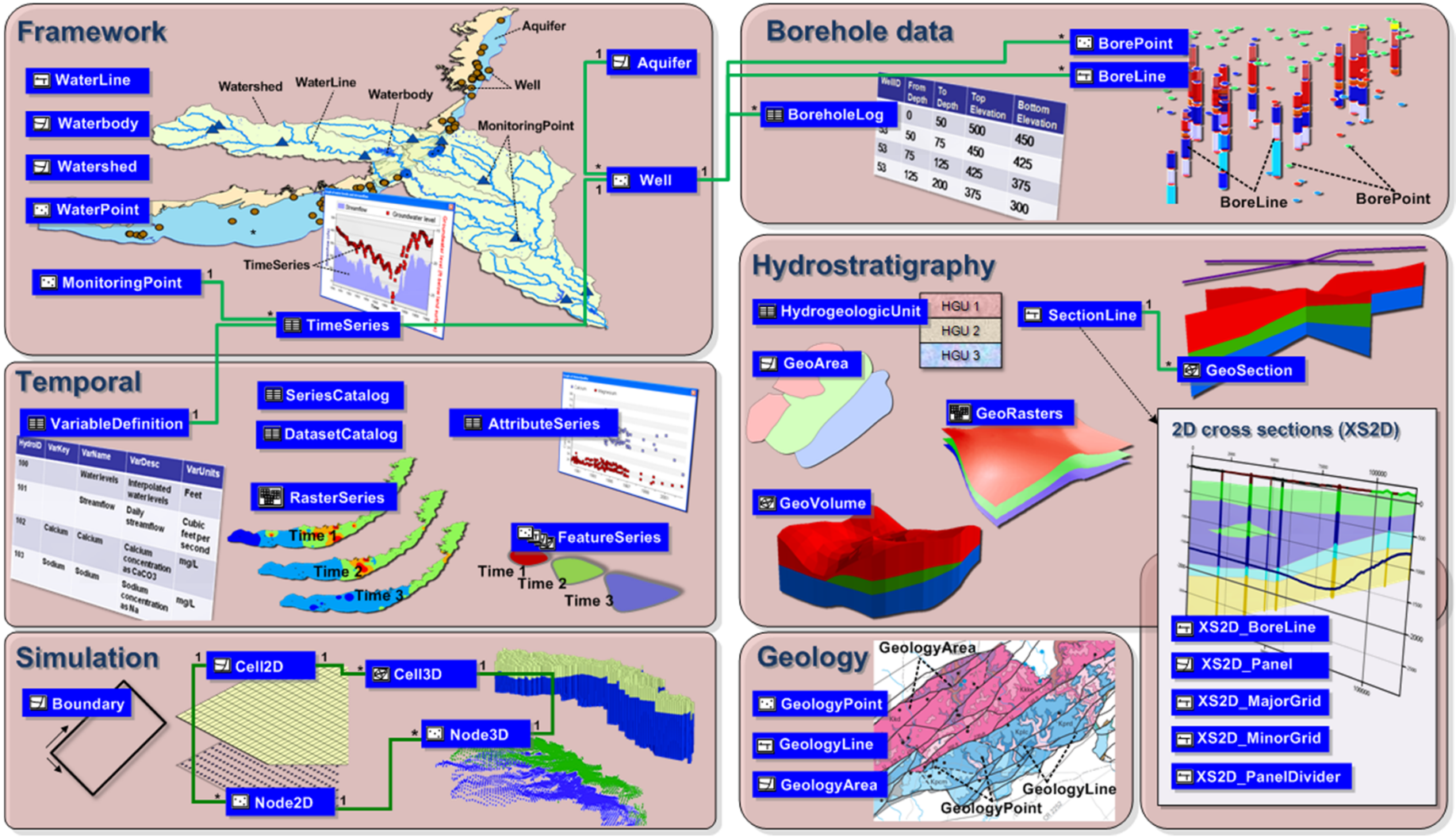
Norm Jones
Brigham Young University

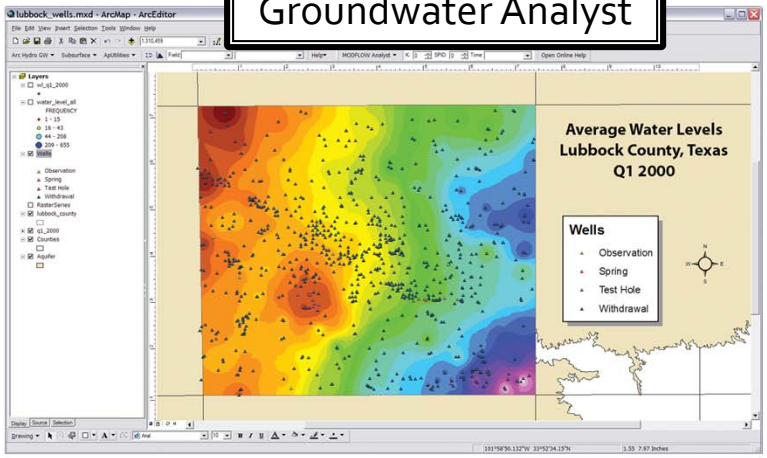
# MODFLOW Simulations on the Cloud

# Arc Hydro GW Data Model

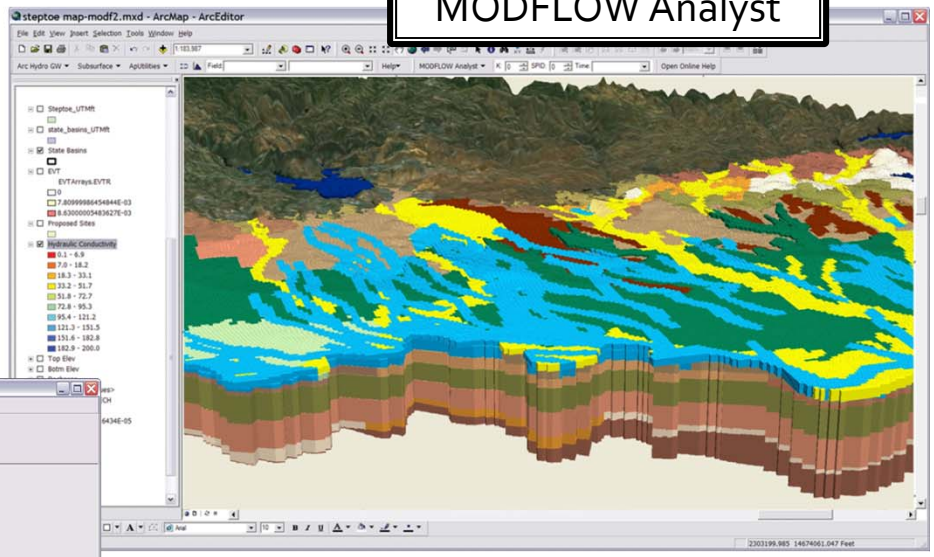


# Arc Hydro GW Tools

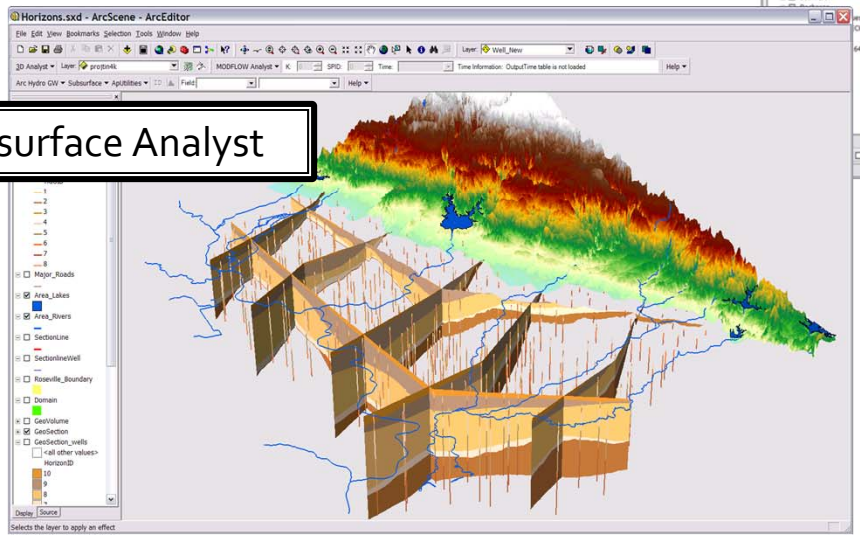
Groundwater Analyst



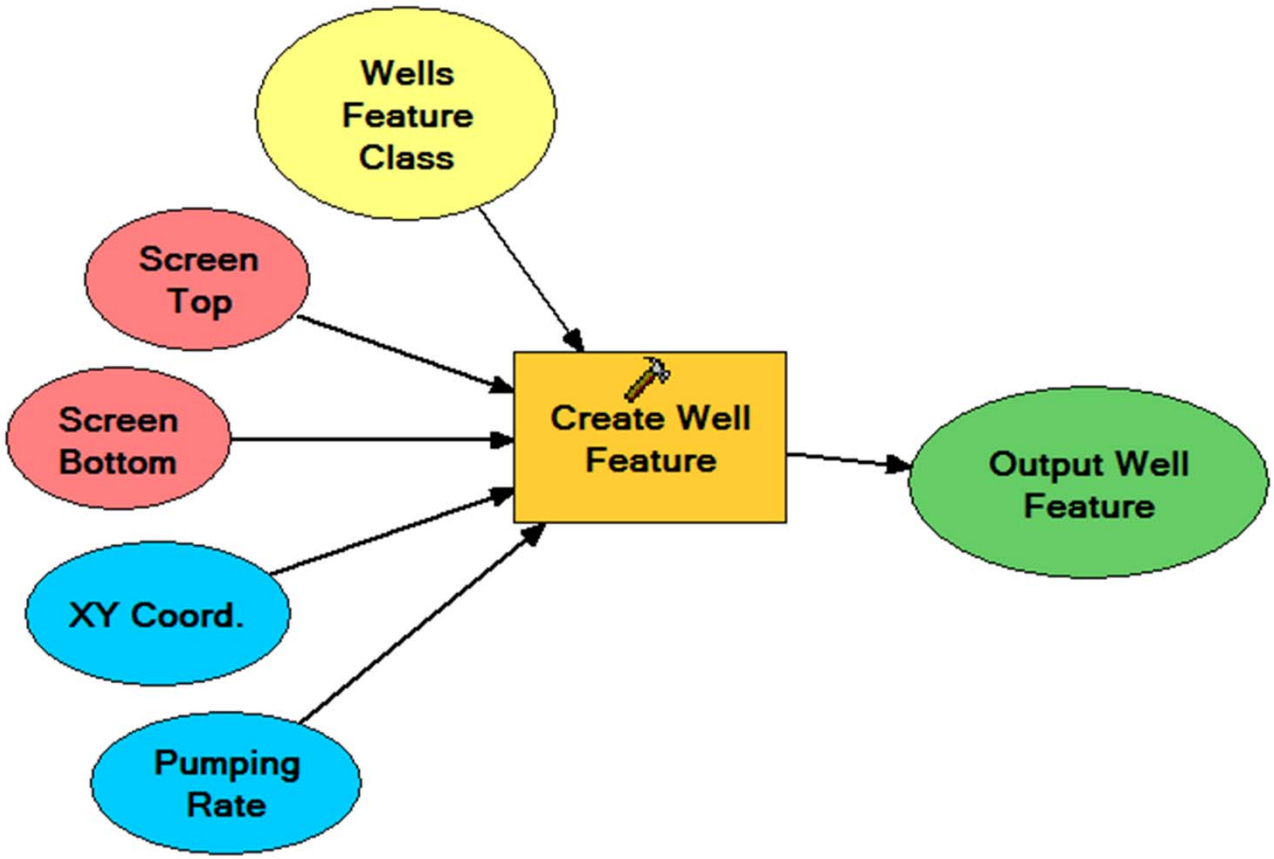

MODFLOW Analyst




Subsurface Analyst

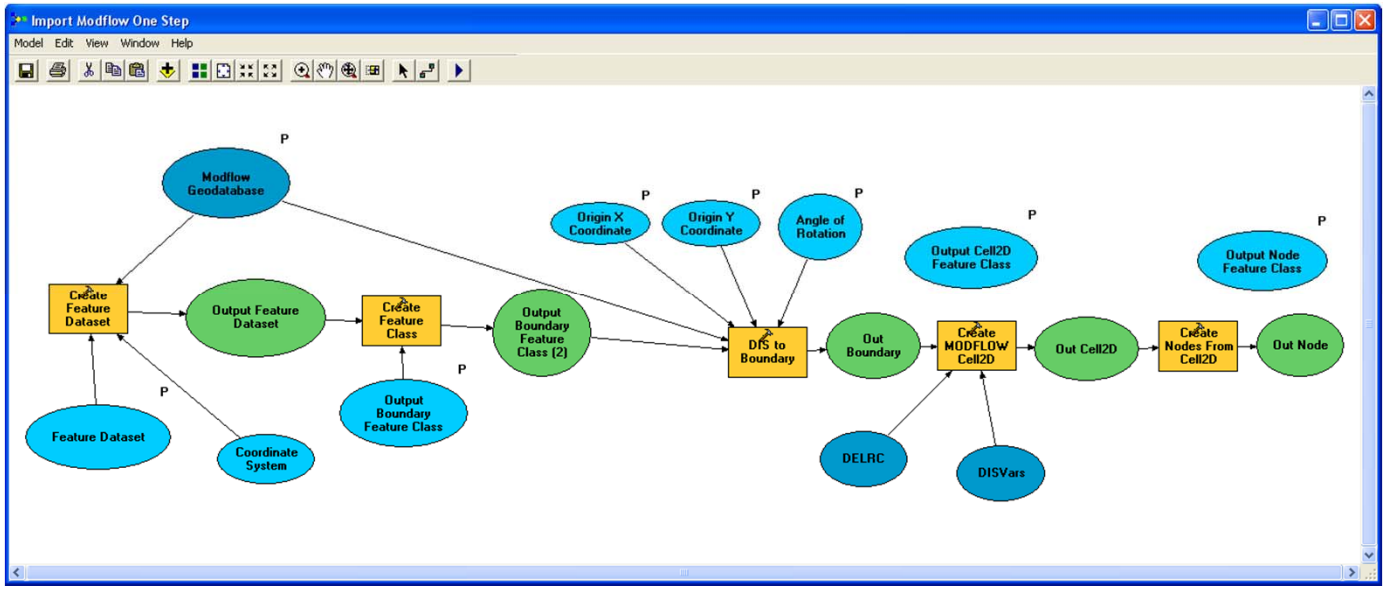


# Geoprocessing Tools



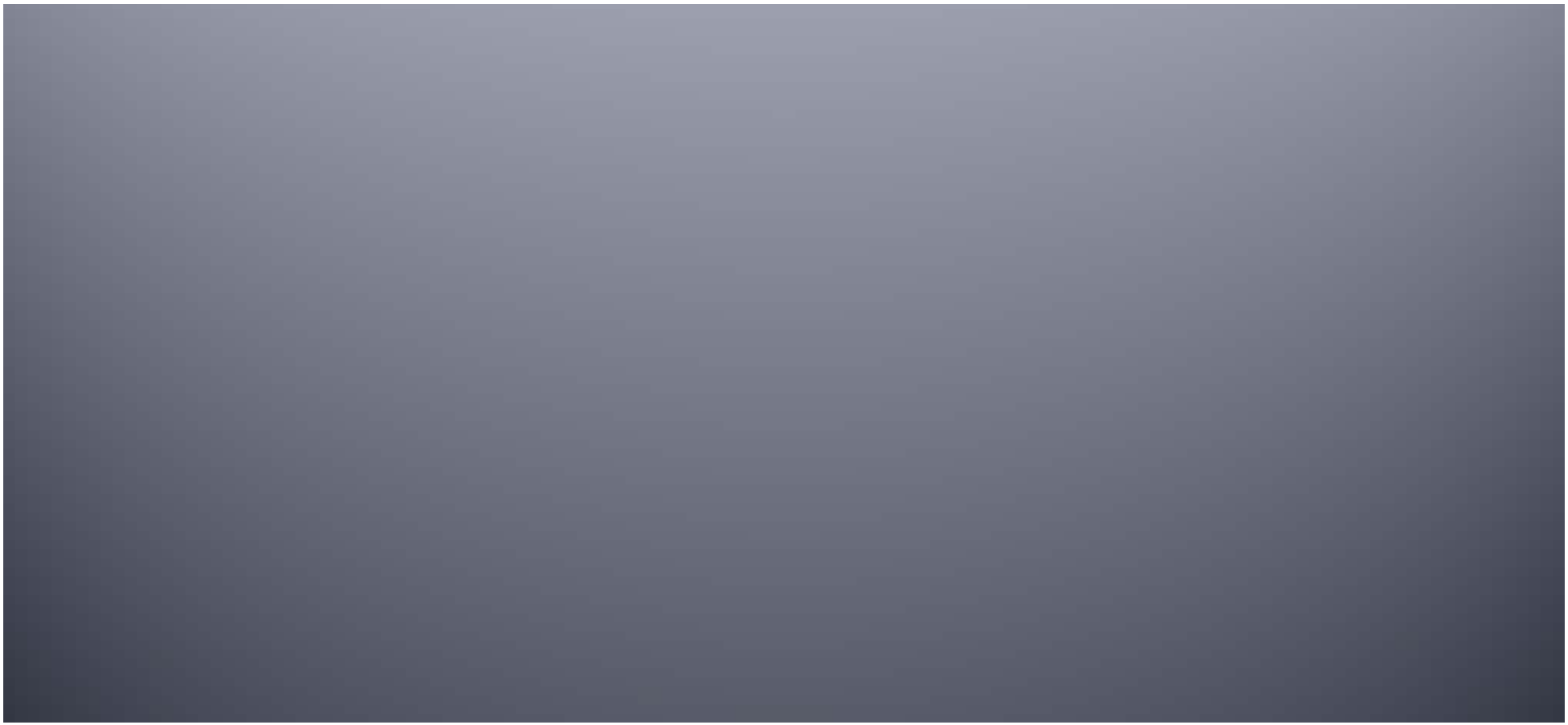
# Geoprocessing Tools - Workflows

- GP tools enable the development of workflows as models or scripts
- Extendable – You can create your own workflows
- Leverage low-level tools to create new tools

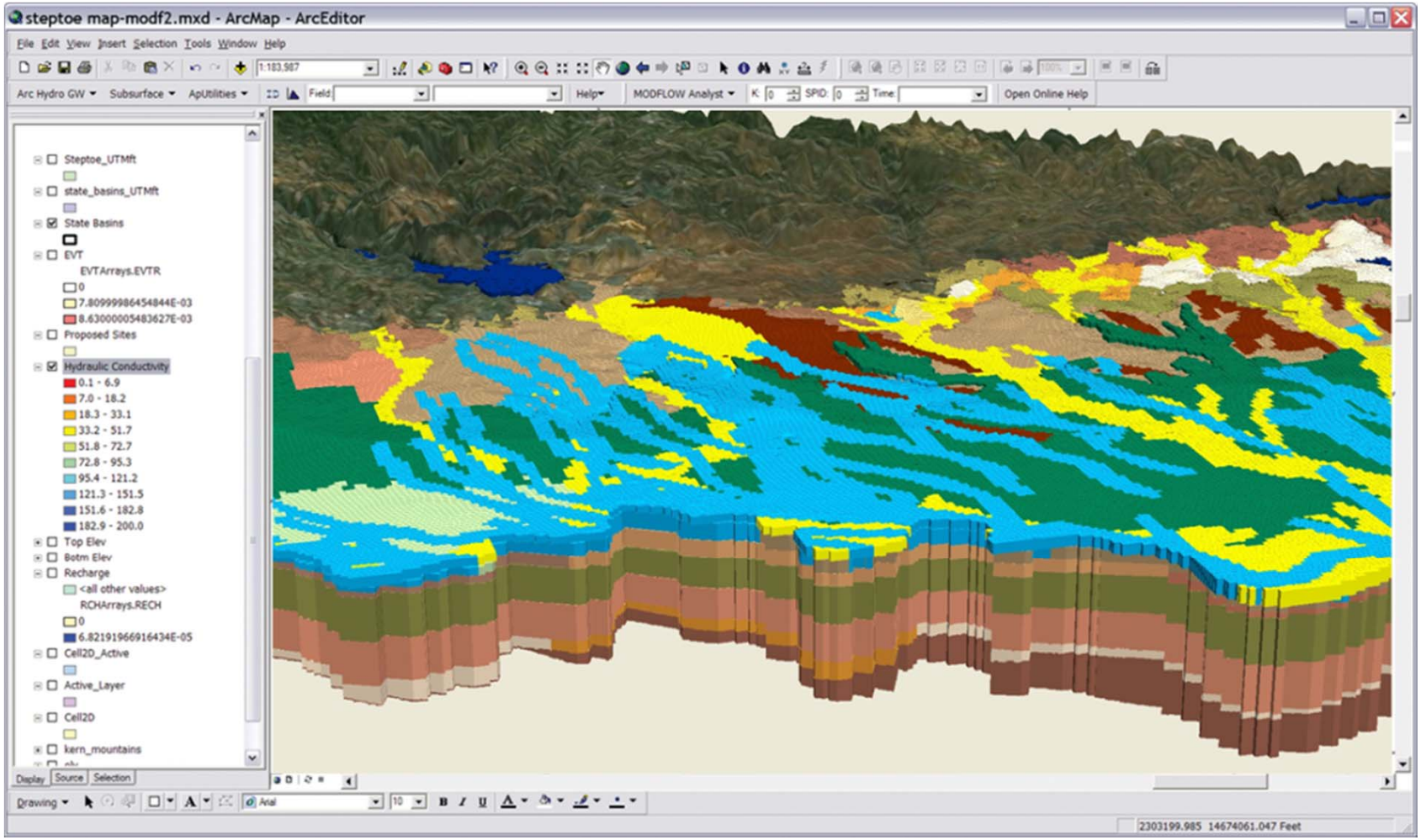


# Automated Well Impact Analysis

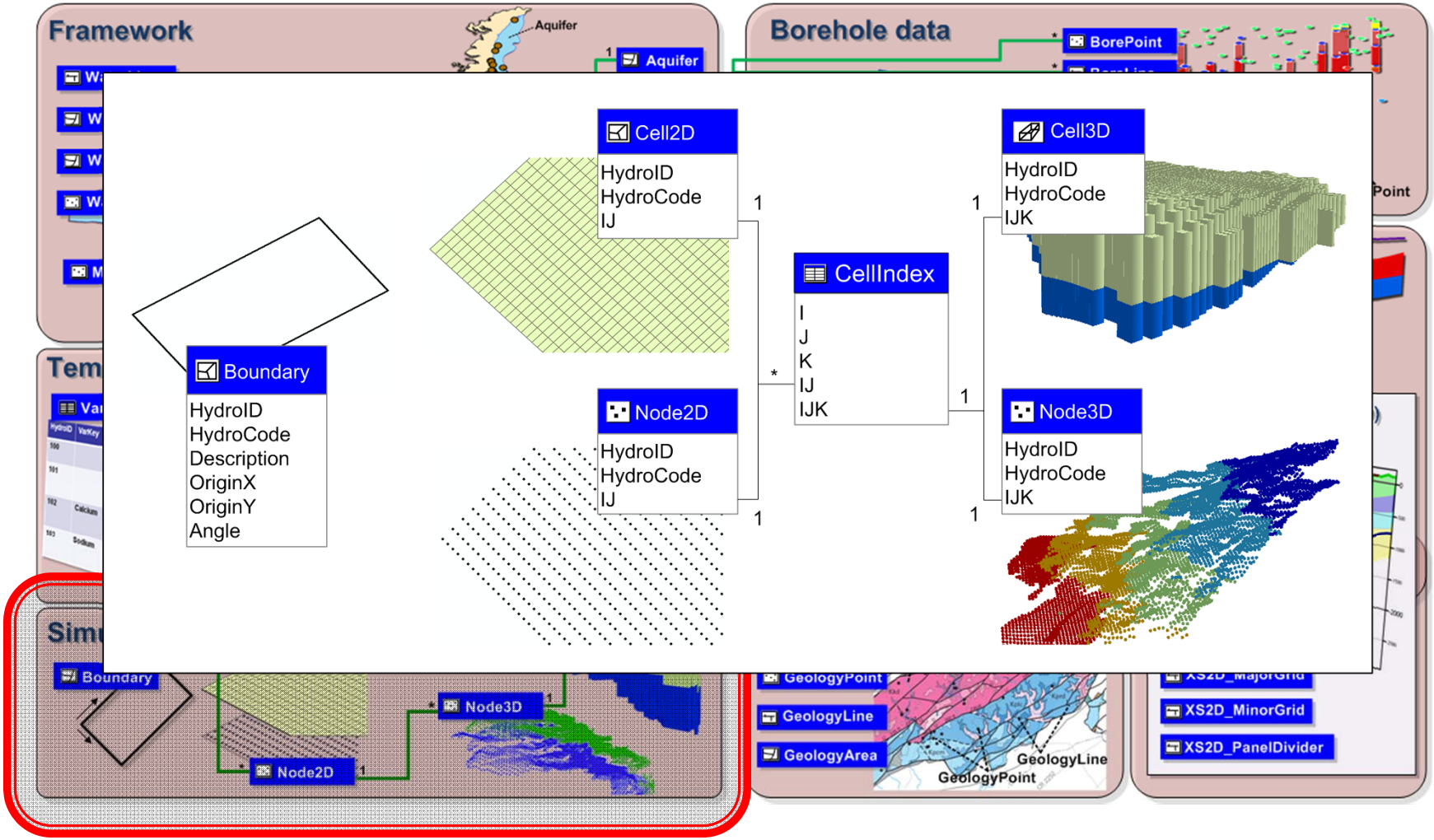
Scripting MODFLOW simulations



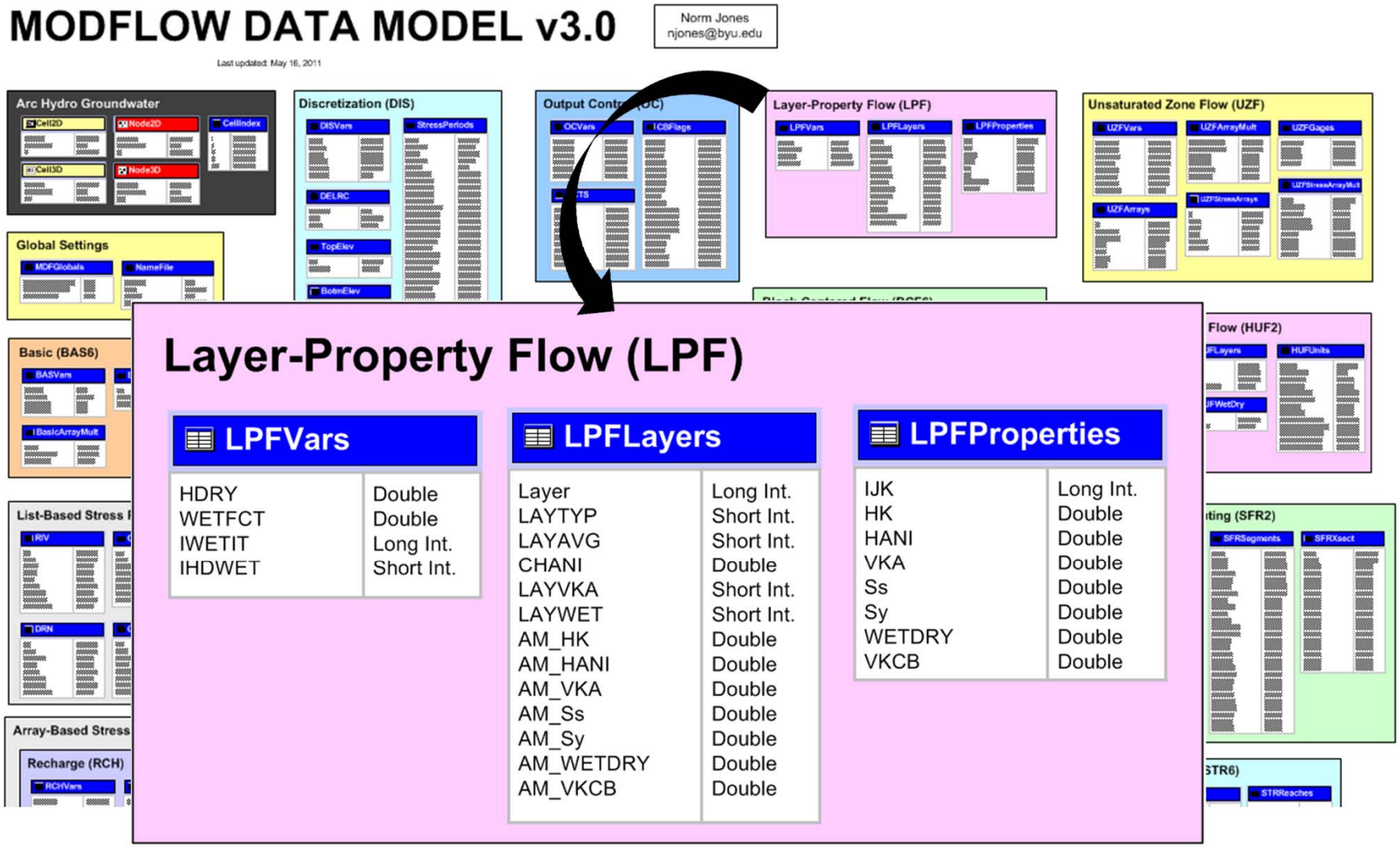
# MODFLOW


steptoe map-modf2.mxd - ArcMap - ArcEditor
File Edit View Insert Selection Tools Window Help
Arc Hydro GW
Subsurface
ApUtilities
MODFLOW Analyst
Open Online Help
Steptoe_UTMft
state_basins_UTMft
State Basins
EVT
EVTArrays.EVTR
0
7.80999986454844E-03
8.63000005483627E-03
Proposed Sites
Hydraulic Conductivity
0.1 - 6.9
7.0 - 18.2
18.3 - 33.1
33.2 - 51.7
51.8 - 72.7
72.8 - 95.3
95.4 - 121.2
121.3 - 151.5
151.6 - 182.8
182.9 - 200.0
Top Elev
Botm Elev
Recharge
<all other values>
RCHArrays.RECH
0
6.82191966916434E-05
Cell2D_Active
Active_Layer
Cell2D
kern_mountains
Display
Source
Selection
Drawing
Arial
2303199.985 14674061.047 Feet

# Simulation Feature Data Set

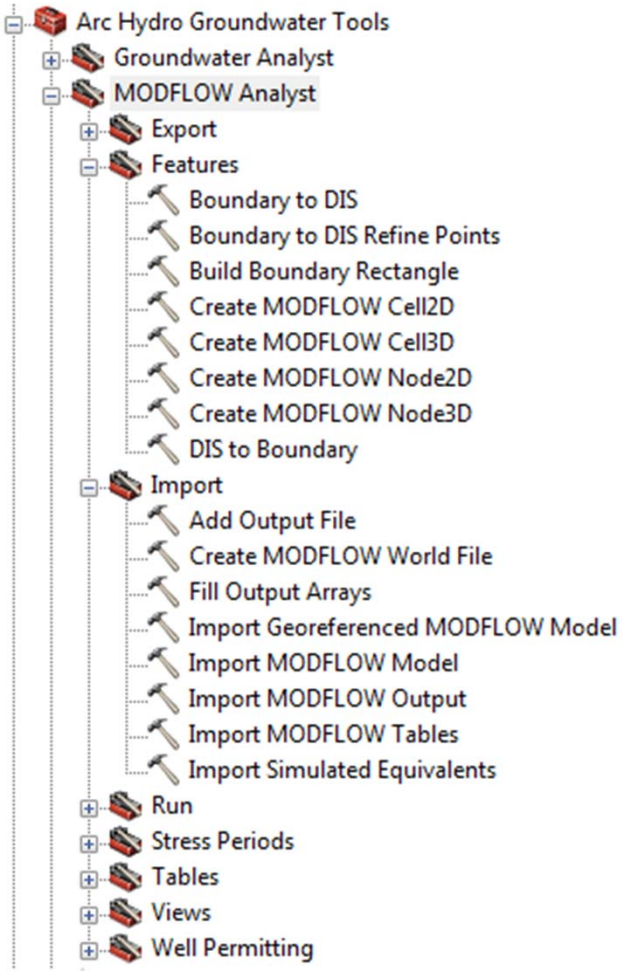


# MODFLOW Data Model

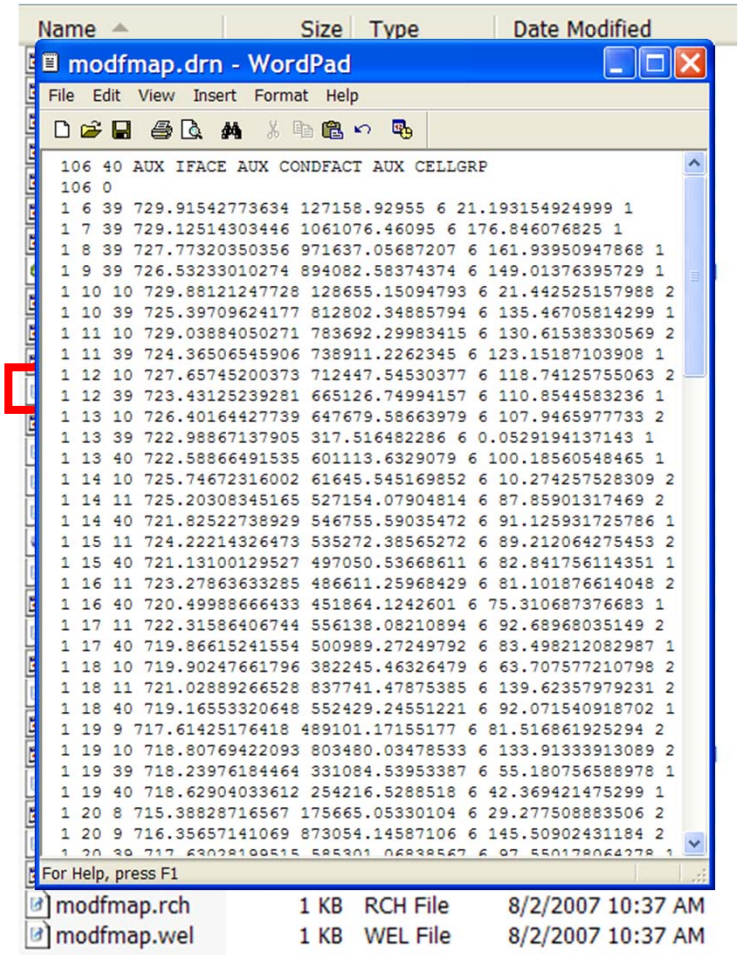


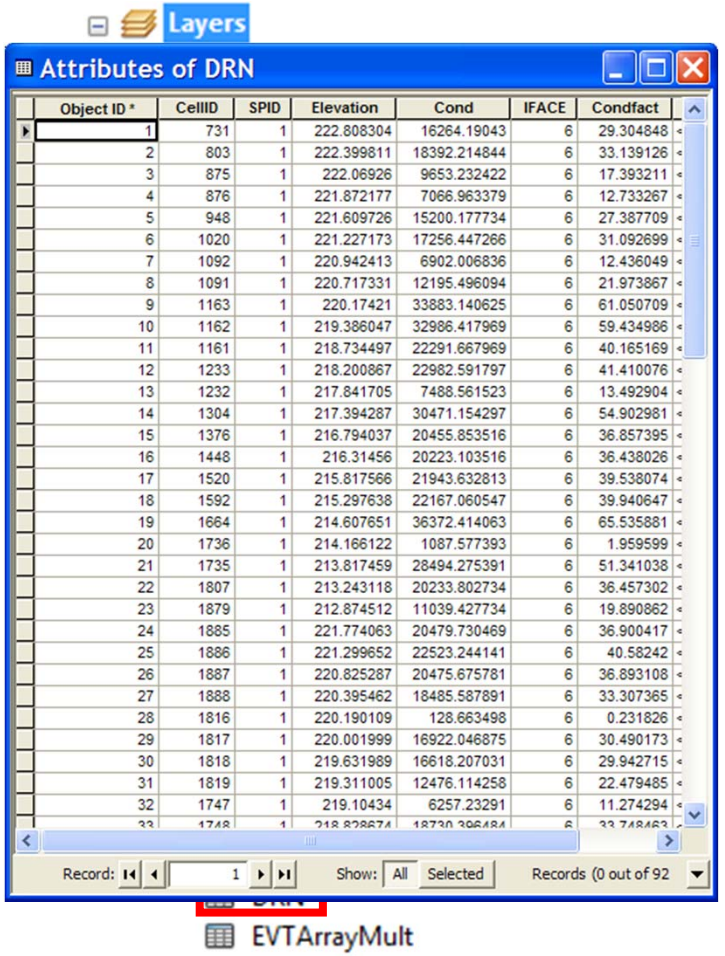
# MODFLOW Analyst Tools

- Developed as geoprocessing (GP) tools
- Classes of tools
  - Import
  - Export
  - Visualization/Map Layers
  - Model editing
  - Building package input
  - Working with transient input/solutions



# Import MODFLOW Model Tool



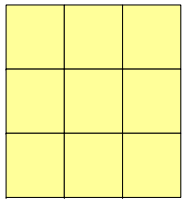

**INPUT** **OUTPUT**

# Make MODFLOW Features Tool

Attributes of DRN

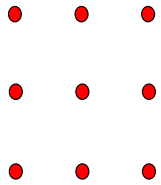
| Object ID * | CellID | SPID | Elevation | Cond |
|---|---|---|---|---|
| 1 | 731 | 1 | 222.808304 | 16264.19043 |
| 2 | 803 | 1 | 222.399811 | 18392.214844 |
| 3 | 875 | 1 | 222.06926 | 9653.232422 |
| 4 | 876 | 1 | 221.872177 | 7066.963379 |
| 5 | 948 | 1 | 221.609726 | 15200.177734 |
| 6 | 1020 | 1 | 221.227173 | 17256.447266 |
| 7 | 1092 | 1 | 220.942413 | 6902.006836 |
| 8 | 1091 | 1 | 220.717331 | 12195.496094 |
| 9 | 1163 | 1 | 220.17421 | 33883.140625 |
| 10 | 1162 | 1 | 219.386047 | 32986.417969 |
| 11 | 1161 | 1 | 218.734497 | 22291.667969 |
| 12 | 1233 | 1 | 218.200867 | 22982.591797 |
| 13 | 1232 | 1 | 217.841705 | 7488.561523 |
| 14 | 1304 | 1 | 217.394287 | 30471.154297 |
| 15 | 1376 | 1 | 216.794037 | 20455.853516 |

+

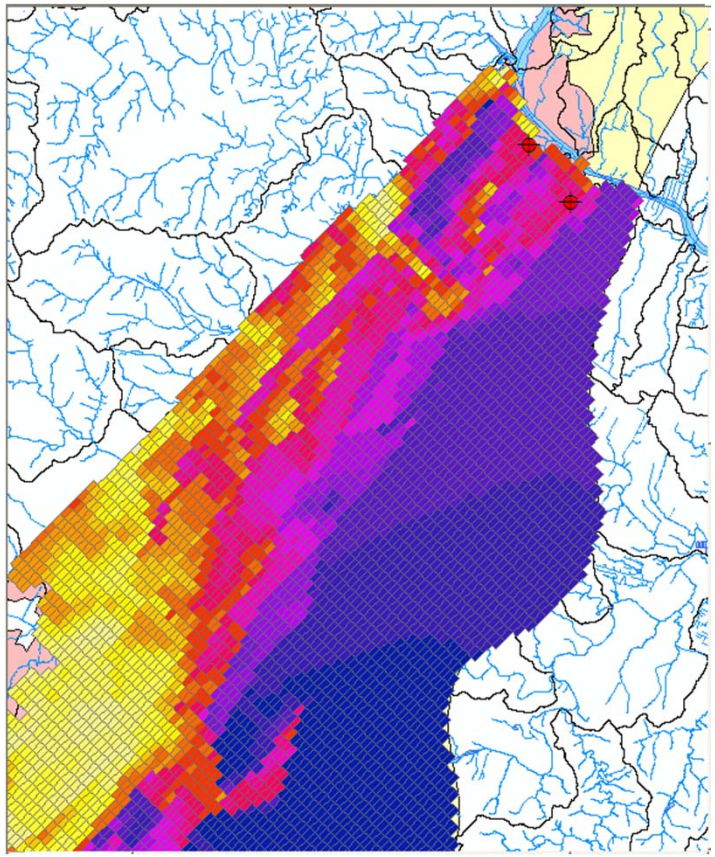


Cell2D

Or



Node2D



**INPUT**

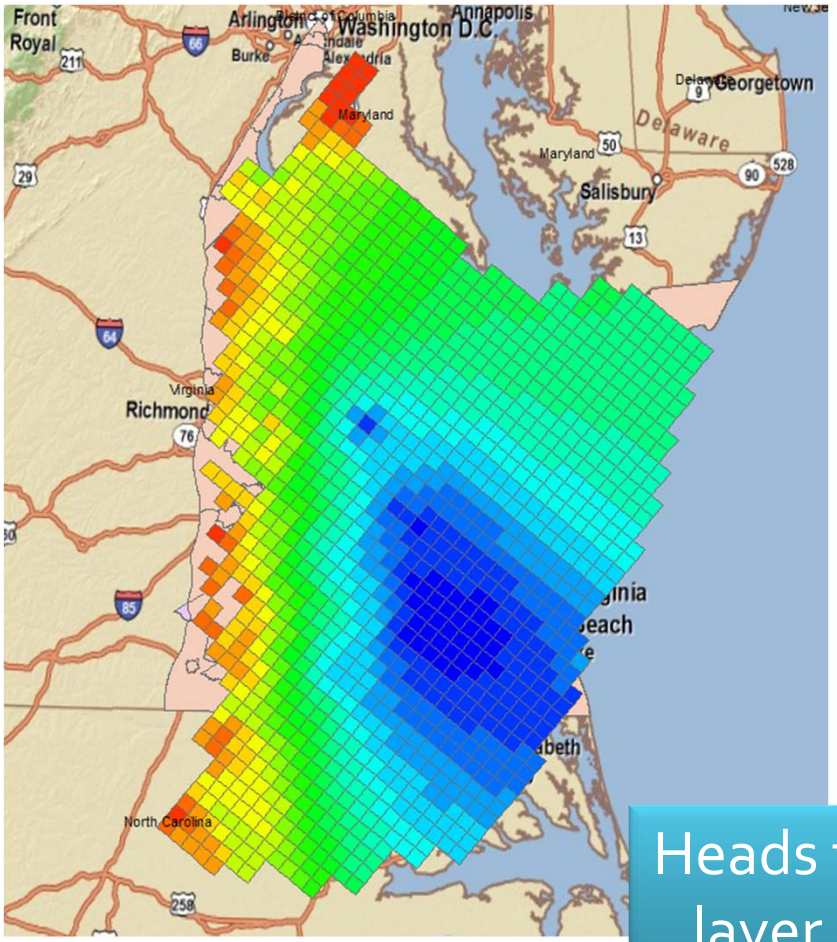
**OUTPUT**

# Automated Well Permitting

- Calibrated regional model is imported to ArcGIS as a "baseline" model
- Candidate wells are added to baseline model using well package.
- Impact of new well is analyzed using MODFLOW and/or SEAWAT

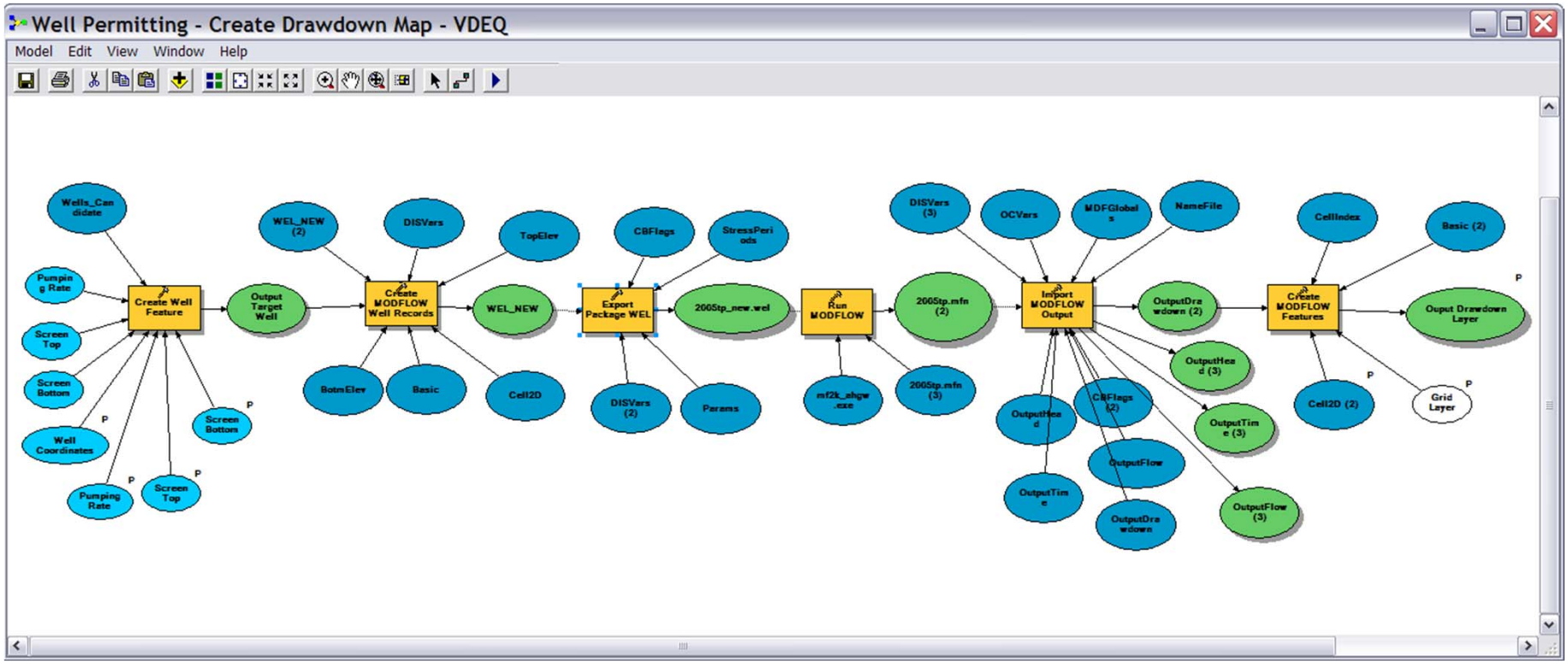
# Case Study #1 – Virginia DEQ

- Virginia Coastal Plain Model (VCPM)
- 10-layer MODFLOW model used to analyze impacts of candidate wells
- Criteria based on state law
  - Potentiometric surface cannot fall below a critical surface (80% drawdown)
  - Area of Impact defined by drawdown = 1 ft




Heads for layer 8

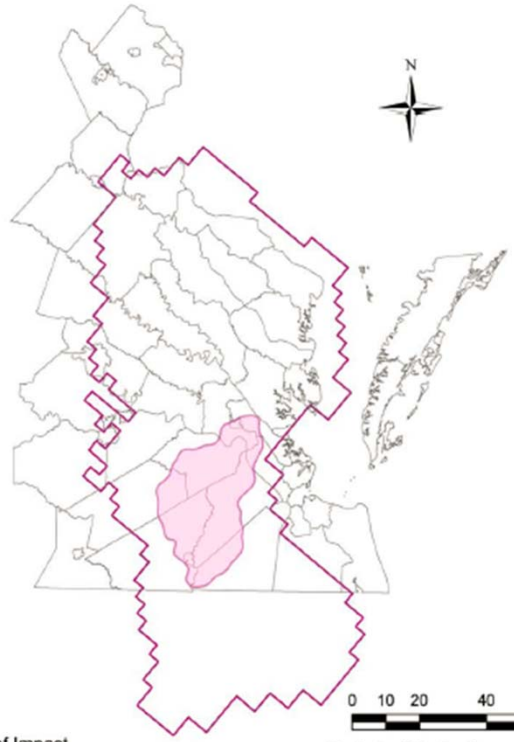
# Well Permitting Workflow




Create new well → update well table → export well package file → run MODFLOW → import solution → build drawdown map layer

# GIS Products

**City of Norfolk**
**Mitigation Area of Impact - Aquia Aquifer**




Area of Impact

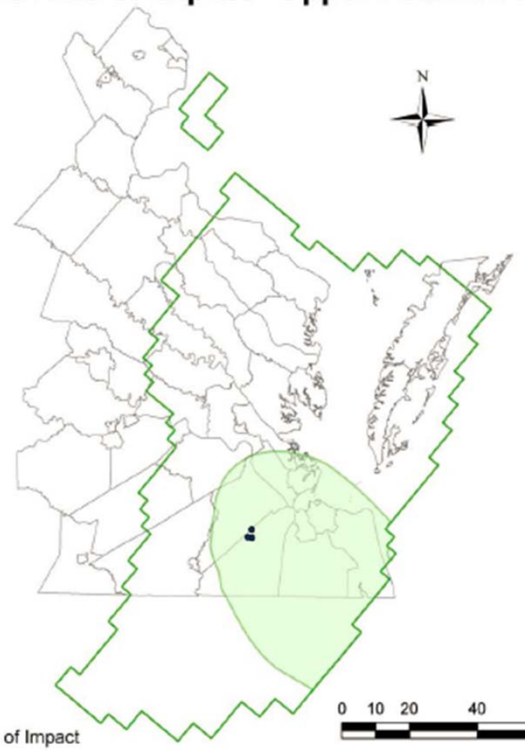
Aquia Aquifer Model Boundary

Simulated drawdown at or exceeding one foot in the Aquia aquifer resulting from an 15,940,000 gpd, 172 day duration, multi-aquifer withdrawal. The Virginia Coastal Plain Model developed in Modflow by the USGS was used to simulate drawdown.

Technical Evaluation
Performed by Alan Lemon
Ground Water Modeler
April 6, 2010

DEQ
Virginia Department of Environmental Quality

**City of Norfolk**
**Stabilized Area of Impact - Upper Potomac Aquifer**




Area of Impact

Production Wells

Upper Potomac Model Boundary

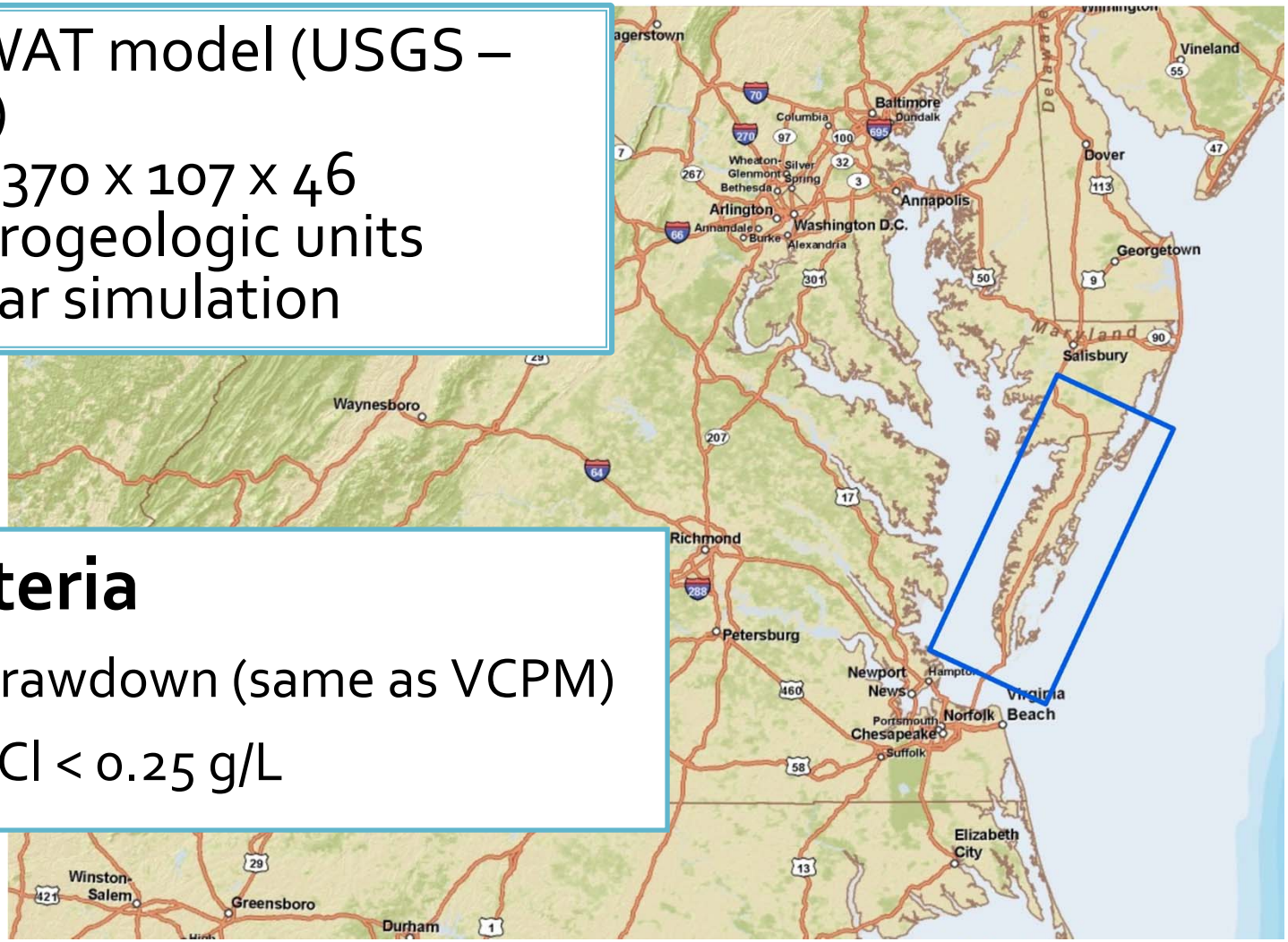
Simulated drawdown at or exceeding one foot in the Upper Potomac aquifer resulting from a 790,000 gpd, steady-state, multi-aquifer withdrawal. The Virginia Coastal Plain Model developed in Modflow by the USGS was used to simulate drawdown.

Technical Evaluation
Performed by Alan Lemon
Ground Water Modeler
April 6, 2010

DEQ
Virginia Department of Environmental Quality

# Eastern Shore Model

- SEAWAT model (USGS – 2009)
- Grid: 370 x 107 x 46
- 7 hydrogeologic units
- 50 year simulation

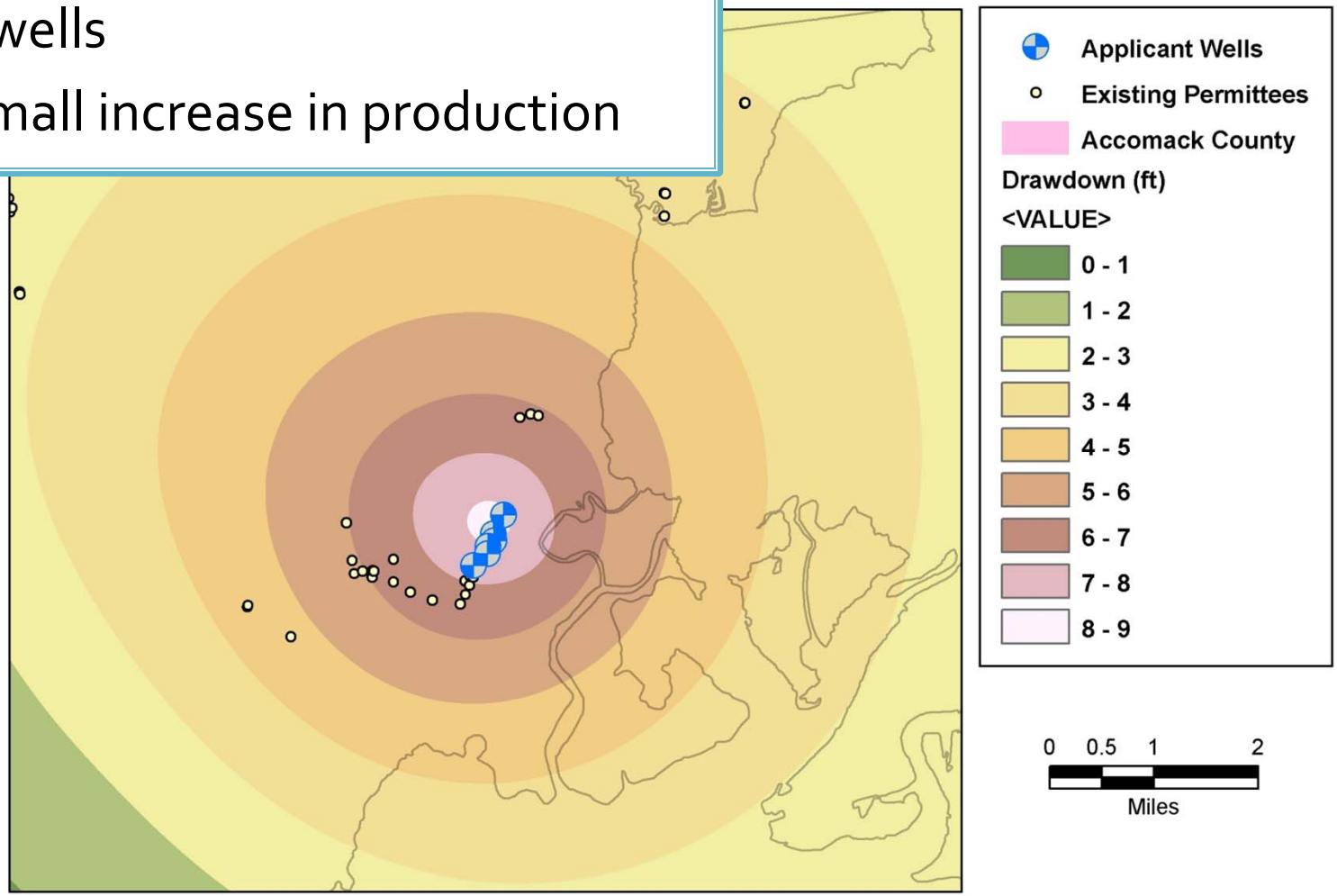



## Criteria

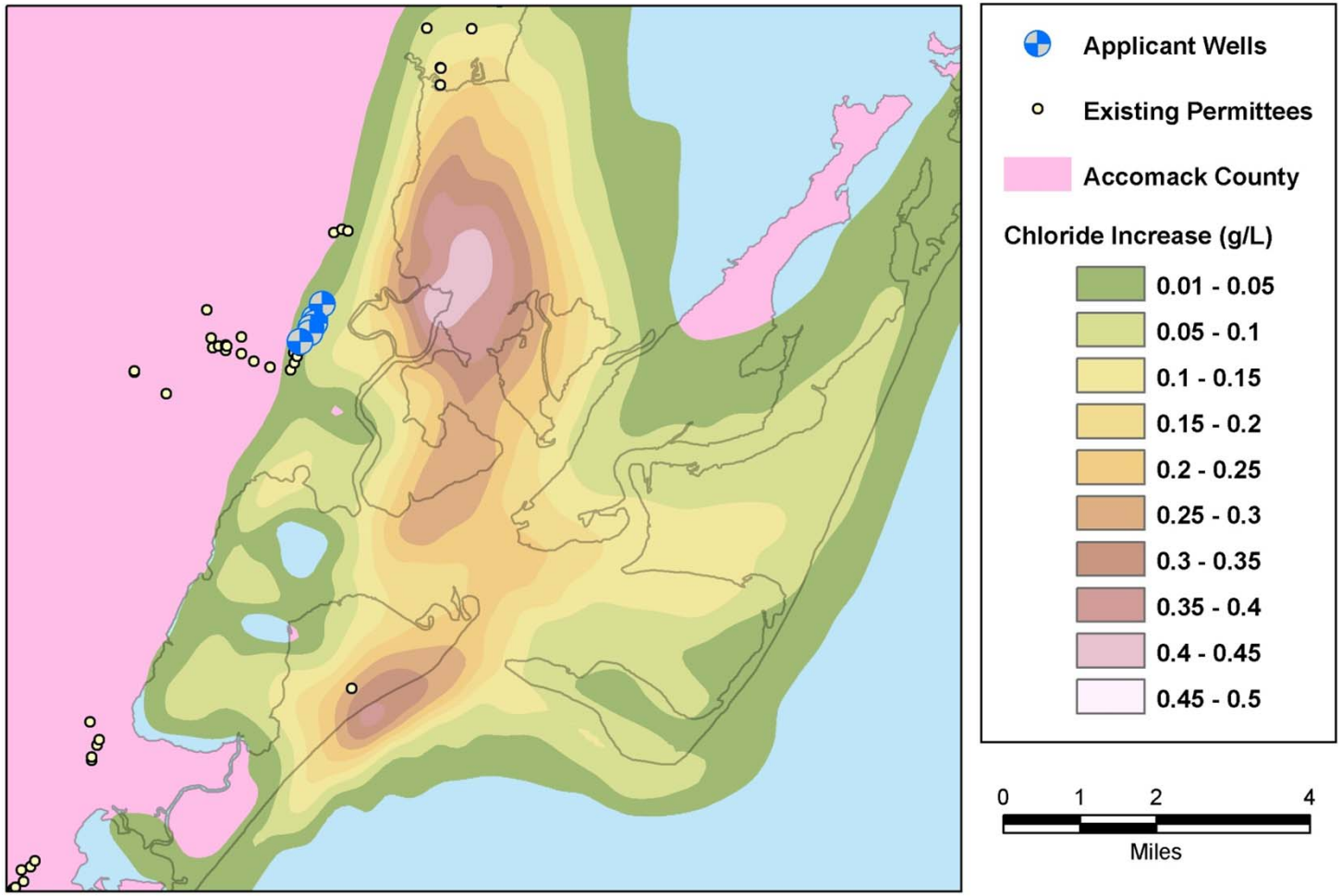
- Drawdown (same as VCPM)
- $\Delta Cl < 0.25$ g/L

# Sample Application

- 7 wells
- Small increase in production

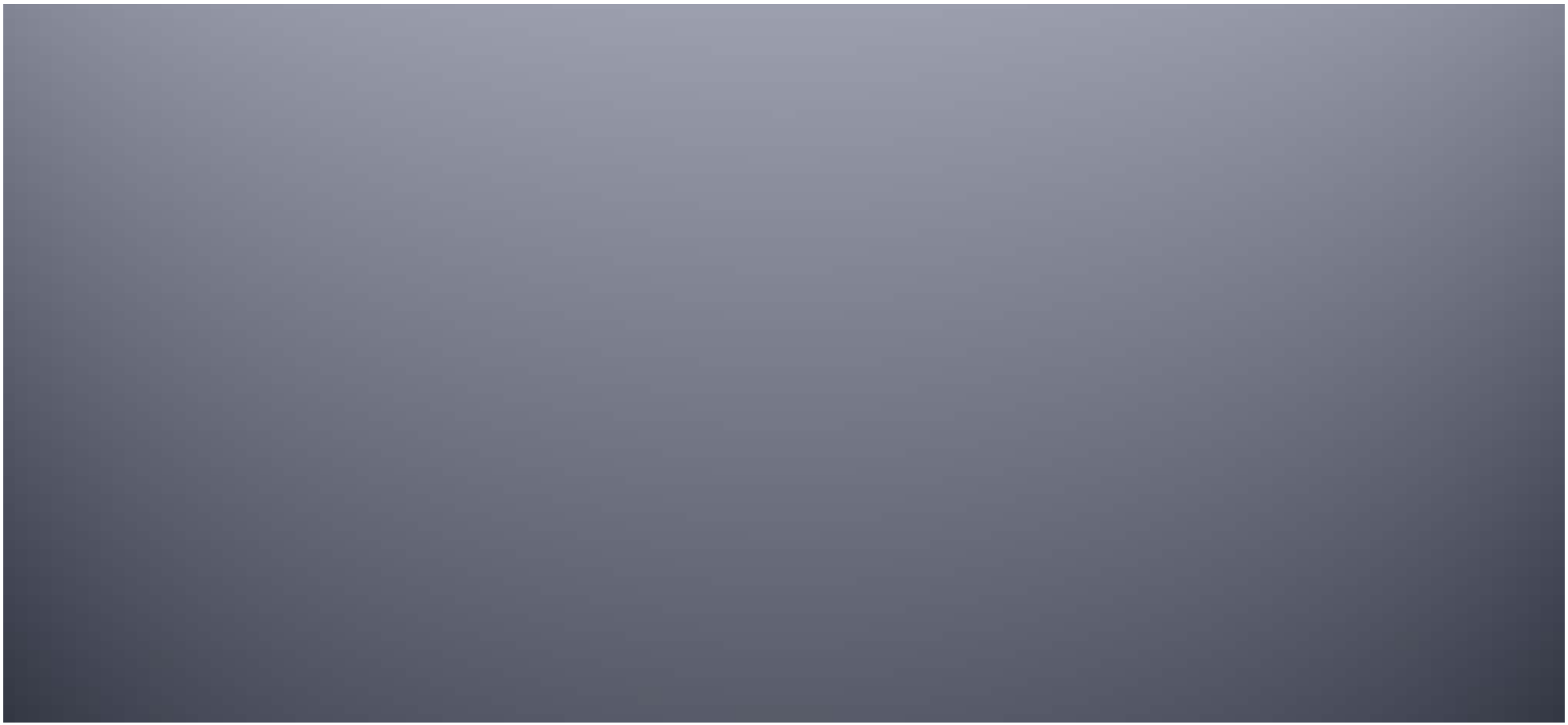


# Changes in Chloride Concentration

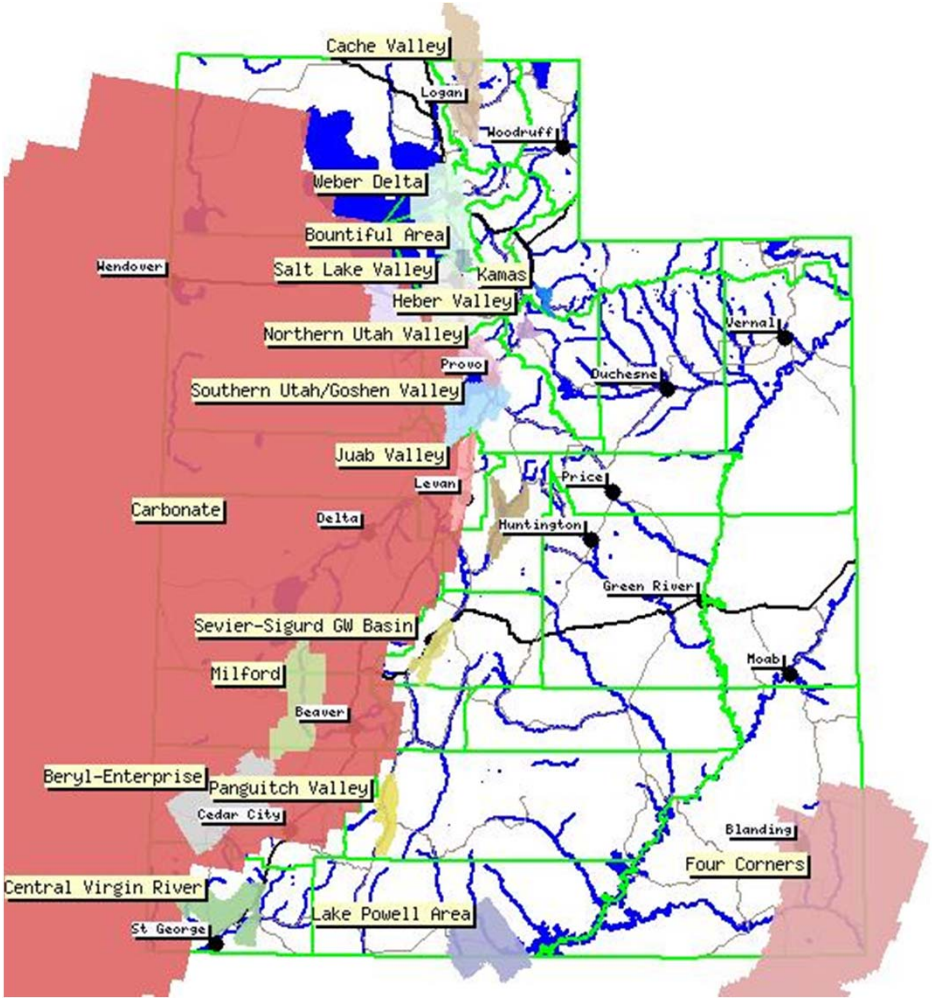


# MODFLOW in the Cloud

Utah Division of Water Rights Well Impact Simulator

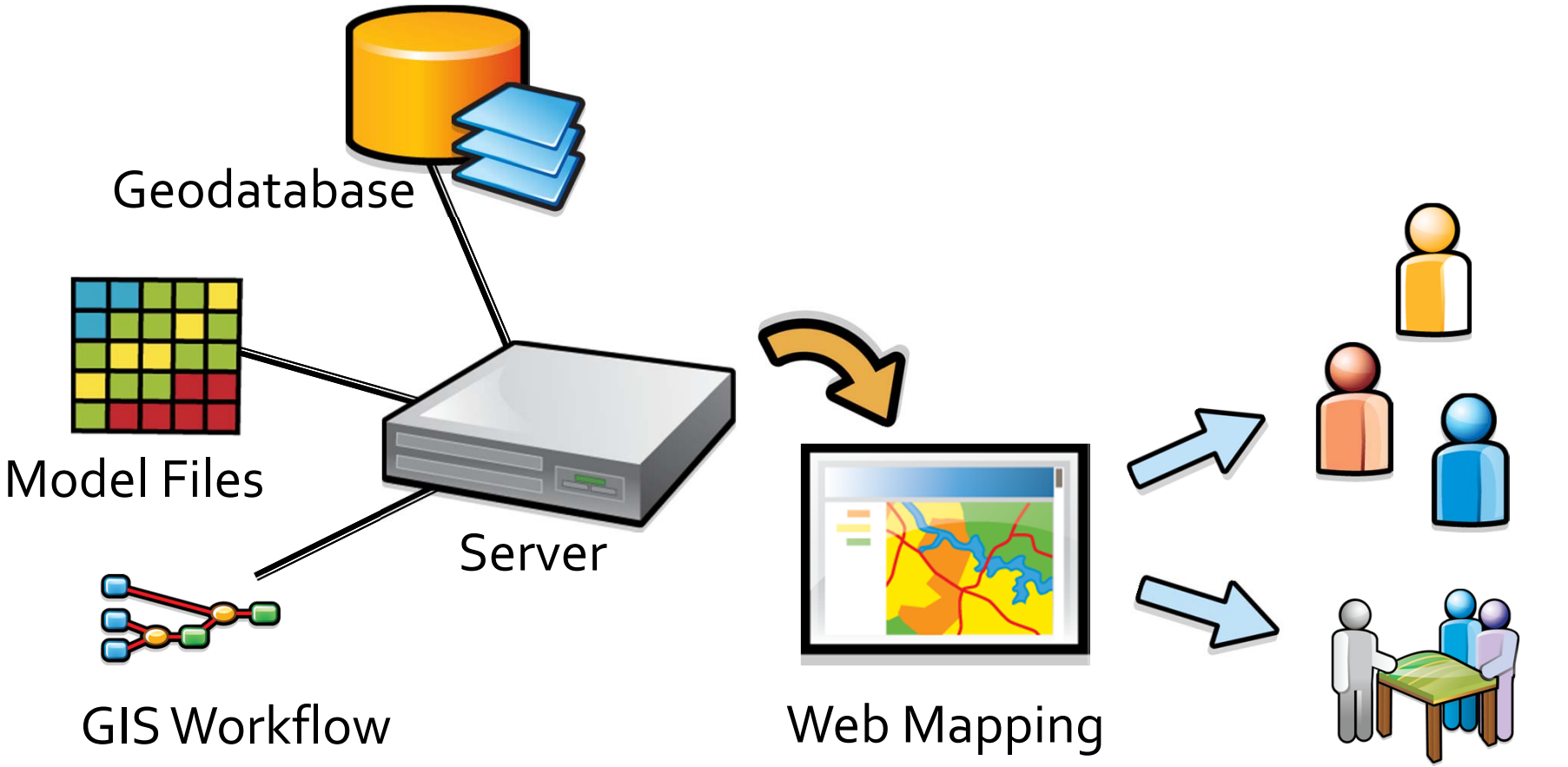


# Utah Division of Water Rights

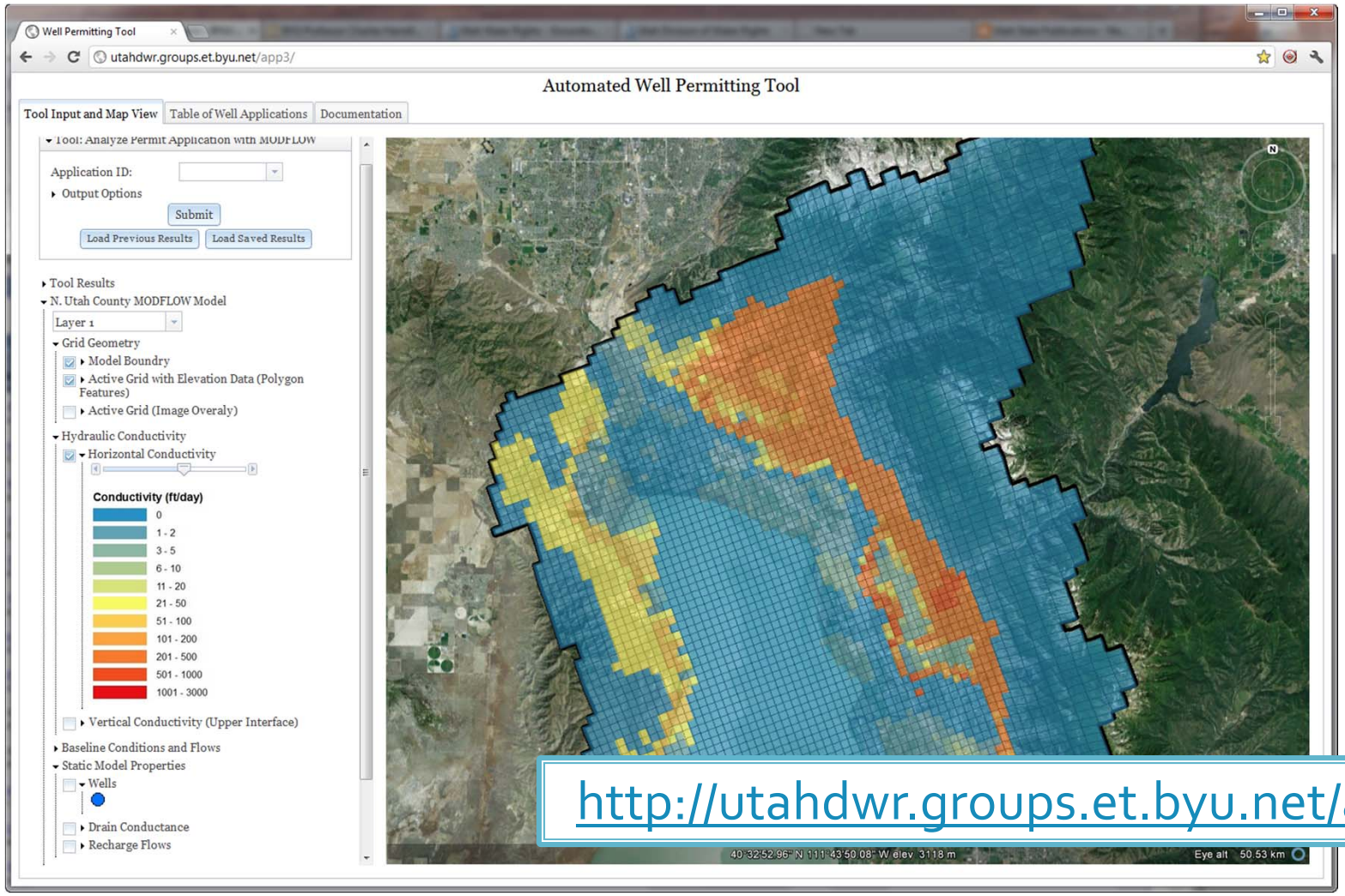



- 31 MODFLOW models used for impact analysis
- Challenges
  - Modeling expertise
  - Software installation and maintenance
  - User error
  - Cost

# Cloud-Based Solution

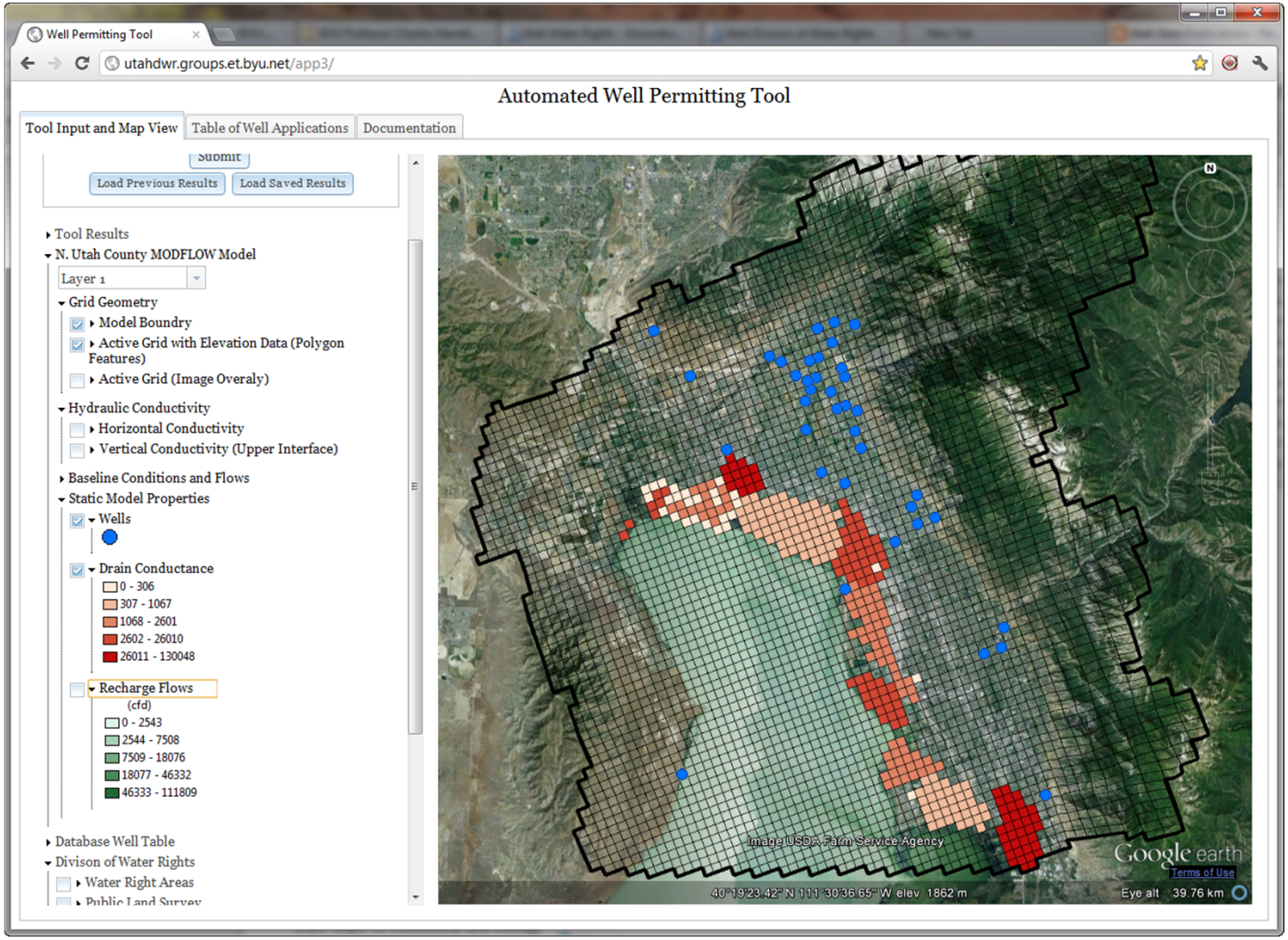


# Web Interface

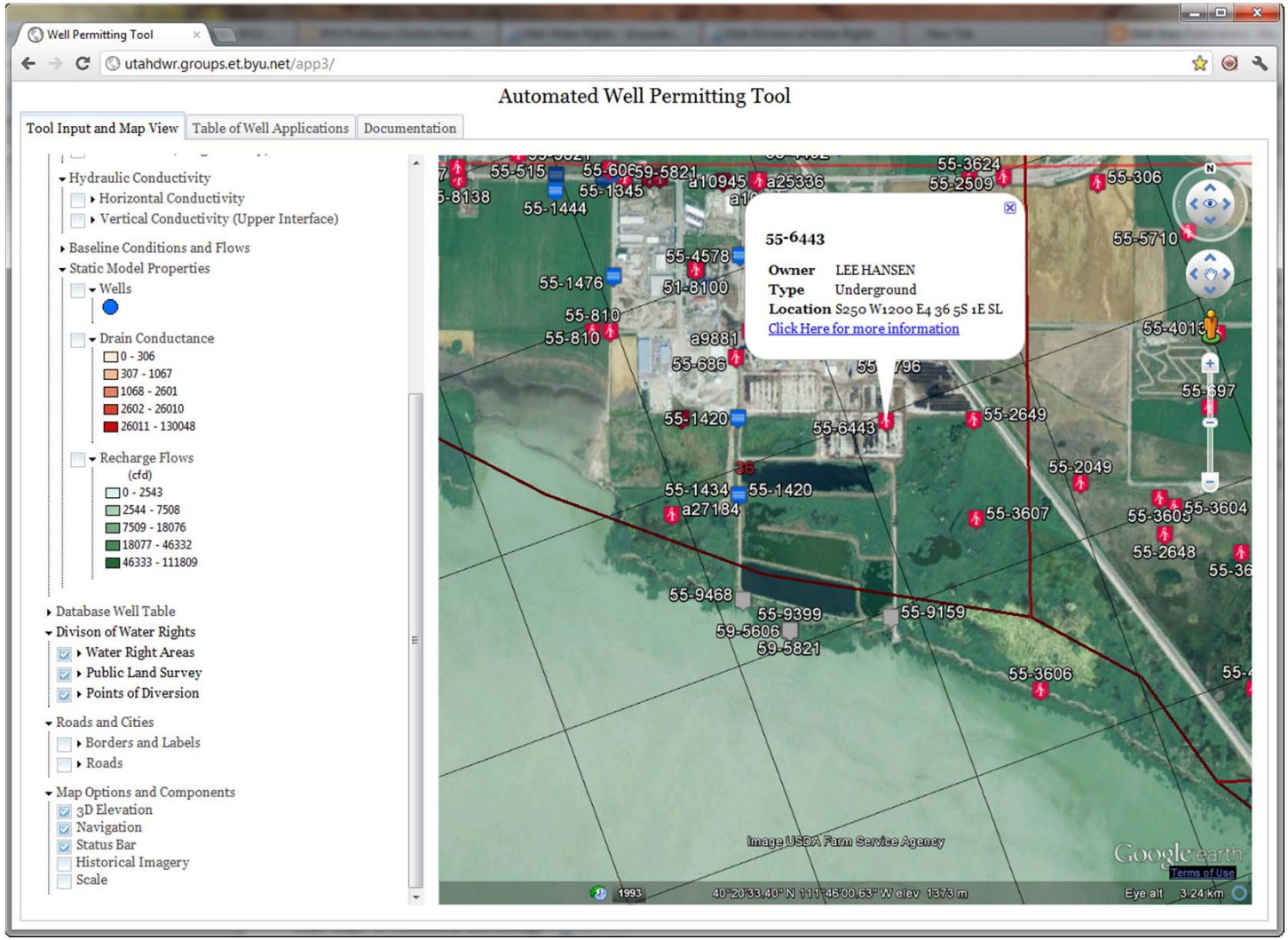



http://utahdwr.groups.et.byu.net/app3/

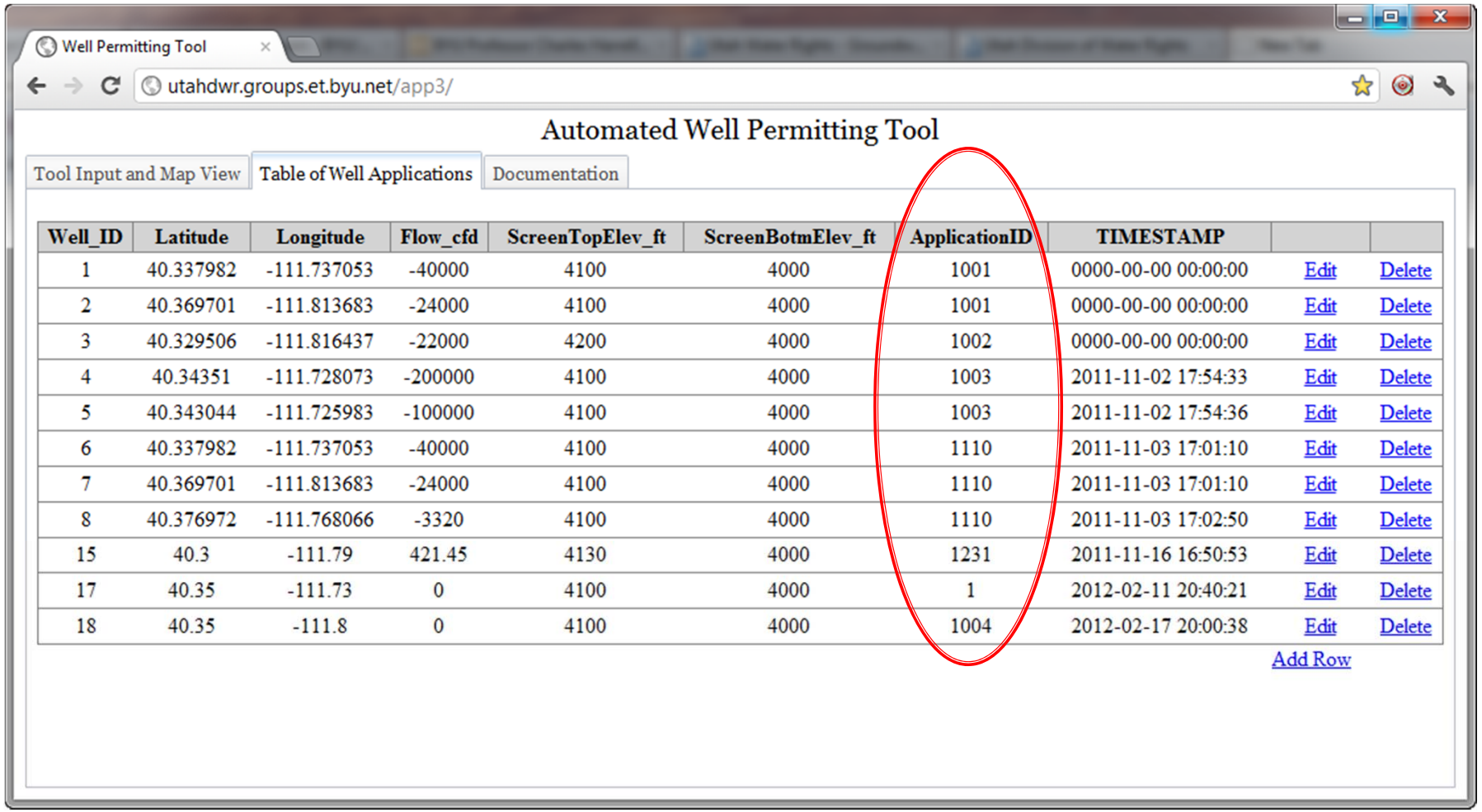
# Static Model Data



# Map Layers from UDWR Server



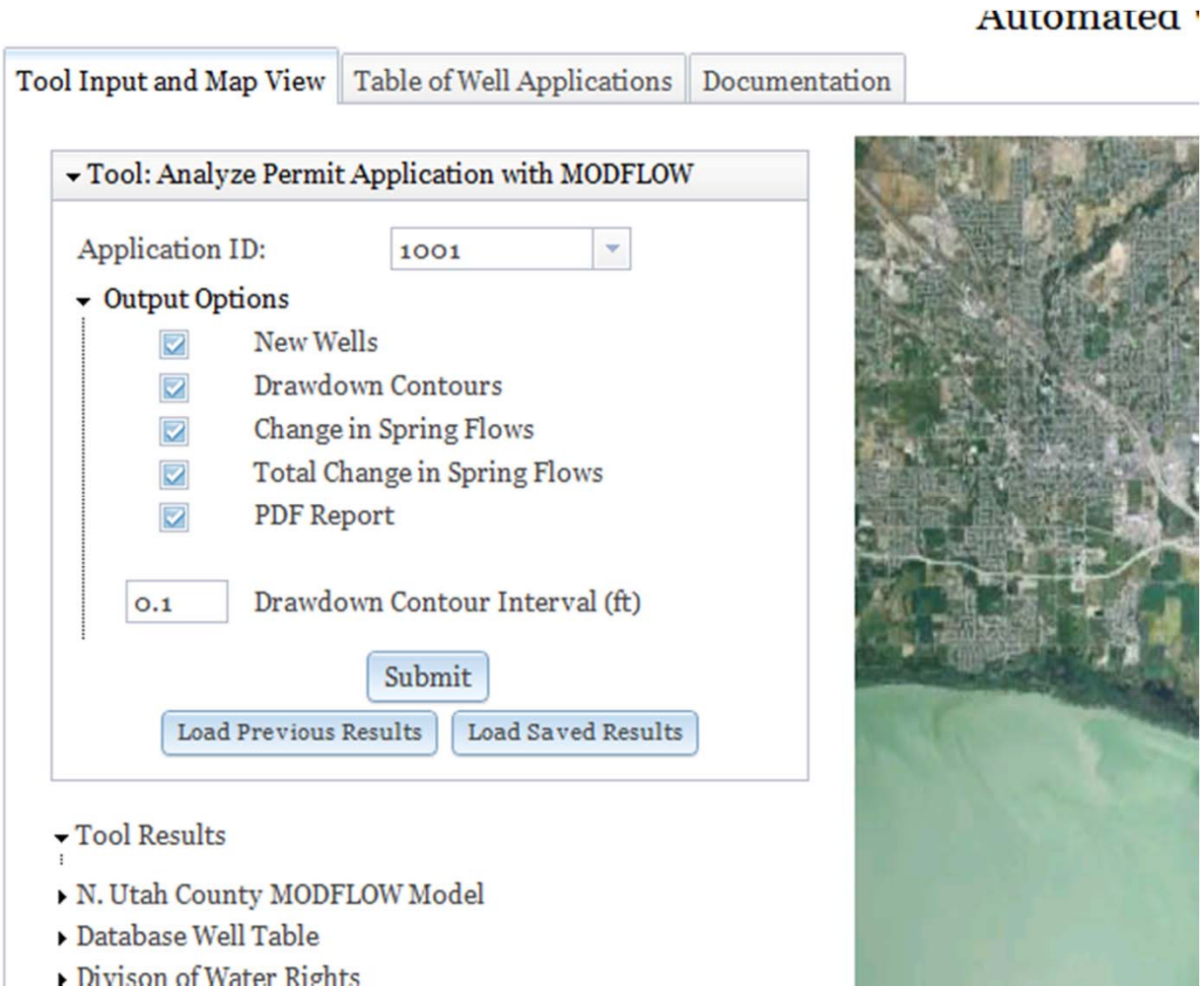
# Table of Well Applications



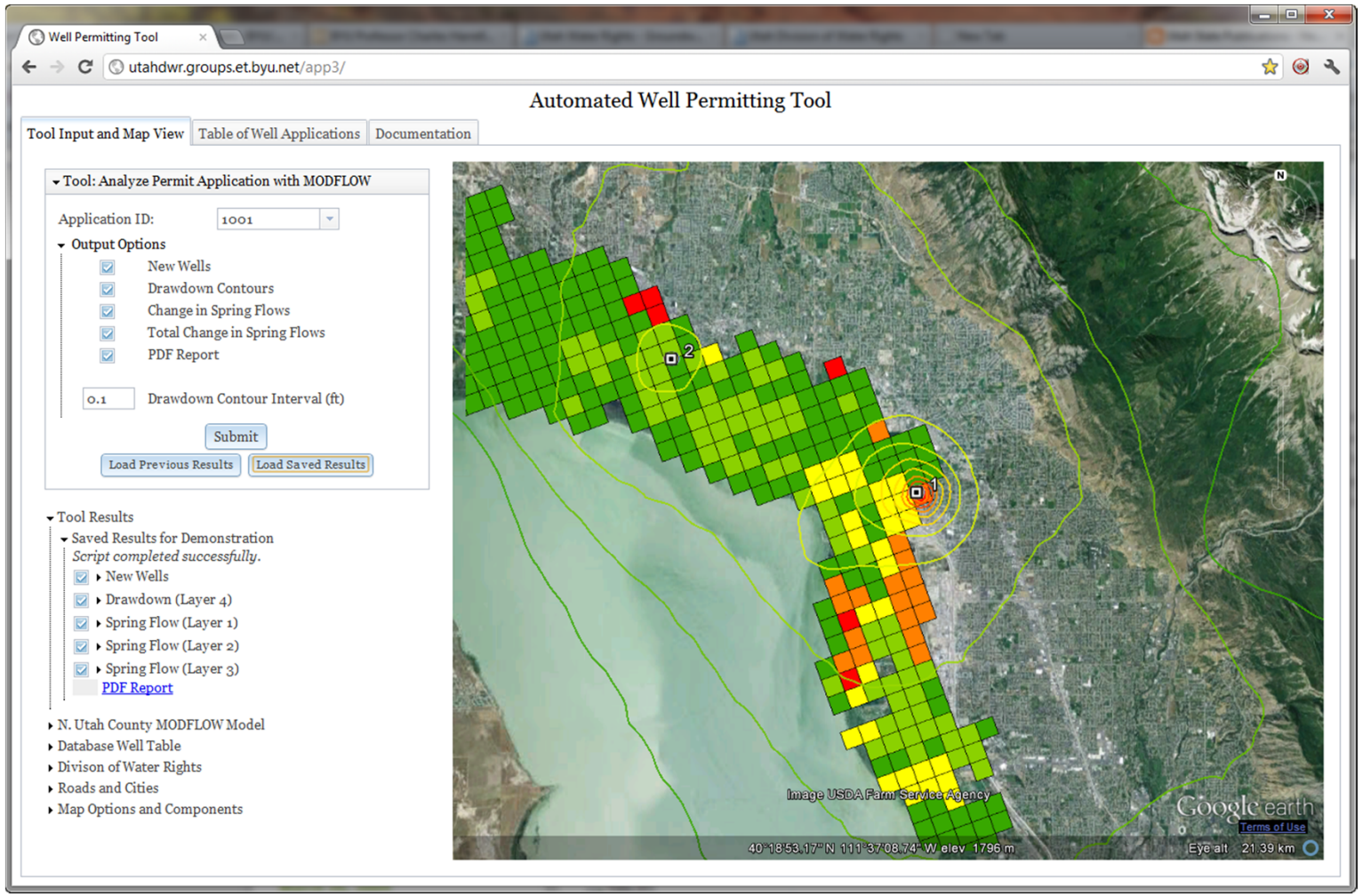

| Well_ID | Latitude | Longitude | Flow_cfd | ScreenTopElev_ft | ScreenBotmElev_ft | ApplicationID | TIMESTAMP | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 40.337982 | -111.737053 | -40000 | 4100 | 4000 | 1001 | 0000-00-00 00:00:00 | Edit | Delete |
| 2 | 40.369701 | -111.813683 | -24000 | 4100 | 4000 | 1001 | 0000-00-00 00:00:00 | Edit | Delete |
| 3 | 40.329506 | -111.816437 | -22000 | 4200 | 4000 | 1002 | 0000-00-00 00:00:00 | Edit | Delete |
| 4 | 40.34351 | -111.728073 | -200000 | 4100 | 4000 | 1003 | 2011-11-02 17:54:33 | Edit | Delete |
| 5 | 40.343044 | -111.725983 | -100000 | 4100 | 4000 | 1003 | 2011-11-02 17:54:36 | Edit | Delete |
| 6 | 40.337982 | -111.737053 | -40000 | 4100 | 4000 | 1110 | 2011-11-03 17:01:10 | Edit | Delete |
| 7 | 40.369701 | -111.813683 | -24000 | 4100 | 4000 | 1110 | 2011-11-03 17:01:10 | Edit | Delete |
| 8 | 40.376972 | -111.768066 | -3320 | 4100 | 4000 | 1110 | 2011-11-03 17:02:50 | Edit | Delete |
| 15 | 40.3 | -111.79 | 421.45 | 4130 | 4000 | 1231 | 2011-11-16 16:50:53 | Edit | Delete |
| 17 | 40.35 | -111.73 | 0 | 4100 | 4000 | 1 | 2012-02-11 20:40:21 | Edit | Delete |
| 18 | 40.35 | -111.8 | 0 | 4100 | 4000 | 1004 | 2012-02-17 20:00:38 | Edit | Delete |

Add Row

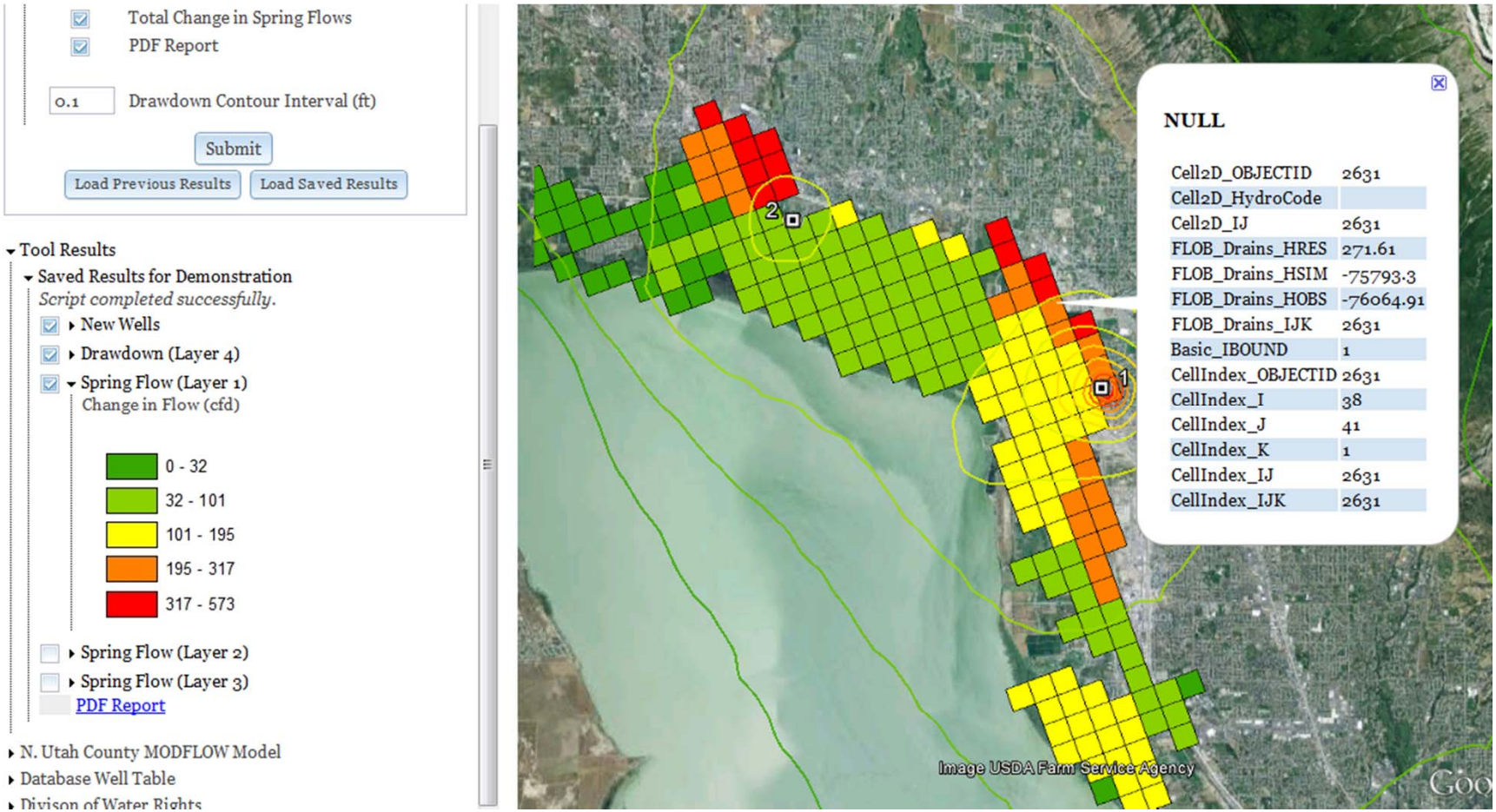
# Submitting a Model Run



# Model Results



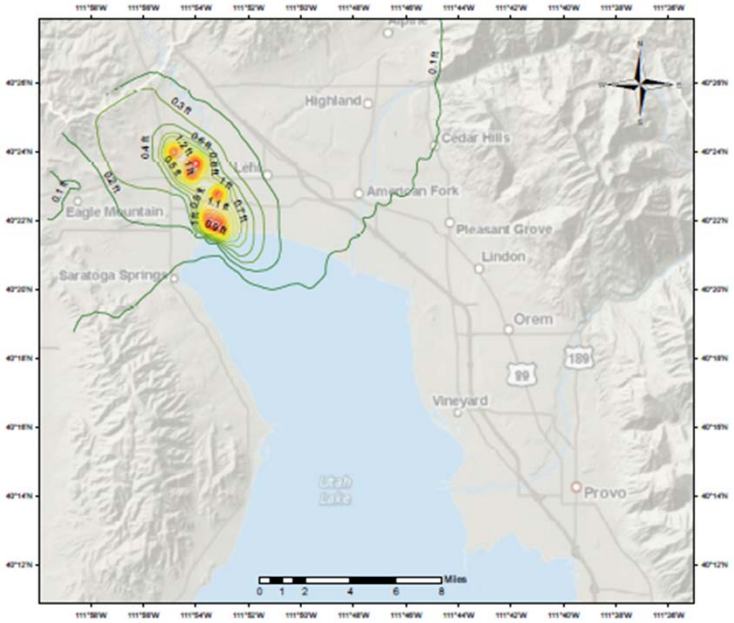
# Impact on Springs



# PDF Output

## Simulated Aquifer Drawdown: Layer 3

North Utah County MODFLOW Model Simulation Results




**Legend**

- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- 1.4 - 1.7

This map was generated by a server-based automated well permitting analysis system using ArcGIS and AHGW geoprocessing tools and the Northern Utah County MODFLOW model created by the USGS.

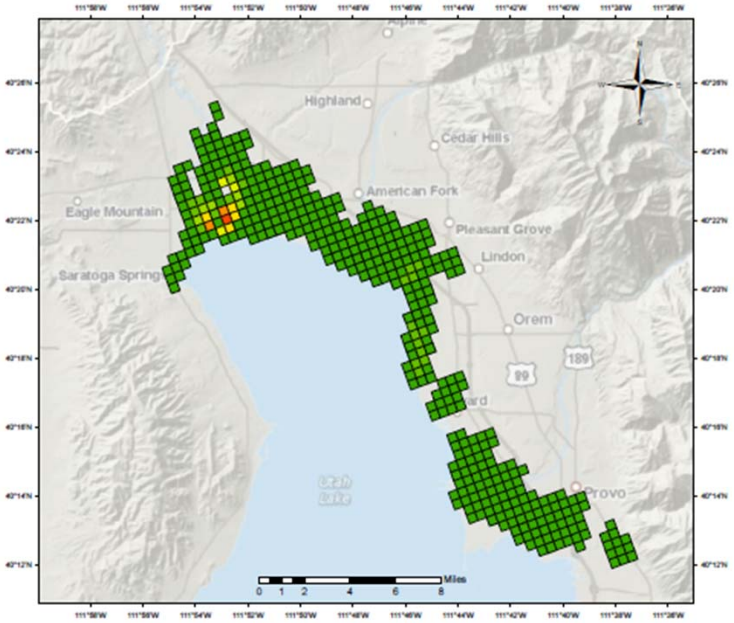
Simulation Executed 5/23/2012 at 5:44:30 PM

AQUAVEO Water Modeling Solutions

BYU

## Simulatated Change in Spring Flow: Layer 3

North Utah County MODFLOW Model Simulation Results




**Legend**

**Change in Spring Flow**
**FLOB_Drains_HRES**

- 0 - 29
- 29 - 59
- 59 - 88
- 88 - 118
- 118 - 147
- 147 - 176
- 176 - 206
- 206 - 235

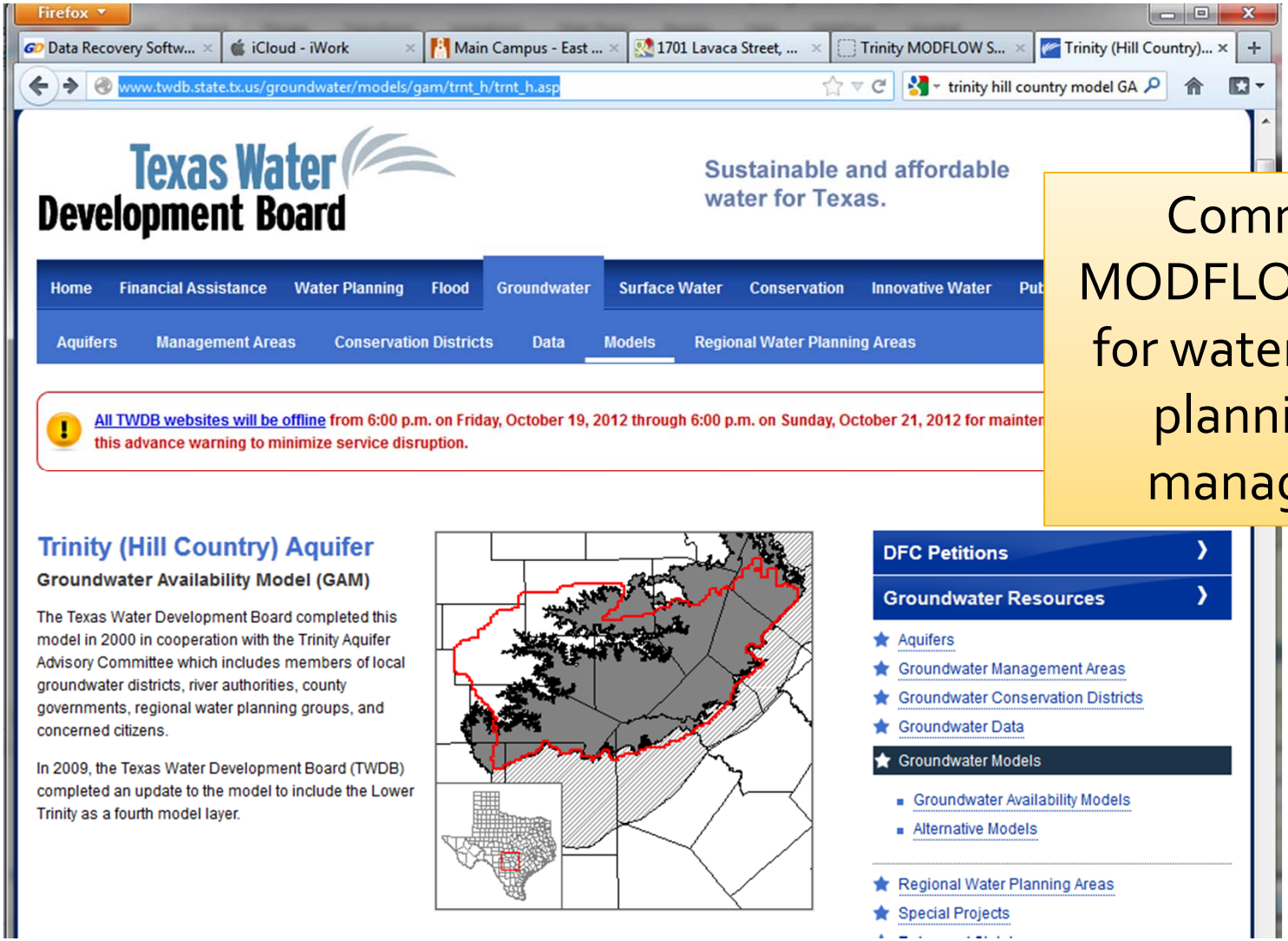
This map was generated by a server-based automated well permitting analysis system using ArcGIS and AHGW geoprocessing tools and the Northern Utah County MODFLOW model created by the USGS.

Simulation Executed 5/23/2012 at 5:50:32 PM

AQUAVEO Water Modeling Solutions

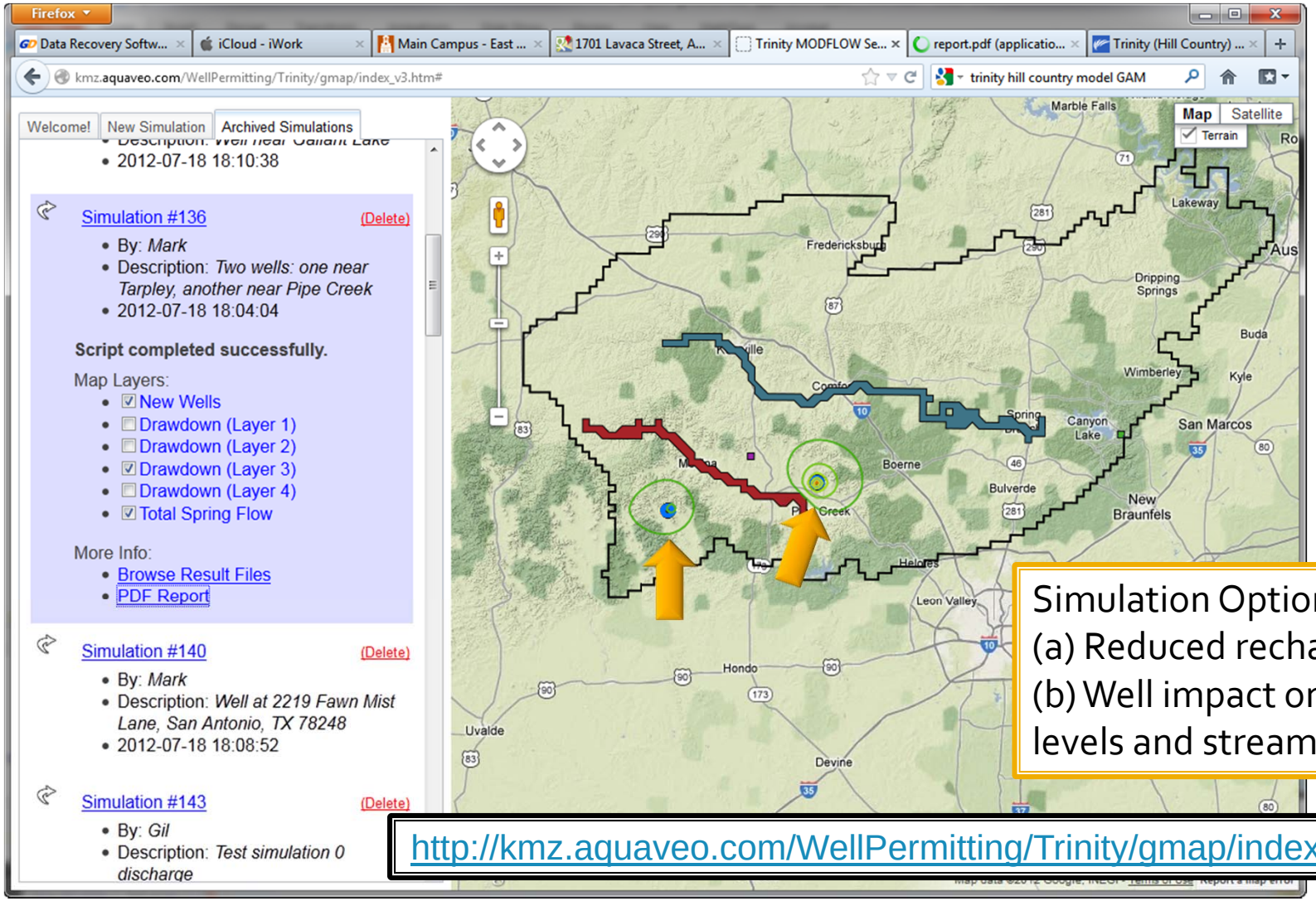
BYU

# Texas Groundwater Availability Models




Community MODFLOW models for water resource planning and management

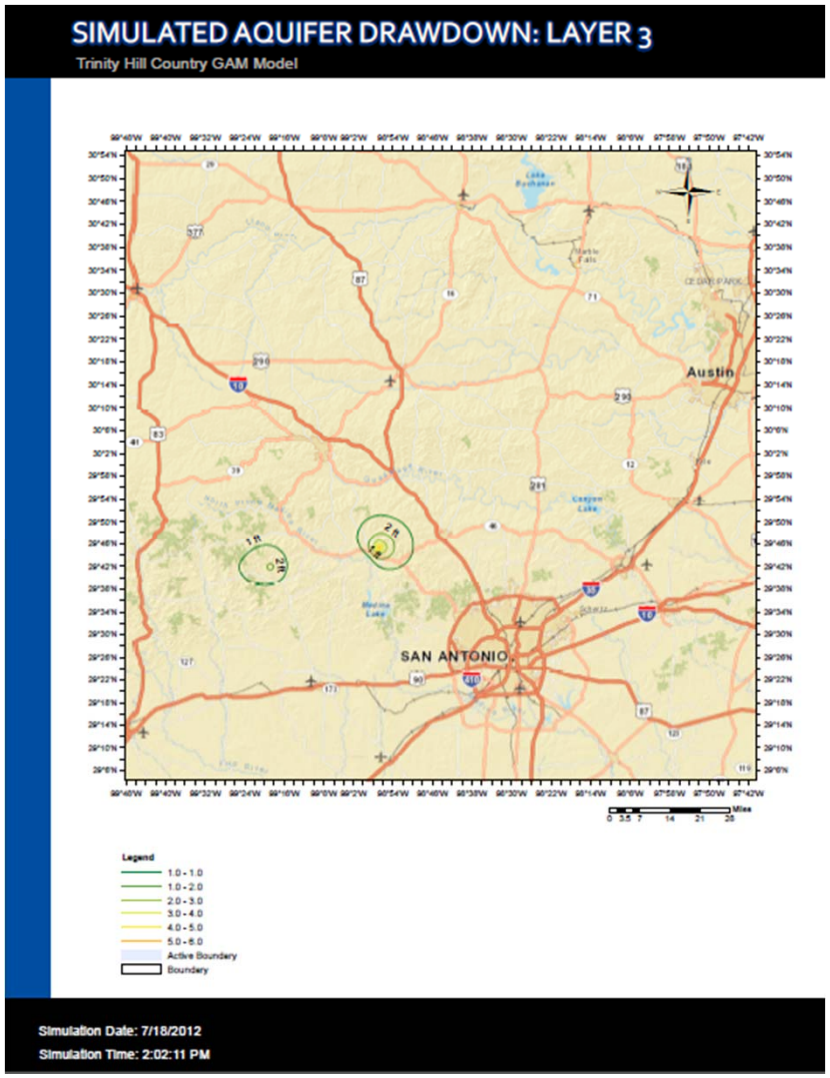
# Trinity (Hill Country) Aquifer GAM

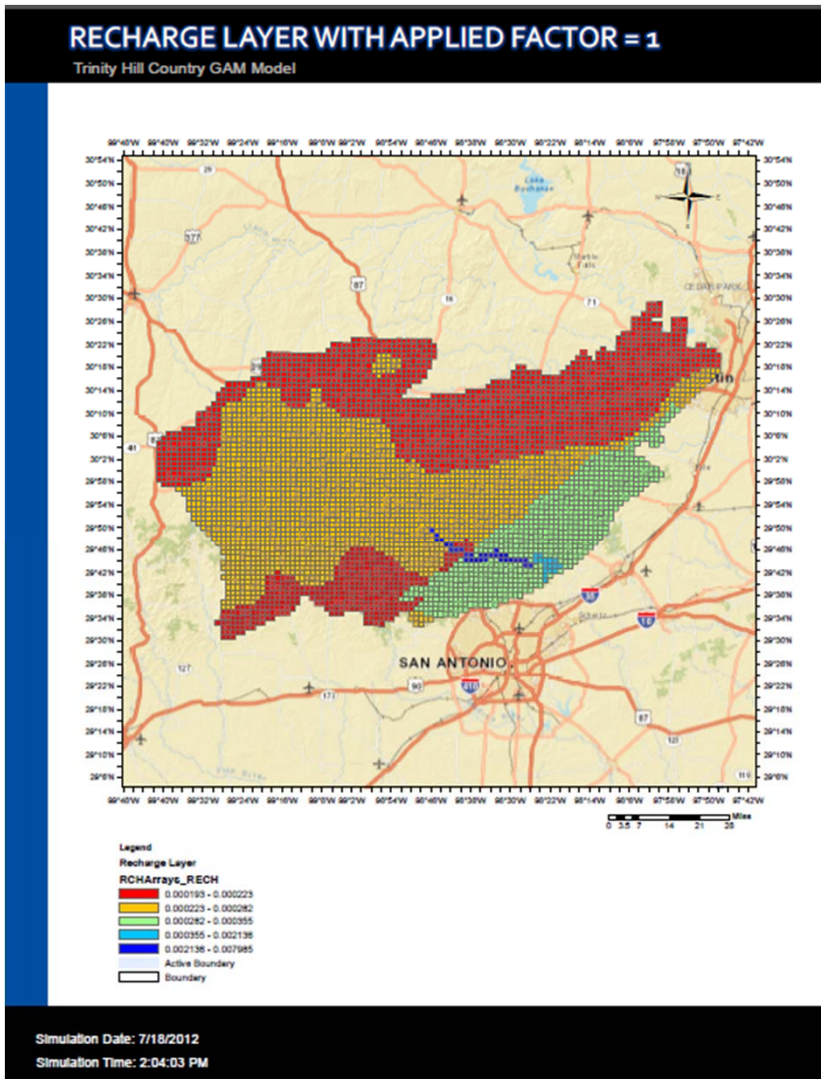



Simulation Options:
(a) Reduced recharge
(b) Well impact on water levels and stream flow

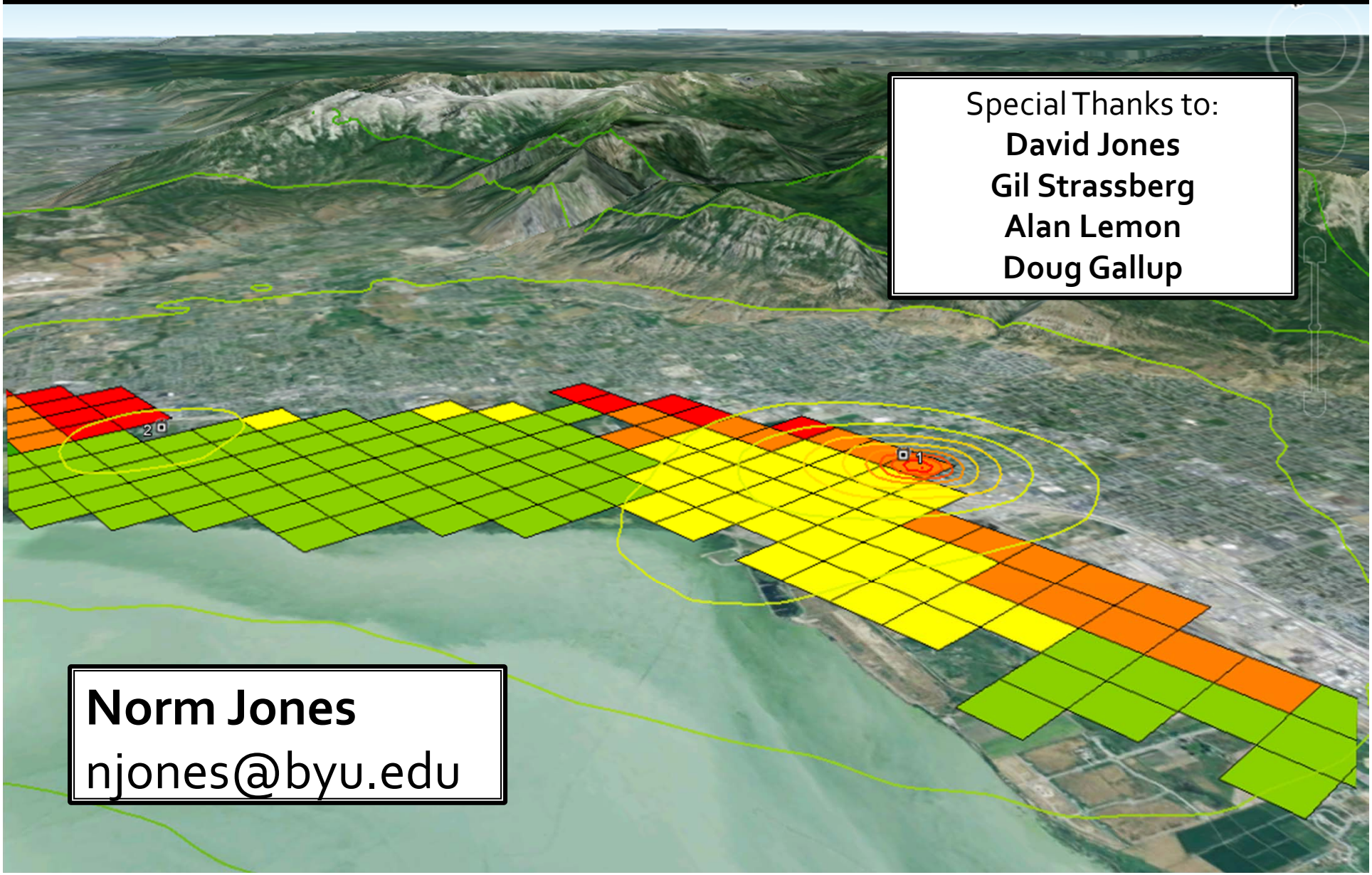
http://kmz.aquaveo.com/WellPermitting/Trinity/gmap/index_v3.htm

# PDF Simulation Report



# Thank You




Special Thanks to:
**David Jones**
**Gil Strassberg**
**Alan Lemon**
**Doug Gallup**

**Norm Jones**
njones@byu.edu