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Groundwater Monitoring & Aggregate Operations in the Villeneuve-Calahoo Area

William Gowdy, BSc. P.Geo

A member of LafargeHolcim

Format of Talk

- General Background Sand and Gravel
- Geology & Formation of Sand and Gravel Deposits in Alberta
- Sturgeon County Regional Groundwater Network
- Groundwater Modelling and Monitoring
- Groundwater Response to Aggregate Operations
- Reclamation & Impacts on Groundwater

What is Aggregate?

- "**Aggregate**" is a broad category of coarse particulate material used in construction, including sand, gravel and crushed stone.

- **Crushed Stone (Quarried Material – Consolidated)**

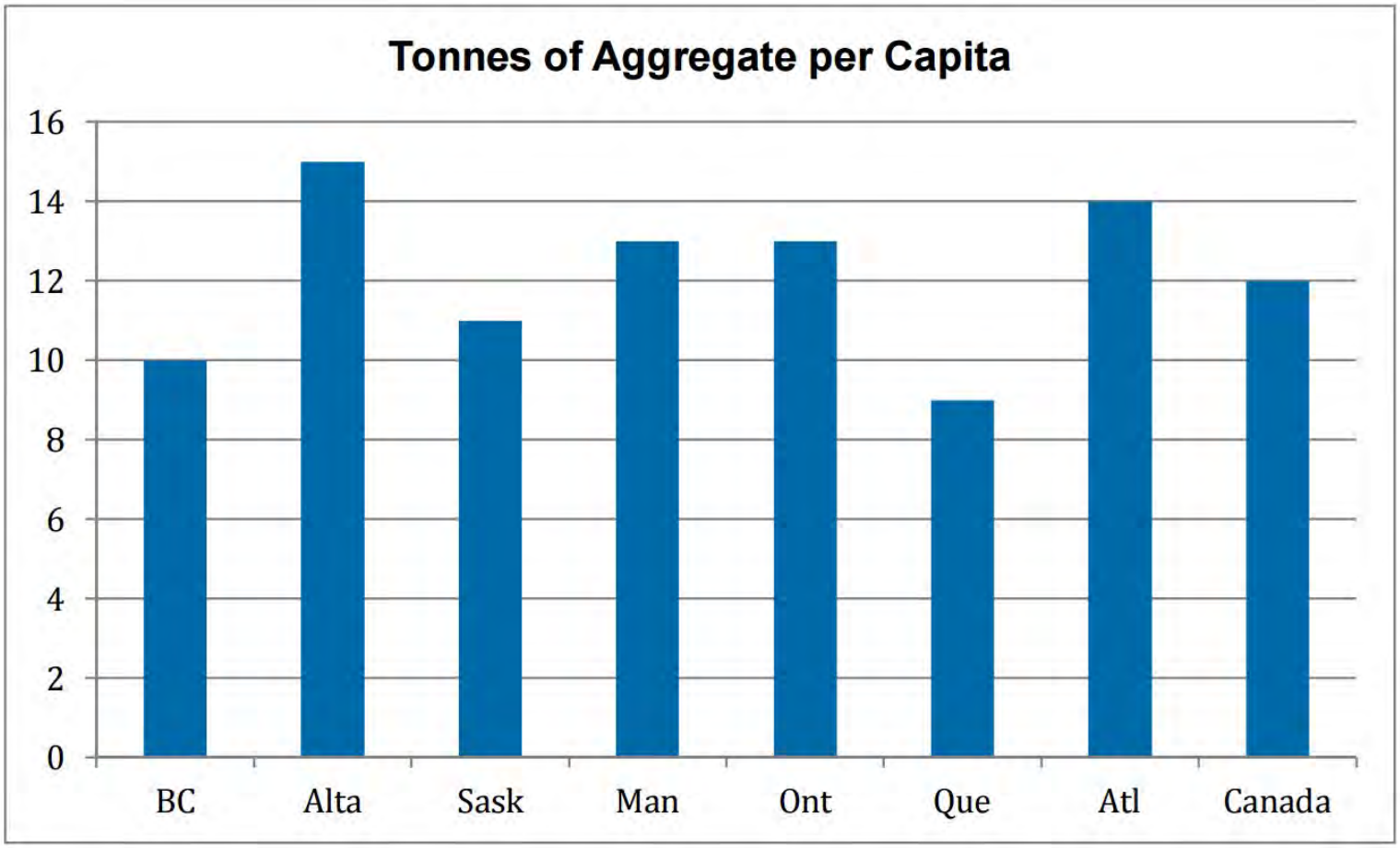
- **Sand and Gravel (Unconsolidated Deposits)**
  - Fluvial or Glaciofluvial (Flowing Water Derived)
  - Lacustrine (Lake Derived)
  - Eolian (Wind Derived)
  - Colluvial (Gravity - Triangle Shape at Base of Mountain)
  - Alluvial Fan – Deposited by Intermittent Streams

Aggregate Production in Canada

Commodity	2016		2017	
	Volume (000 Tonnes)	Value ($ millions)	Volume (000 Tonnes)	Value ($ millions)
Sand and Gravel	280,549.6	$ 2,398.60	290,613.4	$ 2,538.90
Stone (Quarry)	160,016.1	$ 1,664.20	155,254.1	$ 1,603.50

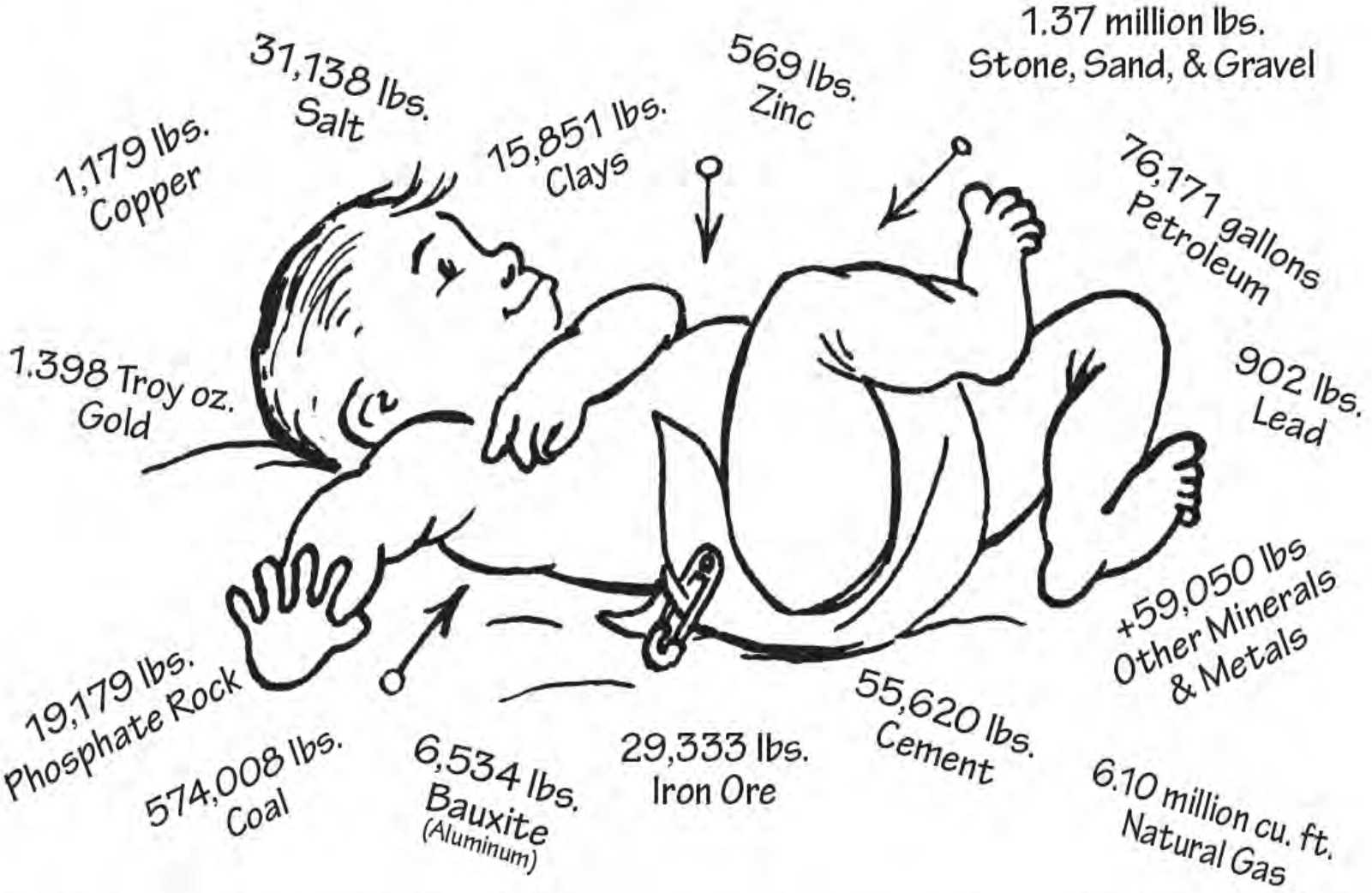
Source: Natural Resources Canada / Statistics Canada
https://www.nrcan.gc.ca/mining-materials/publications/17722

Annual Aggregate Consumption per Capita



Source: Altus Group – December 18, 2009 - State of Aggregate Resource in Ontario Study (SAROS)

Every American Born Will Need...



3.3 million pounds of minerals, metals, and fuels in their lifetime

Learn more at www.mii.org

Aggregate Tidbits

- **Average House Uses 60 Tonnes of Aggregate (House Alone)**
  Reference BGA (British Geological Survey)

- **Average House Uses 440 Tonnes when accounting for associated infrastructure (sewer, driveway, sidewalks, street, patio)**
  Reference OSSGA (Ontario Stone Sand & Gravel Association)

- **Two Lane Road Requires 100,000 Tonnes / mile**
  Reference ASGA (Alberta Sand & Gravel Association)

- **Ready Mix – approx 4000 lb. mix (1 cu. Yd) you will need:**
  - 564 lbs. of cement
  - 1,452 lbs. of sand
  - 1,656 lb. of gravel

  9 x For One Ready Mix Truck

- **Denver International Airport required about 10 million tons of aggregate**
  Reference Lafarge North America Website

AGGREGATE USED IN ONE HOUSE

229 tons

Basement Foundation 39 tons

Drain around Foundation 22 tons

Basement Floor 25 tons

Sidewalk 14 tons

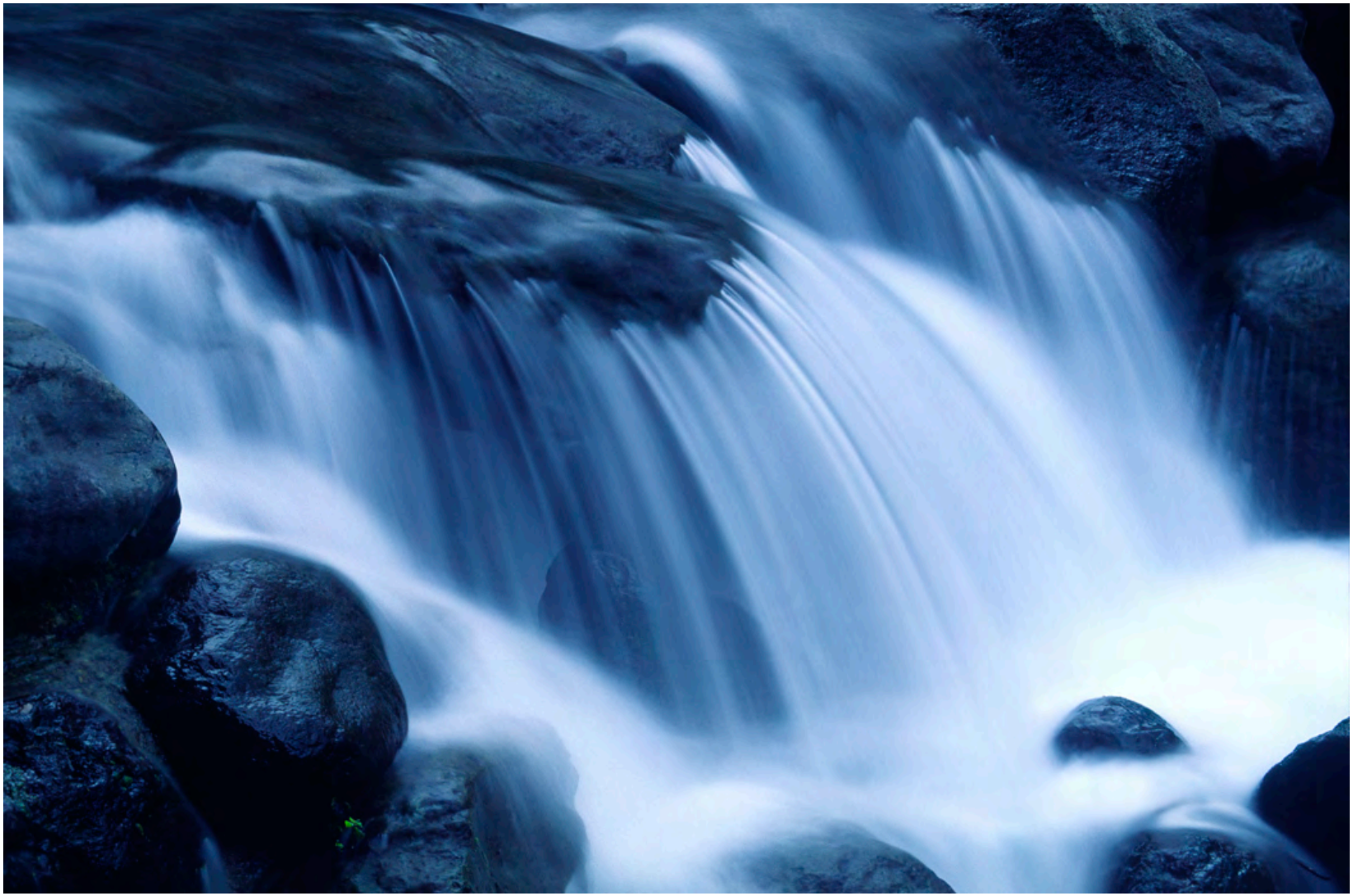
Driveway 19 tons

Garage Floor 10 tons

Half the street in front of the house 100 tons

Source: USGS

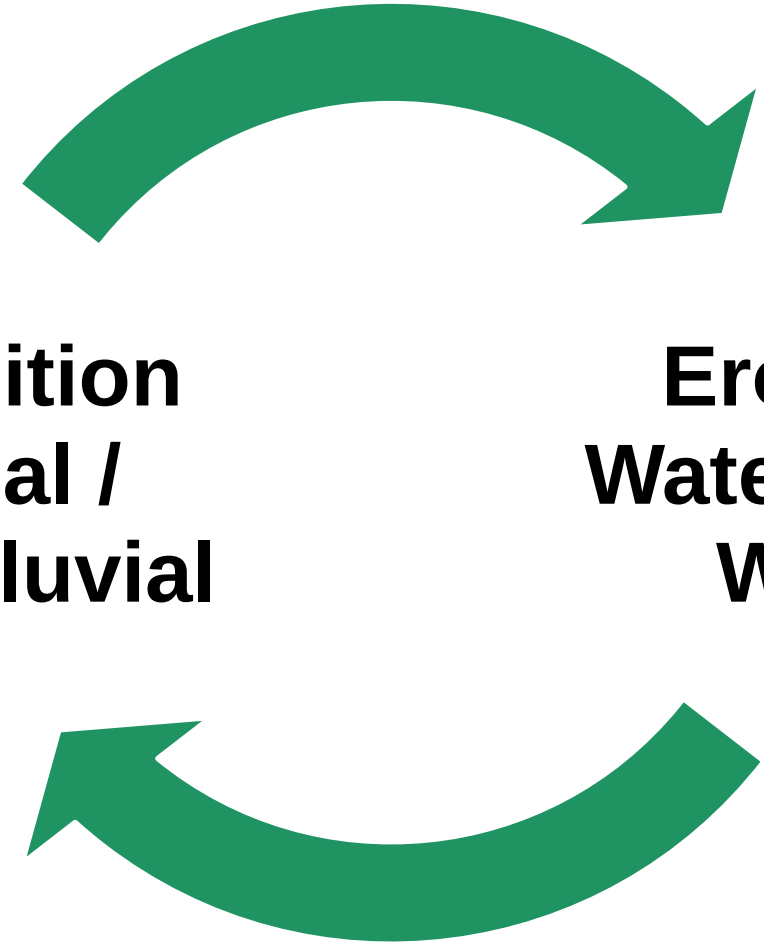
Sand & Gravel – Moving Water Is KEY



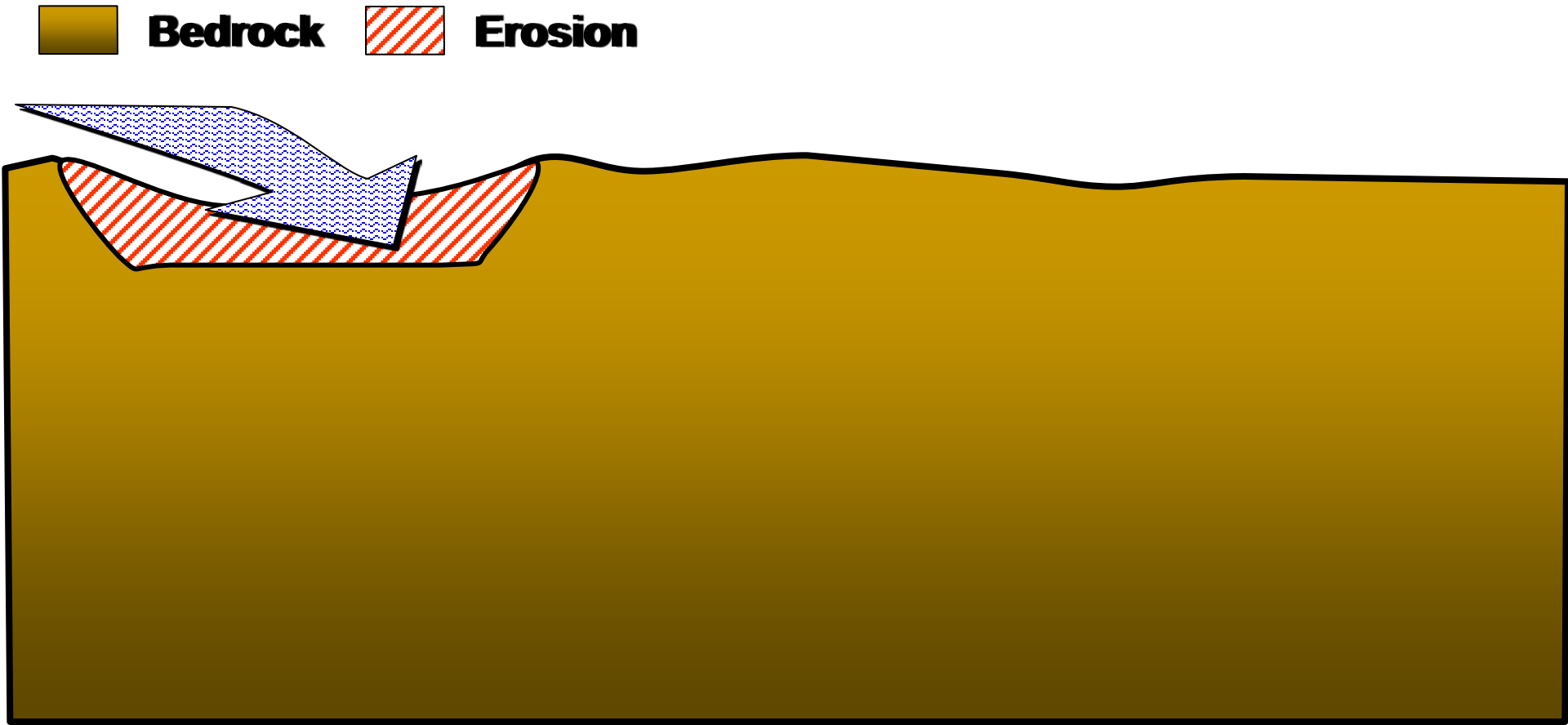

Glacial outwash
Glacial Lake

Aggregate Genesis – Conceptual Model (Over Time)

Repeating Cycles



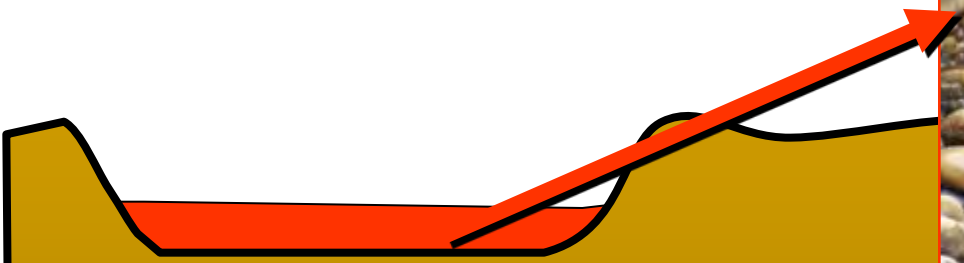
Fluvial erosion; ~40 million years ago



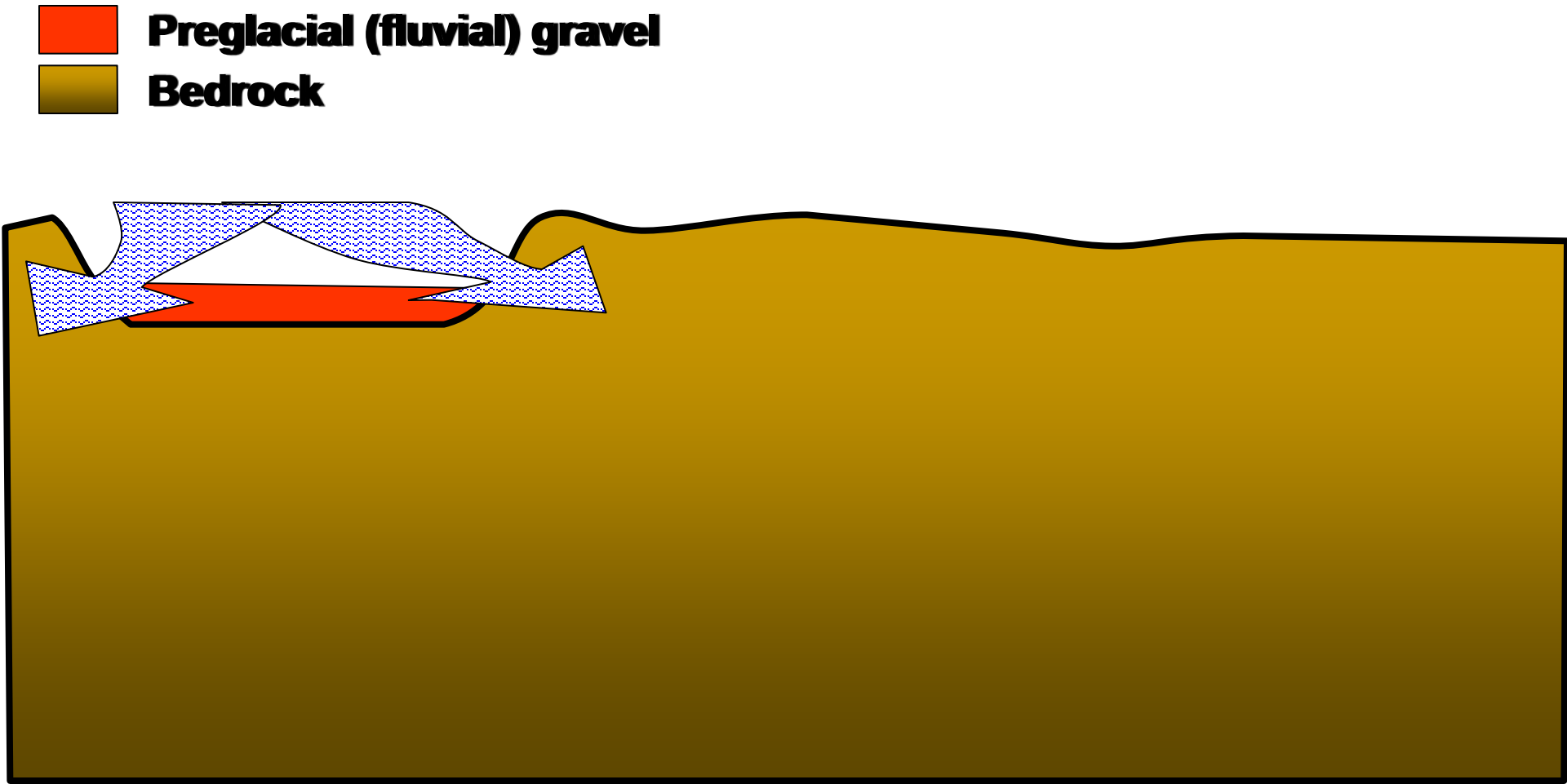
Fluvial deposition; ~40 million years ago

Preglacial (fluvial) gravel

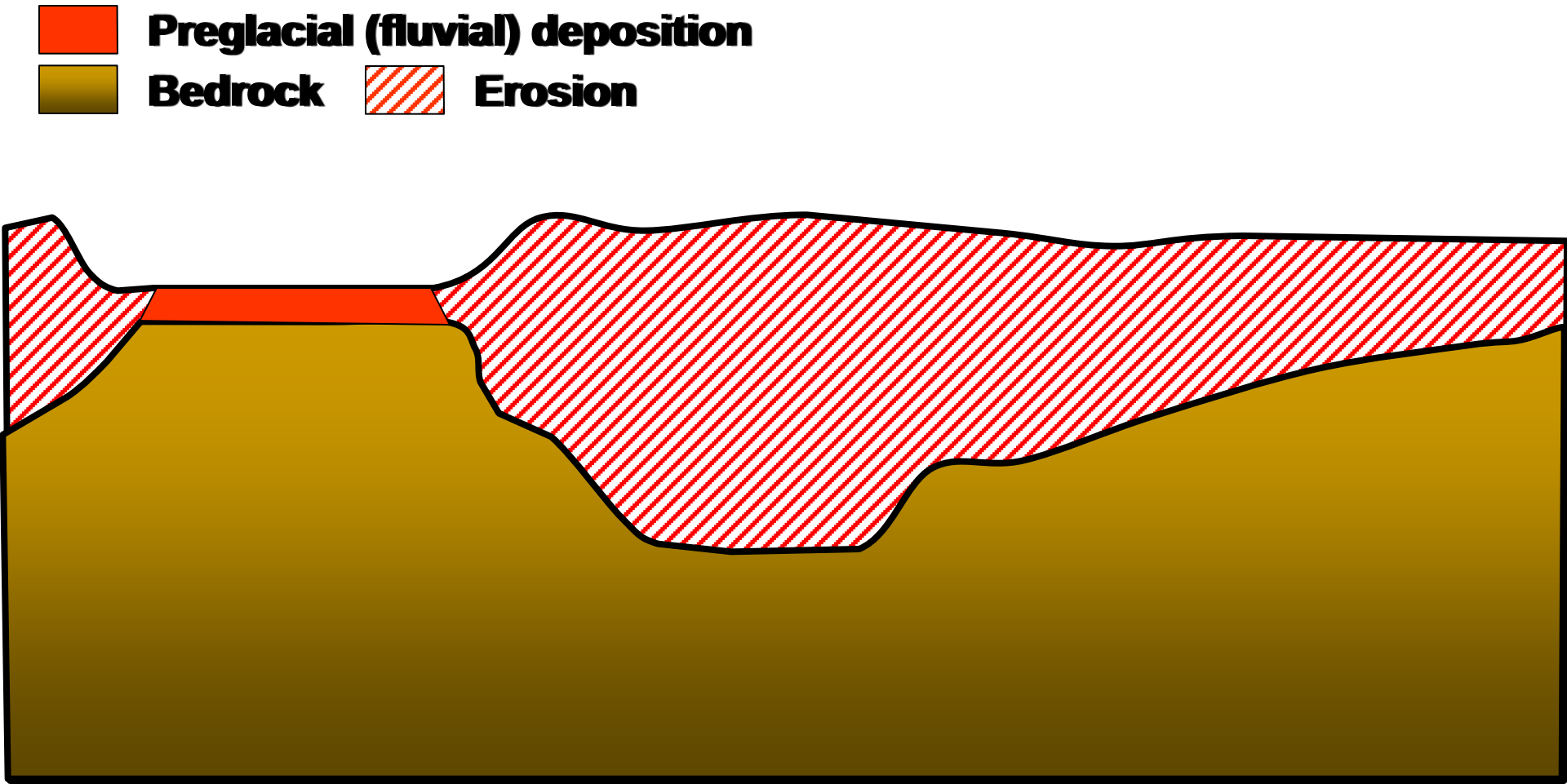
Bedrock



Fluvial erosion; ~40 to 2 million years ago



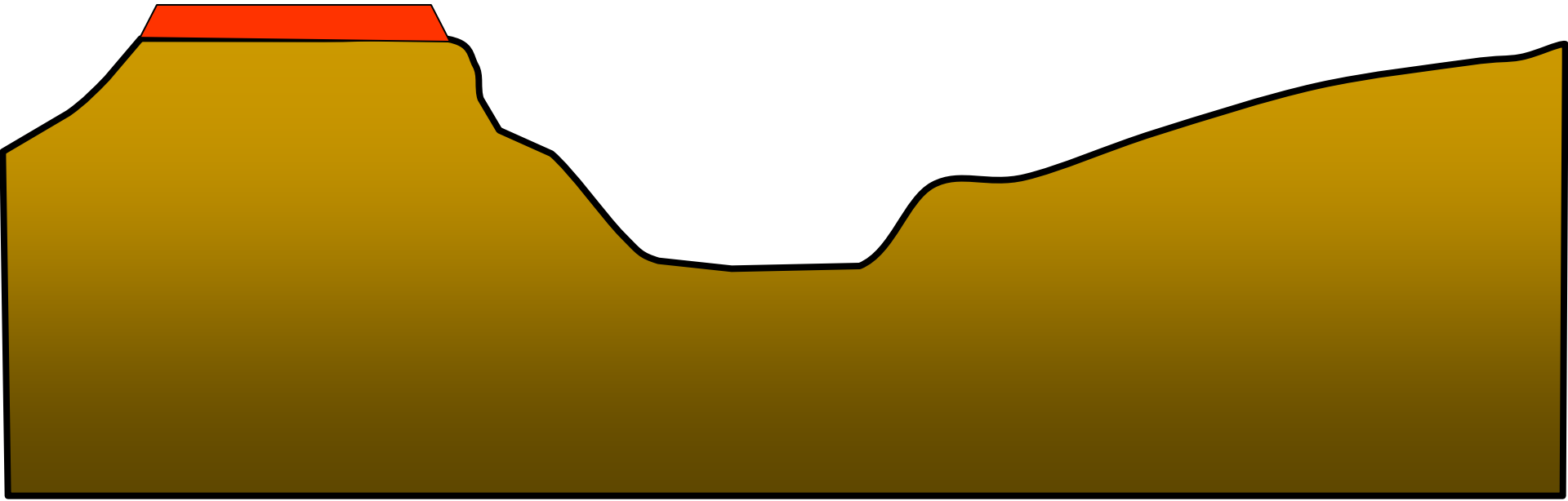
Fluvial erosion; ~40 to 2 million years ago

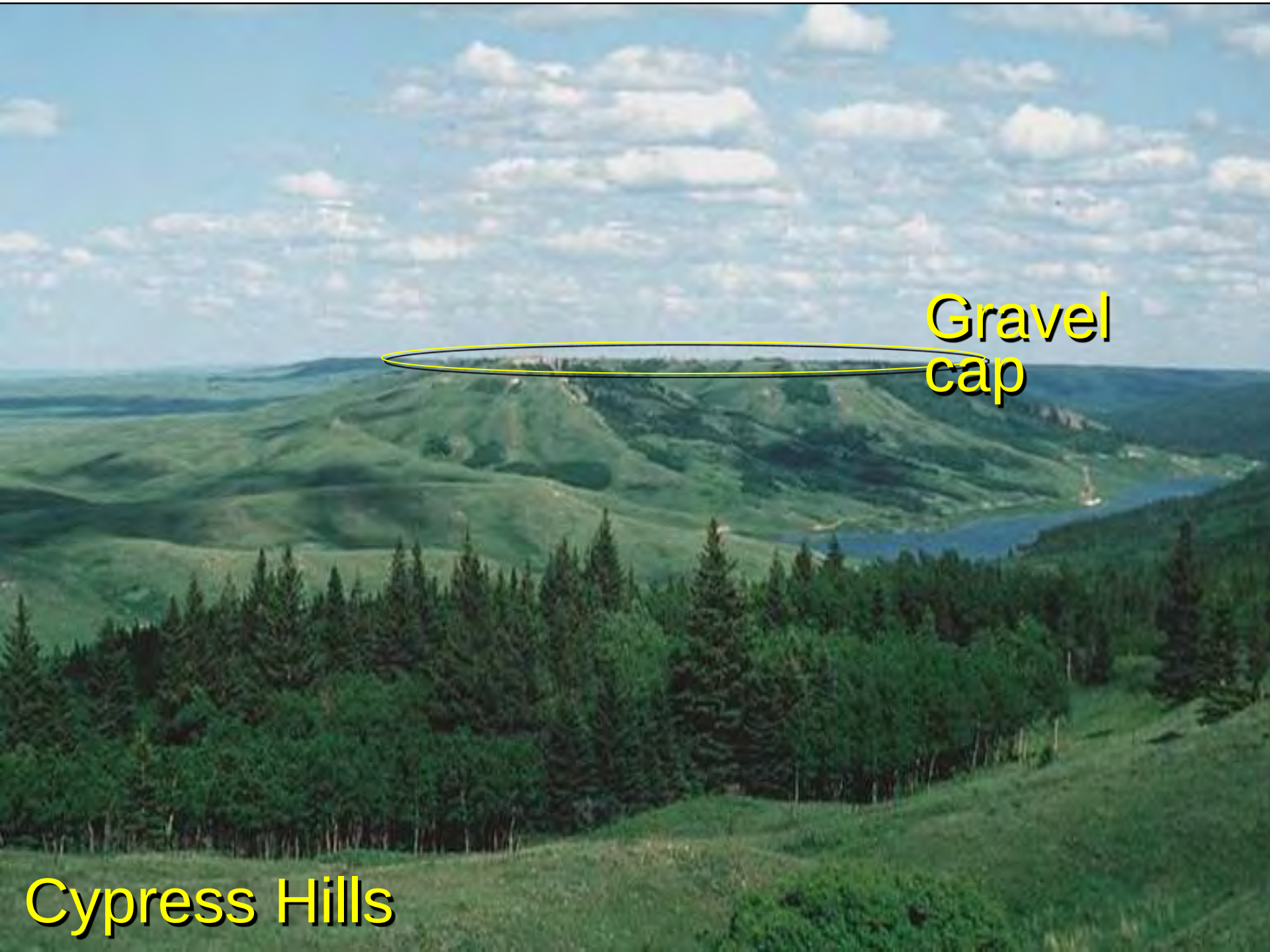


Fluvial erosion; ~40 to 2 million years ago

Preglacial (fluvial) deposition

Bedrock

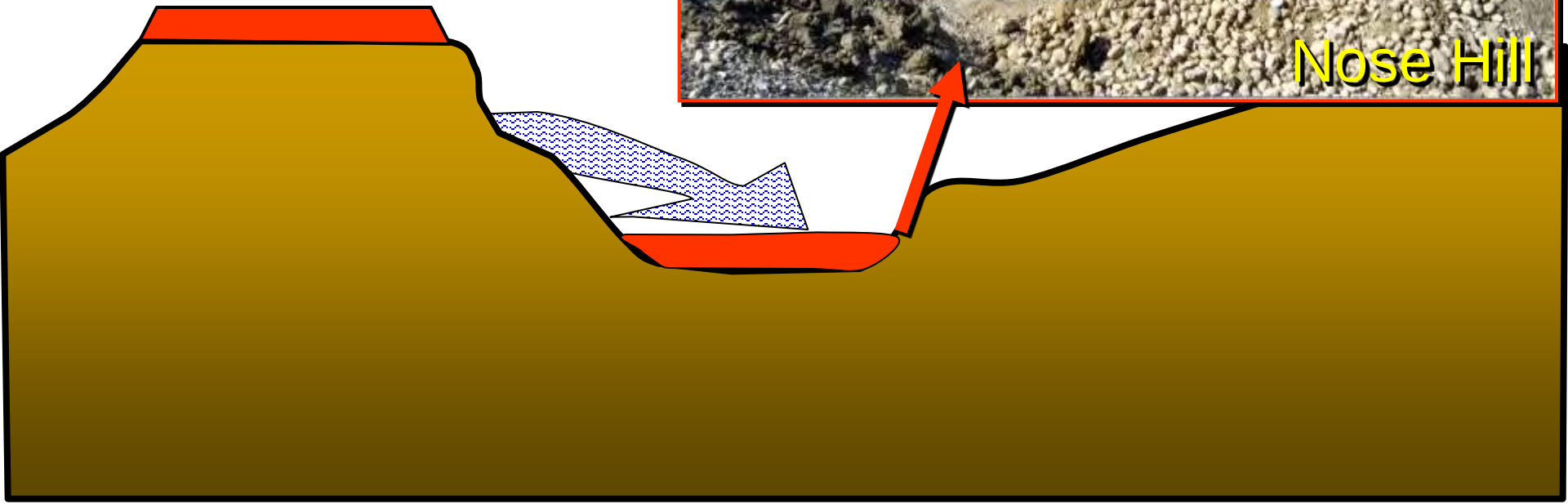



Gravel cap
Cypress Hills

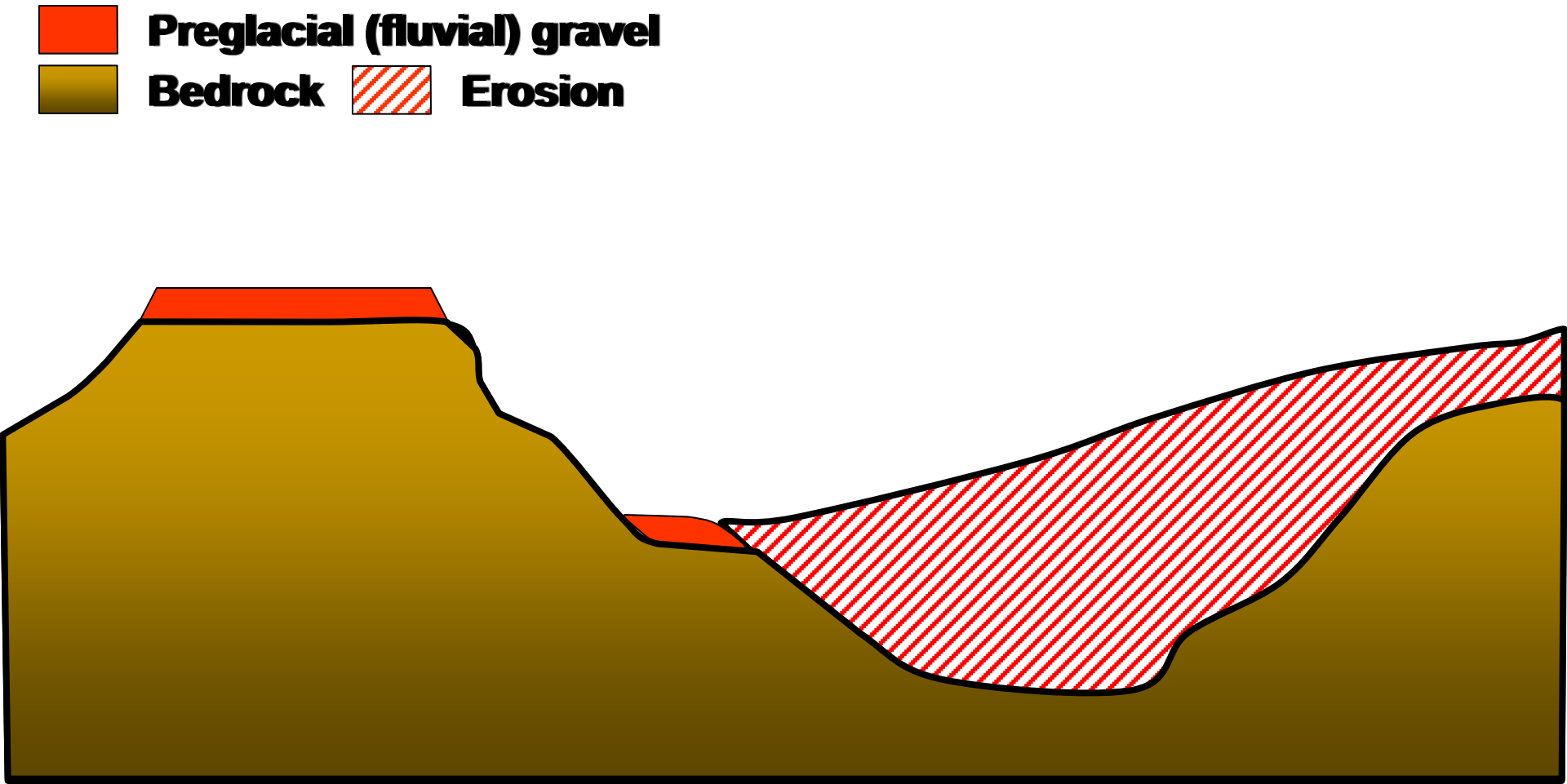
Fluvial deposition; ~2 million years ago

Preglacial (fluvial) gravel

Bedrock



Fluvial deposition; ~2 million to 50,000 years ago




Gravel cap
Bedrock
Hand Hills

Fluvial deposition; ~25,000 years ago

Preglacial (fluvial) gravel

Bedrock

Glacial erosion & deposition; ~25,000 to ~12,000 years ago

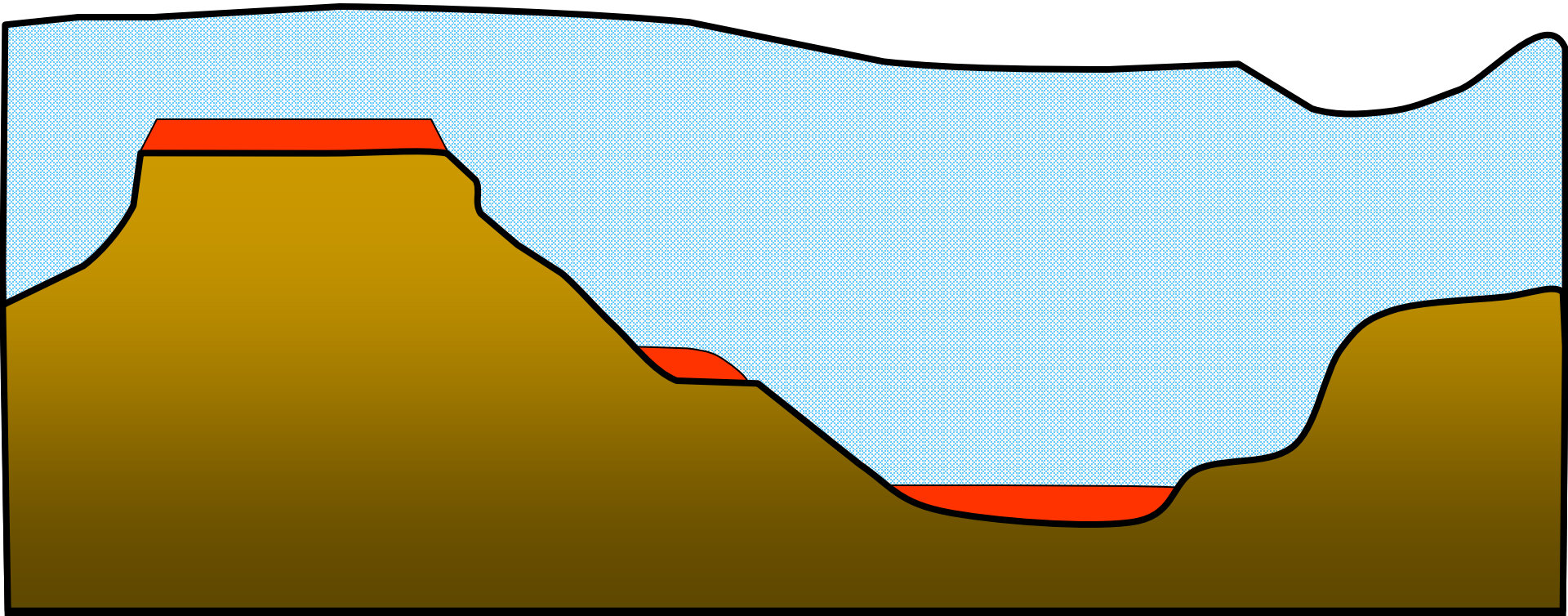
Sand (eolian)

Glacial (outwash)

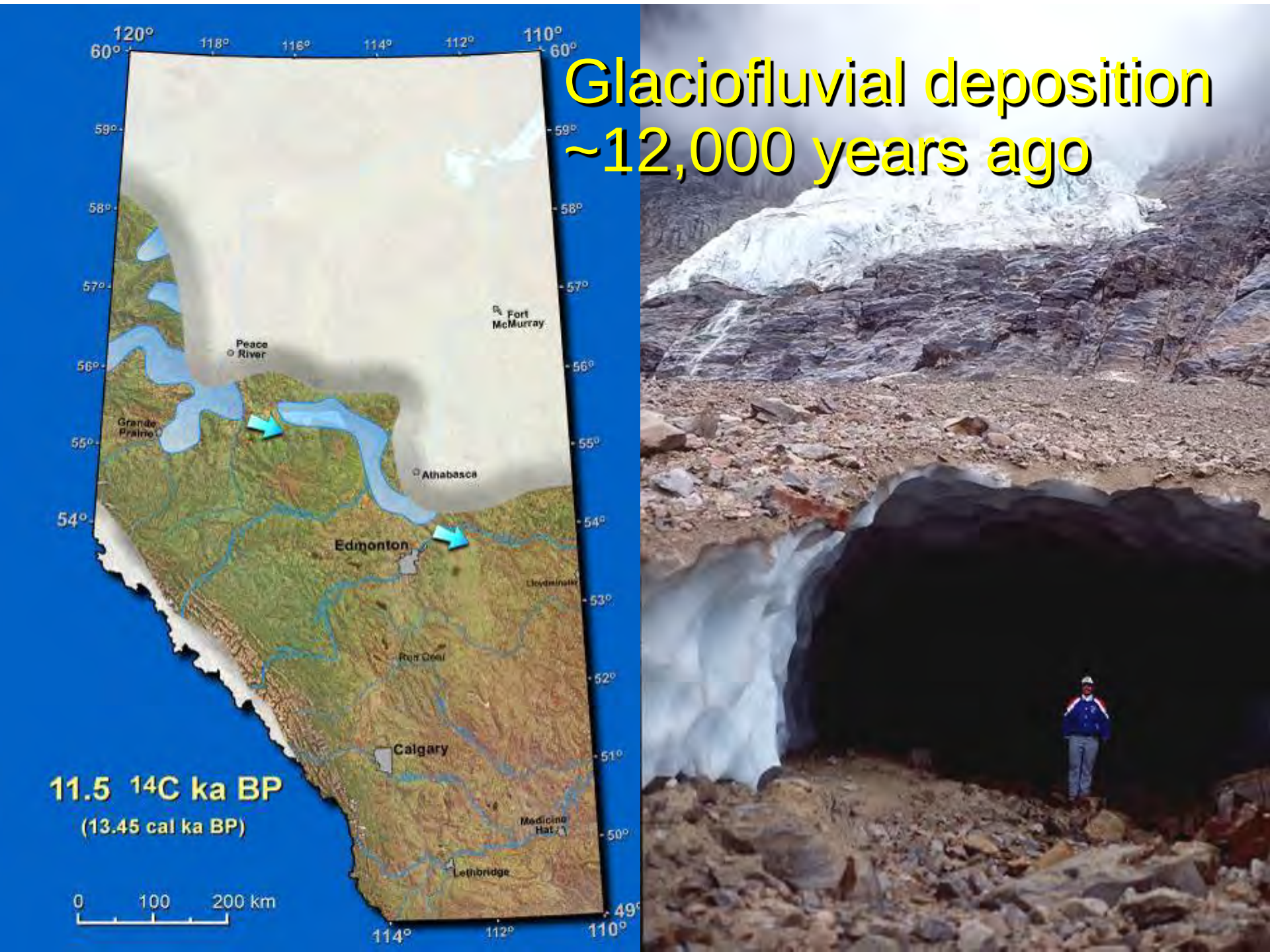
Glacial cover

Preglacial (fluvial) gravel

Bedrock



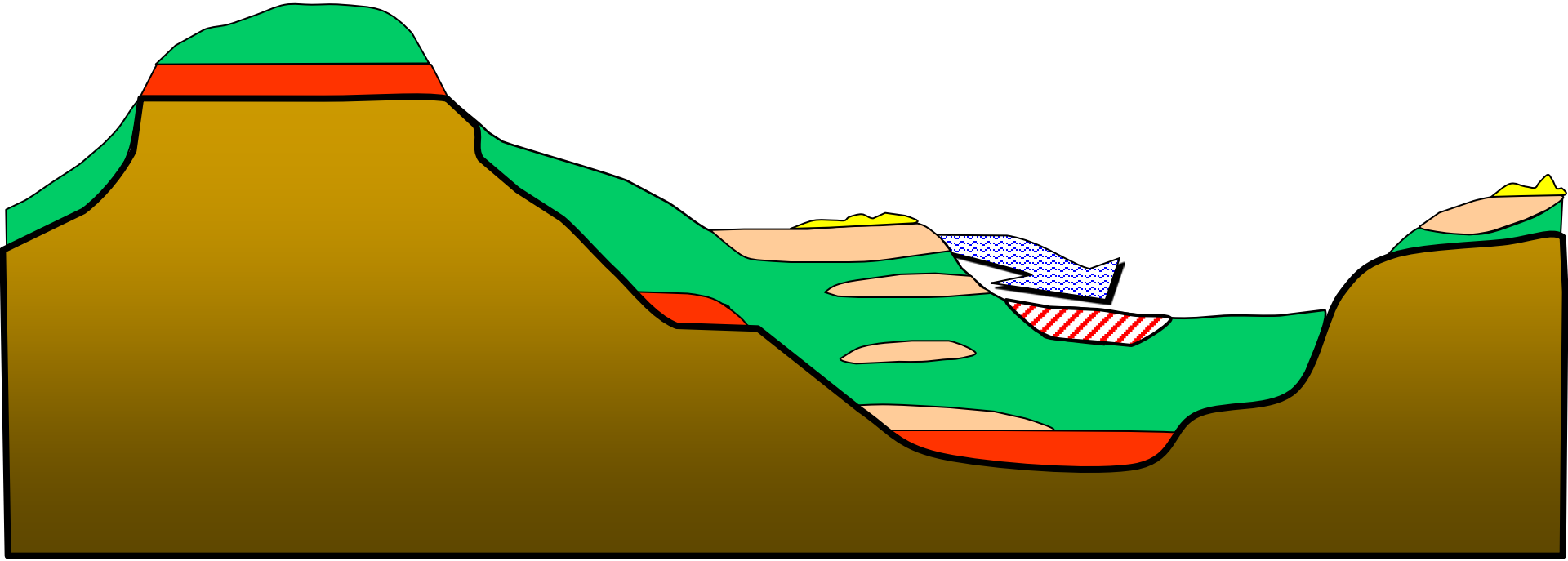

Glaciation


Glaciofluvial deposition
~12,000 years ago
120°
118°
116°
114°
112°
110°
60°
59°
58°
57°
56°
55°
54°
53°
52°
51°
50°
49°
Fort McMurray
Peace River
Grande Prairie
Athabasca
Edmonton
Lloydminster
Red Deer
Calgary
Medicine Hat
Lethbridge
11.5 14C ka BP
(13.45 cal ka BP)
0
100
200 km


Glacial outwash
Elk Point

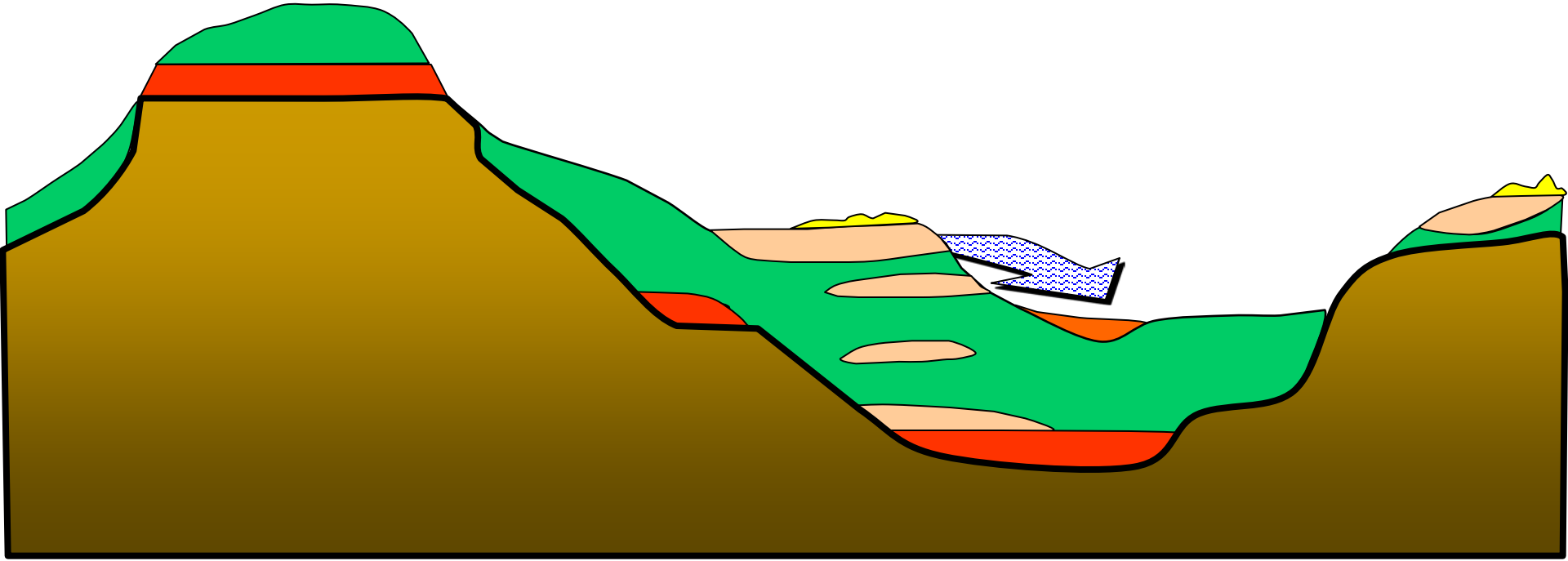
River (fluvial) processes ~12,000 - present

- Sand (eolian)
- Glacial (outwash)
- Till
- Preglacial (fluvial) gravel
- Bedrock

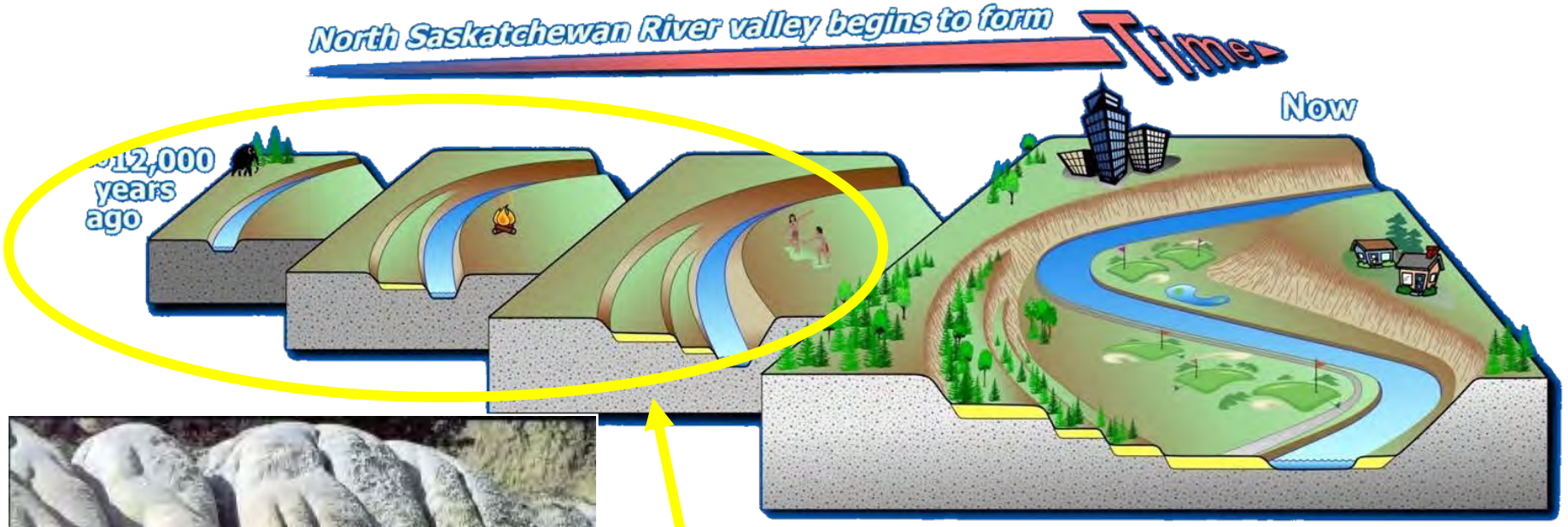


River deposition ~12,000 - 8,500 years ago

- Fluvial gravel
- Sand (eolian)
- Glacial (outwash)
- Till
- Preglacial (fluvial) gravel
- Bedrock

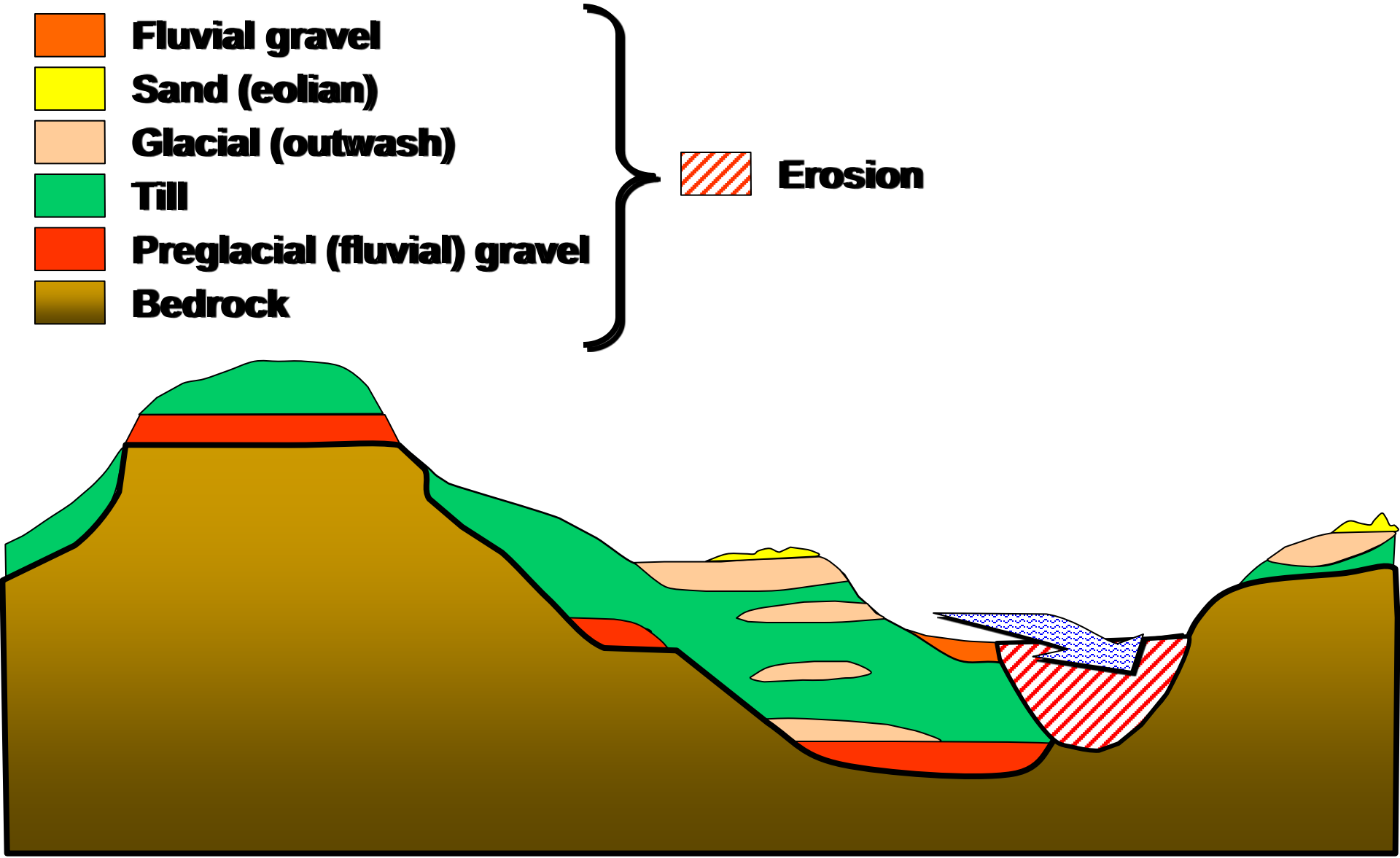


Development of rivers and terraces
~12,000 - 8,500 years ago



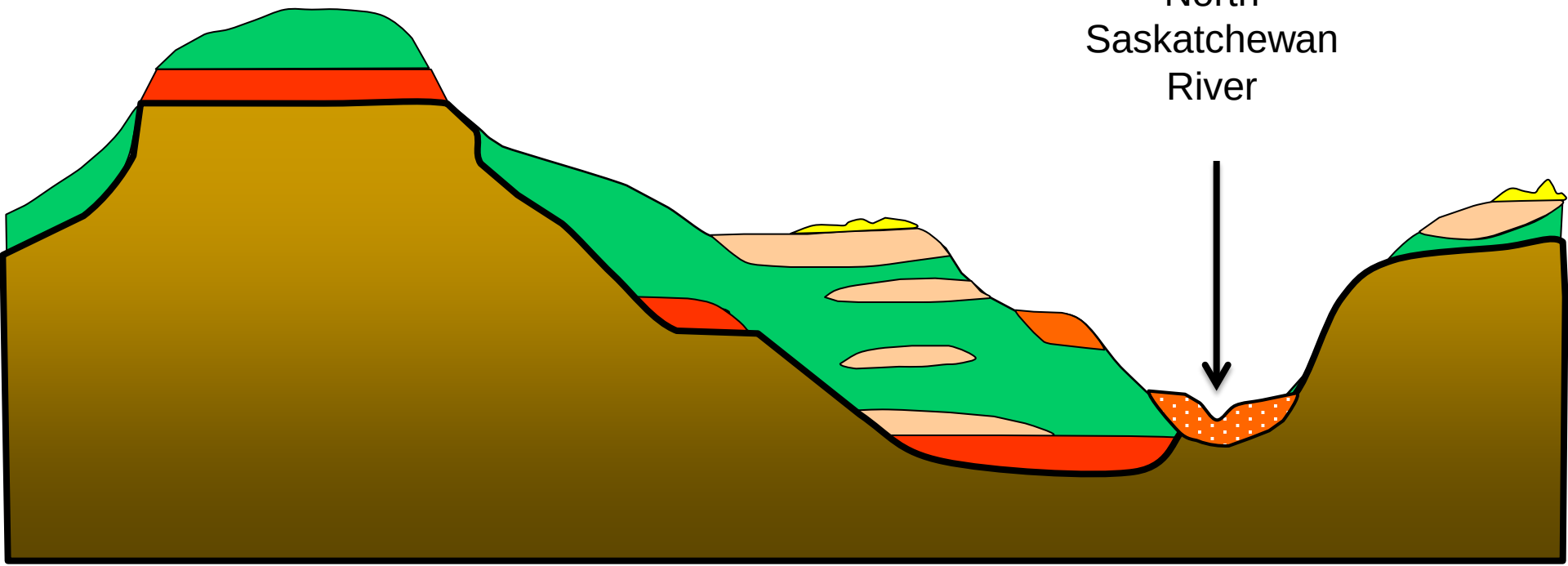
- The rivers quickly cut into the soft sandstone and shale (takes 3000 years and leaves 3 terrace levels)

River erosion ~8,500 years ago to present

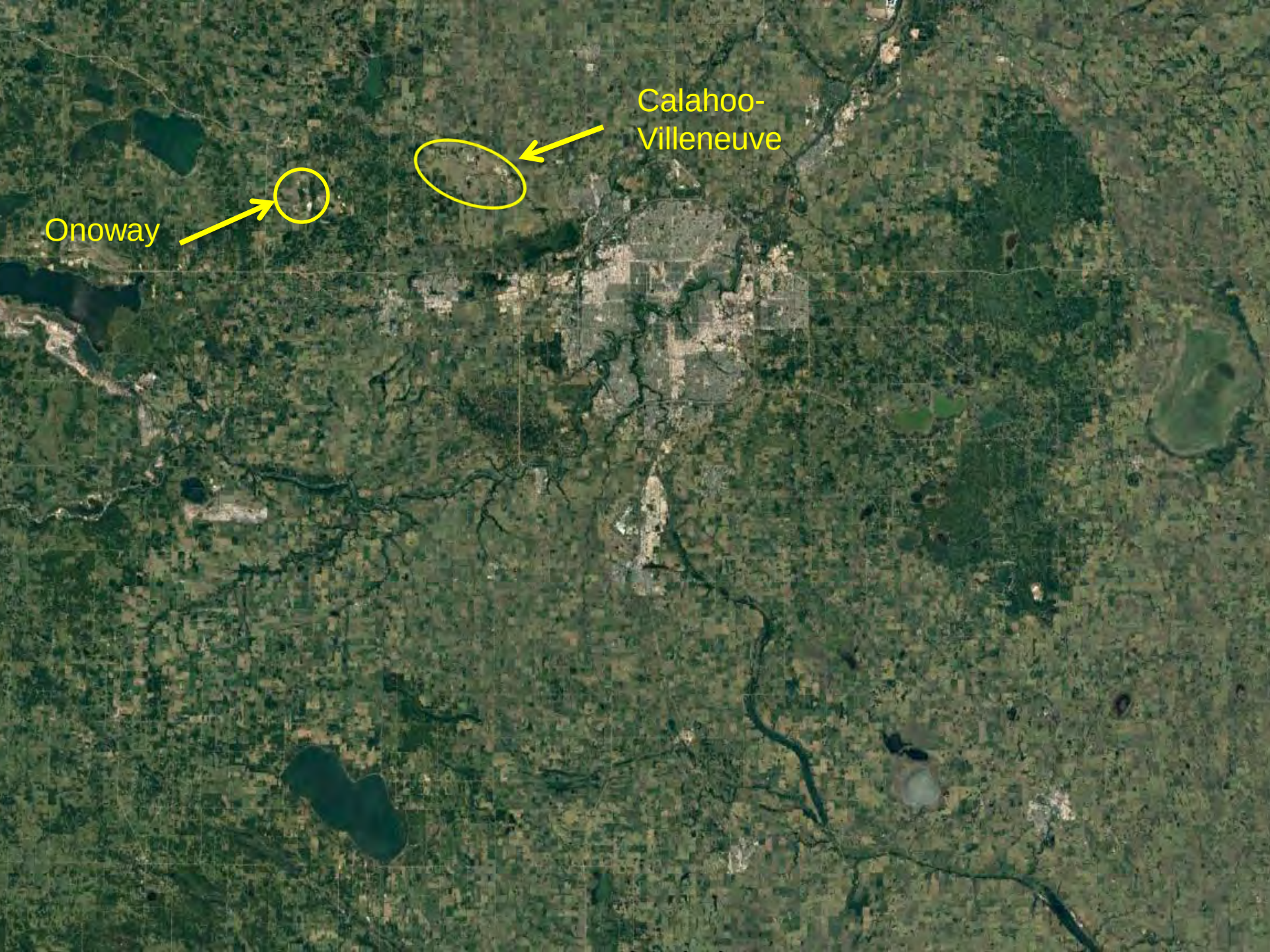


River deposition ~8,500 years ago to present

- Point bar / floodplain
- Alluvial terraces
- Sand (eolian)
- Glacial (outwash)
- Till
- Preglacial (fluvial) gravel
- Bedrock




Beaver River

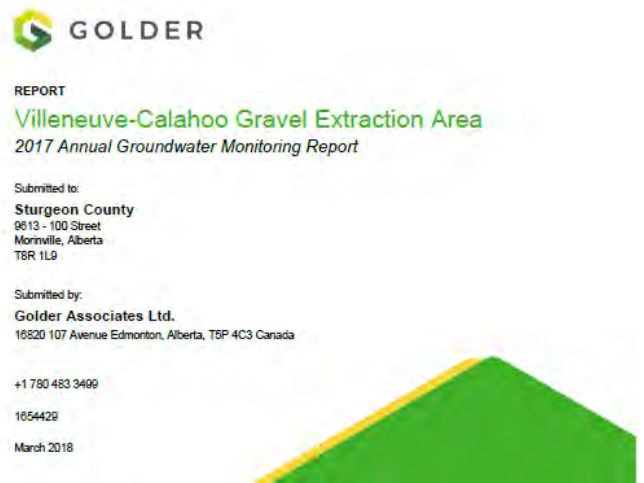

Calahoo-
Villeneuve
Onoway


Calahoo-
Villeneuve
Onoway

Sturgeon Regional Groundwater Network

- Established 2001 – Annual Reports – Publically Available
- Managed By Sturgeon County
- 19 Regional Monitoring Wells – A number of resident wells & aggregate producer wells

  - Groundwater Level Monitoring
    - Monthly Water Level Measurements
    - Data loggers (installed by aggregate producers) measurement 4 times a day to hourly
  - Chemistry
    - General water chemistry
    - Metals


GOLDER

REPORT

Villeneuve-Calahoo Gravel Extraction Area

2017 Annual Groundwater Monitoring Report

Submitted to:

Sturgeon County
9613 - 100 Street
Morinville, Alberta
T8R 1L9

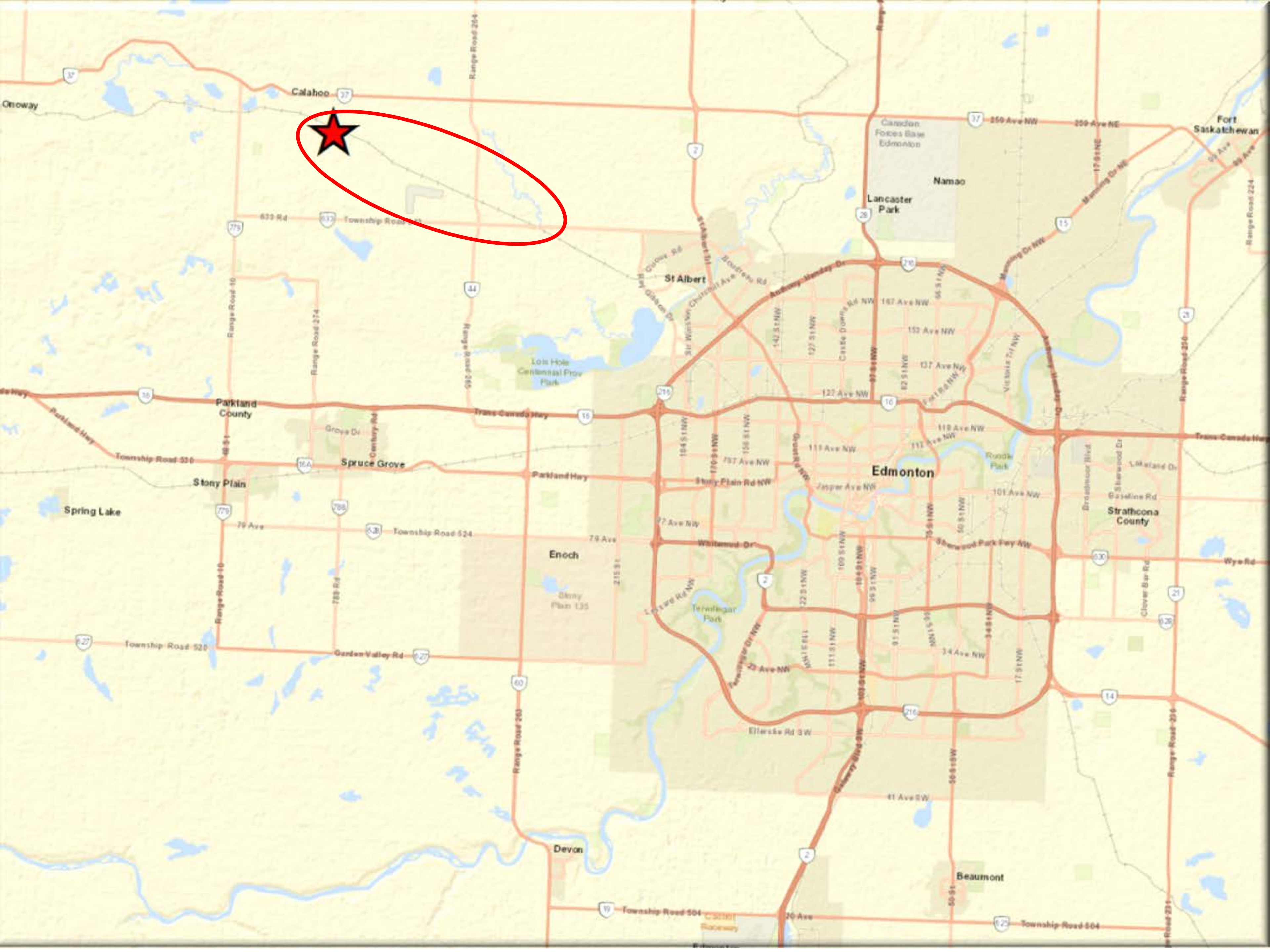
Submitted by:

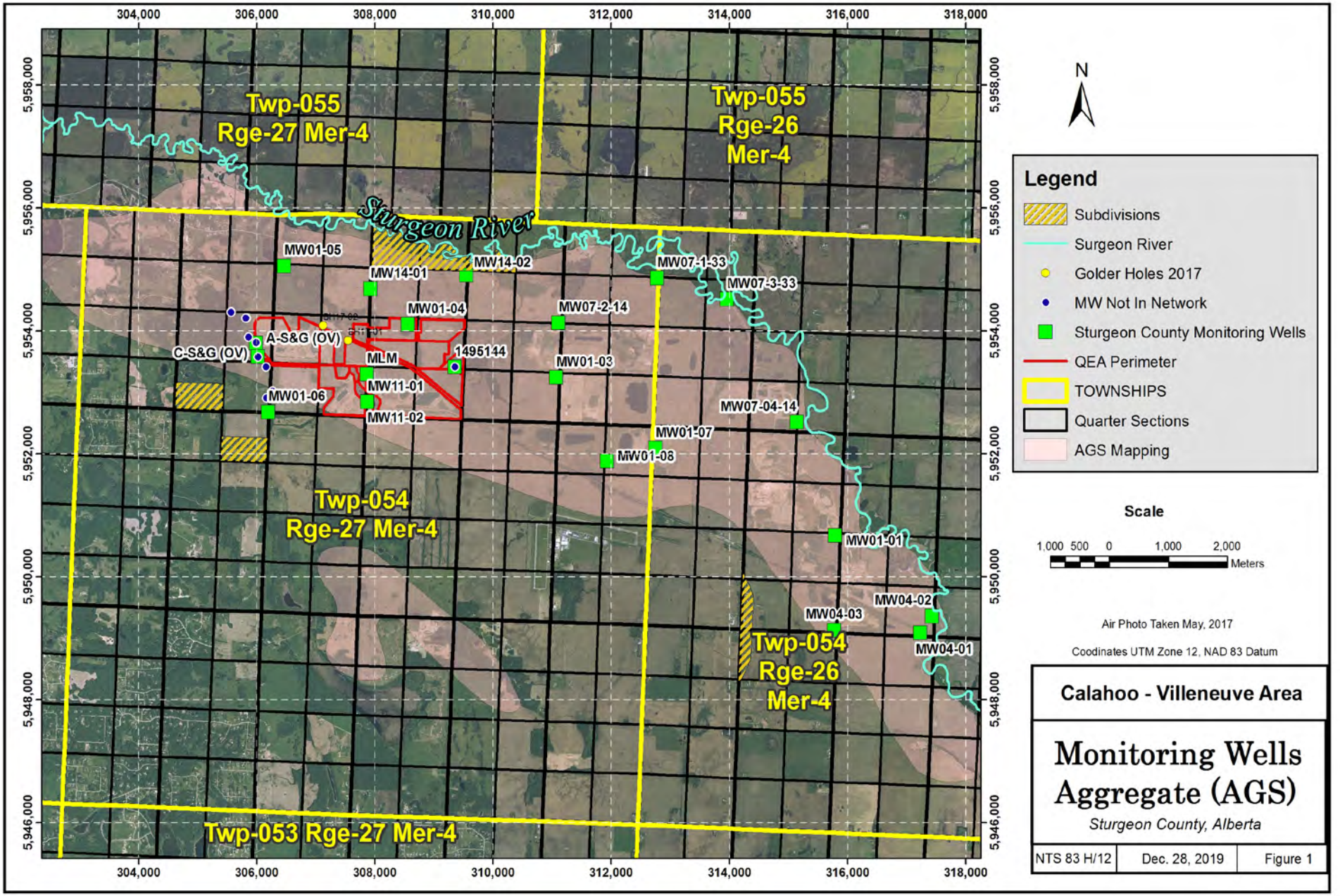
Golder Associates Ltd.
16820 107 Avenue Edmonton, Alberta, T5P 4C3 Canada

+1 780 483 3499

1654429

March 2018


Onoway
Calahoo
Fort Saskatchewan
Canadian Forces Base Edmonton
Namao
Lancaster Park
St Albert
Lois Hole Centennial Prov Park
Parkland County
Spruce Grove
Stony Plain
Spring Lake
Enoch
Edmonton
Strathcona County
Devon
Beaumont
Trans Canada Hwy
Parkland Hwy
Township Road 530
Township Road 524
Township Road 520
Garden Valley Rd
Township Road 504
Anthony Henday Dr
Manning Dr NW
Whitemud Dr
Sherwood Park Fwy NW
Yellowhead Trail NW
Stony Plain Rd NW
Jasper Ave NW
Ellerslie Rd SW
Wye Rd
Baseline Rd
Range Road 10
Range Road 274
Range Road 265
Range Road 264
Range Road 260
Range Road 231
Range Road 224
Gateway Blvd SW
Terwillegar Park
Rundle Park
Stony Plain 135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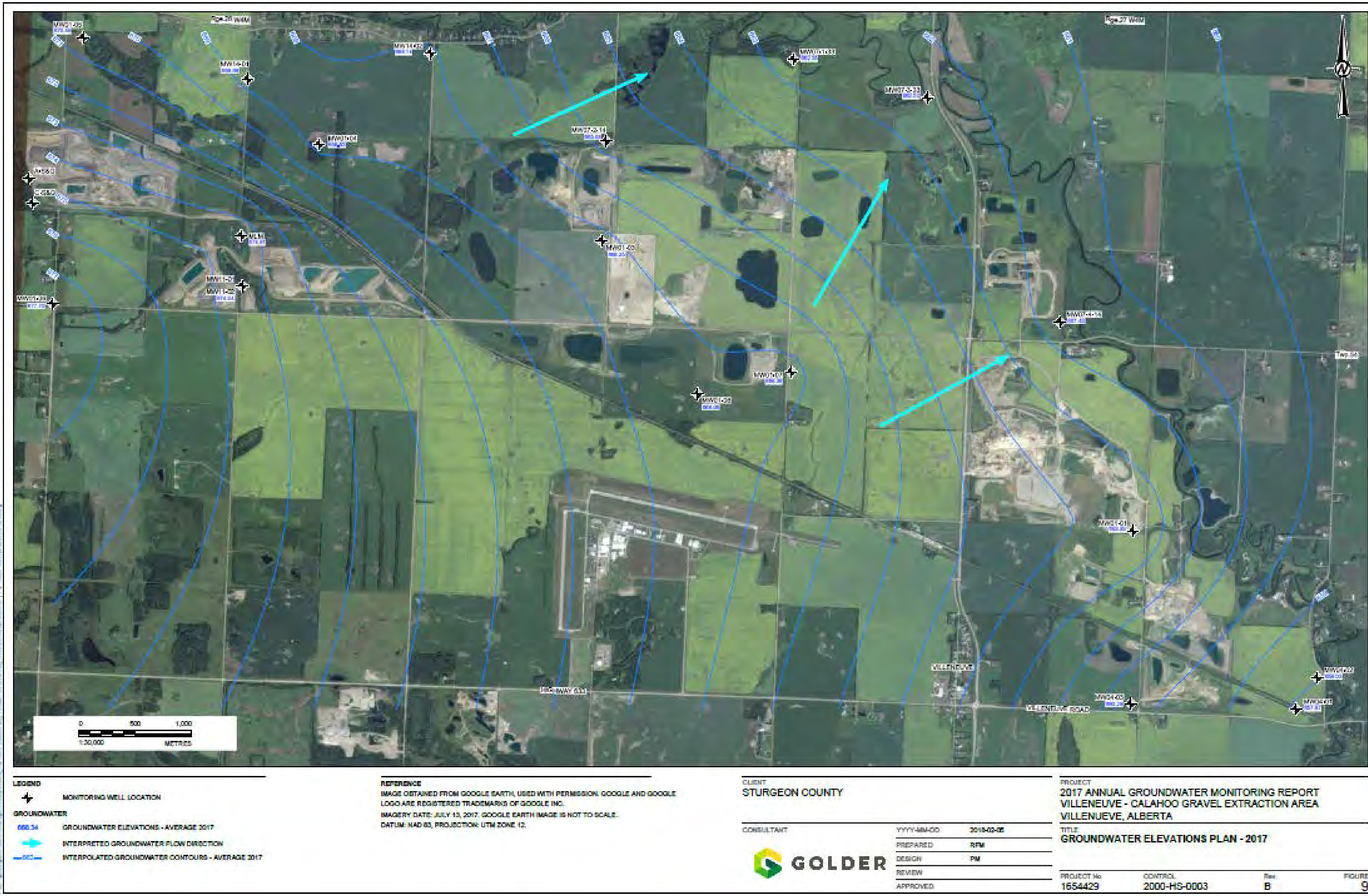
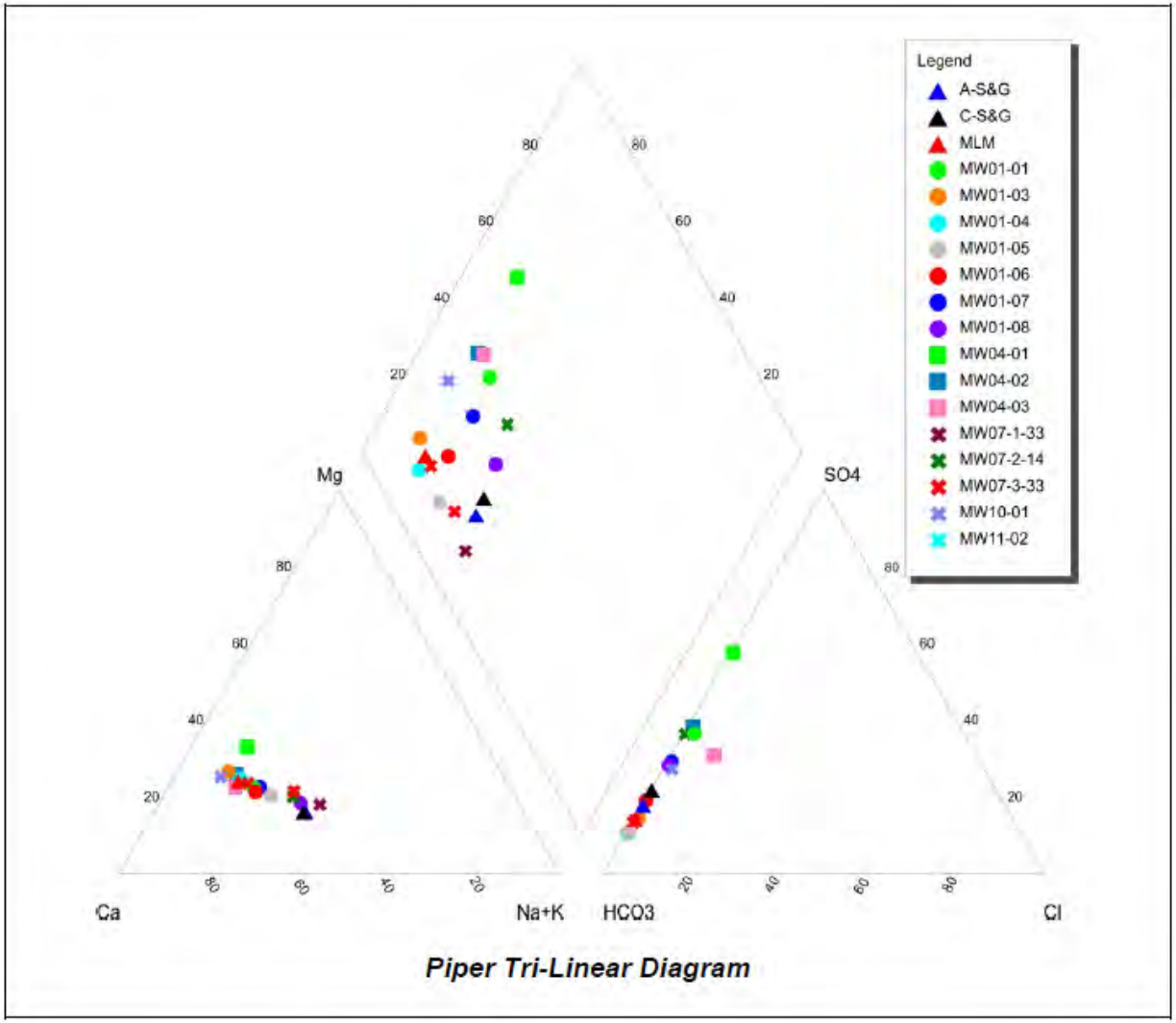
314,000
316,000
318,000
5,958,000
5,956,000
5,954,000
5,952,000
5,950,000
5,948,000
5,946,000
Twp-055
Rge-27 Mer-4
Twp-055
Rge-26
Mer-4
Sturgeon River
MW01-05
MW14-01
MW14-02
MW07-1-33
MW07-3-33
MW01-04
MW07-2-14
A-S&G (OV)
C-S&G (OV)
MLM
1495144
MW01-03
MW11-01
MW01-06
MW11-02
MW07-04-14
MW01-07
MW01-08
Twp-054
Rge-27 Mer-4
MW01-01
MW04-02
MW04-03
MW04-01
Twp-054
Rge-26
Mer-4
Twp-053 Rge-27 Mer-4
N
Legend
Subdivisions
Surgeon River
Golder Holes 2017
MW Not In Network
Sturgeon County Monitoring Wells
QEA Perimeter
TOWNSHIPS
Quarter Sections
AGS Mapping
Scale
1,000 500 0 1,000 2,000
Meters
Air Photo Taken May, 2017
Coodinates UTM Zone 12, NAD 83 Datum
Calahoo - Villeneuve Area
Monitoring Wells
Aggregate (AGS)
Sturgeon County, Alberta
NTS 83 H/12
Dec. 28, 2019
Figure 1

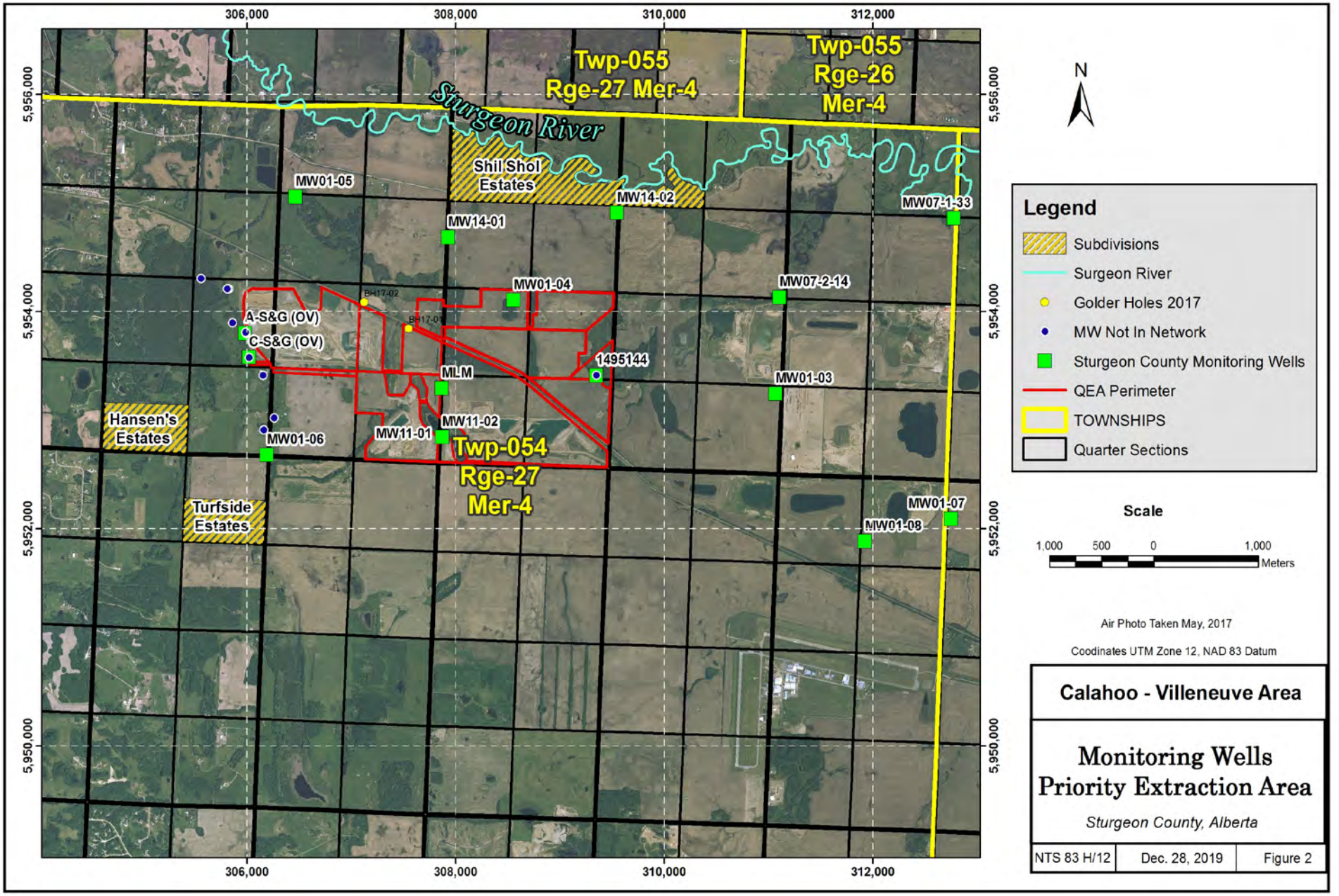
Groundwater Flow



Groundwater Chemistry

- Piper Plots
- Calcium-bicarbonate (Ca-HCO3/SO4) type water
- Groundwater Chemistry Consistent Since Start of Monitoring (2001)

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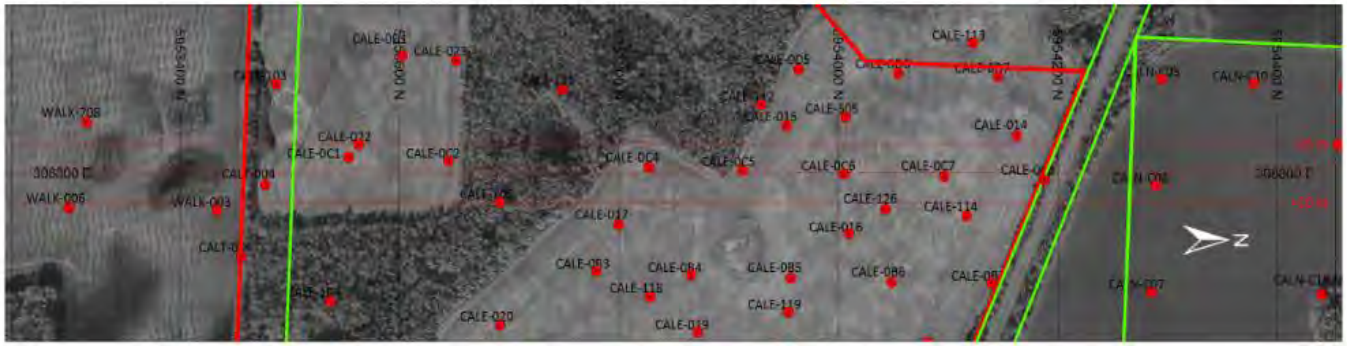
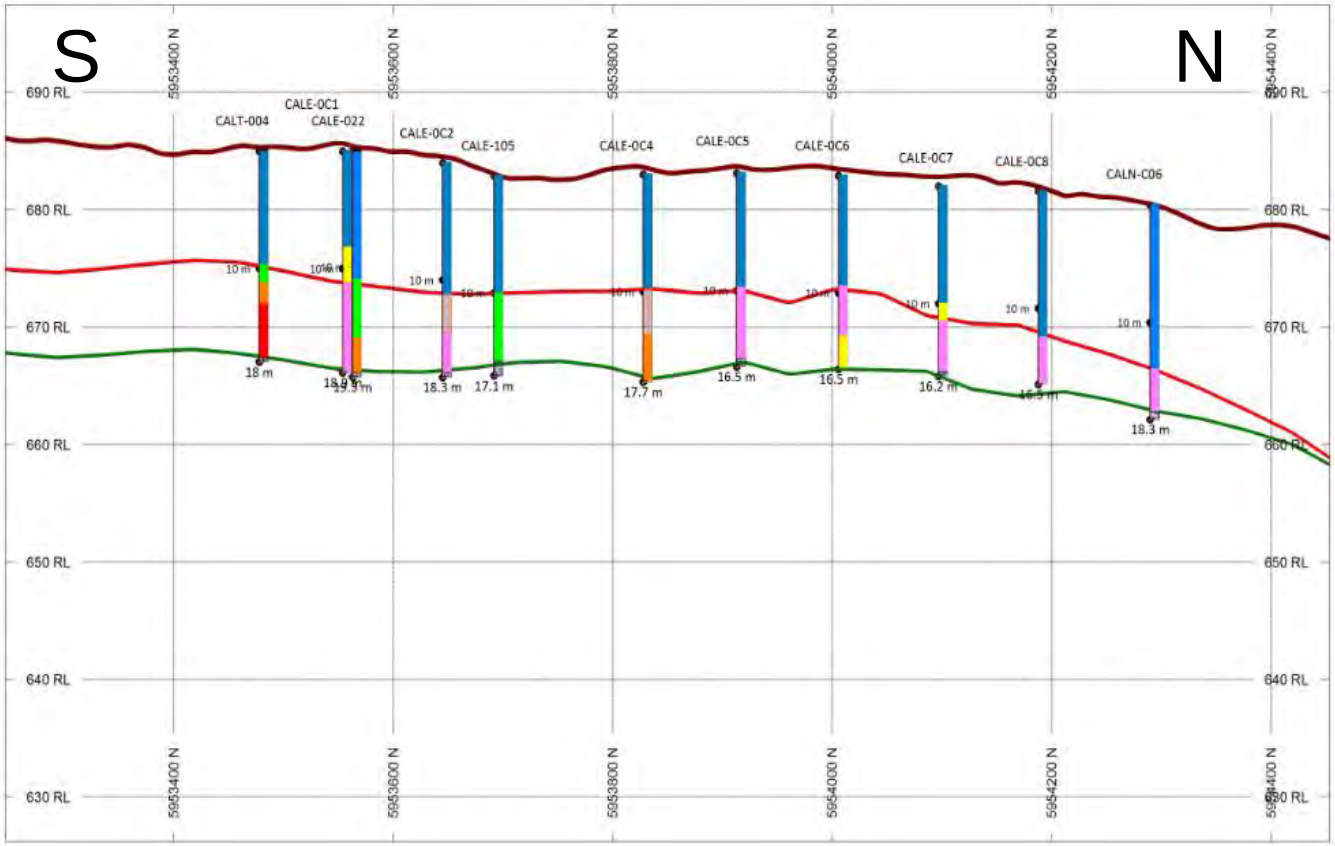
5,950,000
Twp-055
Rge-27 Mer-4
Twp-055
Rge-26
Mer-4
Sturgeon River
Shil Shol
Estates
MW01-05
MW14-02
MW07-1-33
MW14-01
MW01-04
MW07-2-14
BH17-02
BH17-03
A-S&G (OV)
C-S&G (OV)
1495144
MLM
MW01-03
Hansen's
Estates
MW01-06
MW11-01
MW11-02
Twp-054
Rge-27
Mer-4
Turfside
Estates
MW01-07
MW01-08
N
Legend
Subdivisions
Surgeon River
Golder Holes 2017
MW Not In Network
Sturgeon County Monitoring Wells
QEA Perimeter
TOWNSHIPS
Quarter Sections
Scale
1,000 500 0 1,000
Meters
Air Photo Taken May, 2017
Coodinates UTM Zone 12, NAD 83 Datum
Calahoo - Villeneuve Area
Monitoring Wells
Priority Extraction Area
Sturgeon County, Alberta
NTS 83 H/12
Dec. 28, 2019
Figure 2





HOLES PLOTTED

TOTAL 11

CALE-022	CALE-0C1	CALE-0C2	CALE-0C4
CALE-0C5	CALE-0C6	CALE-0C7	CALE-0C8
CALE-105	CALN-C06	CALT-004	

Legend

- Test Holes
- WCAN_Properties
- Mining Perimeter

TOPOGRAPHY

- Bottom Of Gravel
- Top Of Gravel
- Original Ground Surface

ROCK CODES	PAT	LABEL	DESCRIPTION
ROCK_01		BR	Bedrock
		CLAY	Clay
		FG	Fair Gravel
		GG	Good Gravel
		GRAV	Gravel
		PG	Poor Gravel
		SAND	Sand
		TS	Topsoil
		OVB	Overburden
		SDGR	Sandy Gravel
		MG	Medium Gravel

SECTION SPECS:

REF. PT. E, N	306800 m	5953850 m
EXTENTS	1207 m	71.25 m
SECTION TOP, BOT	697.4 m	626.2 m
TOLERANCE +/-	25 m	
VERTICAL EXAG.	10	

SCALE

(m)

-40 0 40 80 120 160

*unknown

AZIMUTH = 0°

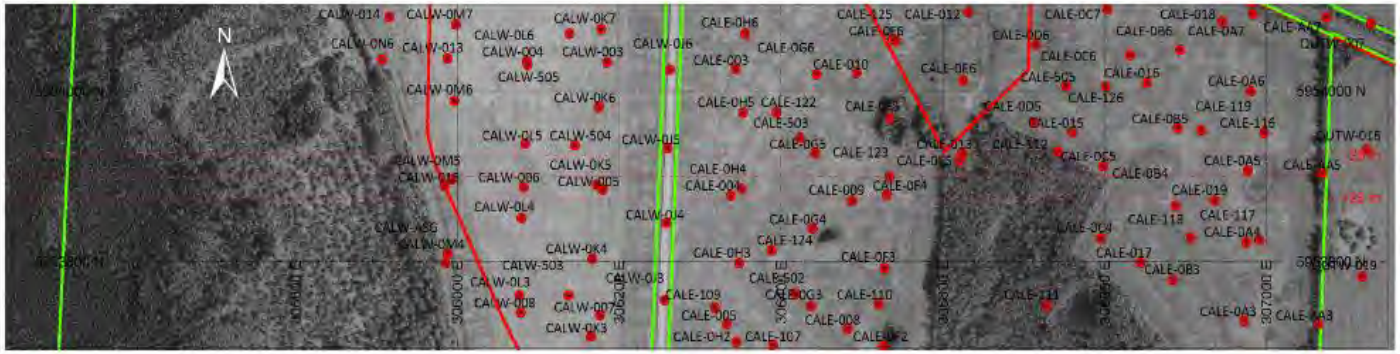
N W E S

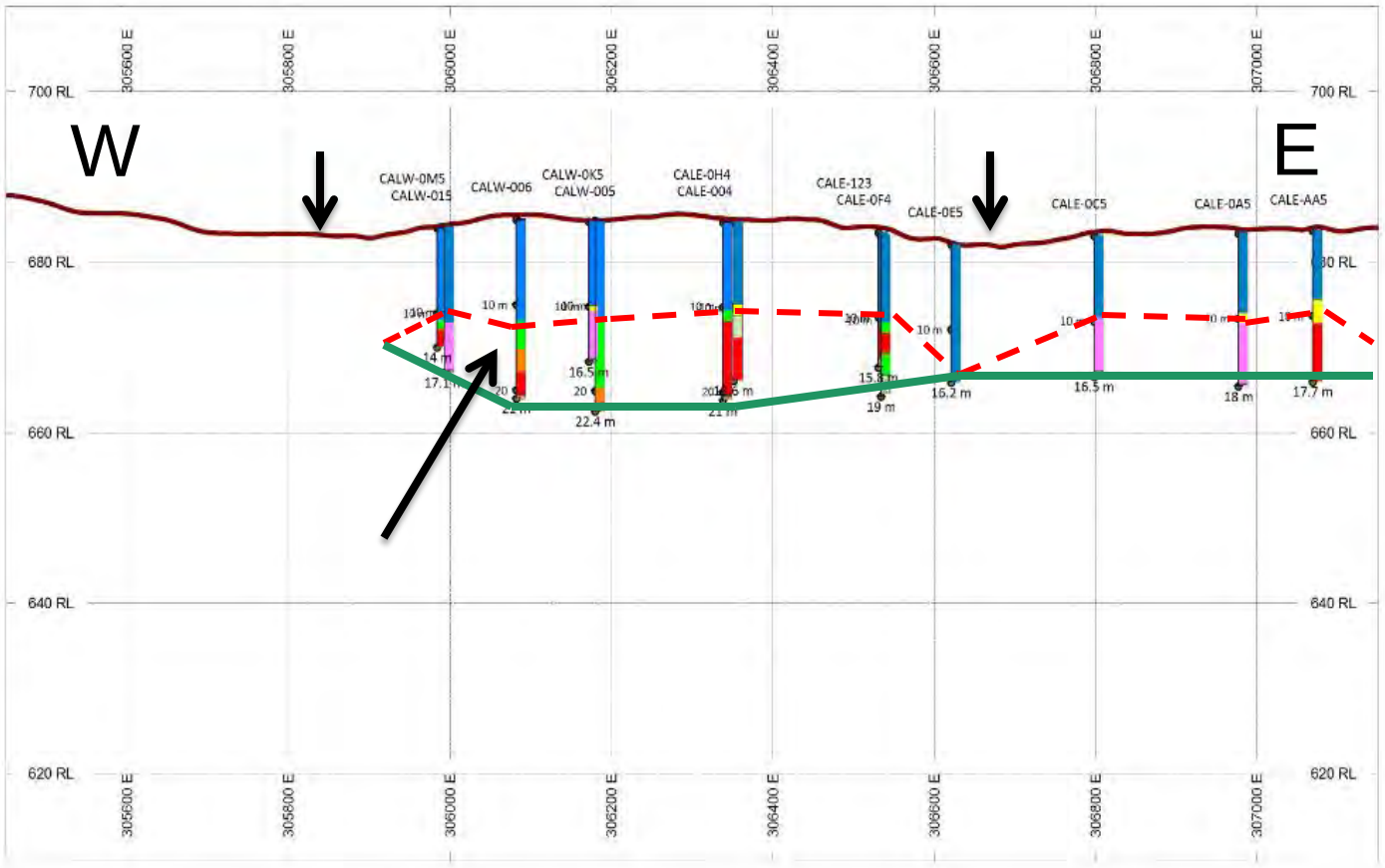
Lafarge Canada Inc.

Calahoo

Cross Section 306,800E

Looking West





HOLES PLOTTED

TOTAL 13

CALE-004	CALE-0A5	CALE-0C5	CALE-0E5
CALE-0F4	CALE-0H4	CALE-123	CALE-AA5
CALW-005	CALW-006	CALW-015	CALW-0K5
CALW-0M5			

Legend

- Test Holes
- WCAN_Properties
- Mining Perimeter

TOPOGRAPHY

QEAGrid(15m)LiDAR_KRG.GRD

ROCK CODES	PAT	LABEL	DESCRIPTION
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		CLAY	Clay
		FG	Fair Gravel
		GG	Good Gravel
		GRAV	Gravel
		PG	Poor Gravel
		SAND	Sand
		TS	Topsoil
		OVB	Overburden
		SDGR	Sandy Gravel

SECTION SPECS:

REF. PT. E, N	306300 m	5953900 m
EXTENTS	1700 m	100.3 m
SECTION TOP, BOT	710 m	609.7 m
TOLERANCE +/-	25 m	
VERTICAL EXAG.	10	

SCALE

(m)

-50 0 50 100 150 200 250

*unknown

AZIMUTH = 90°

N W E S

Lafarge Canada Inc.

Calahoo

Cross Section 5,953,900N

Looking North

Area Concerns

- Over the past several years, Sturgeon County has heard concerns and received complaints from residential well owners, related to water level changes, well pumping performance, etc.

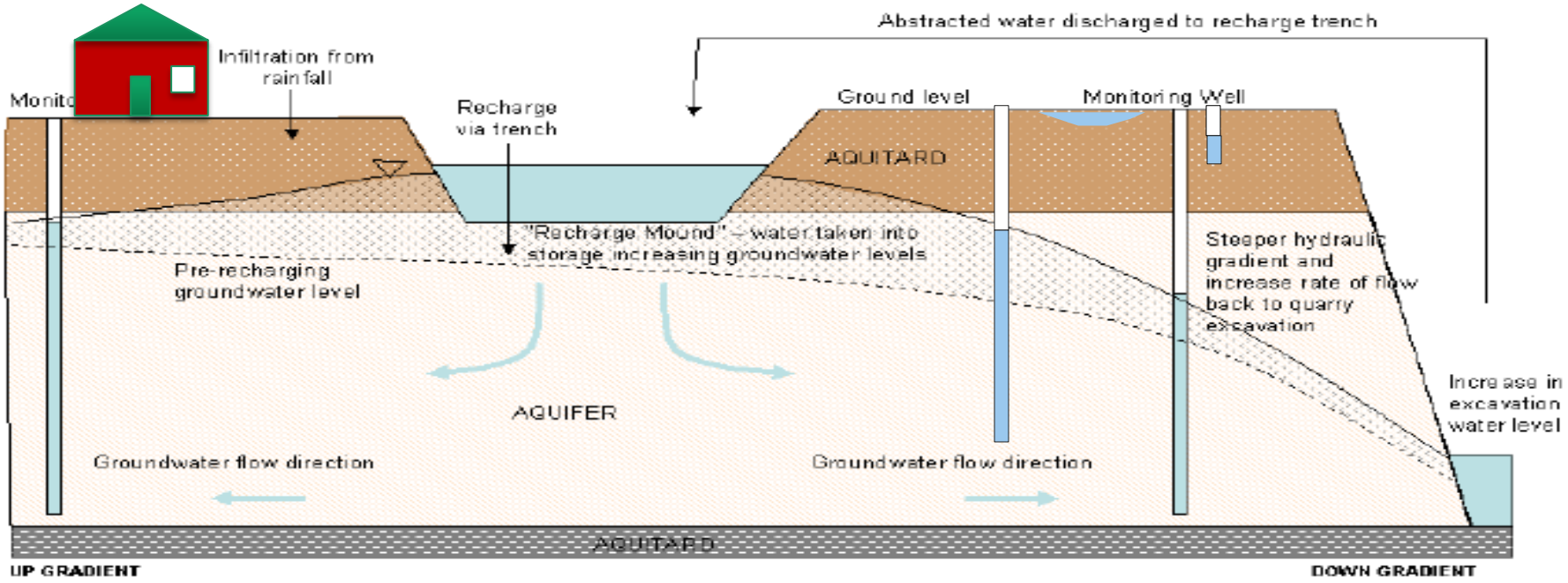
- Complaints received from well owner locations have greatly varied, sometimes up to 10 kms from active mining areas. Tendency for mining to be ‘guilty by proximity’, by being in the general area

- Sturgeon County identified the need for guidance to predict how aquifer groundwater levels may change, from shifting aggregate mining activities.

Groundwater Drawdown

- Groundwater Modelling (Predictive)

- Groundwater Monitoring (Actual)



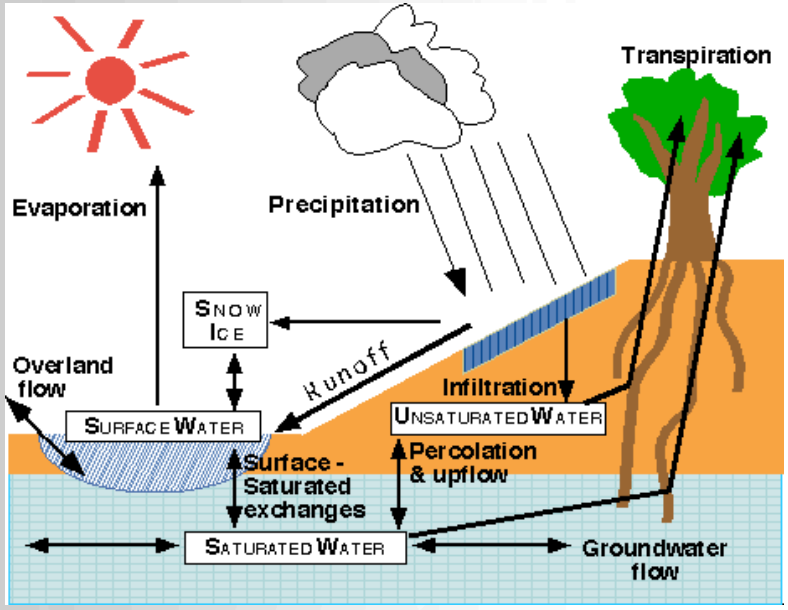
Aquifer Groundwater Change Prediction

Preliminaries

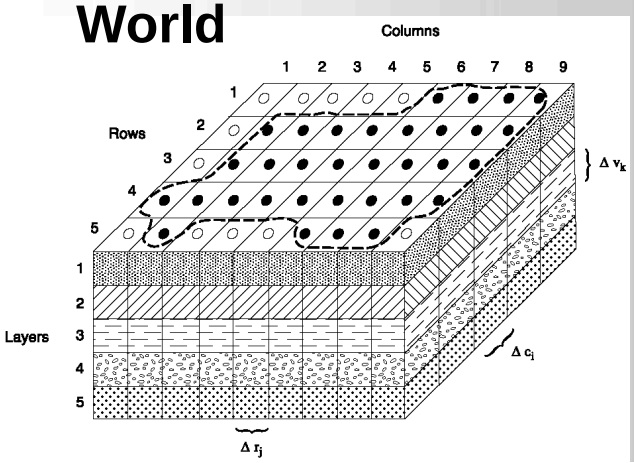
Groundwater flow models are based on:

- The physics principle of Conservation of Mass
- Darcy's Law.

Real World



Numerical Model World

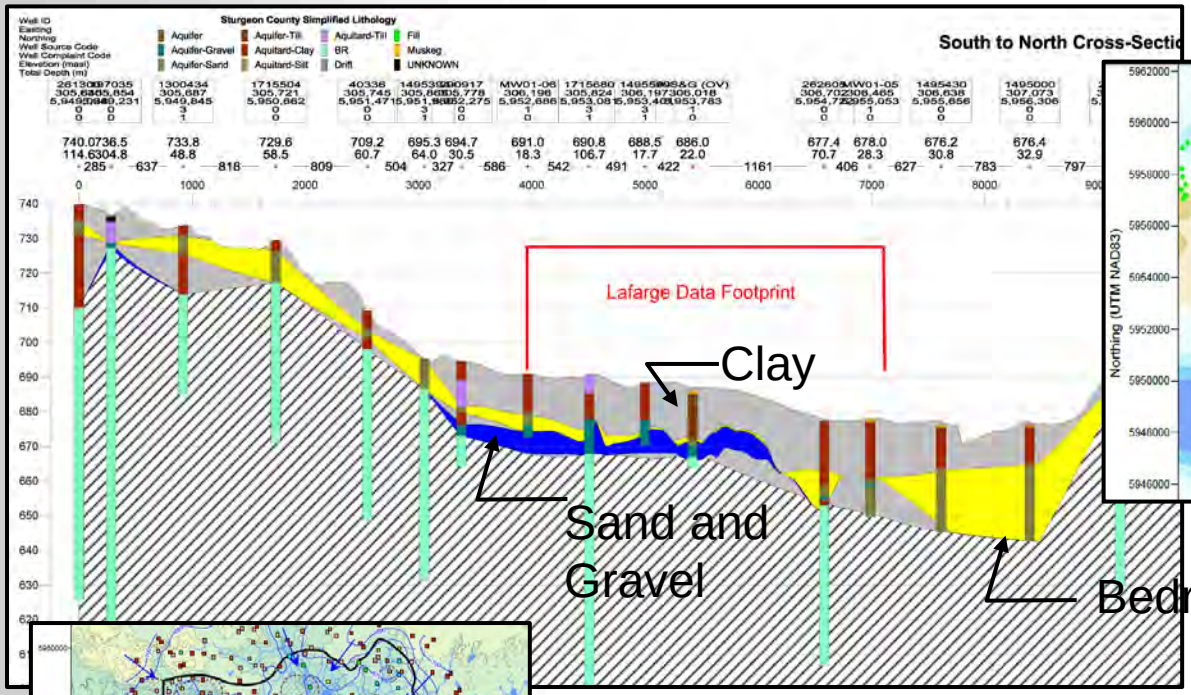


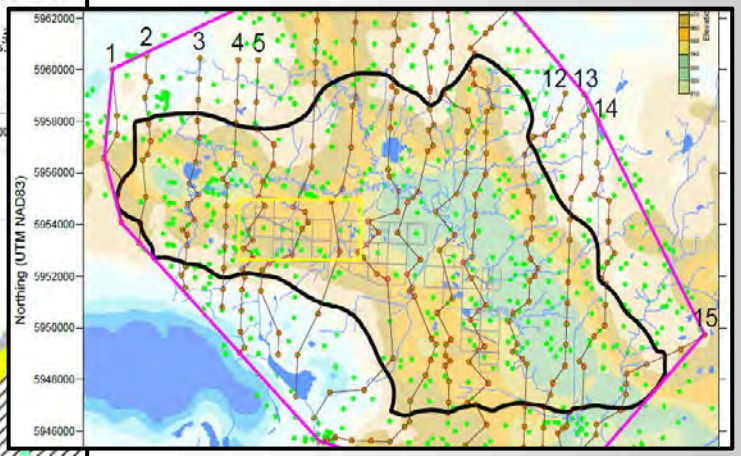
Aquifer Parameters:
h - hydraulic head
K - hydraulic conductivity
S_s - storage coefficient

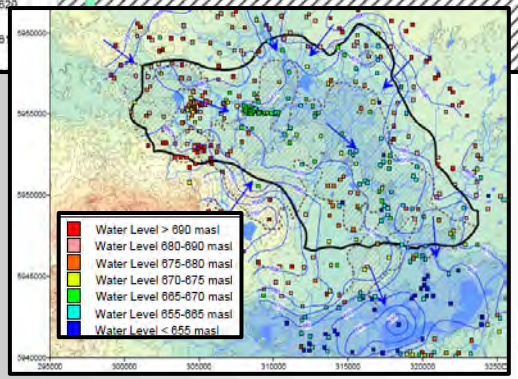
Aquifer Groundwater Change Prediction

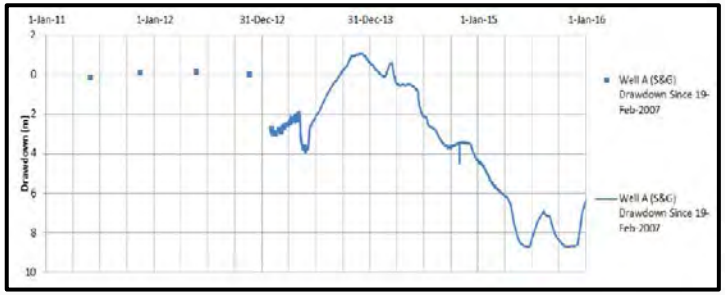
Building a Numerical Groundwater Model

Develop Conceptual Model









23	Gravel	Aquifer-Gravel
24	Gravel & Boulders	Aquifer-Gravel
33	Pea Gravel	Aquifer-Gravel
5	Boulders	Aquifer-Gravel
34	Quicksand	Aquifer-Sand
36	Sand	Aquifer-Sand
37	Sand & Boulders	Aquifer-Sand

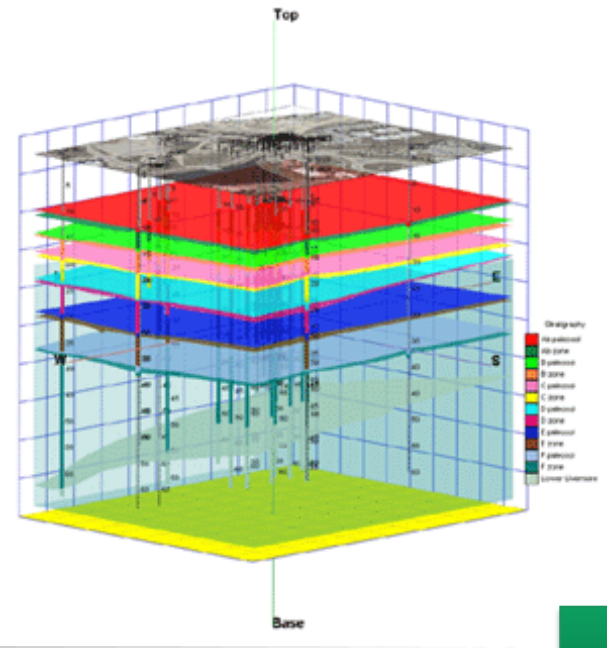
6	Clay	Aquitard-Clay
7	Clay & Boulders	Aquitard-Clay
8	Clay & Coal	Aquitard-Clay

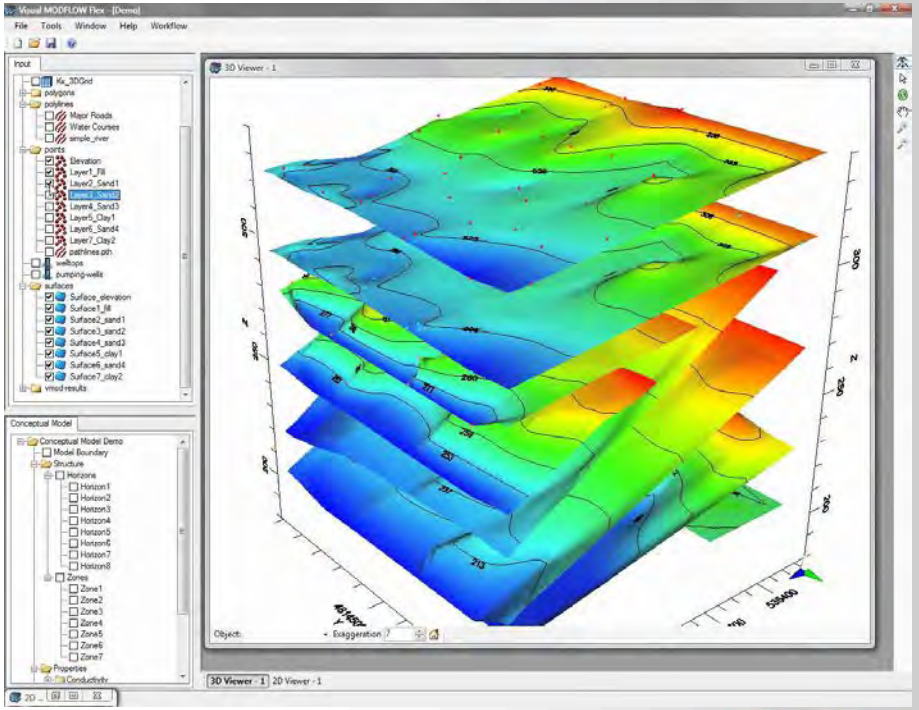
73	Till	Aquitard-Till
74	Till & Clay	Aquitard-Till
76	Till & Rocks	Aquitard-Till
47	Sandrock	Bedrock
3	Bedrock	Bedrock

Aquifer Groundwater Change Prediction

Building a Numerical Groundwater Model

Develop Numerical Model





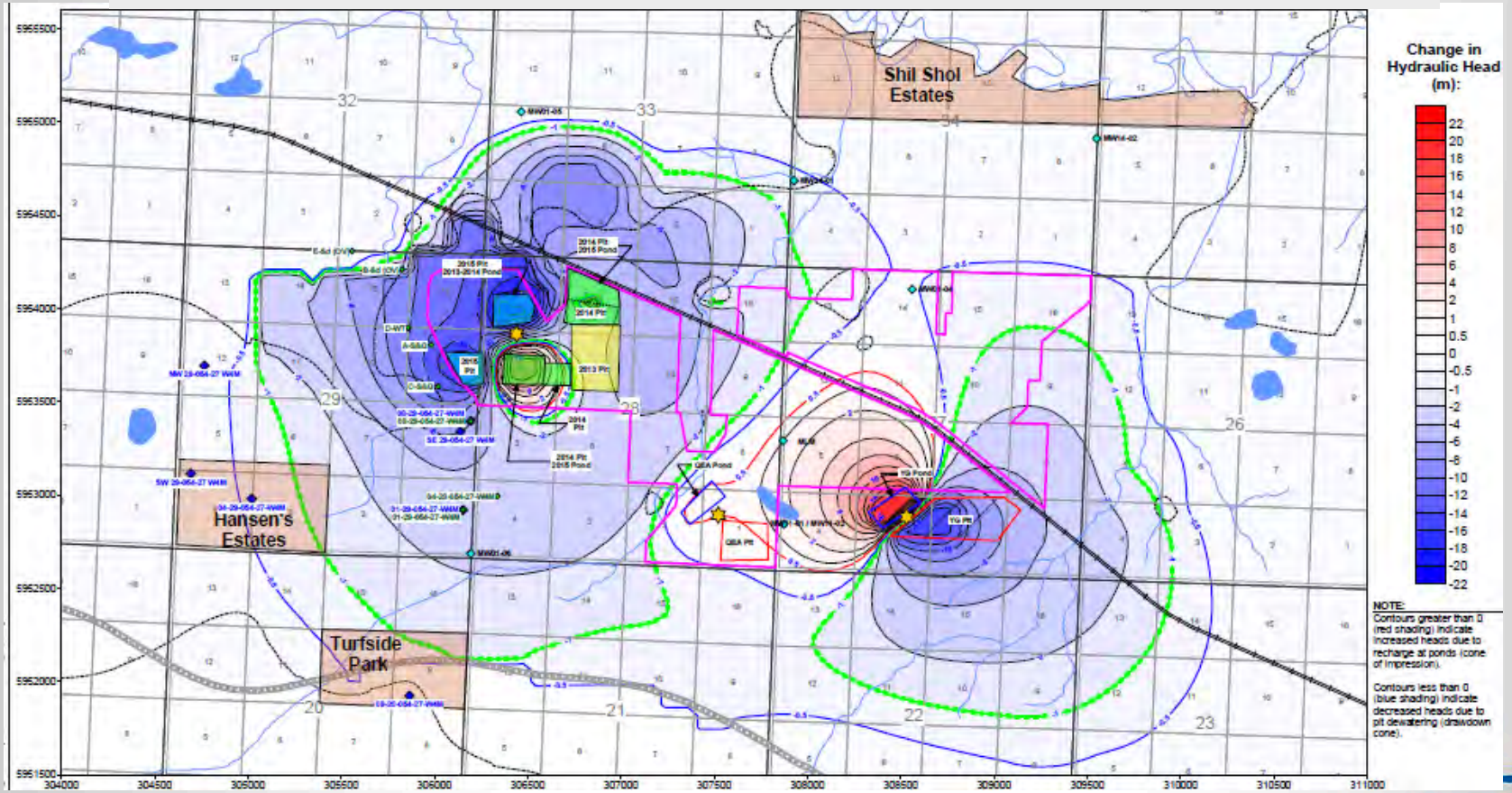
Sturgeon County

Aquifer Groundwater Change Prediction

Stages of a Modelling Project

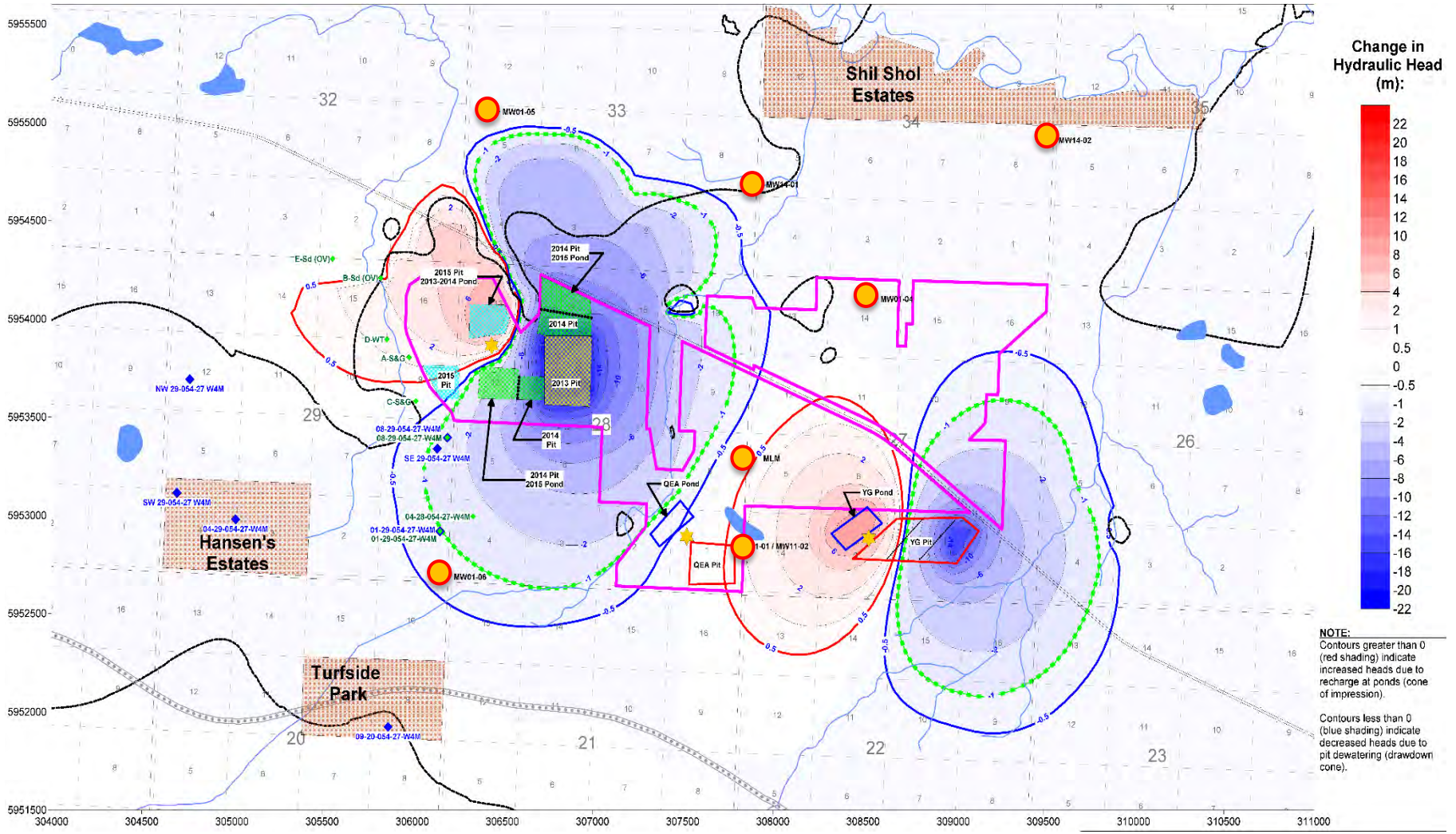
Make Predictions to Meet Project Goals

(Monitoring Network Design / Assess Impacts from Operations / Assess Mitigation Option etc.)



Sturgeon County

Simulated Hydraulic Head Change Due to Mining Dewatering - End of 2013

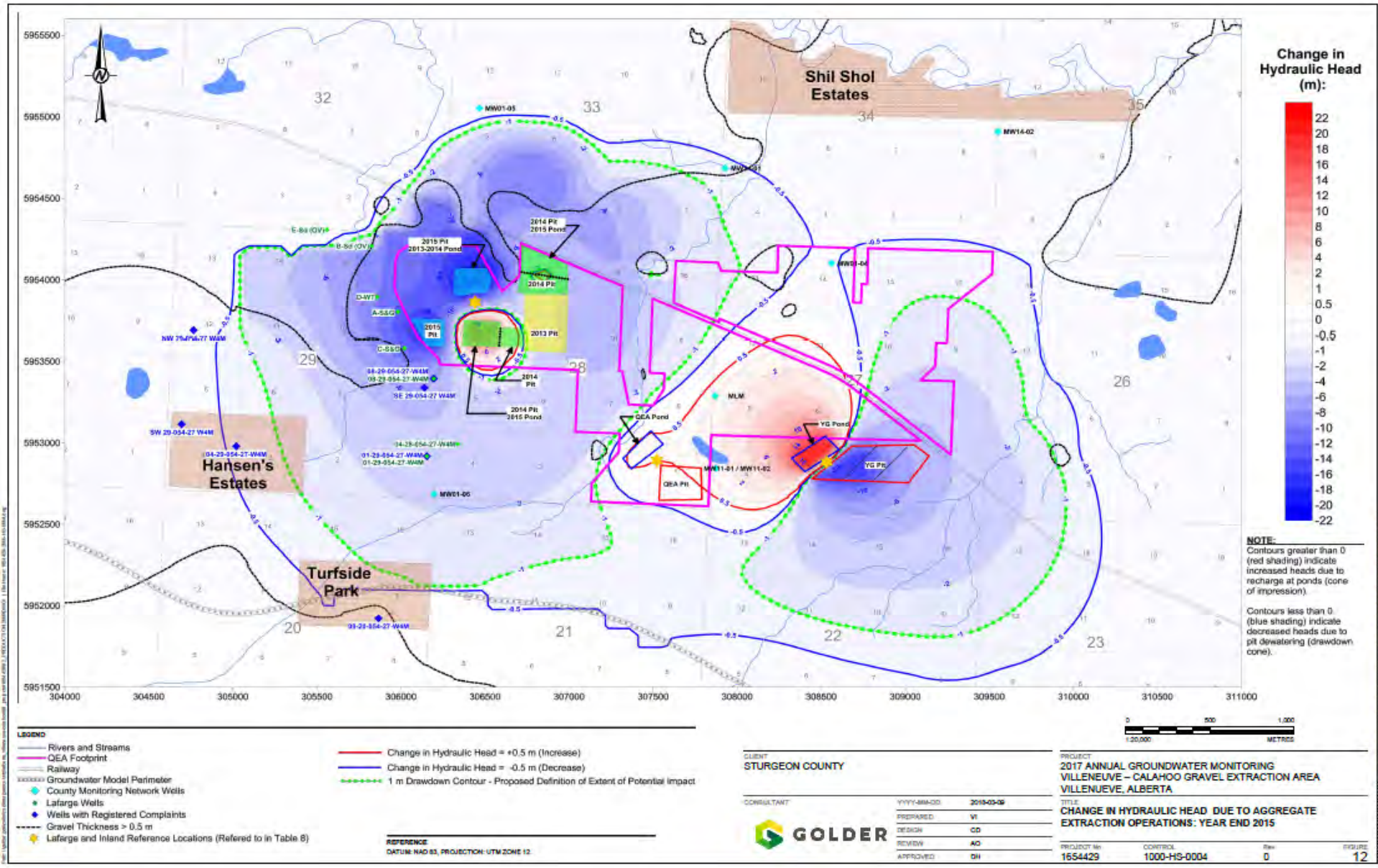


LEGEND

- Rivers and Streams
- QEA Footprint
- Railway
- Groundwater Model Perimeter
- County Monitoring Network Wells
- Lafarge Wells
- Wells with Registered Complaints
- Gravel Thickness > 0.5 m
- Lafarge and Inland Reference Locations (Refered to in Table 8)
- Change in Hydraulic Head = +0.5 m (Increase)
- Change in Hydraulic Head = -0.5 m (Decrease)
- 1 m Drawdown Contour - Proposed Definition of Extent of Potential Impact

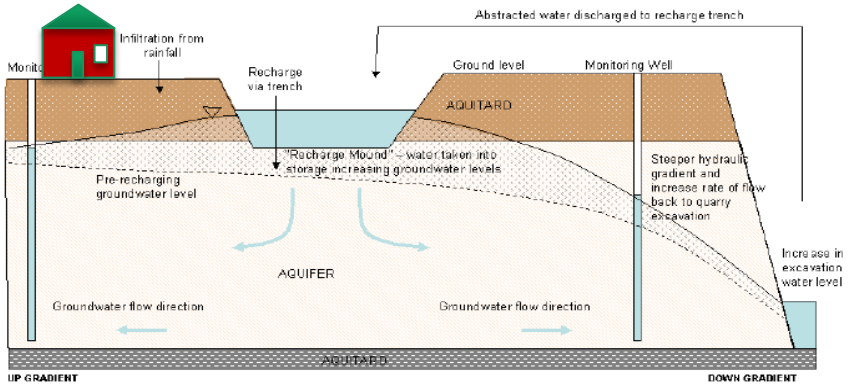
Golder Associates

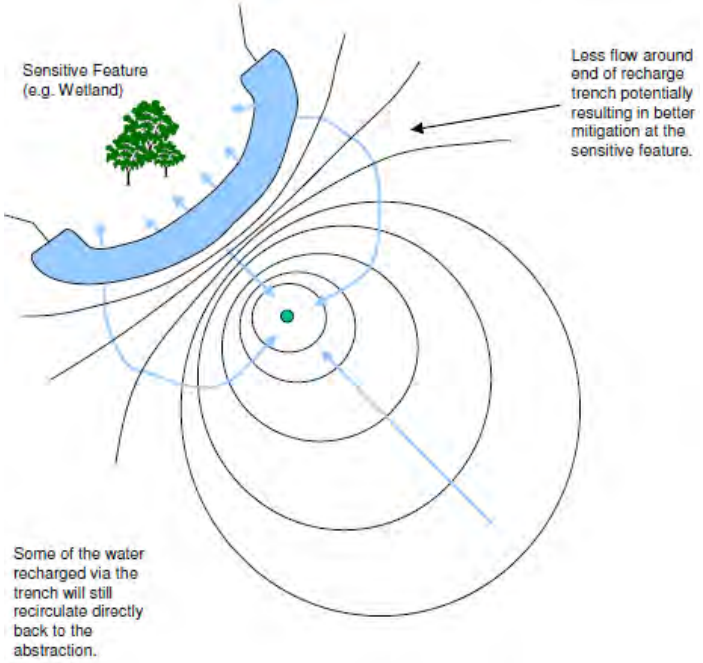
Simulated Hydraulic Head Change Due to Mining Dewatering - End of 2015



Calahoo-Villeneuve Model Applications

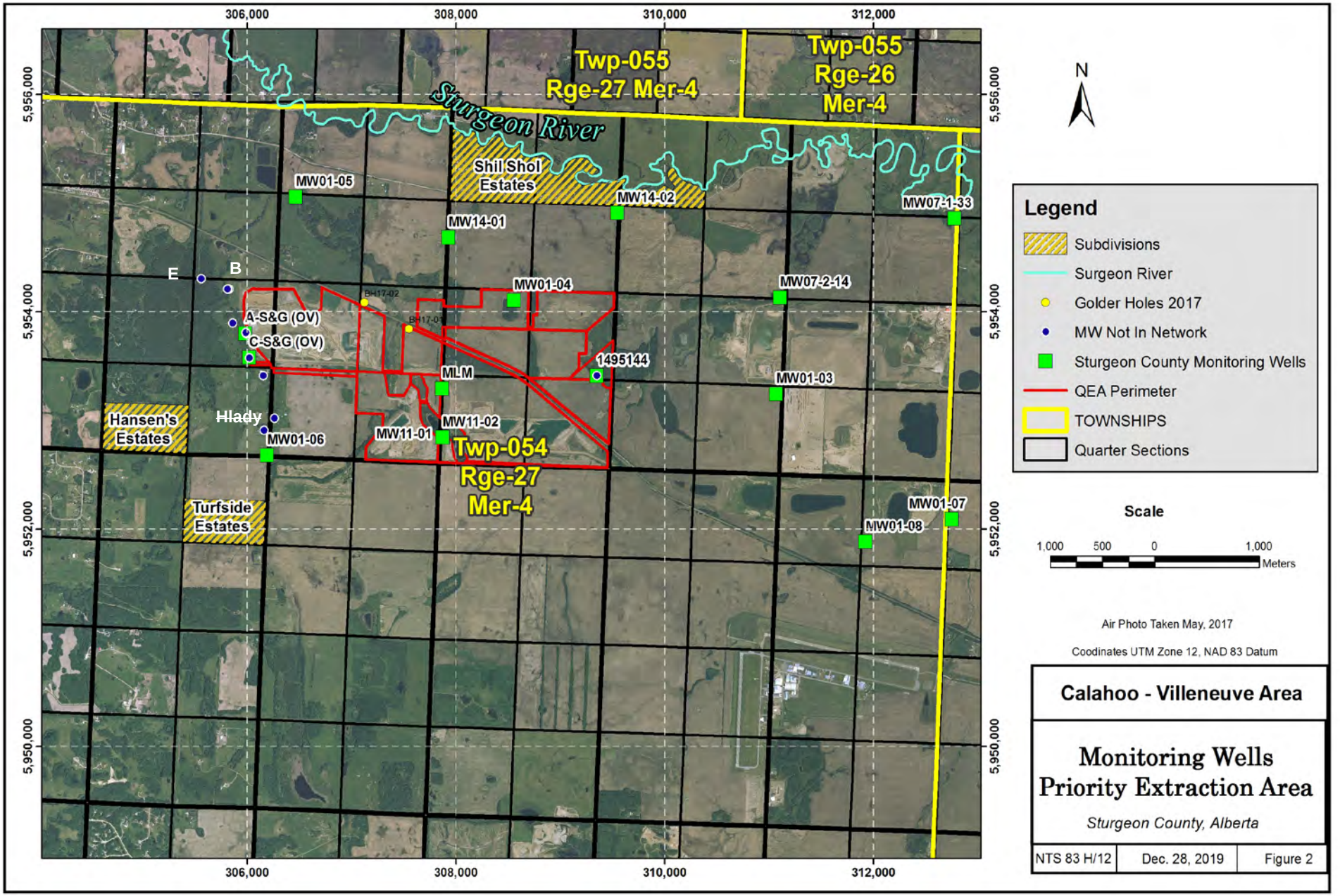
Off-site Groundwater 'Buffering'





- Modelling can help to plan dewatering-recharge alternatives, notably:
  - Drawdown impacts to sensitive off-site areas.

- Modelling can also potentially be used to predict long-term, post-closure groundwater conditions of alternate reclamation designs.


306,000
308,000
310,000
312,000
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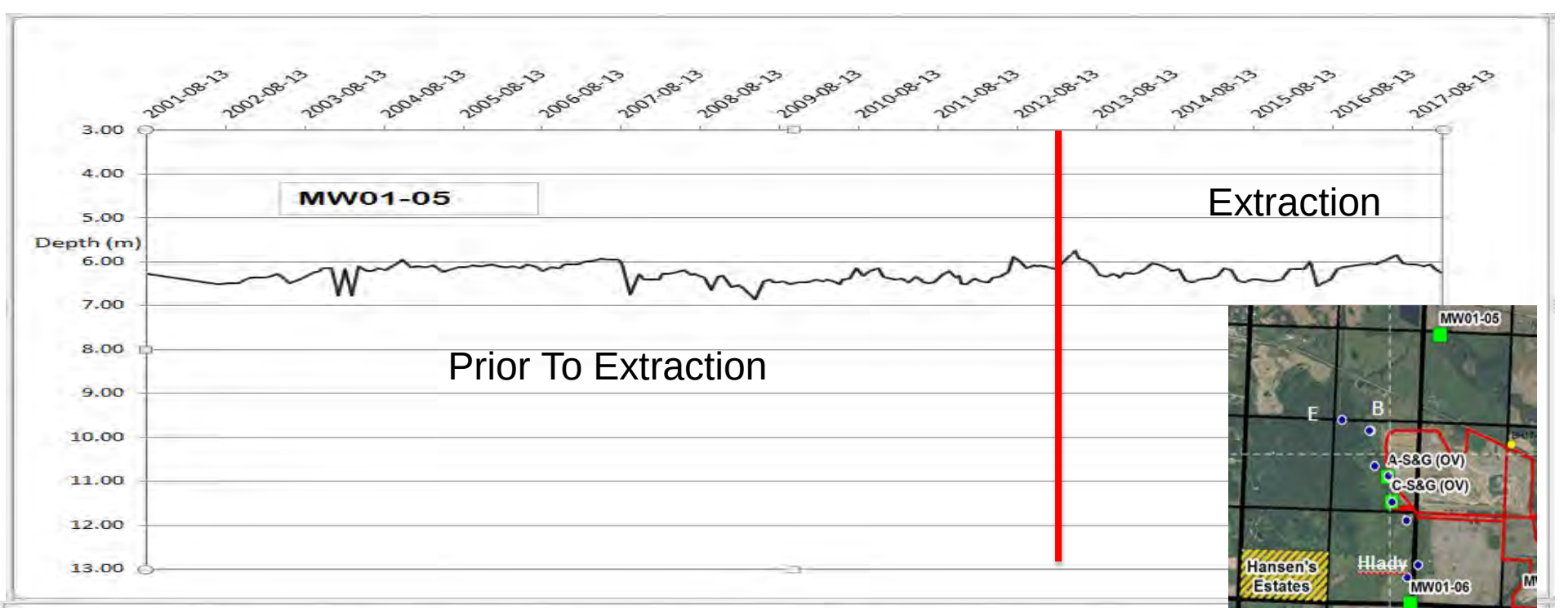
5,954,000
5,952,000
5,950,000
Twp-055
Rge-27 Mer-4
Twp-055
Rge-26
Mer-4
Sturgeon River
Shil Shol
Estates
MW01-05
MW14-02
MW14-01
MW07-1-33
E
B
MW01-04
MW07-2-14
BH17-02
BH17-01
A-S&G (OV)
C-S&G (OV)
1495144
MLM
MW01-03
Hansen's
Estates
Hlady
MW11-02
MW11-01
MW01-06
Twp-054
Rge-27
Mer-4
Turfside
Estates
MW01-07
MW01-08
N
Legend
Subdivisions
Surgeon River
Golder Holes 2017
MW Not In Network
Sturgeon County Monitoring Wells
QEA Perimeter
TOWNSHIPS
Quarter Sections
Scale
1,000 500 0 1,000
Meters
Air Photo Taken May, 2017
Coodinates UTM Zone 12, NAD 83 Datum
Calahoo - Villeneuve Area
Monitoring Wells
Priority Extraction Area
Sturgeon County, Alberta
NTS 83 H/12
Dec. 28, 2019
Figure 2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2002-08-13
2003-08-13
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2005-08-13
2006-08-13
2007-08-13
2008-08-13
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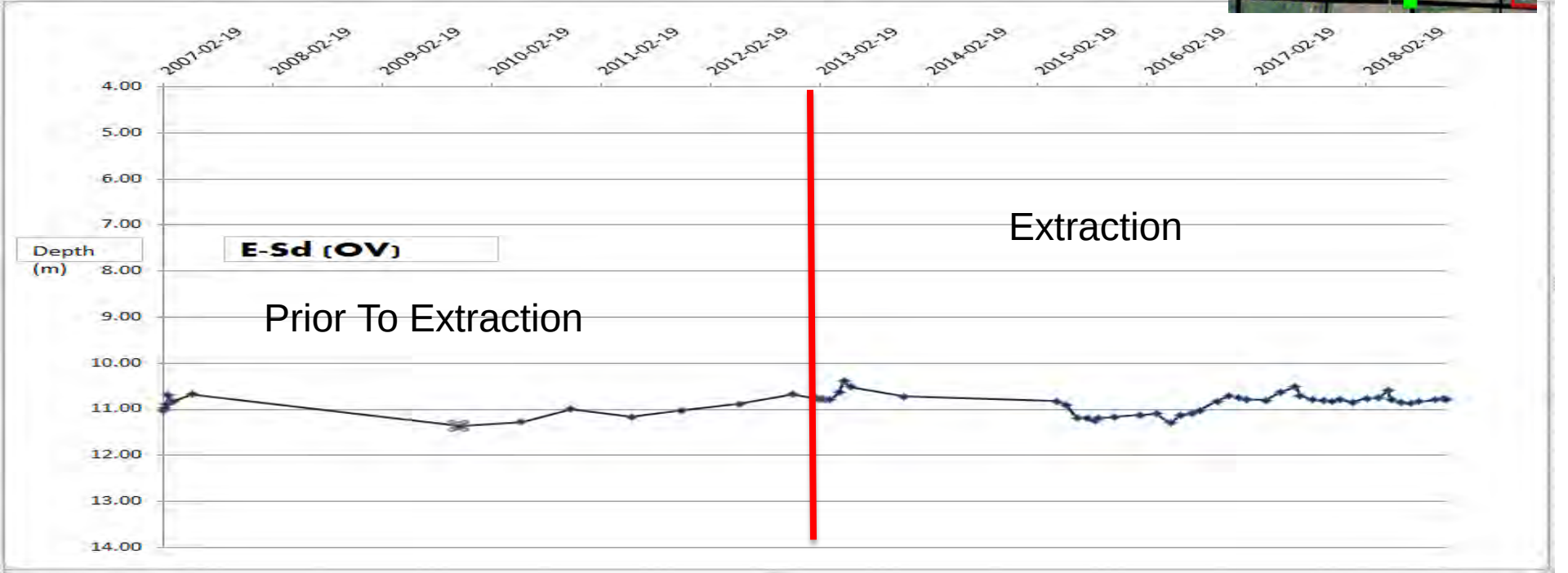
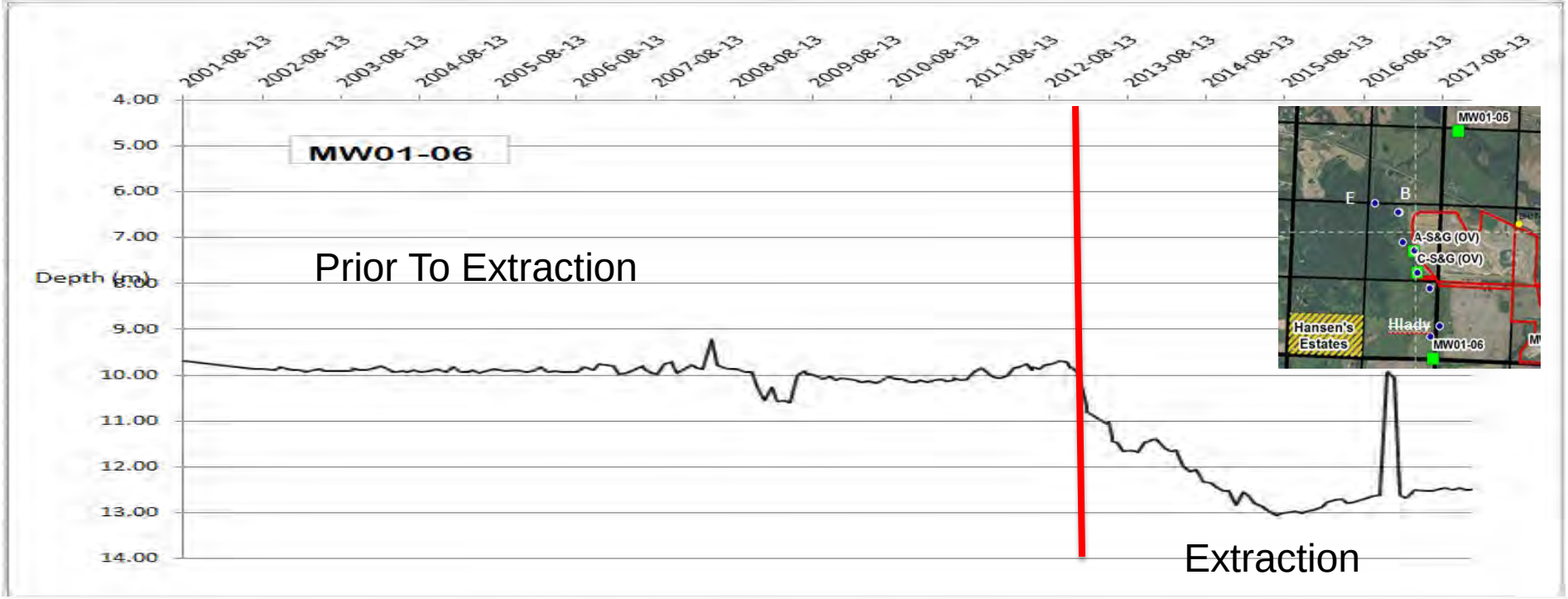
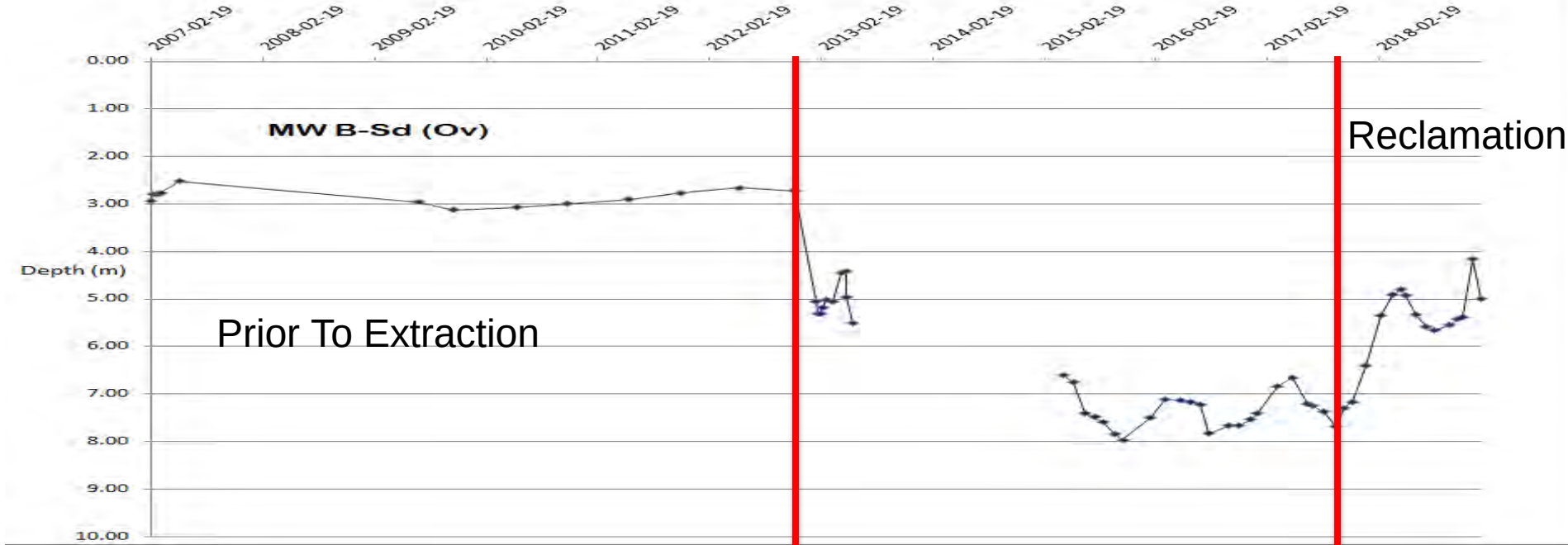
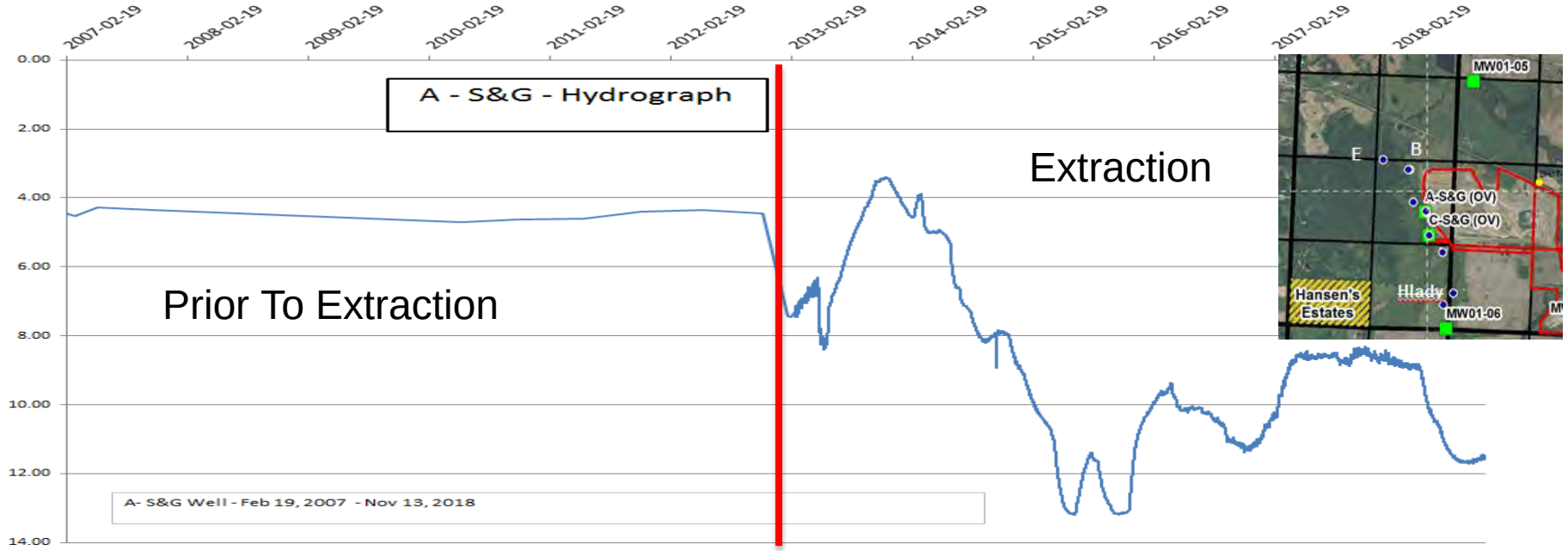
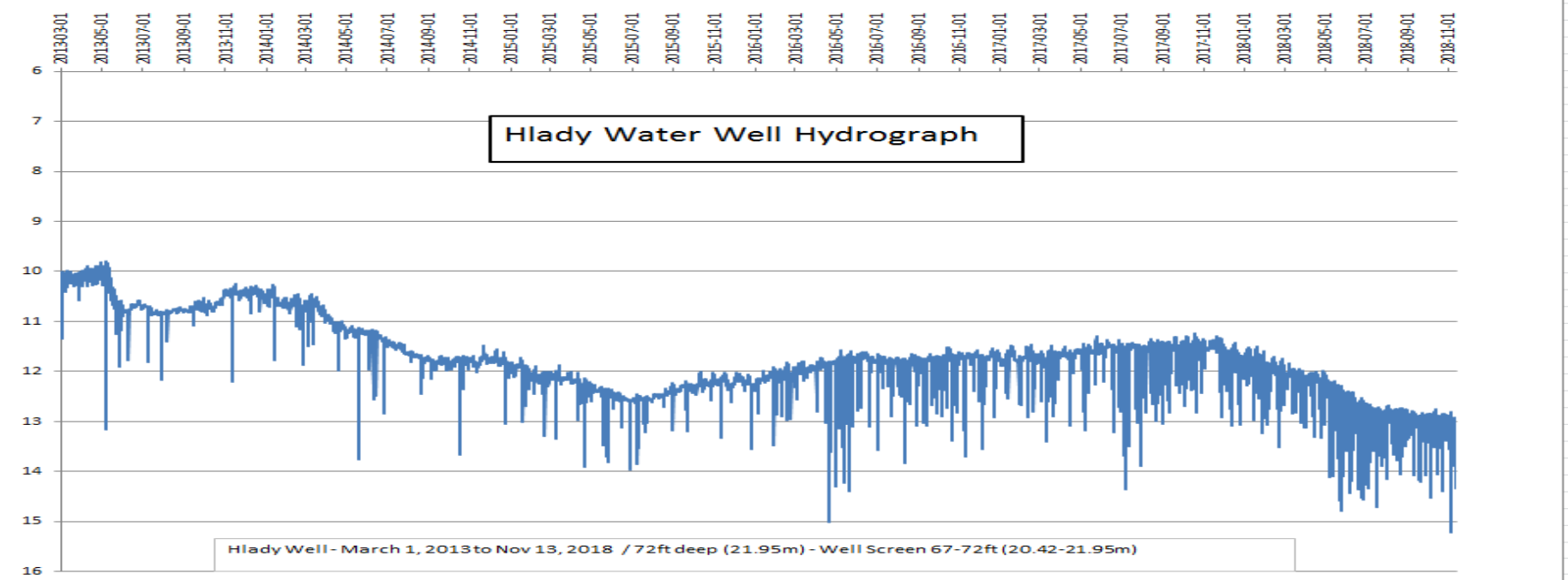
2010-08-13
2011-08-13
2012-08-13
2013-08-13
2014-08-13
2015-08-13
2016-08-13
2017-08-13
3.00
4.00
5.00
Depth (m)
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
MW01-05
Extraction
Prior To Extraction
MW01-05
E
B
A-S&G (OV)
C-S&G (OV)
Hansen's Estates
Hlady
MW01-06


2007-02-19
2008-02-19
2009-02-19
2010-02-19
2011-02-19
2012-02-19
2013-02-19
2014-02-19
2015-02-19
2016-02-19
2017-02-19
2018-02-19
4.00
5.00
6.00
7.00
Depth (m)
8.00
9.00
10.00
11.00
12.00
13.00
14.00
E-Sd (OV)
Extraction
Prior To Extraction


MW01-06
Depth (m)
Prior To Extraction
Extraction
MW01-05
E
B
A-S&G (OV)
C-S&G (OV)
Hansen's Estates
Hlady
MW01-06

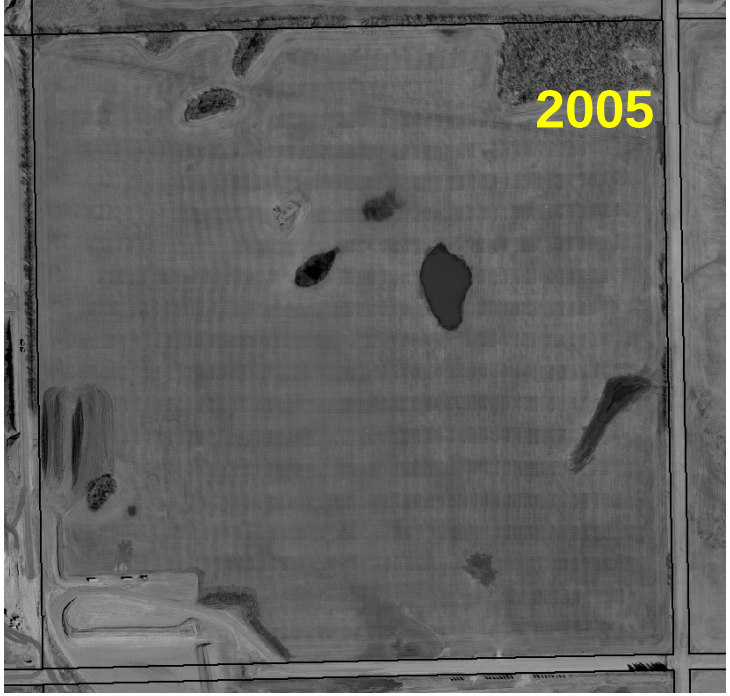

MW B-Sd (Ov)
Depth (m)
Prior To Extraction
Reclamation

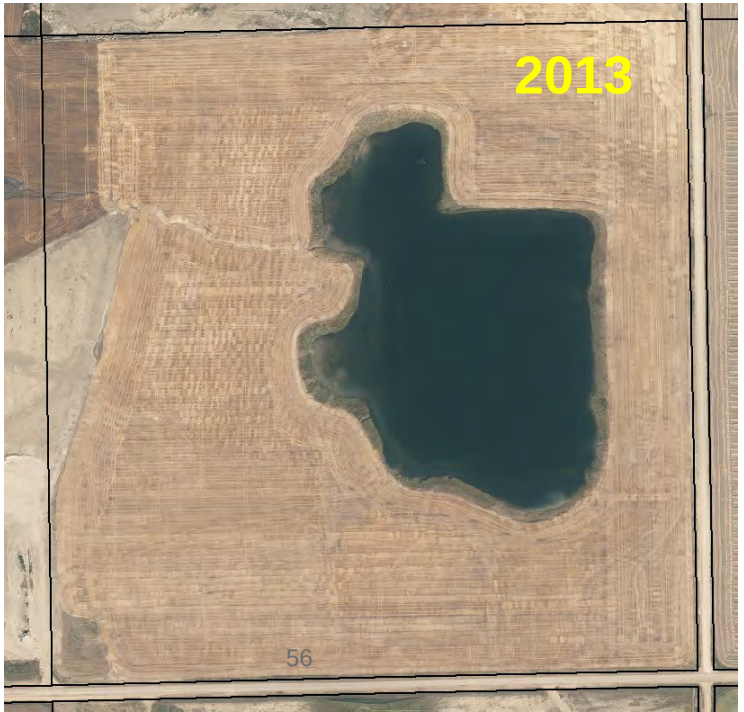

A - S&G - Hydrograph
Extraction
Prior To Extraction
A- S&G Well - Feb 19, 2007 - Nov 13, 2018
MW01-05
E
B
A-S&G (OV)
C-S&G (OV)
Hansen's Estates
Hlady
MW01-06


Hlady Water Well Hydrograph
Hlady Well - March 1, 2013 to Nov 13, 2018 / 72ft deep (21.95m) - Well Screen 67-72ft (20.42-21.95m)

Reclamation Examples

Stollery Pit





LAFARGE

Gravel Pit Reclaimed to Wetland

Reclaimed Gravel Pit – Lafarge Villeneuve

(Reclamation Certificate Received)

In Summary

- Water Chemistry Remains Consistent - Before / During / After Mining
- There is an impact associated with pit dewatering (draw down of water table to facilitate aggregate extraction)
- Impacts of water drawdown found to be on the order of about 500-600m from pit operations (asymmetric) – diminish with distance
- Surface Water & Groundwater not connected (lacustrine clay)
- Geology is critical to understanding where impacts can occur. Location of impacts will vary :
  - Stratigraphy (not necessarily horizontal)
  - Presence of barriers (aquatards)
  - Hydraulic conductivity of units

LAFARGE 60 YEARS BUILDING CANADA