Incorporating Geologic Models into Groundwater Flow Models for Basal Aquifer Depressurization

Presented by Rudy Maji, Ph.D.

Golder Associates

Talk Outline

- Demonstrate how we are capable of directly honouring detailed geologic models in our groundwater modelling projects.
- Basal Aquifer Depressurization (DP) for a surface mineable oil sands project provides context.
- An alternative approach incorporating 3D geologic modelling results is compared and contrasted with the conventional modelling method.

Golder Associates

Methodologies

Conventional Methodology

- “Layer Cake” Geology.
- Good for Homogeneous Systems.

Alternative Methodology

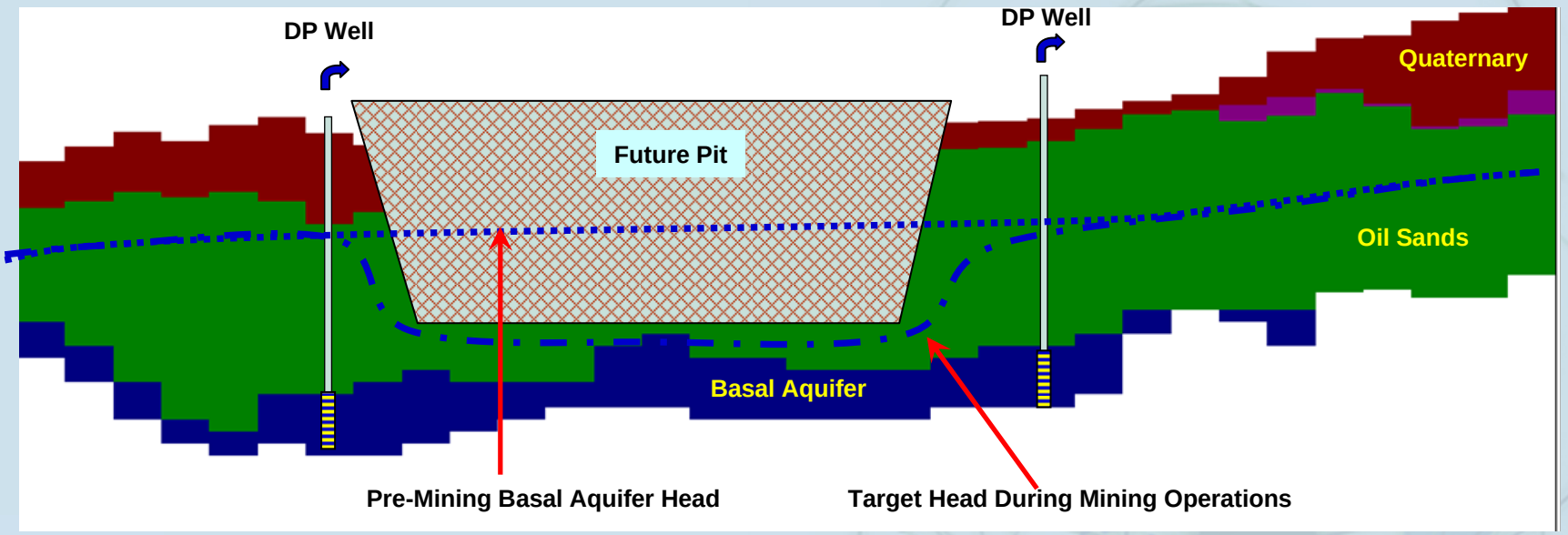
- Heterogeneous 3D Geology.
- Honours Complex Inter-bedded Geology.
- Honours Oil Companies Detailed geologic model into groundwater flow model.

Sometimes depositional environment is so complex that it is not easy to lump into layer cake model.

Golder Associates

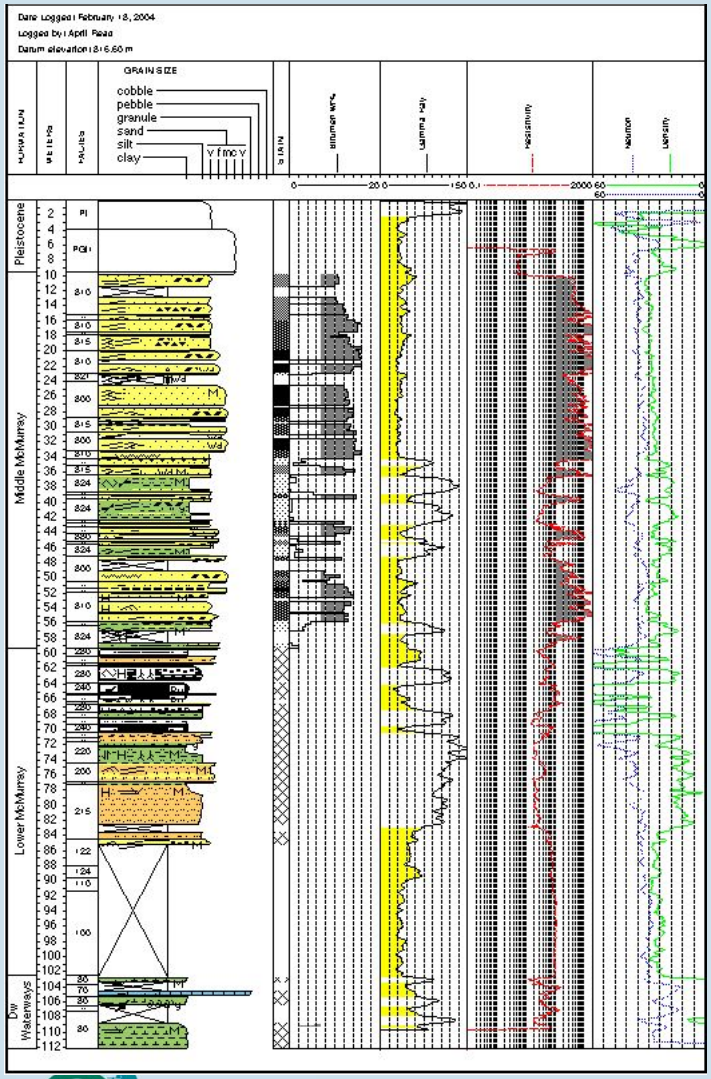
Project Objective

- To depressurize the water saturated sands in the lower McMurray Fm so the bitumen saturated McMurray sands can be safely mined by open pit mining methods.



Golder Associates

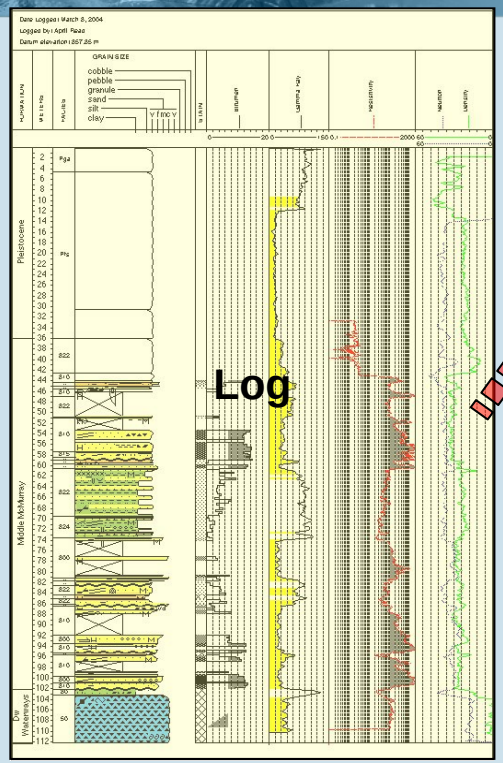
Geologic Setting



- Bitumen ore zone within the McMurray Fm over the project area.
- Predominantly inter-bedded Sands with Shales and other low K materials.
- Traditional interpretation consists of fluvial channels in the Lower McM; estuarine sequences in the Middle and Upper McM.
- “Water Sands” generally found lower in the sequence, but sand lenses can be separated by non-aquifer material.
- The ore zone has significant bitumen saturation resulting in poor hydraulic conductivity (aquitard).

Golder Associates

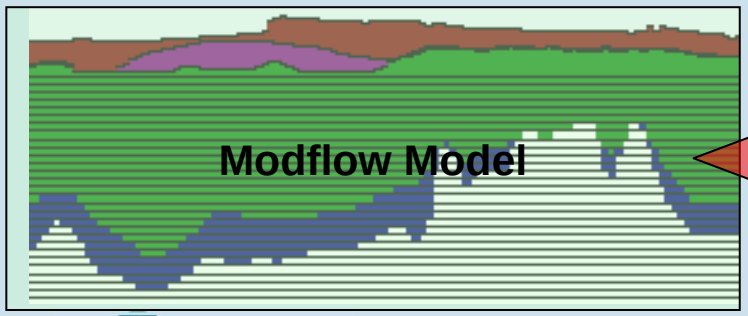
Conventional Study Methodology

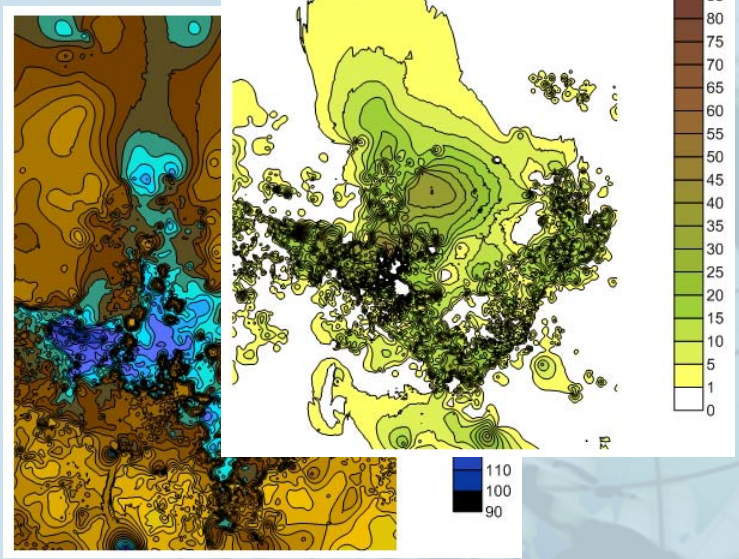


Stratigraphic Picks Table
(cumulative sand thickness inferred to be part of the basal McMurray aquifer + Fm structures)

WellID	WELLNUMBER	EASTING	NORTHING	GSURFACE	Pleistocene Base	KmTop	BottMid	WsTop	Wsiso	DvTop	BoreholeComp Date
13	010										02/15/2001
14	010										01/12/1990
15	011										02/01/1990
16	011										05/12/1905
17	011										02/11/1982
18	011										02/10/1982
19	011										02/01/1986
20	011										01/28/1988
21	011										01/01/1976
22	0118AA9508	483694	6343685	329.8	322	322	252	181	0	181	03/10/1988
23	0120AA9508	484555	6345463	332.5	322	322	256	247	9	227	02/14/1986
24	0120AB9508	484460	6345248	332.4	322	322	256	229	3	226	02/05/1988
25	0121AA9508	486190	6345437	336.6	324	324	250	230	3	227	01/28/1985
26	0121AB9508	486297	6345338	337.4	322	322	251	242	0	242	03/05/1986

Data Transfer to Golder





Structure & Isopach Maps of Idealized Hydrostratigraphic Conceptual Model

Golder Associates

Motivation For Alternative Approach

- Difficulty in making the water sand isopach pick in more complex geologic environments (which sand lenses to include as part of the basal aquifer?).
- Difficulty in vertically setting the aquifer – stacked directly on the Devonian Unconformity or “hung” from an interpreted aquifer top structure?

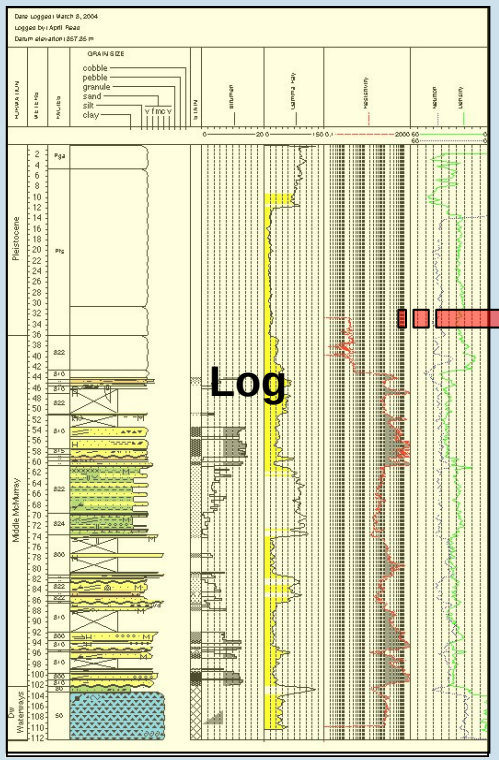
Golder Associates

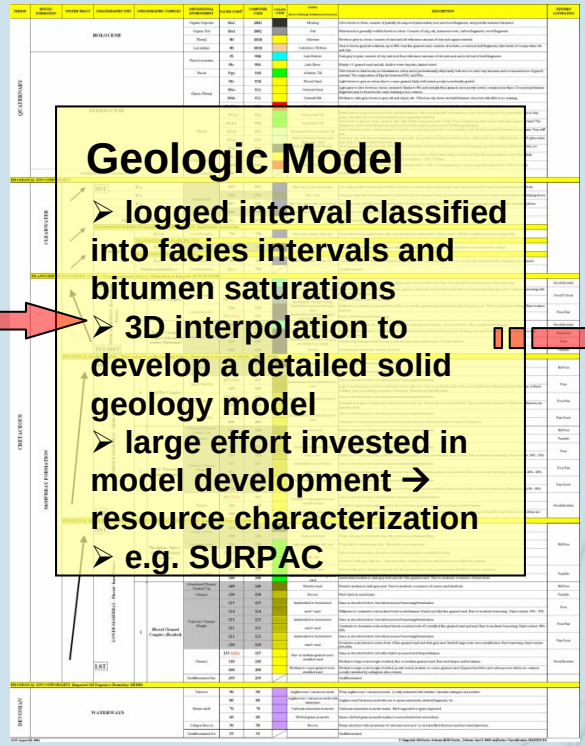
Motivation For Alternative Approach

- If aggressive depressurization occurs, the heads in parts of the basal aquifer may drop to within the aquifer → unconfined conditions & pore dewatering.
- If the aquifer isopach is not vertically placed correctly, the model will not simulate this behaviour.
- More realistic conceptual model for areas with more complex hydrostratigraphy → allows for additional investigations to aid decision making (perched water sand dewatering / geotechnical considerations etc.).

Golder Associates

Methodology





Geologic Model

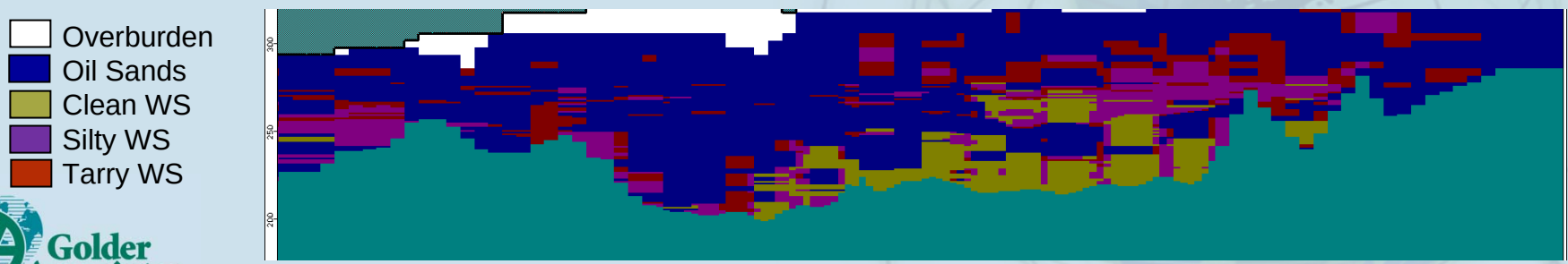
- logged interval classified into facies intervals and bitumen saturations
- 3D interpolation to develop a detailed solid geology model
- large effort invested in model development → resource characterization
- e.g. SURPAC

Data Transfer to Golder

Processing:

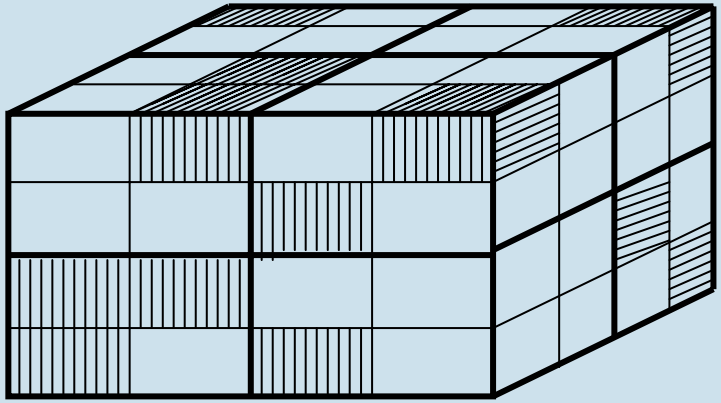
- K-assignment to geocodes.
- upscaling (possibly).
- merging local scale hydrostratigraphy with regional interpretations.
- specialized codes developed to generate the input files for the groundwater modelling software.

Modflow Model

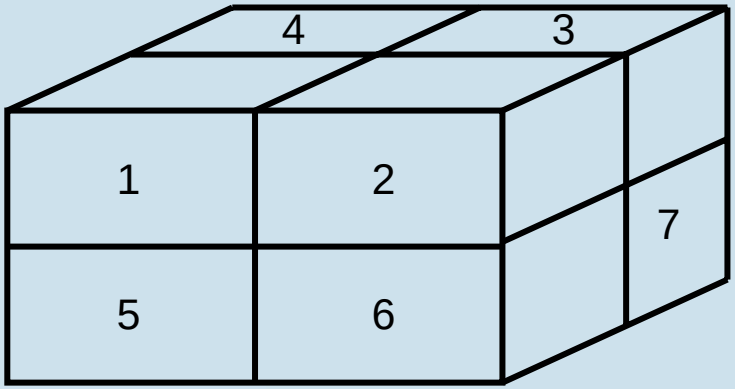


Golder Associates

Methodology - Upscaling



Total No. of Blocks = 64



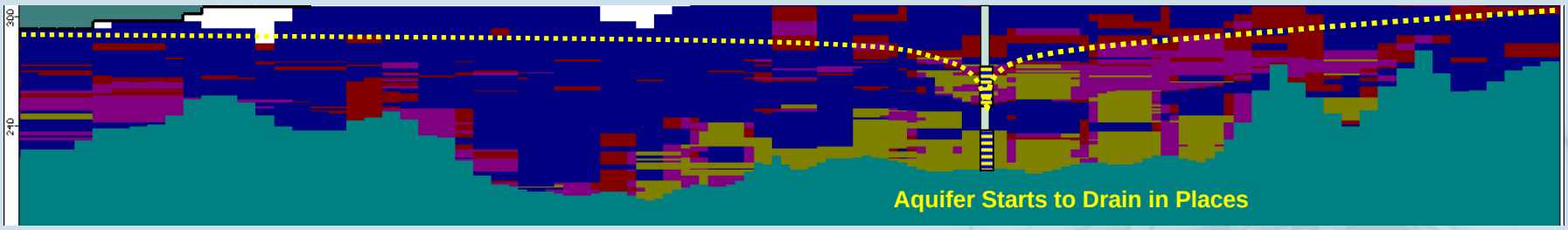
Total No. of Blocks = 8

- Upscaling geology to coarser grids for numerical efficiency can be accomplished by:
  1. Assigning hydraulic conductivities to local scale geologic blocks.
  2. Determining the geometric mean of a grouping of local scale blocks.
  3. “Binning” the resultant K’s of the upscaled blocks and assigning a geocode.

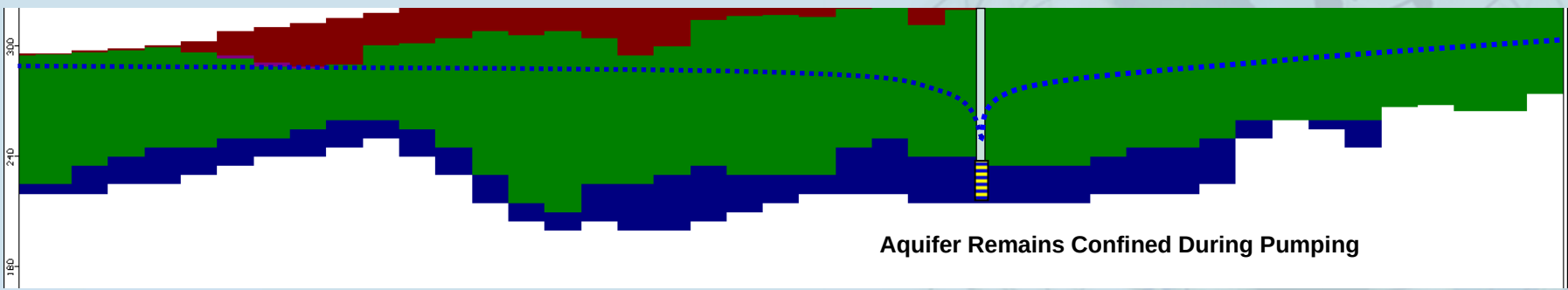
Golder Associates

Methodology

Example Section Using Alternative Methodology



Example Section Using Conventional Methodology



Golder Associates

Lessons Learned

- Honouring detailed geologic models is feasible with current computing resources.
- Care must be taken to ensure aquifer connectivity is maintained during the Upscaling Process.
- Post-processing is not as straightforward as for a traditional “layer cake” type of model.

Golder Associates

Alternative Approach (Pros/Cons)

Pros

- Honours Client's Geology Directly.
- Provides More Realistic Head Distribution for Complex Hydrostratigraphic Settings.
- Opportunities to Map Various Aquifers Perched and Otherwise.
- More Sophisticated Management Tool.

Cons

- Additional Pre/Post-processing is Required.
- Longer Execution Time; It Means Faster Computers are Required.

Golder Associates

Applications

- A great deal of effort has spent in developing detailed 3D geologic models – we can now honour these high-resolution dataset in our groundwater models where that level of detail is deemed appropriate for the project at hand.

Golder Associates

Applications

- Useful tool for identifying data gaps that helps in planning field programs
  - High-resolution 3D geologic model provides a more realistic site conceptual model when planning pumping tests in more complex settings.
- Easy to map water sands above and below the base of mineable ore.
  - Accordingly, depressurization/dewatering plans can be refined for more complex settings.

Golder Associates

Handling Drawbacks

- Faster Computers are essential to simulate alternative approach.
  - For Alternative approach the model takes 4 to 5 hours to complete the simulation, while the Conventional Approach takes only half an hour to one hour.
  - We would like to run the model in our Golder Linux Cluster system (total 250 CPUs cost about $100K)
- Parallel Computing may be required to speed up the solution time.

Golder Associates

Future Applications

- Application with FEFLOW
- Upscaling method would be tricky for Finite Element Mesh.

Golder Associates

Other Applications

- Stochastic Simulations to obtain the uncertainty involved in number of DP wells due to aquifer heterogeneity.

Golder Associates

The Team

- Rudy Maji – Calgary
- Karl Lawrence - Calgary
- Don Haley – Calgary
- Ken Baxter - Calgary

Golder Associates