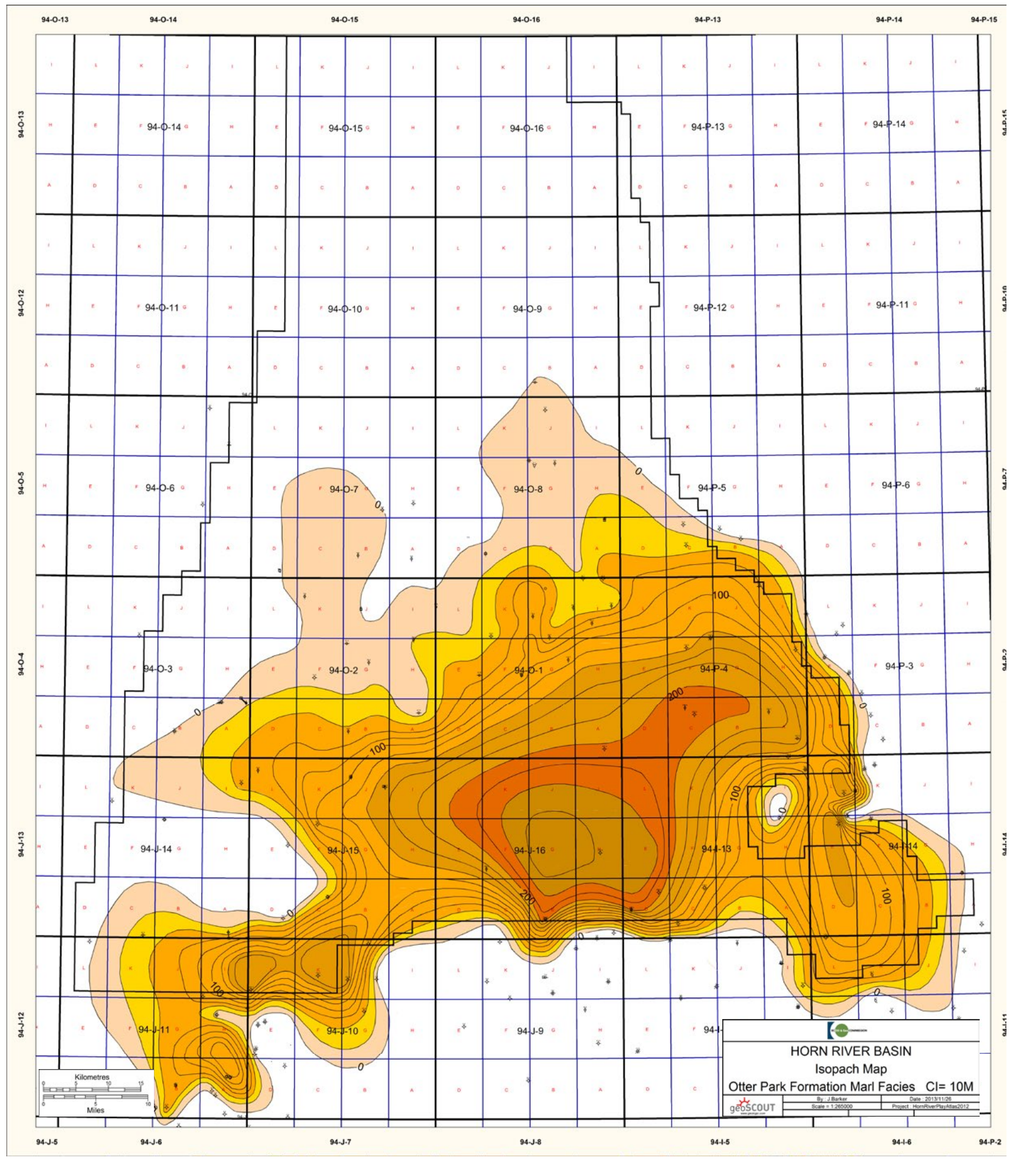
Map 4: Horn River Basin: Muskwa Otter Park Isopach



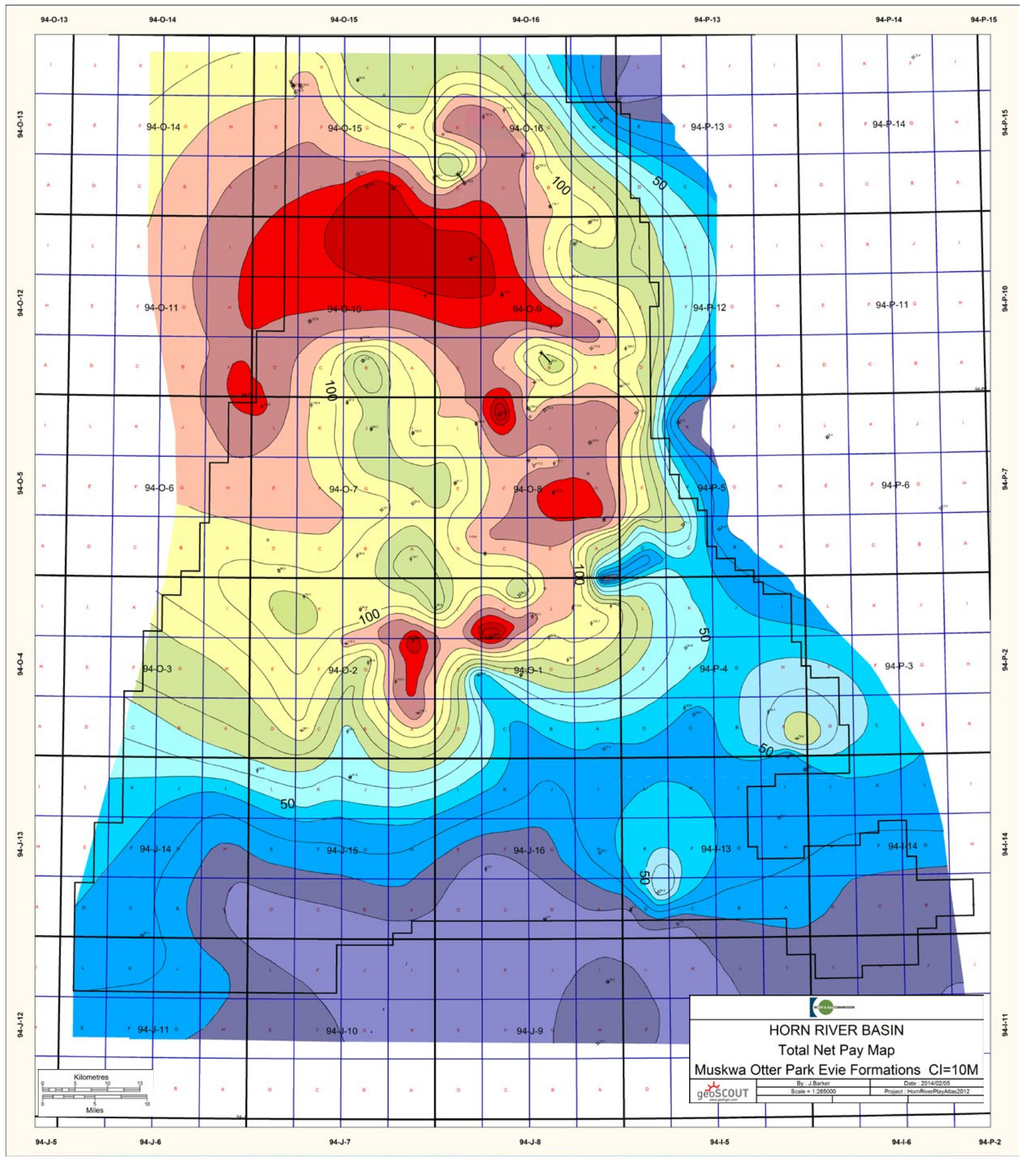
Map 5: Horn River Basin: Evie Isopach



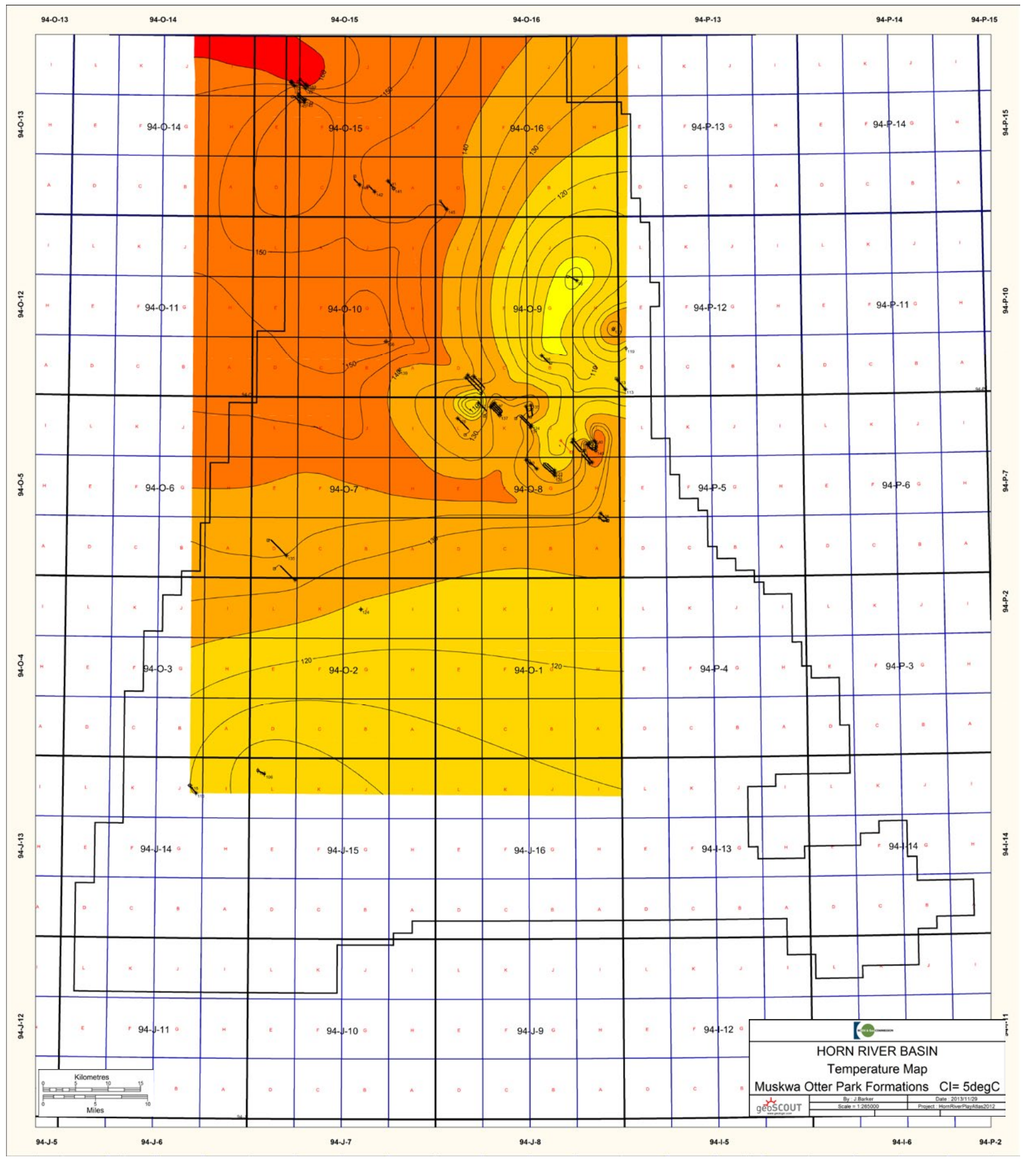
Map 6: Horn River Basin: Otter Park Marl Isopach



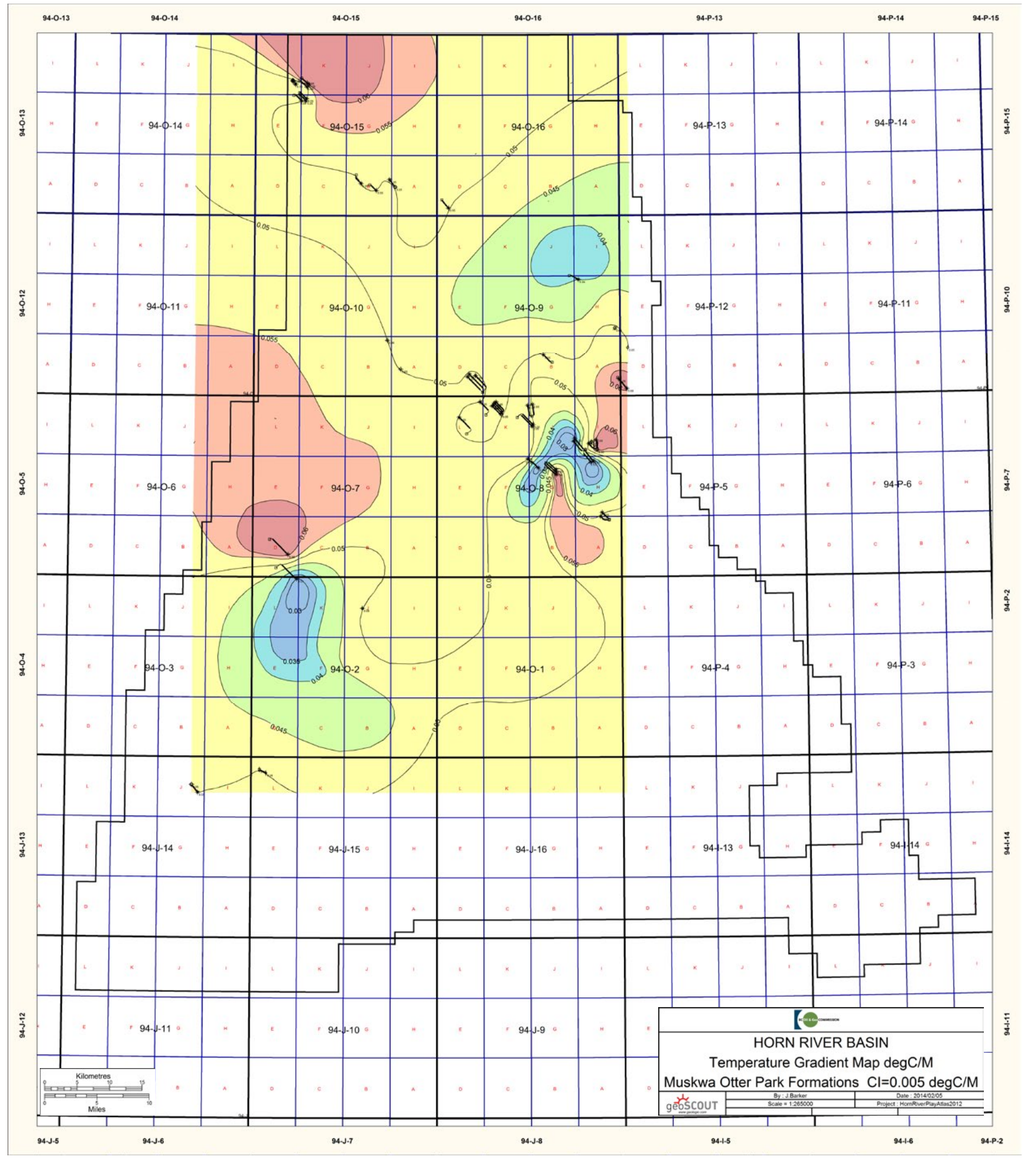
Map 7: Horn River Basin: Muskwa Otter Park Evie Total Net Pay



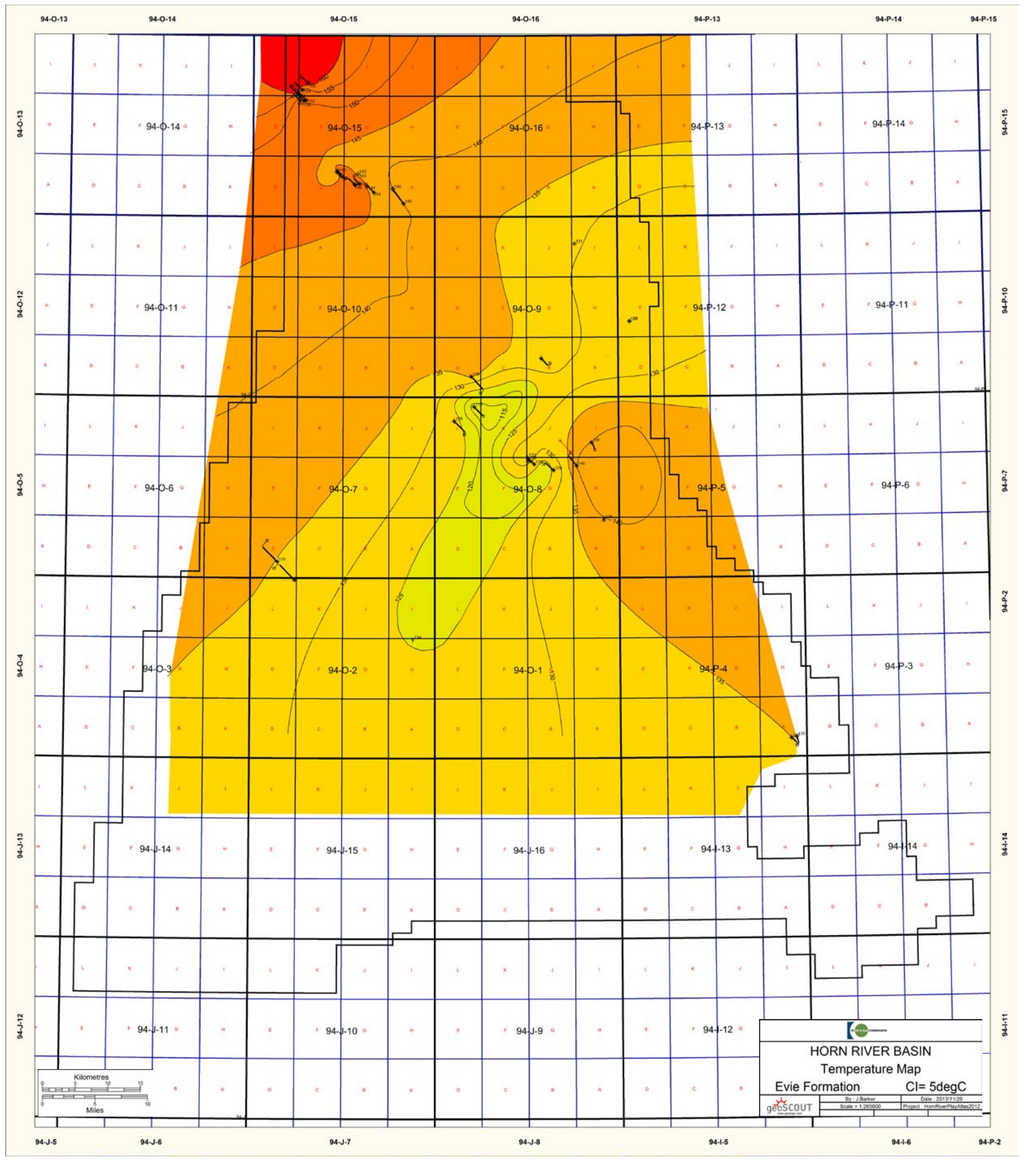
Map 8: Horn River Basin: Muskwa Otter Park Temperature



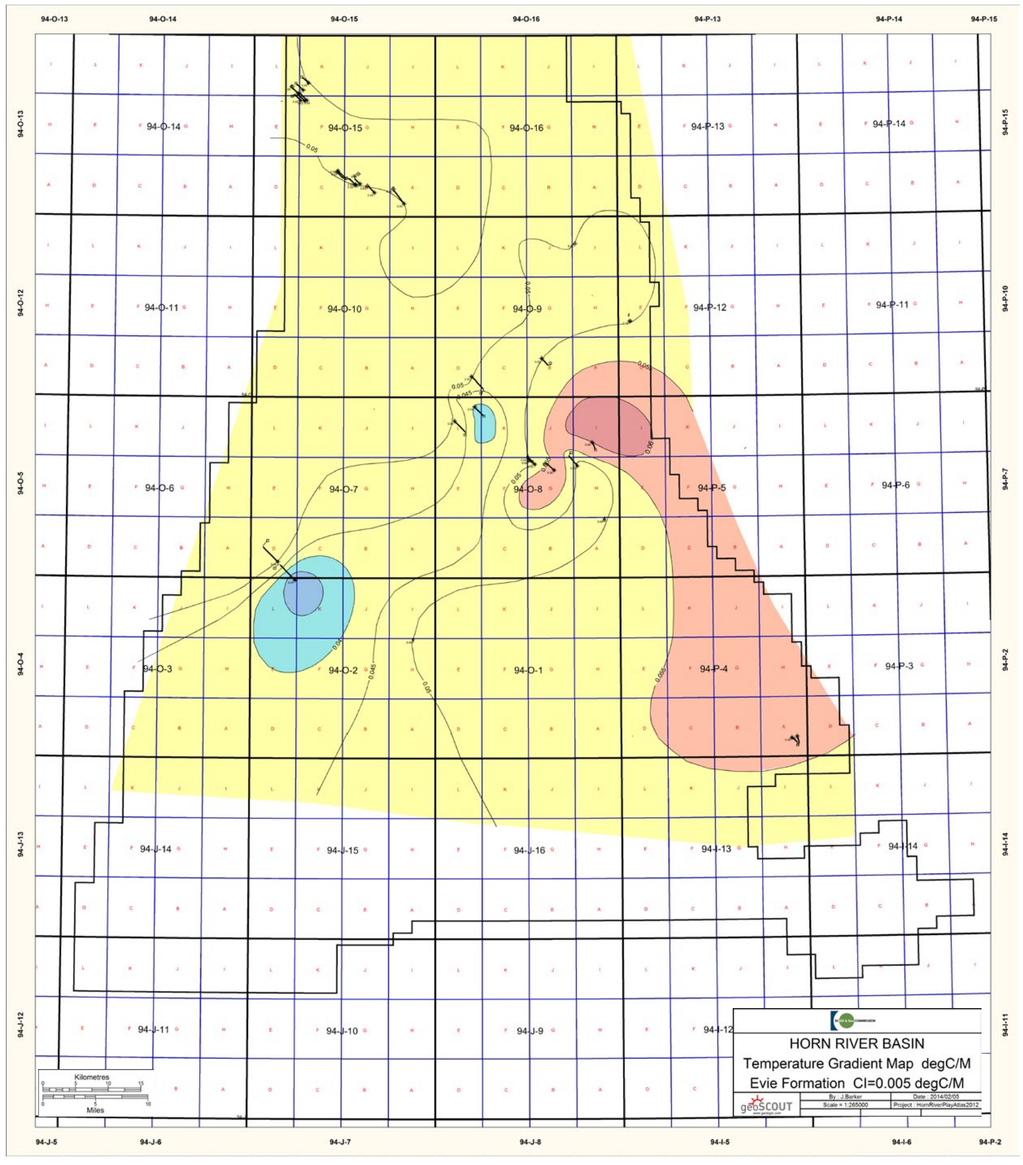
Map 9: Horn River Basin: Muskwa Otter Park Temperature Gradient



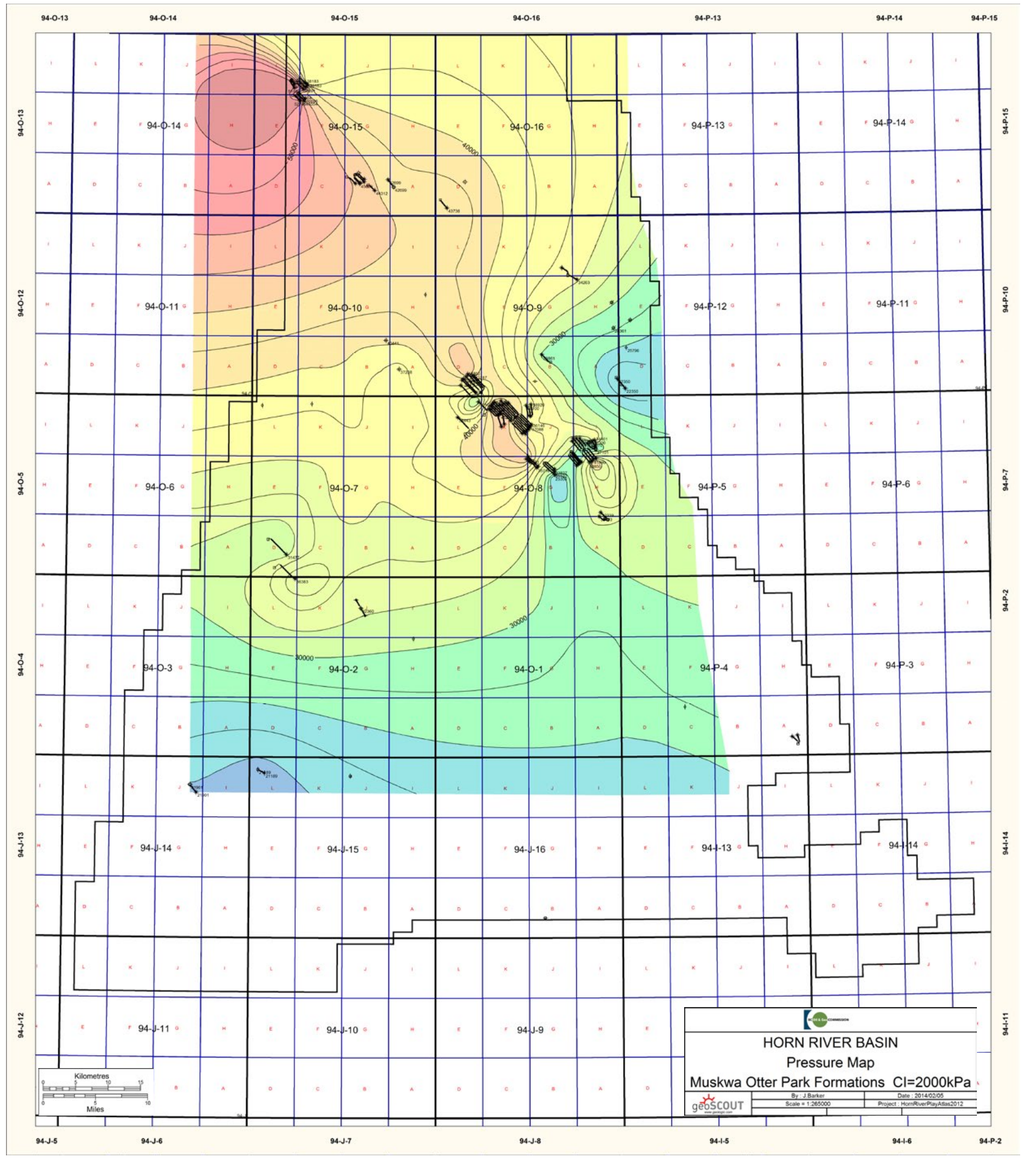
Map 10: Horn River Basin: Evie Temperature



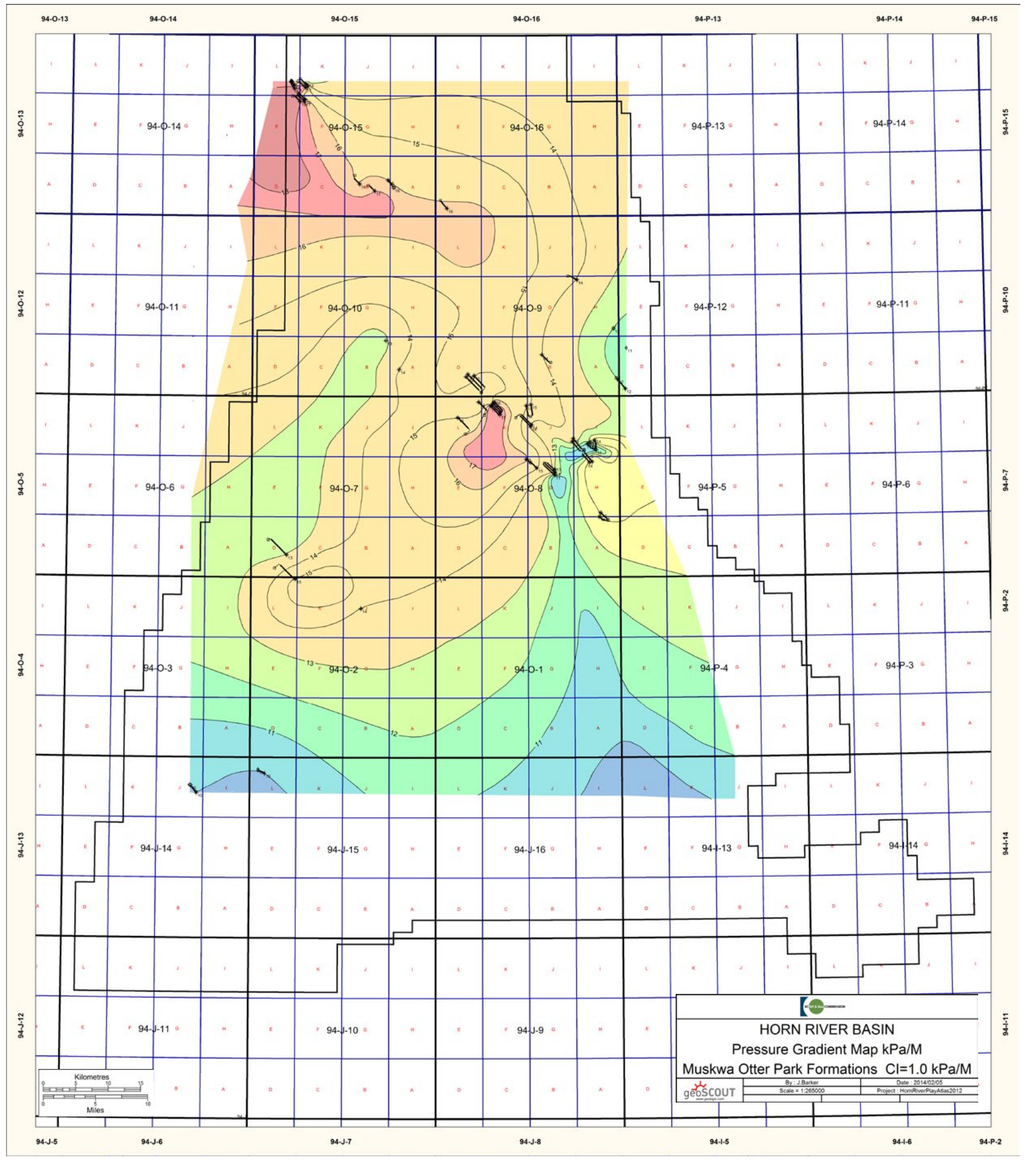
Map 11: Horn River Basin: Evie Temperature Gradient



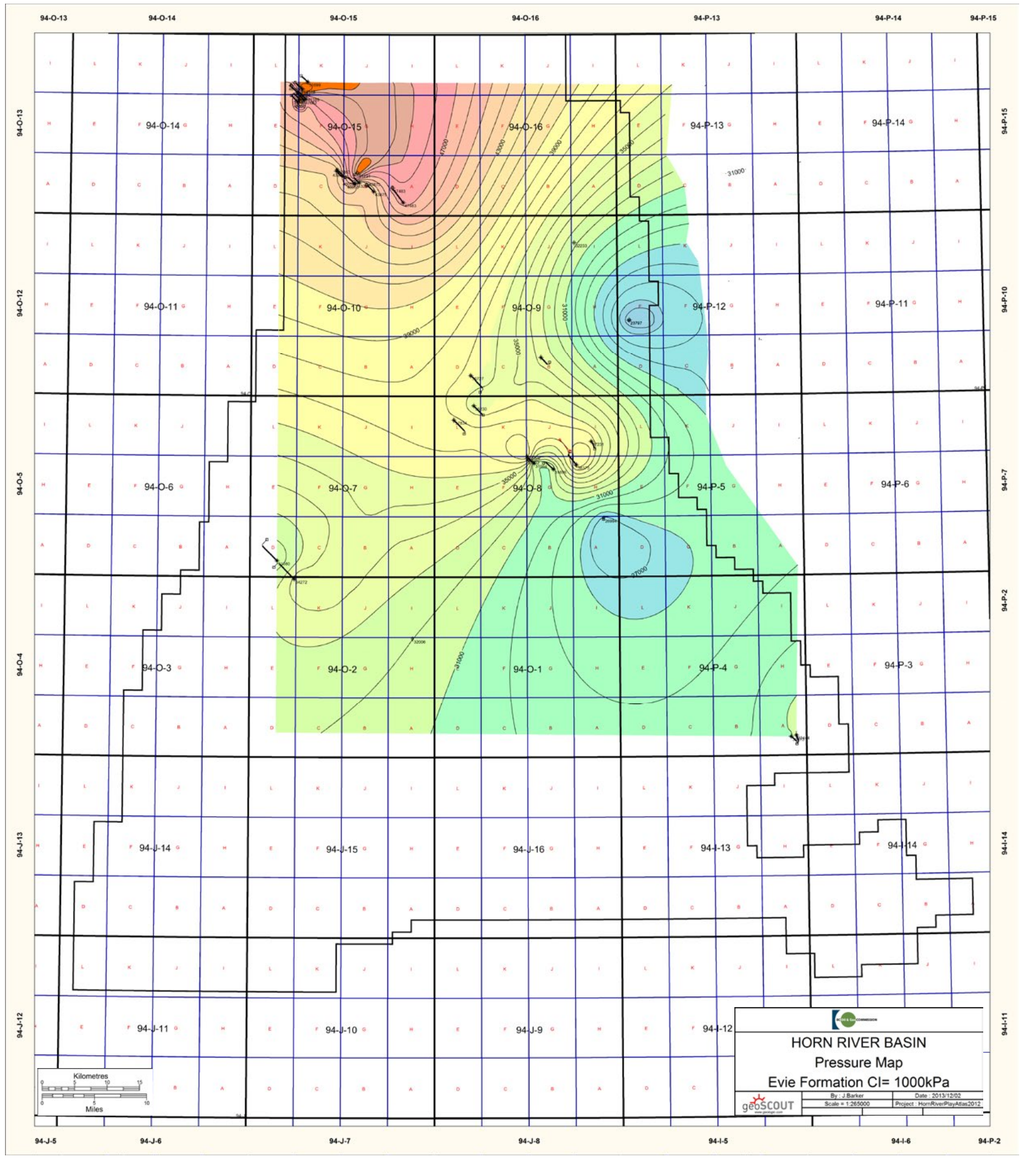
Map 12: Horn River Basin: Muskwa Otter Park Pressure



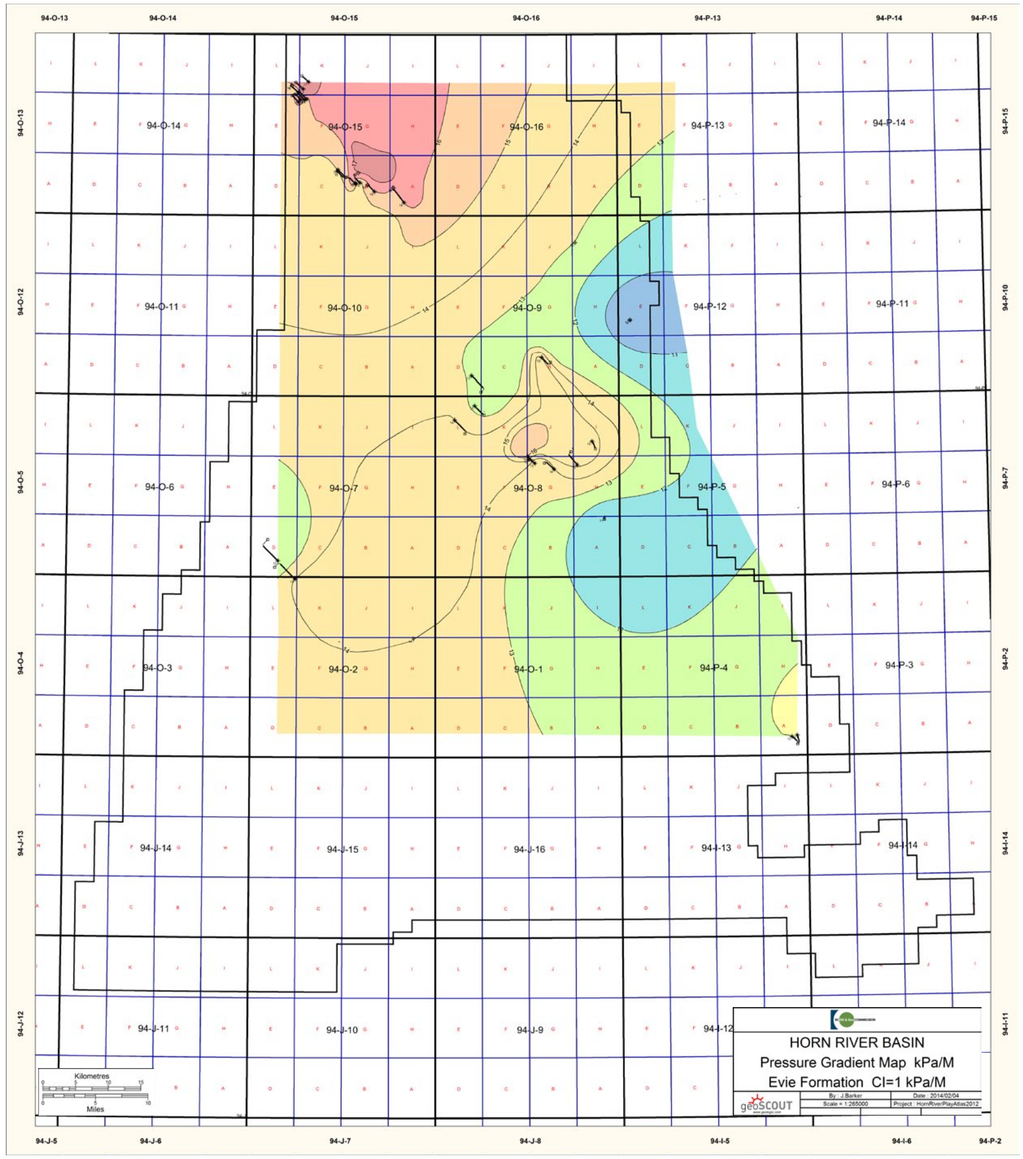
Map 13: Horn River Basin: Muskwa Otter Park Pressure Gradient



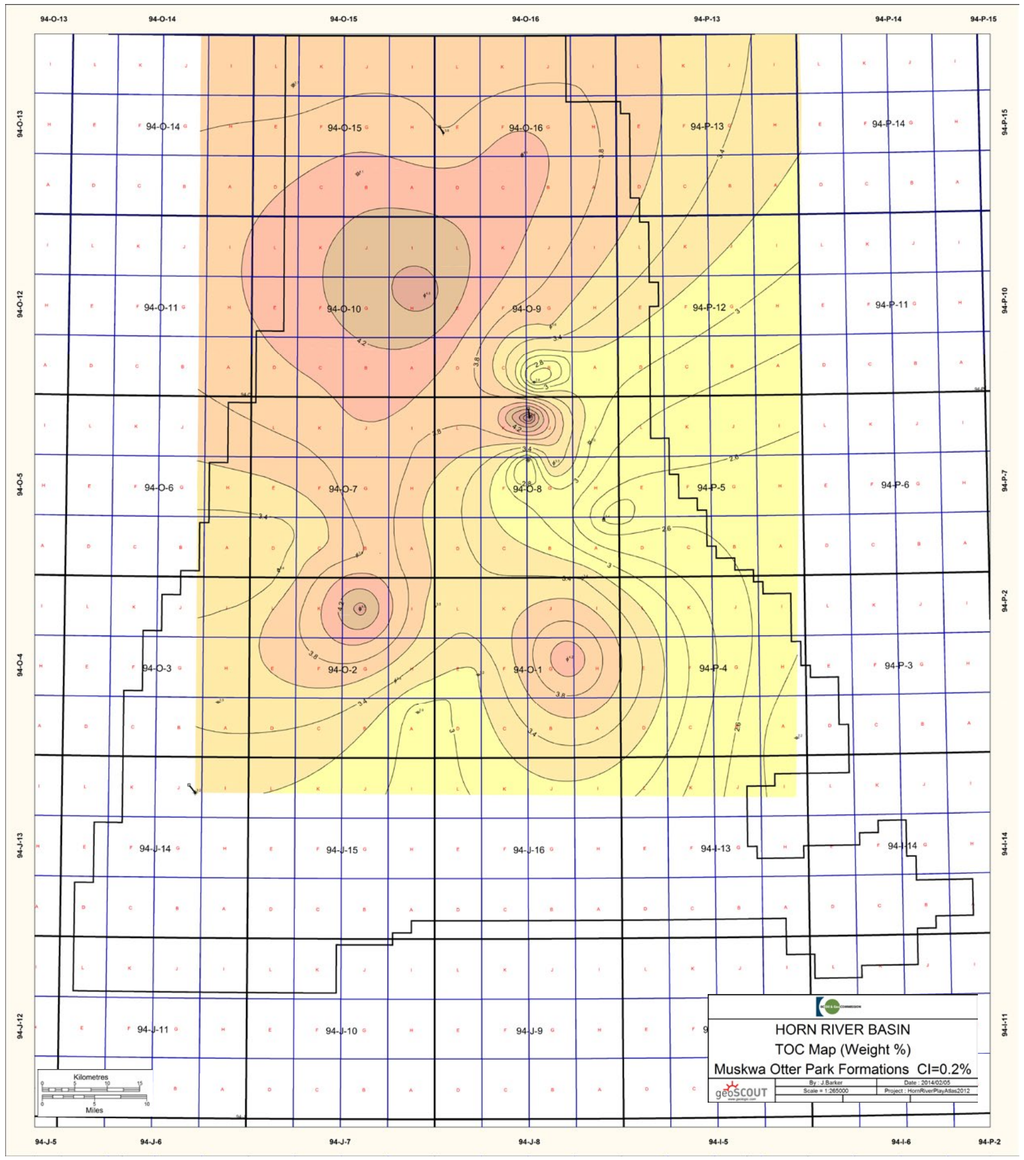
Map 14: Horn River Basin: Evie Pressure



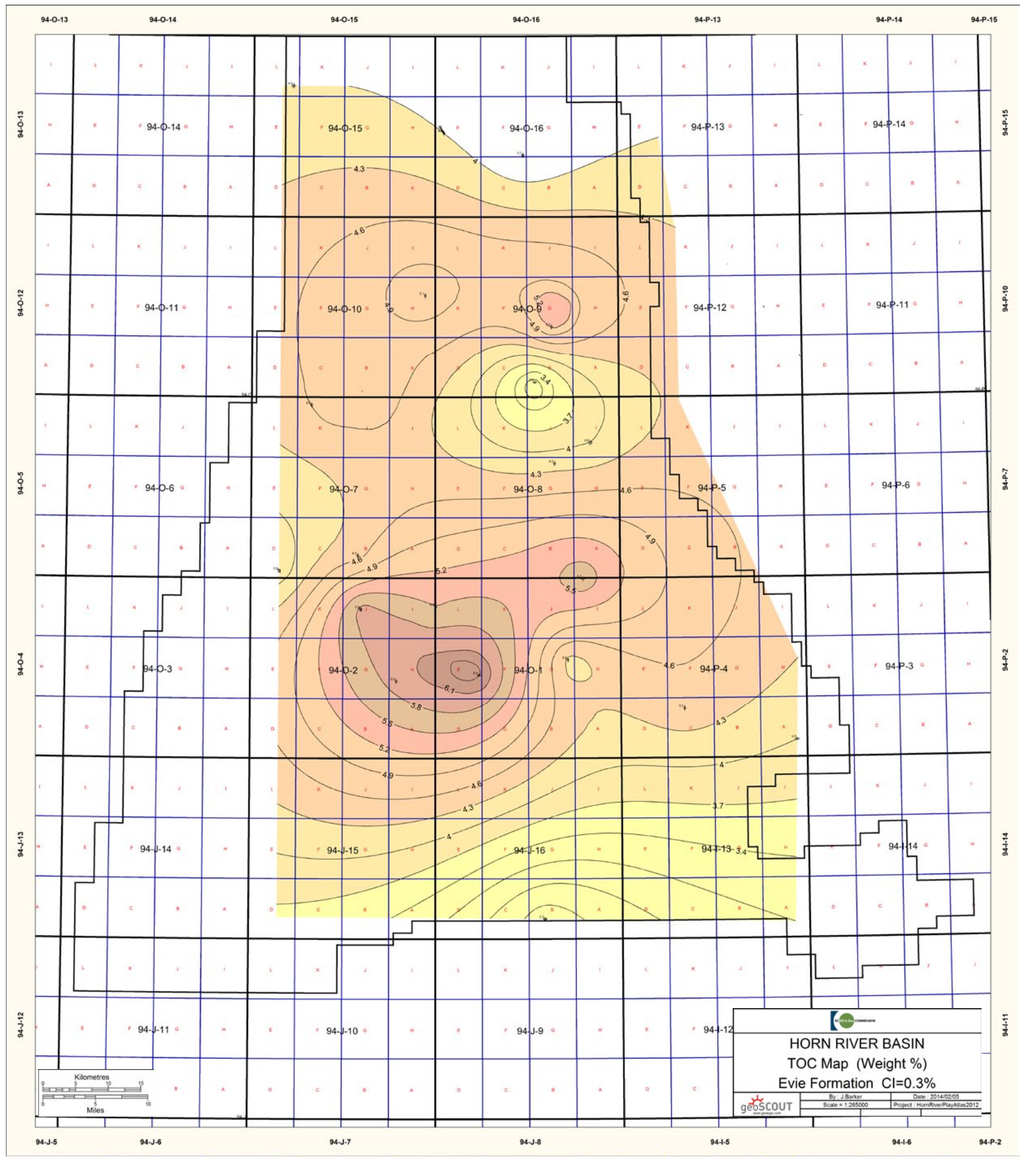
Map 15: Horn River Basin: Evie Pressure Gradient



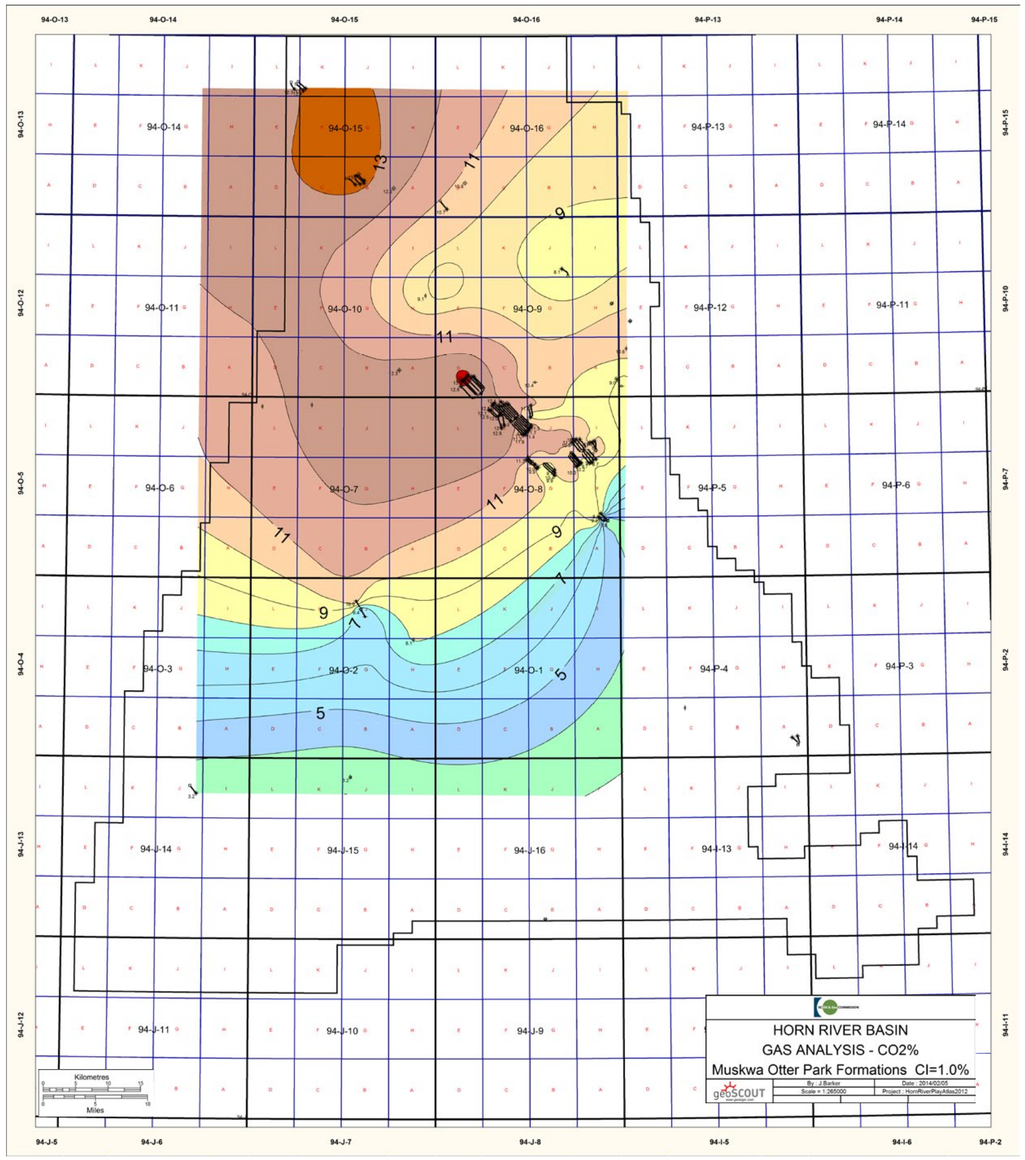
Map 16: Horn River Basin: Muskwa Otter Park TOC



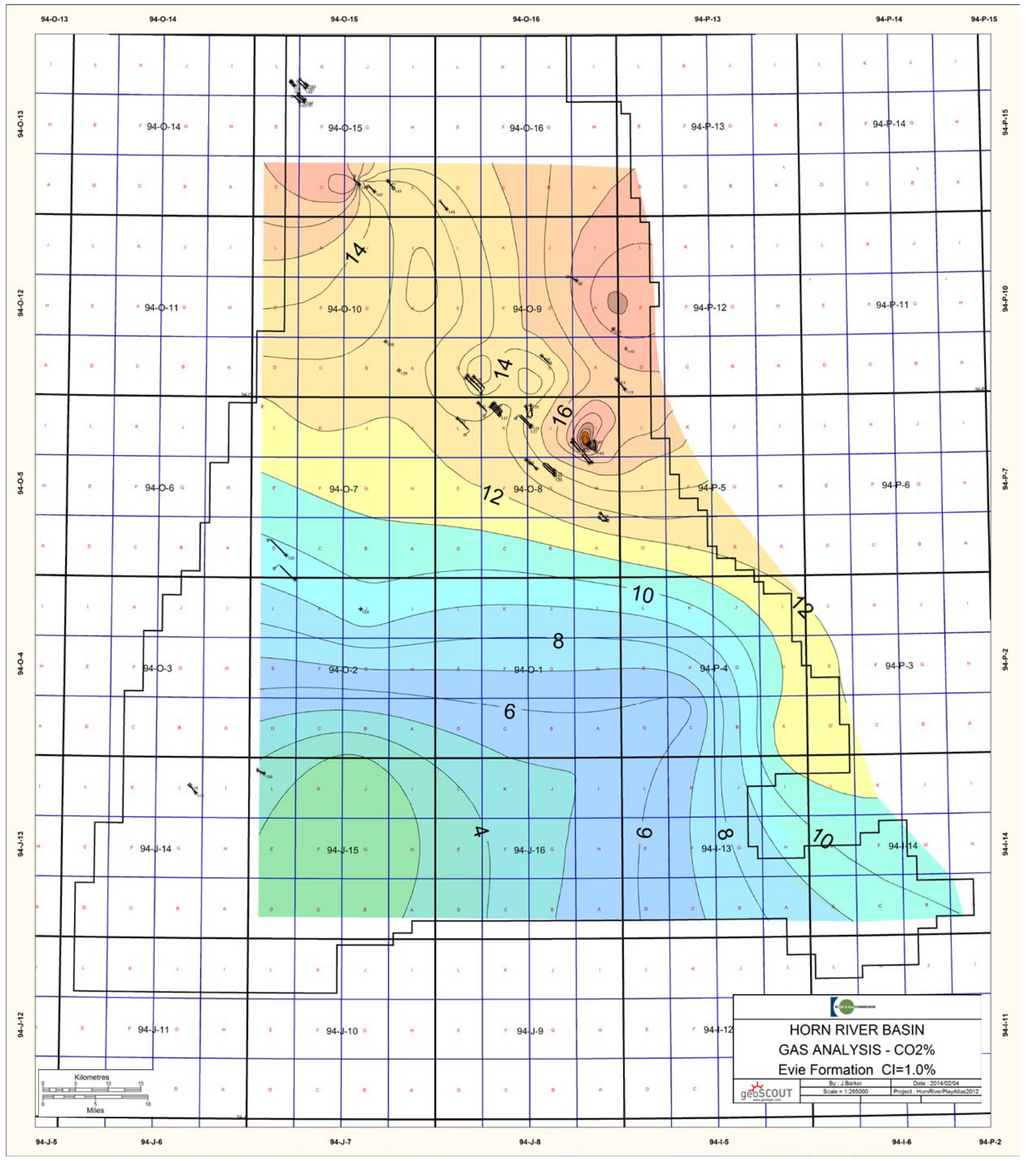
Map 17: Horn River Basin: Evie TOC



Map 18: Horn River Basin: Muskwa Otter Park CO^2 Per Cent



Map 19: Horn River Basin: Evie CO^2 Per Cent



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