2018 Pennsylvania Groundwater Symposium
State College, Pennsylvania

WellFootprint and ModelMuse

A New Map App for Visualizing the Magnitude of Pumping

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Dennis W. Risser

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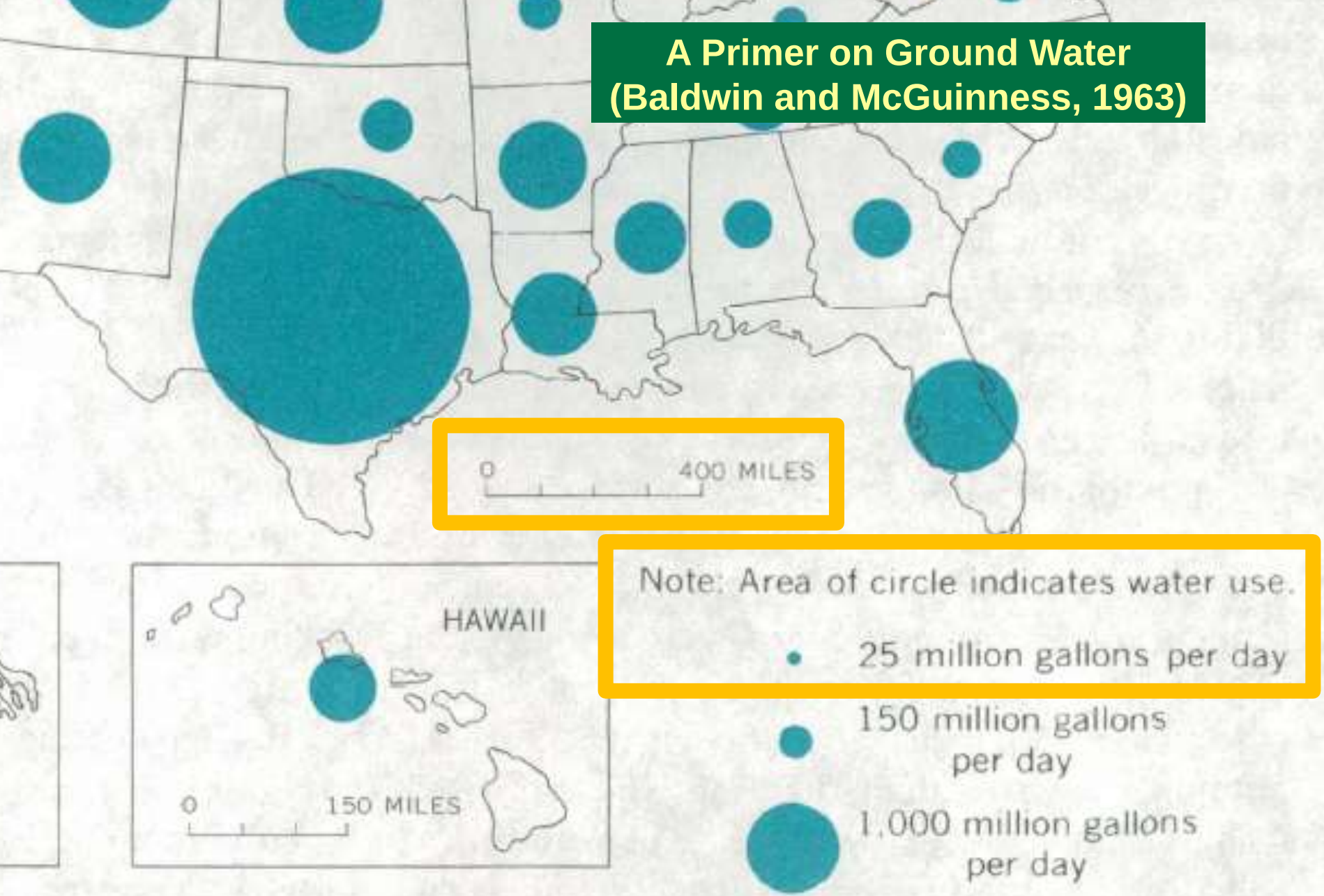
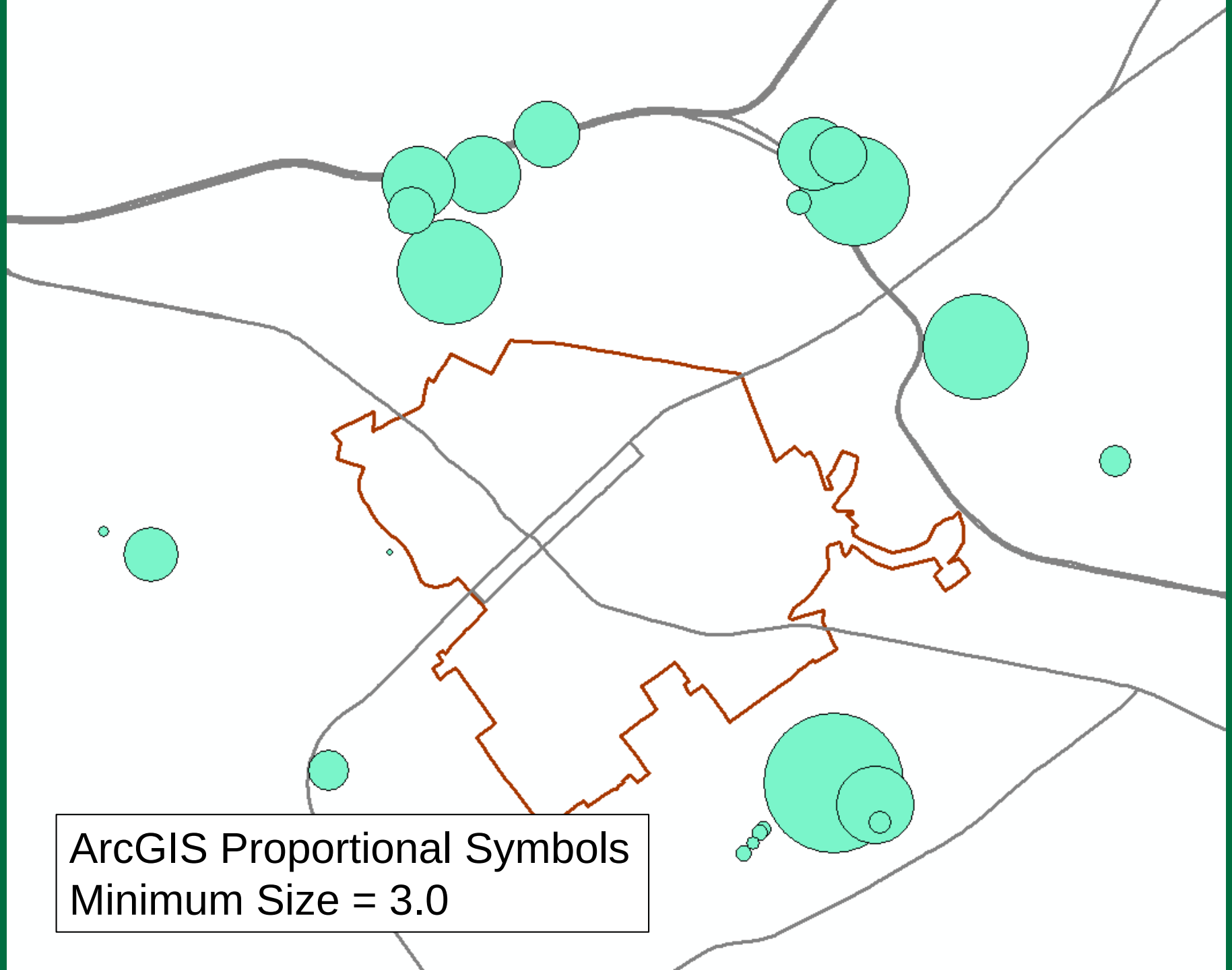
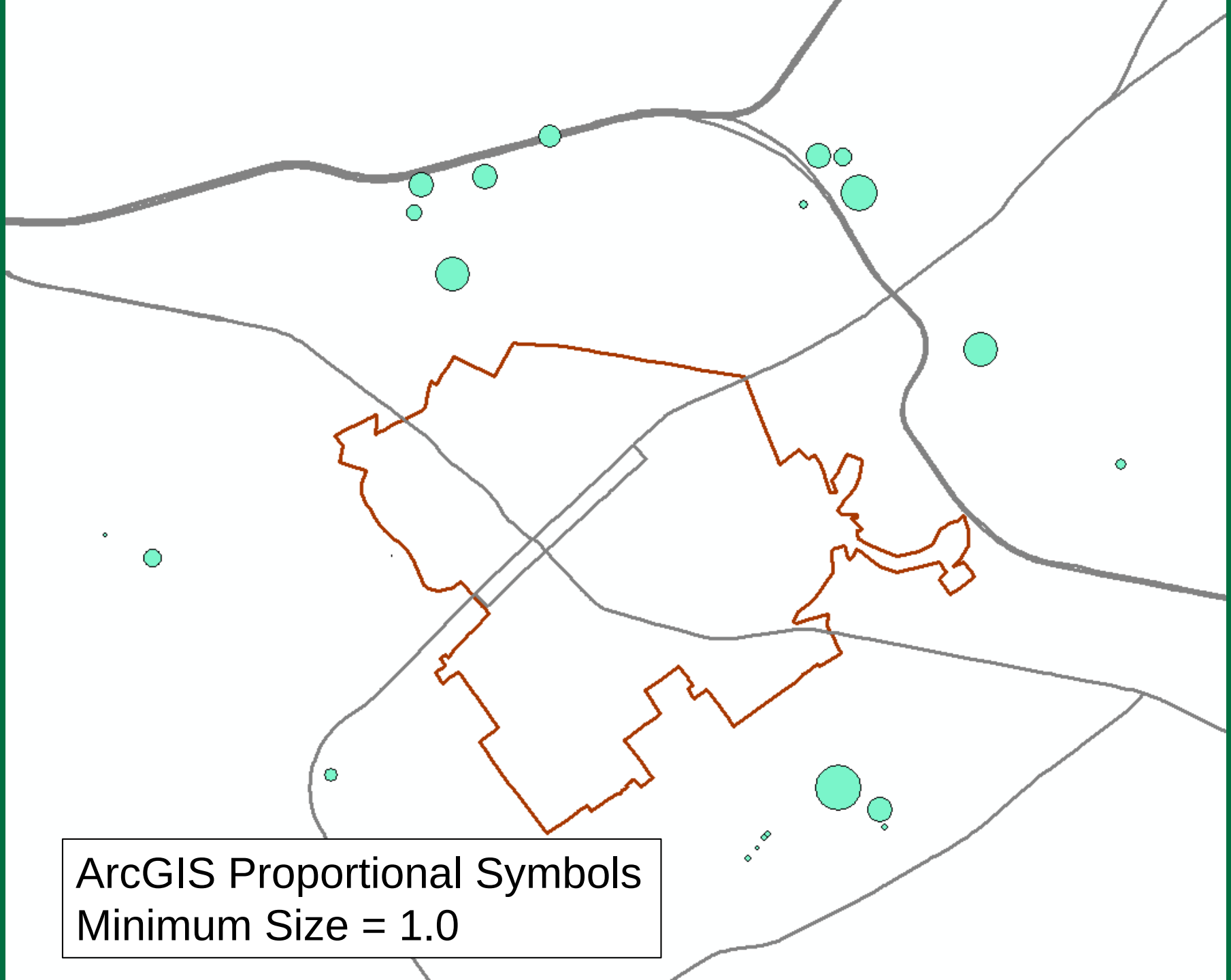
A Primer on Ground Water (Baldwin and McGuinness, 1963)



—*Total use of ground water in the United States, 1960.*


ArcGIS Proportional Symbols
Minimum Size = 3.0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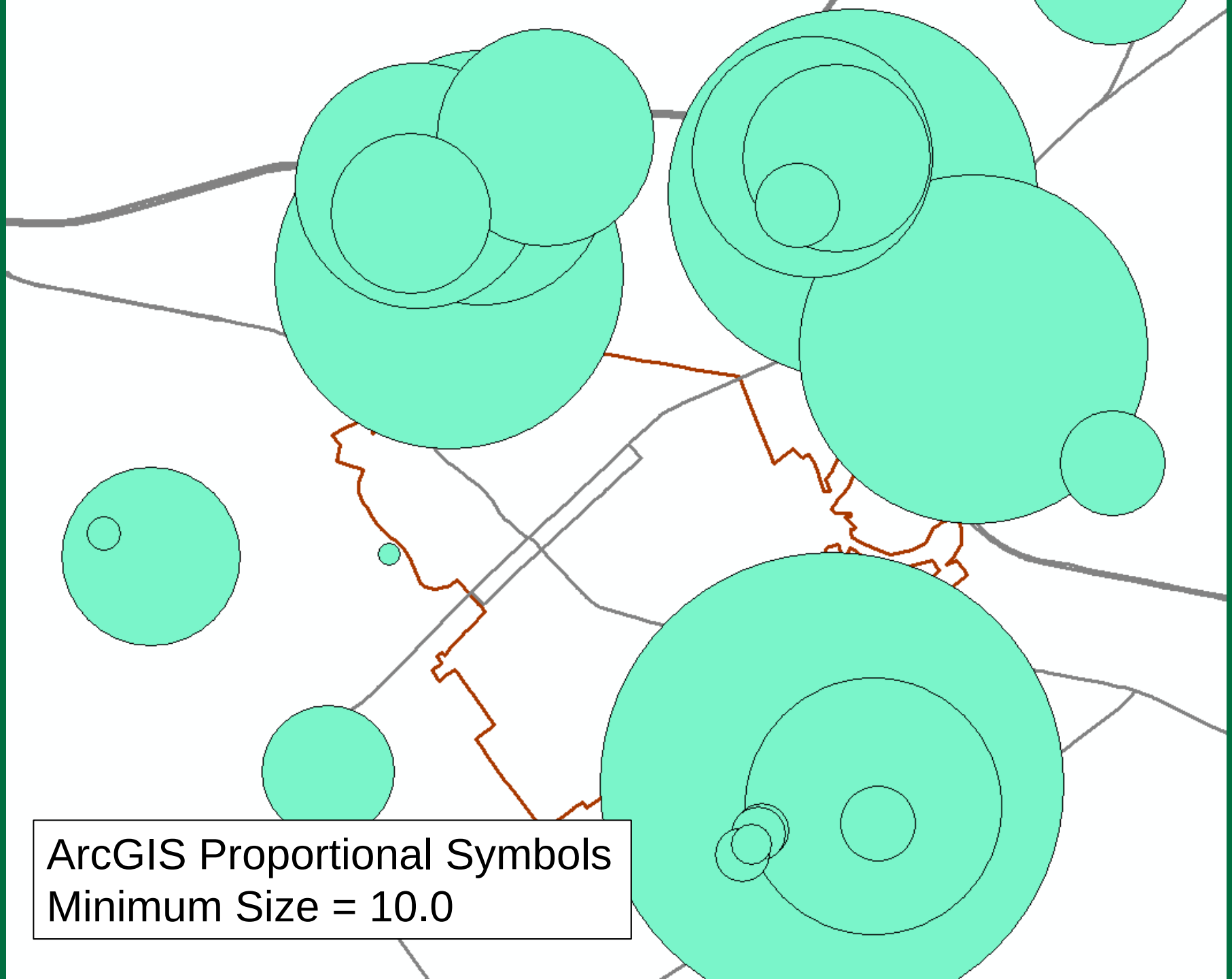
ArcGIS Proportional Symbols
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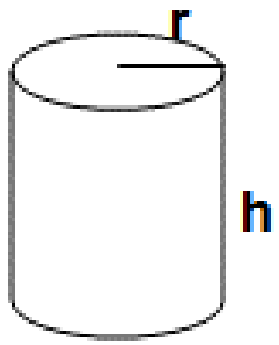
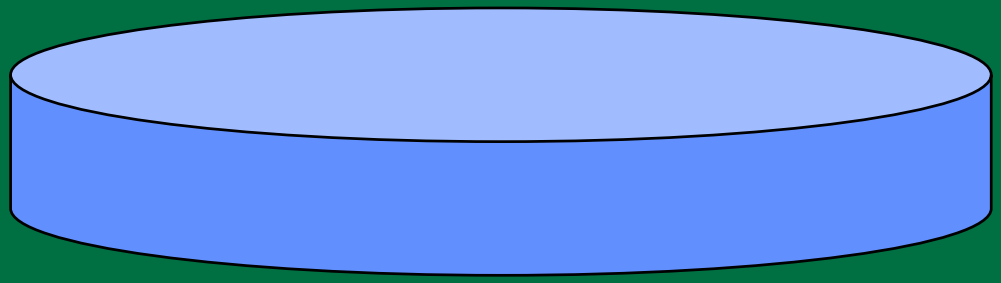


Volume = area of base • height

Volume = $\pi\ r^2\ h$

** The base is a circle, so the area of a circle is $\pi\ r^2$

Height → {



$$\textbf{Area of Symbol} = \frac{\textbf{Volume}}{\textbf{Height}}$$

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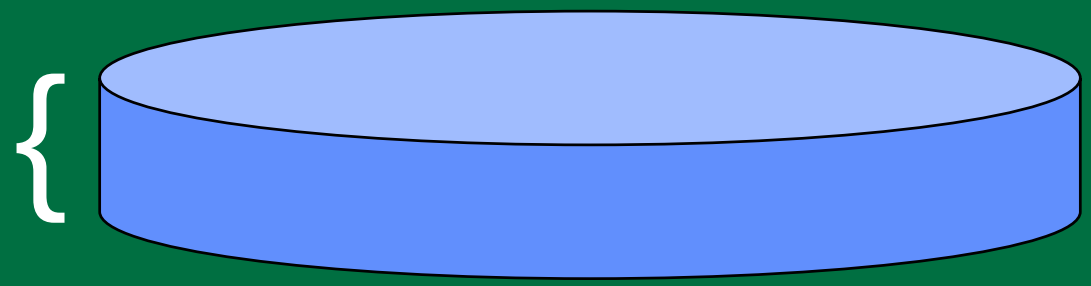
$$\text{Symbol Area} = \frac{\text{Withdrawal Rate}}{\text{Depth per Time}}$$

Depth of Water per Time



"Well Withdrawal Footprint"

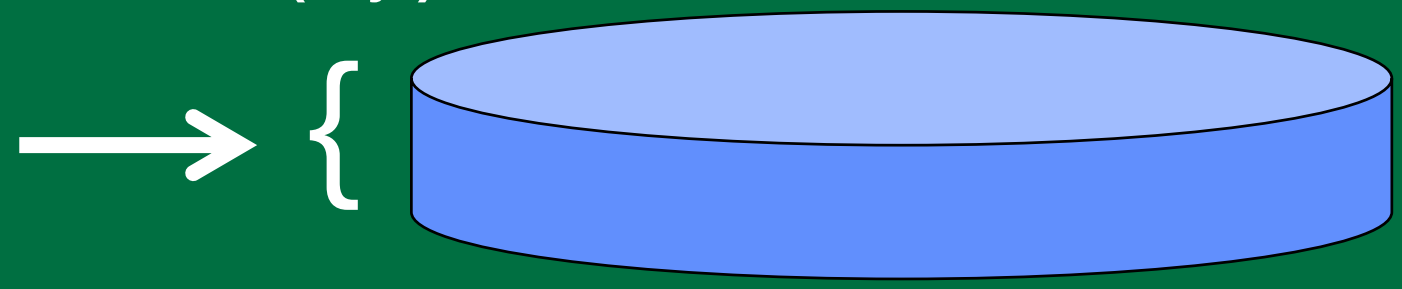
- "Depth-Rate Index" == Depth of Water per Time
- Depth-Rate Index is the *Scale* of the Footprint

Depth-Rate Index Example

- **Recharge rate (e.g. inches / year)**
  - **The volume of water that recharges through the footprint area equals the well withdrawal rate**
  - ***NOT a capture zone; No hydrogeologic basis; Does NOT show where the water comes from!***
  - **Shows size (volume) of withdrawals, as areas centered on well locations**

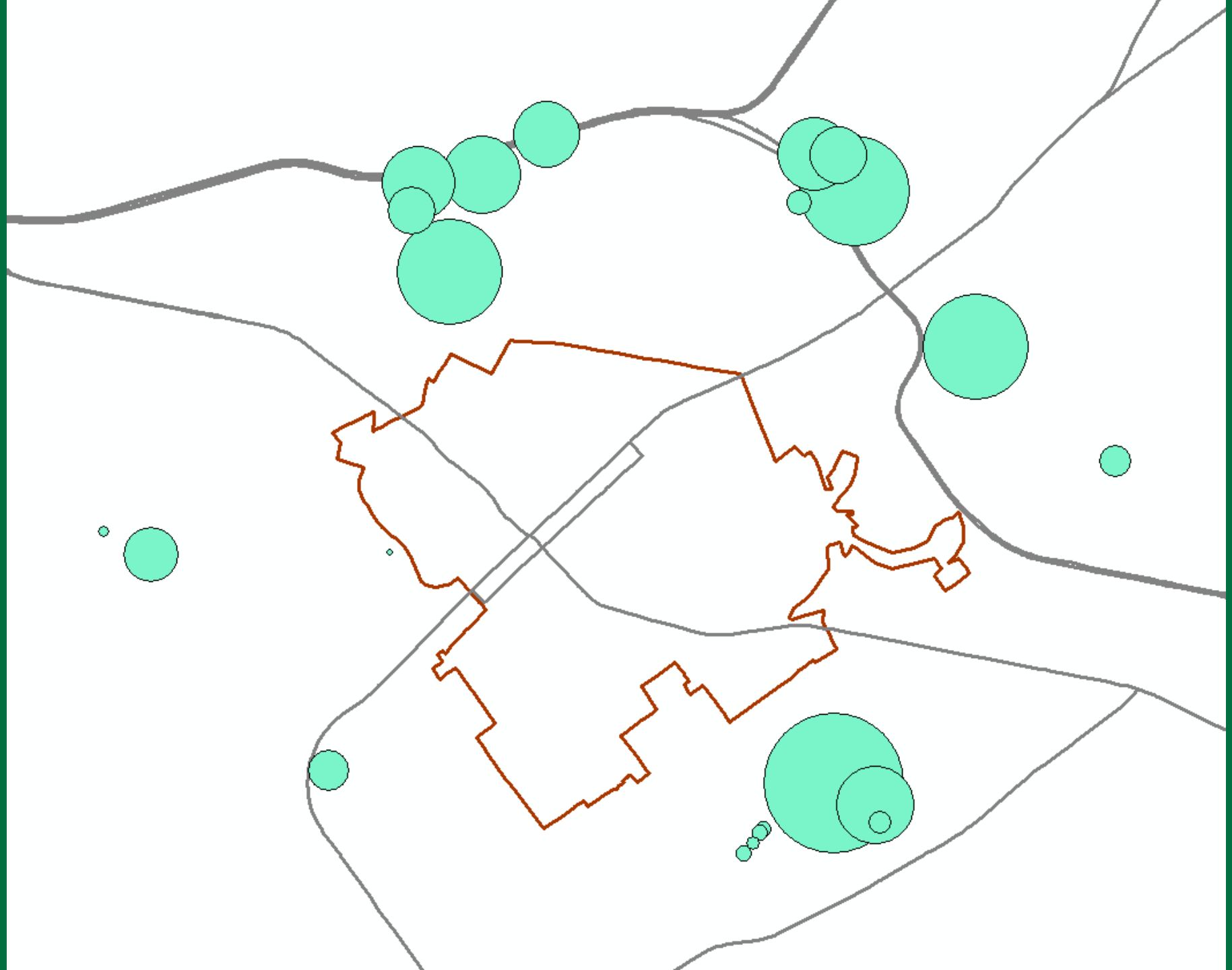
$$\text{Area (in}^2\text{)} = \frac{Q\ (\text{in}^3/\text{yr})}{R\ (\text{in/yr})}$$

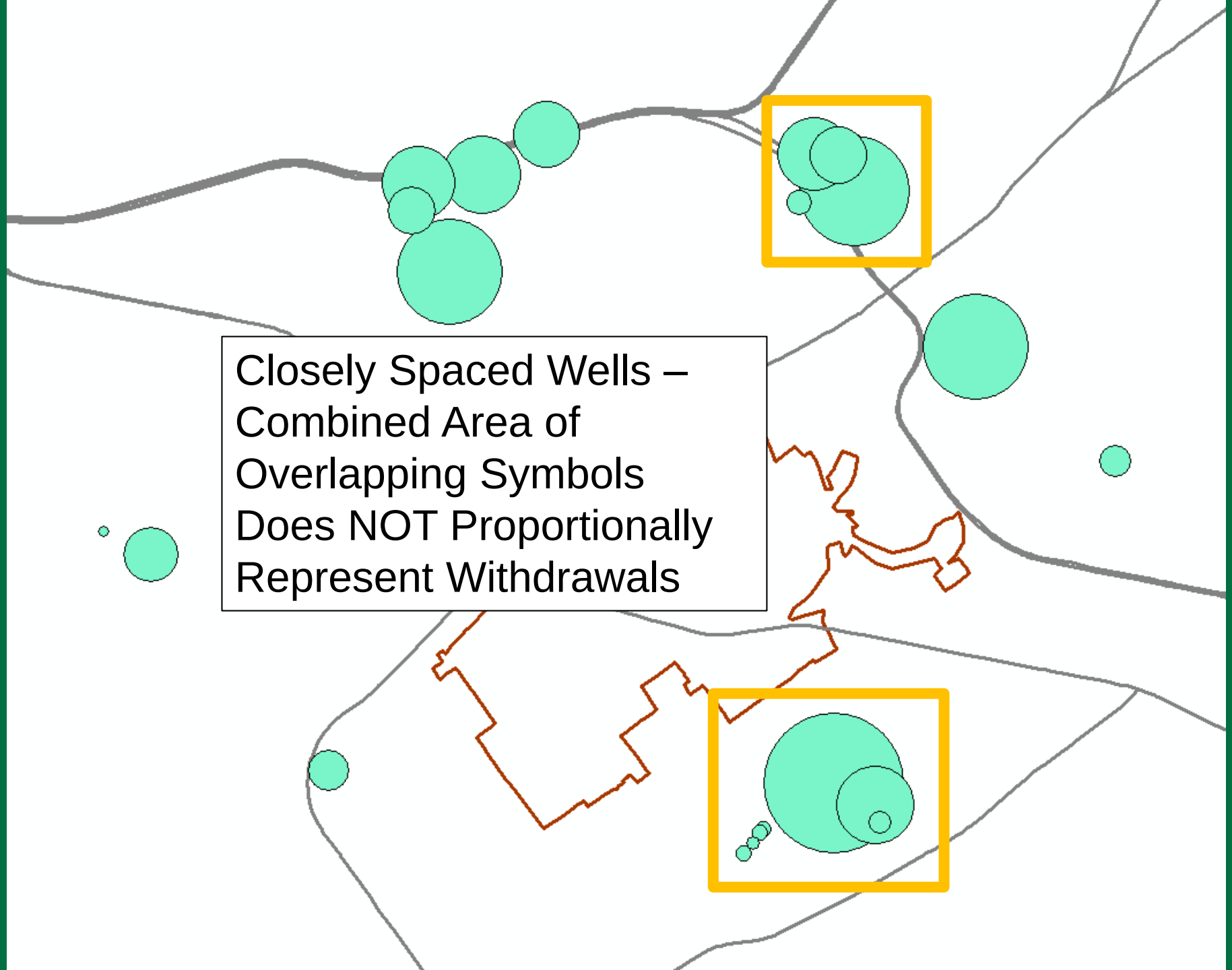
Recharge rate

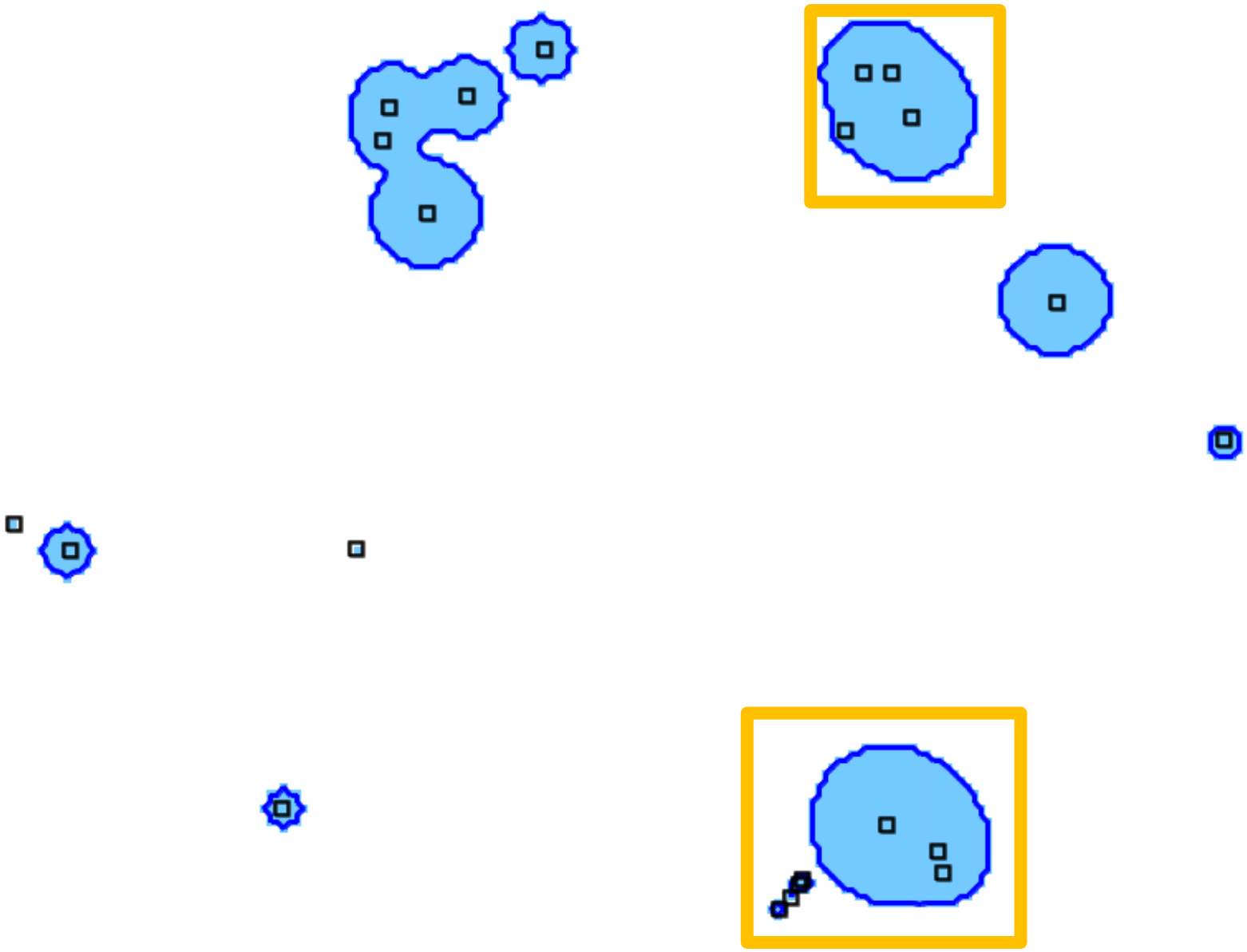


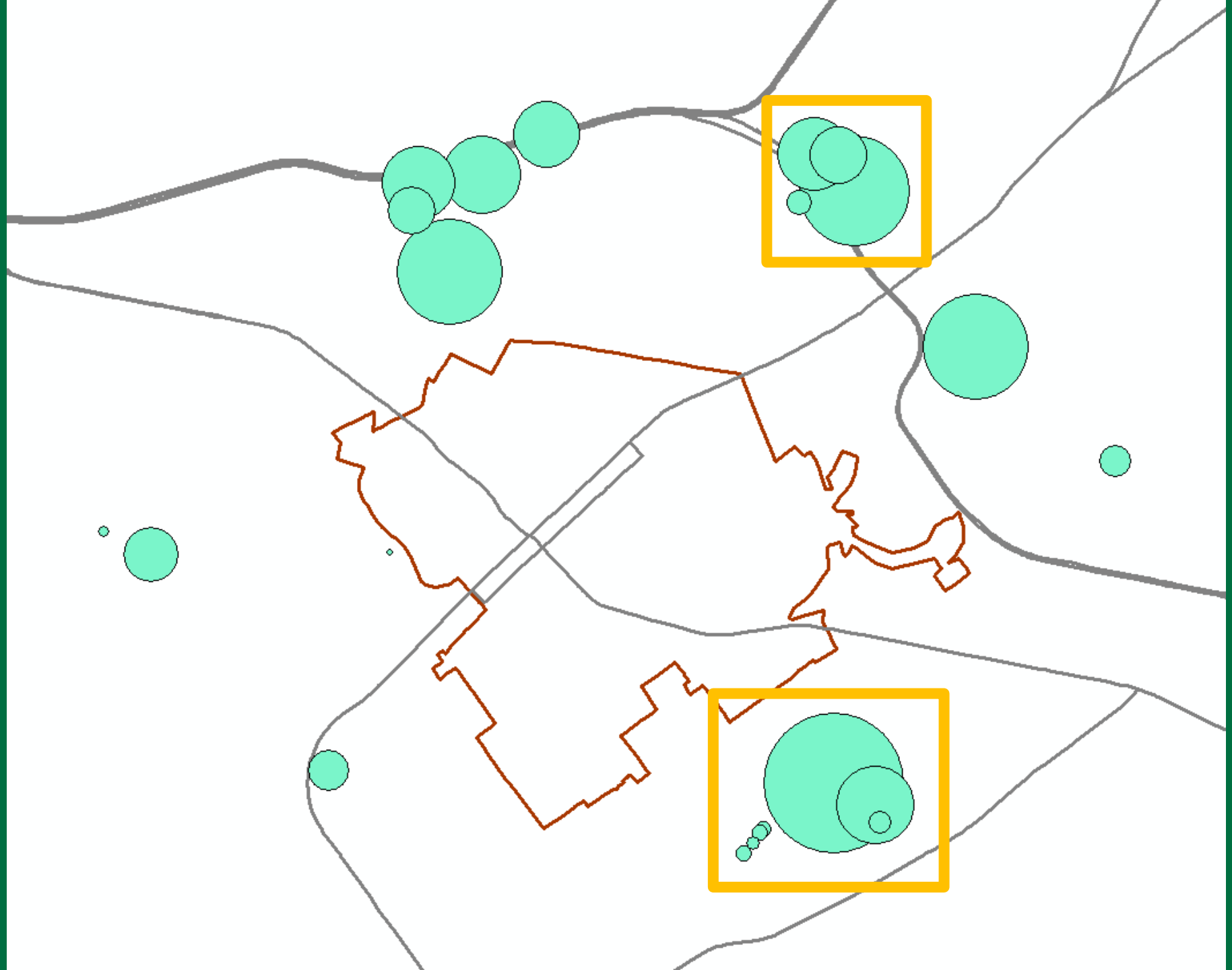
Example Depth-Rate Indexes

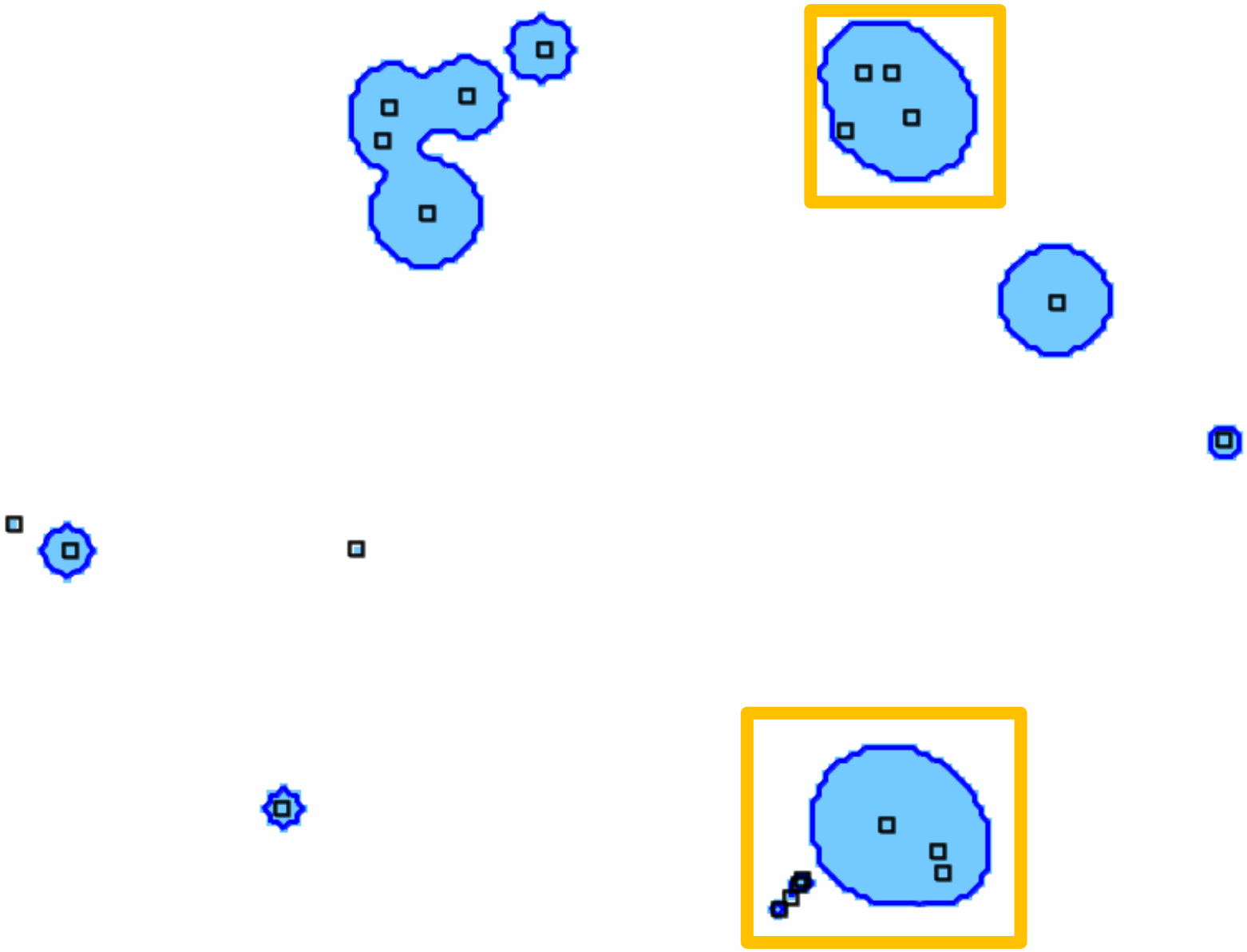
- **Water-Resource Metric**
  - Recharge
  - Stream Base-flow Statistic / Drainage Area
  - Total Natural Inflow / Aquifer Area
  - Water-Level Decline Rate (scaled by S_y)
- **Management**
  - Allocation Limit / Area
- **Cartographic Design**
  - User-Selected – Depth-Rate Index is ‘Scale’ of Withdrawal Footprint Map



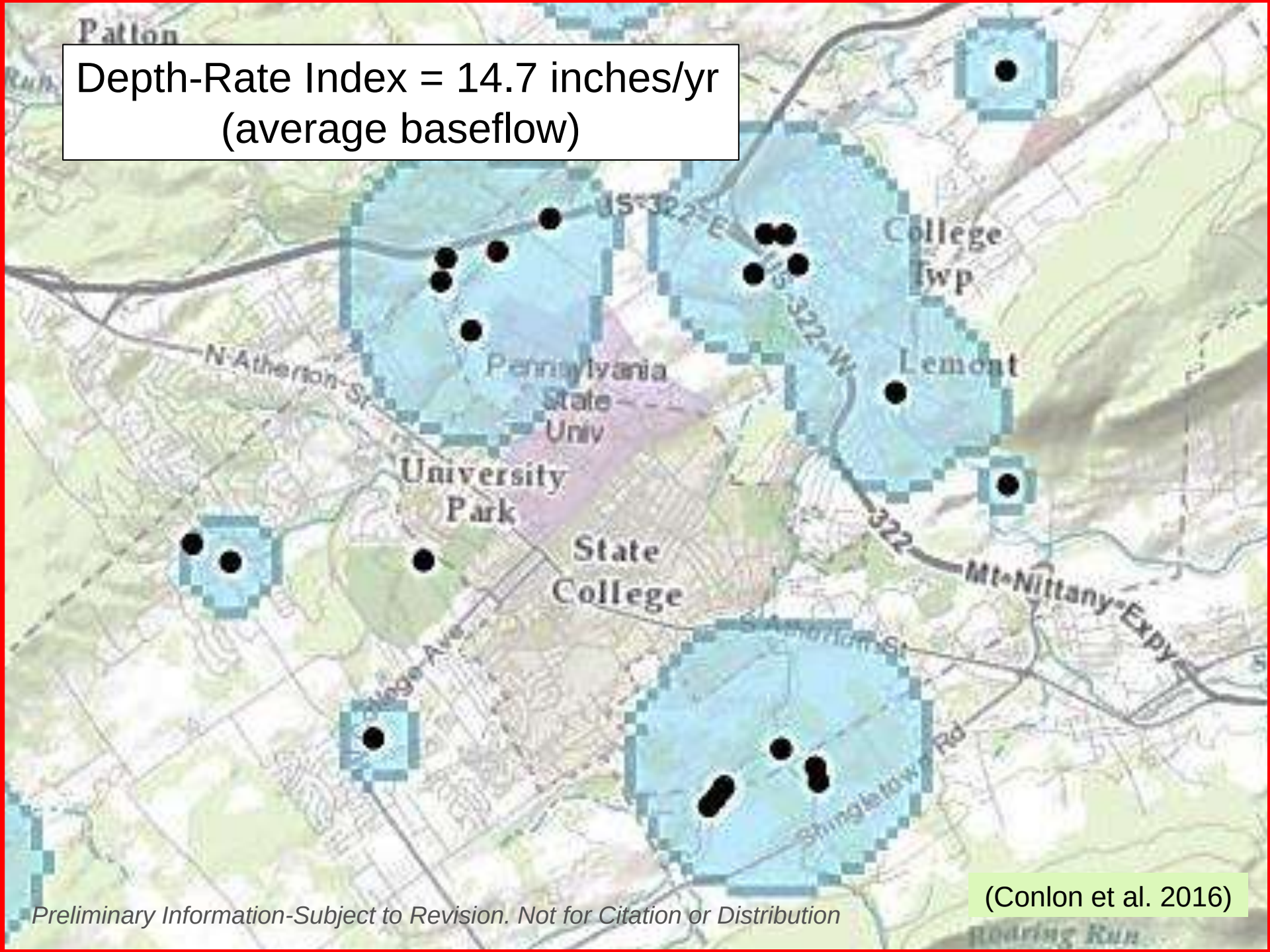

Closely Spaced Wells – Combined Area of Overlapping Symbols Does NOT Proportionally Represent Withdrawals







Depth-Rate Index = 14.7 inches/yr
(average baseflow)



(Conlon et al. 2016)

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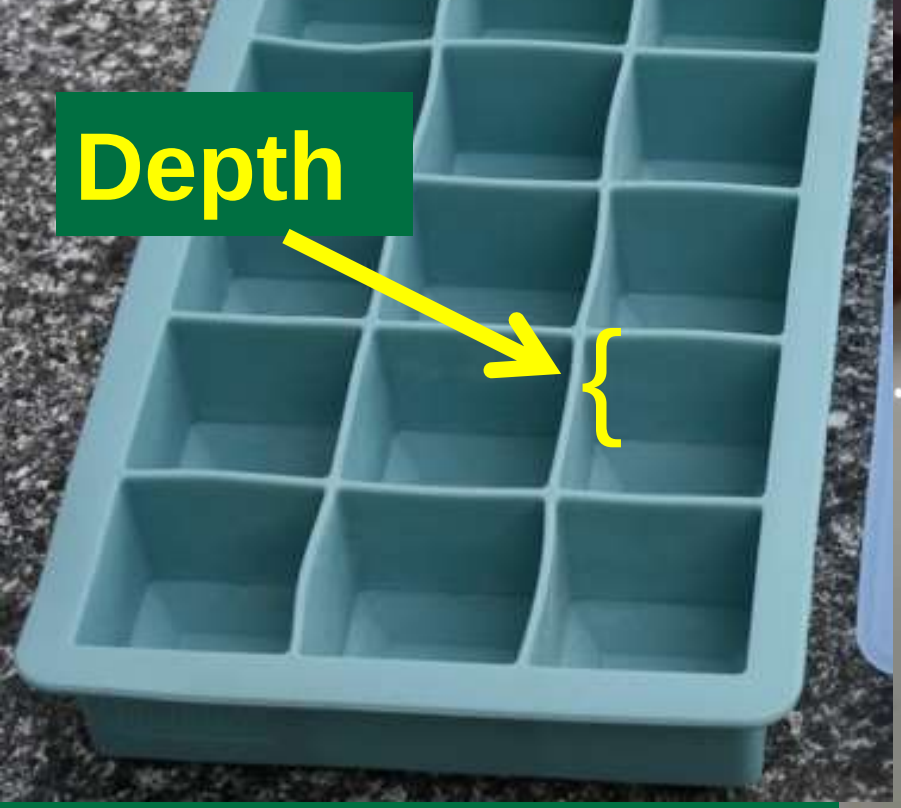

Algorithm Cascades Excess Q to Adjacent Cells

Water Resources Ground

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- Variably-Saturated Flow and Transport
- Hydrograph-Separation and other Streamflow-Based Programs
- Analysis of Aquifer Tests and Slug Tests
- Graphical User Interfaces and Post Processors
- Miscellaneous Software
- Legacy and Superseded Software

- WellFootprint (Win) Version 1.0.0.0, 2017/12/19
  A Program for Visualization of Groundwater Withdrawals

USGS

Visualization of groundw

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Visualization of groundwater withdrawals

Open-File Report 2017-1137

By: Richard B. Winston and Daniel J. Goode

https://doi.org/10.3133/ofr20171137

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Links

- Document: **Report** (1 MB pdf)
- Application Site: **Application Site** - WellFootprint source code and examples: U.S. Geological Survey software release
- Download citation as: RIS | Dublin Core

Abstract

Generating an informative display of groundwater withdrawals can sometimes be difficult because the symbols for closely spaced wells can overlap. An alternative method for displaying groundwater withdrawals is to generate a "footprint" of the

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- Variably-Saturated Flow and Transport
- Hydrograph-Separation and other Streamflow-Based Programs
- Analysis of Aquifer Tests and Slug Tests
- Graphical User Interfaces and Post Processors
- Miscellaneous Software
- Legacy and Superseded Software

- NEW ModelMuse (Windows) Version 3.10.0.0, 2018/3/2
  ModelMuse: A Graphical User Interface for MODFLOW-2005, MODFLOW-LGR, MODFLOW-LGR2, MODFLOW-NWT, MODFLOW-CFP, MODFLOW-OWHM, MT3DMS, SUTRA, PHAST, MODPATH, ZONEBUDGET and WellFootprint

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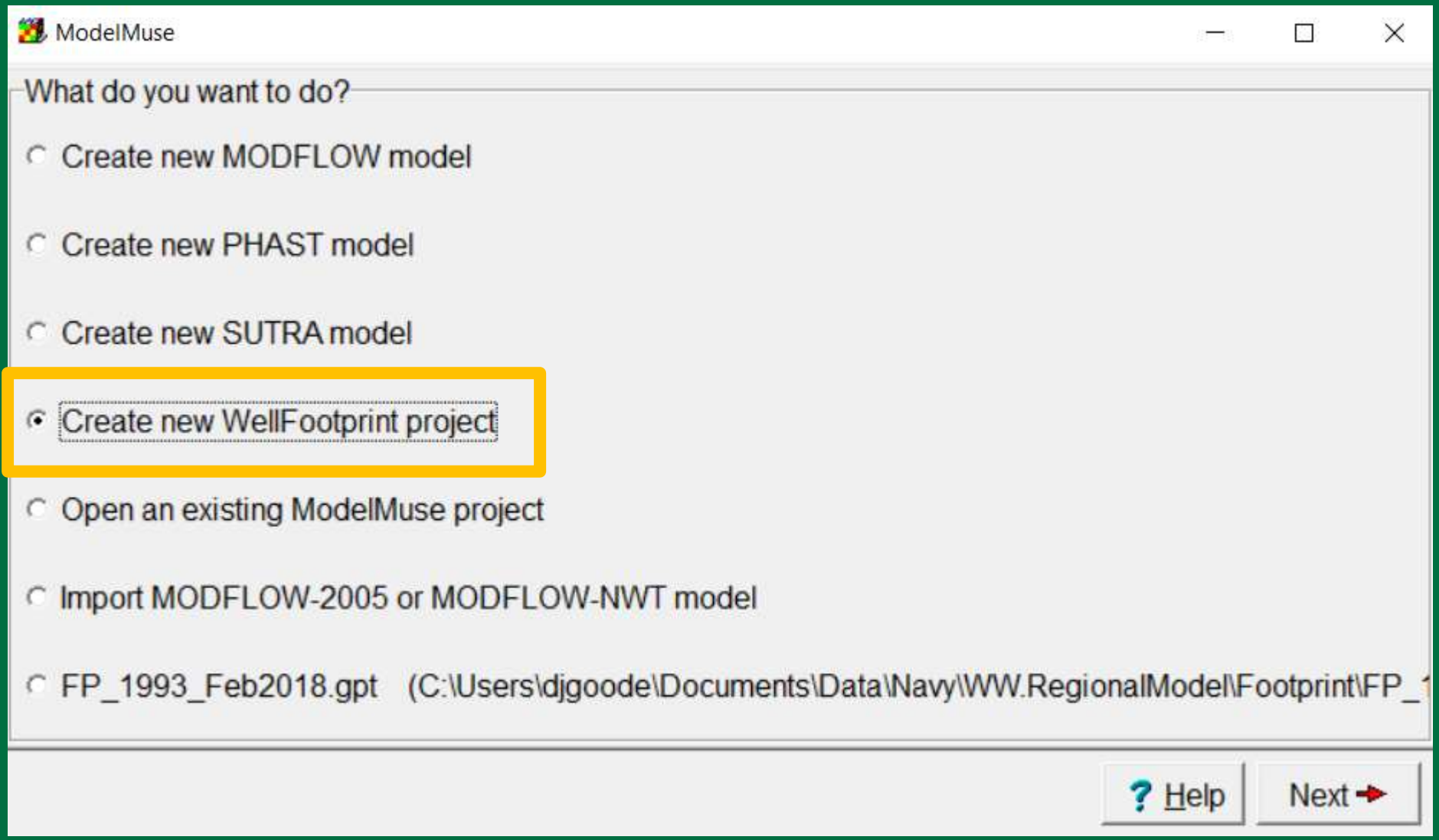
ModelMuse
What do you want to do?
Create new MODFLOW model
Create new PHAST model
Create new SUTRA model
Create new WellFootprint project
Open an existing ModelMuse project
Import MODFLOW-2005 or MODFLOW-NWT model
FP_1993_Feb2018.gpt (C:\Users\djgoode\Documents\Data\Navy\WW.RegionalModel\Footprint\FP_
Help
Next

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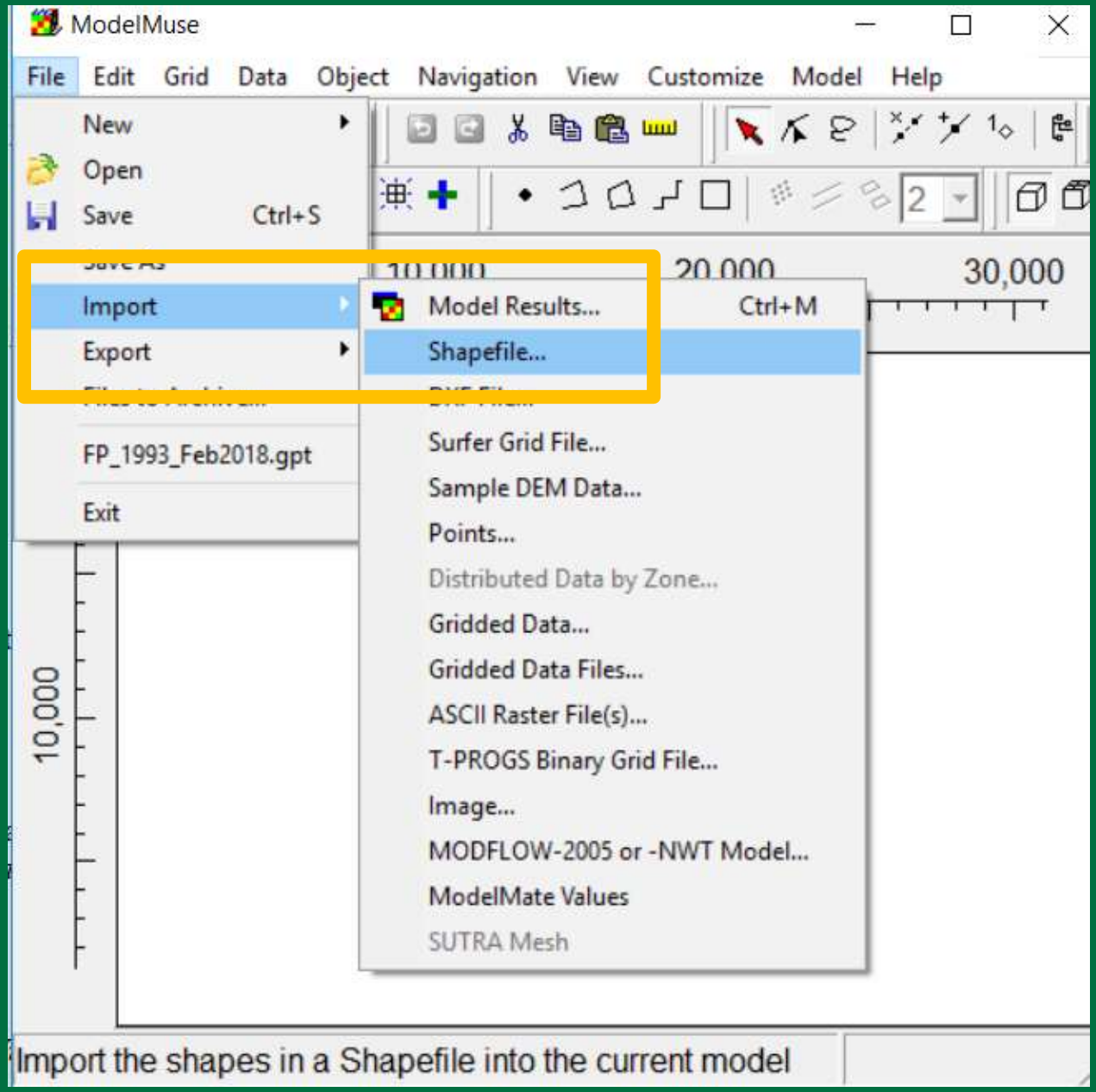
Define Domain for Map



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Define
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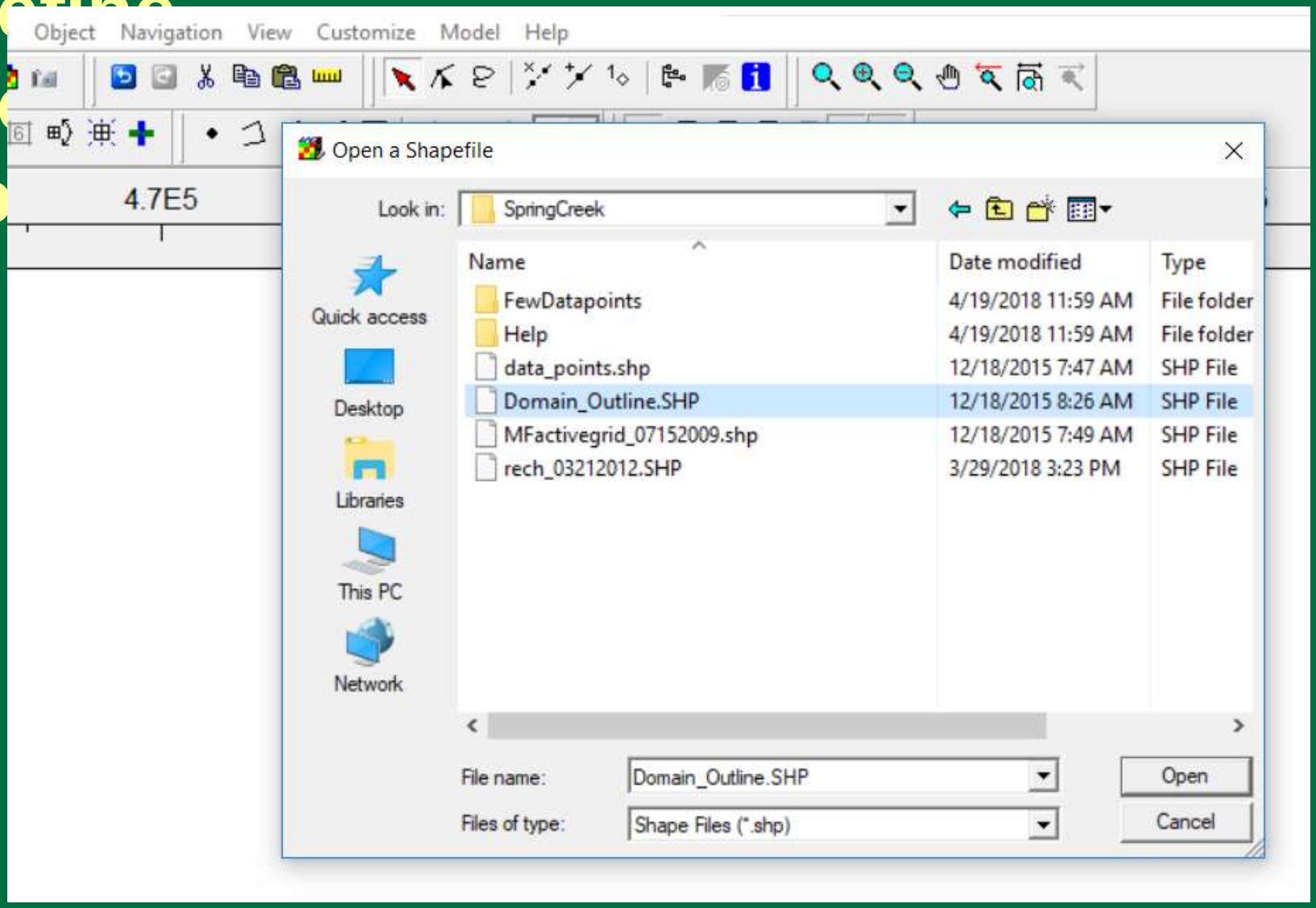

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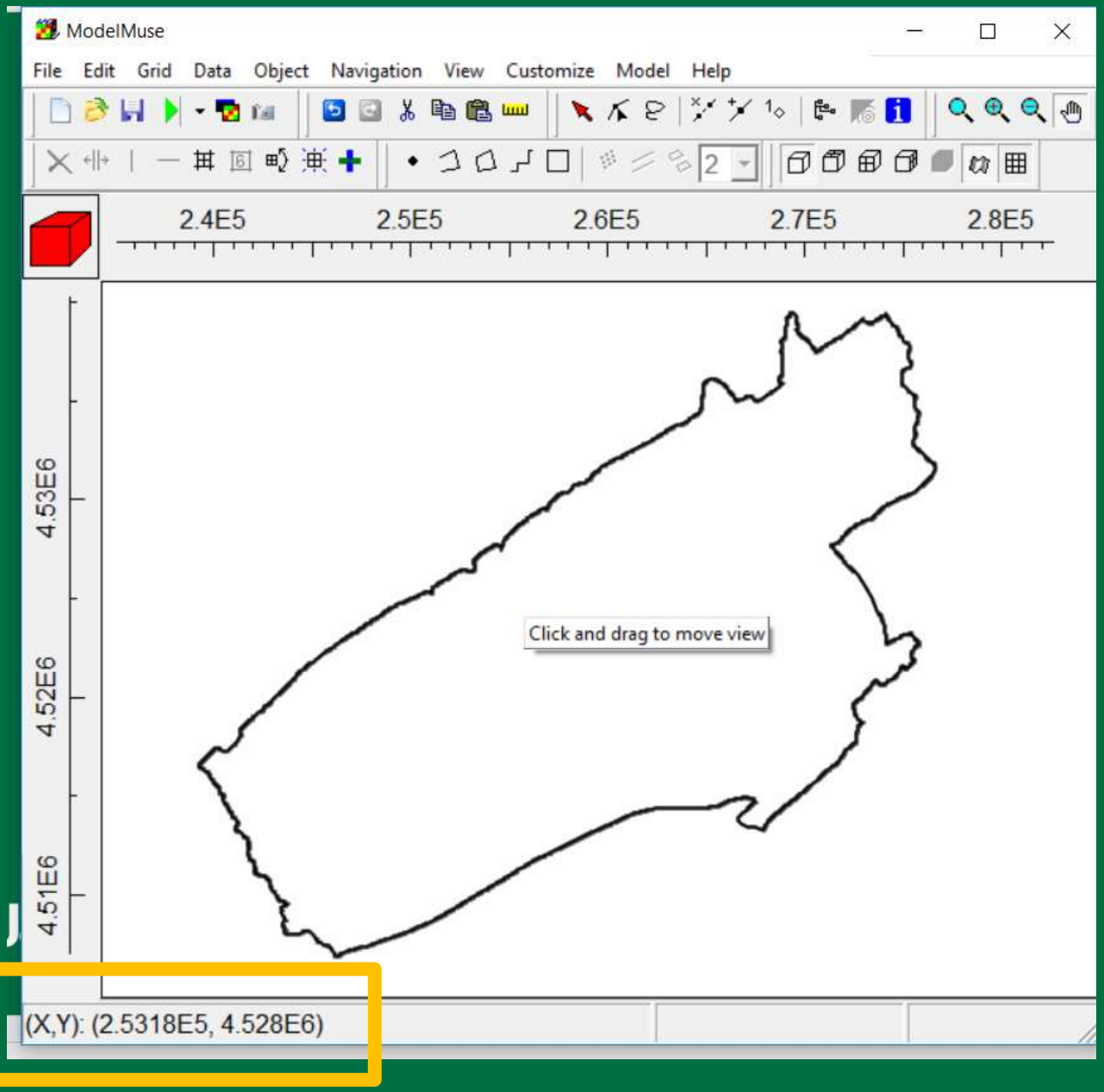
Pumping Rate Volume Units match Map Length Units



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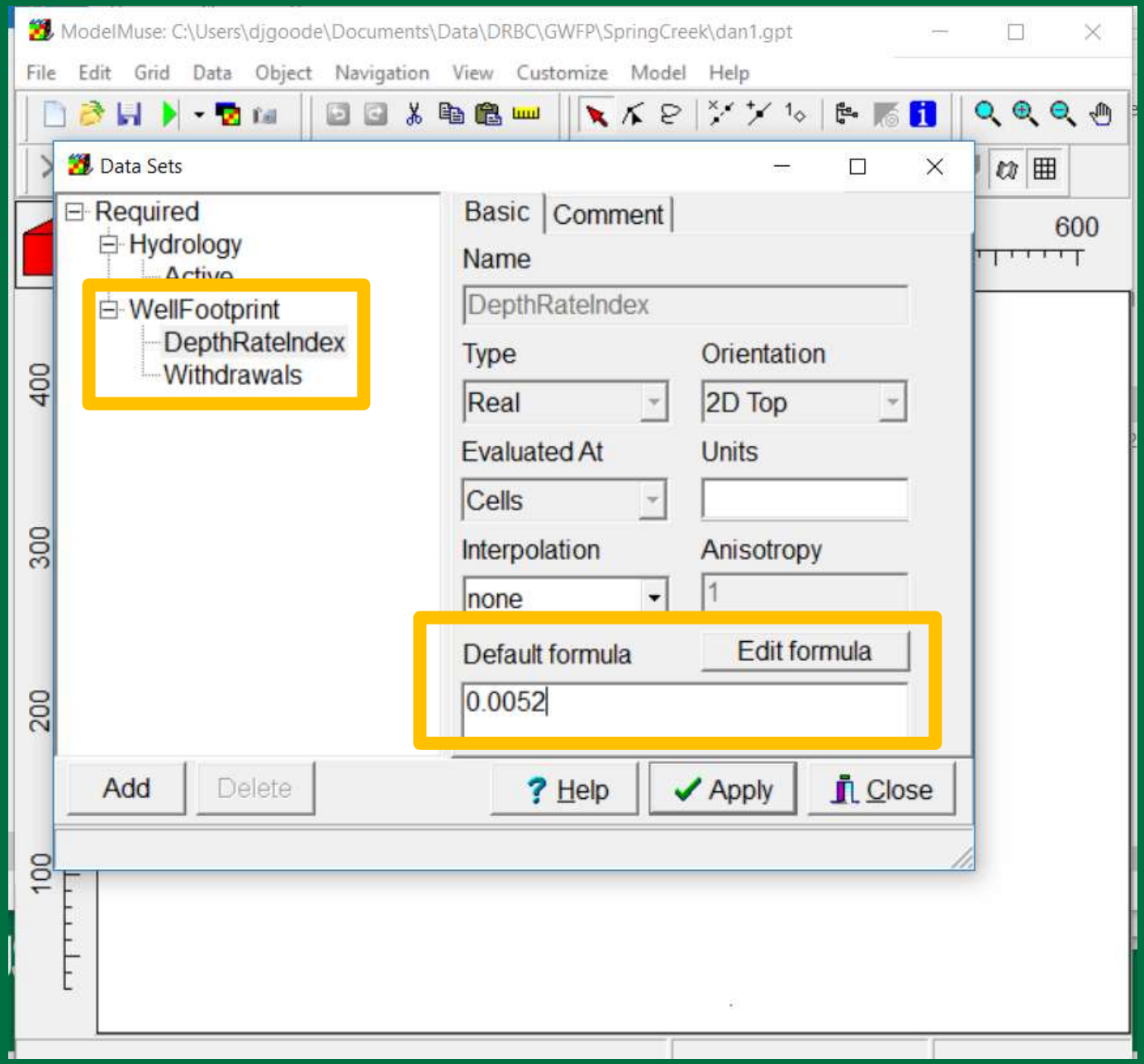
Depth-Rate Index (in map length units, and Q time units)



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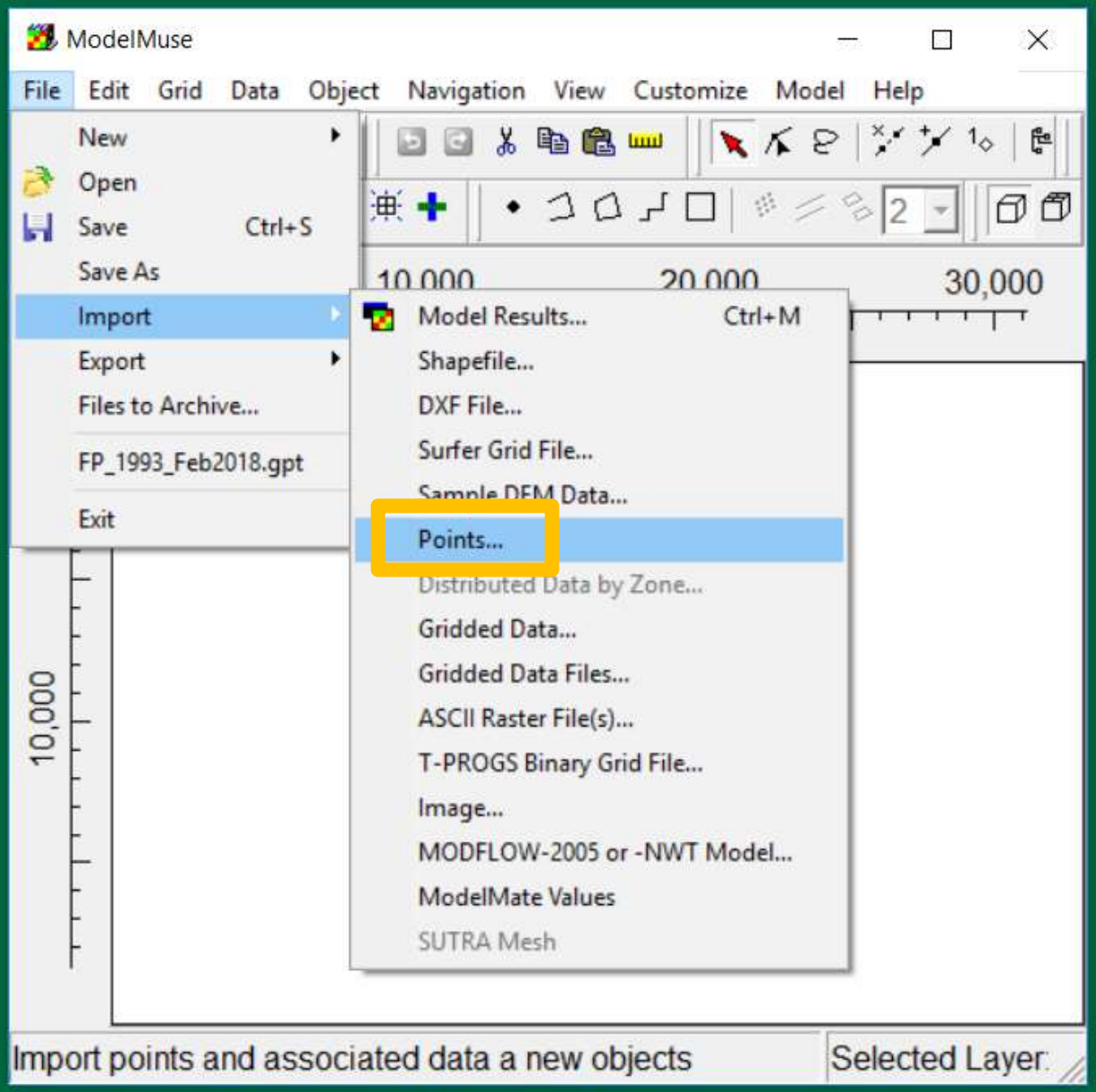
Well Data



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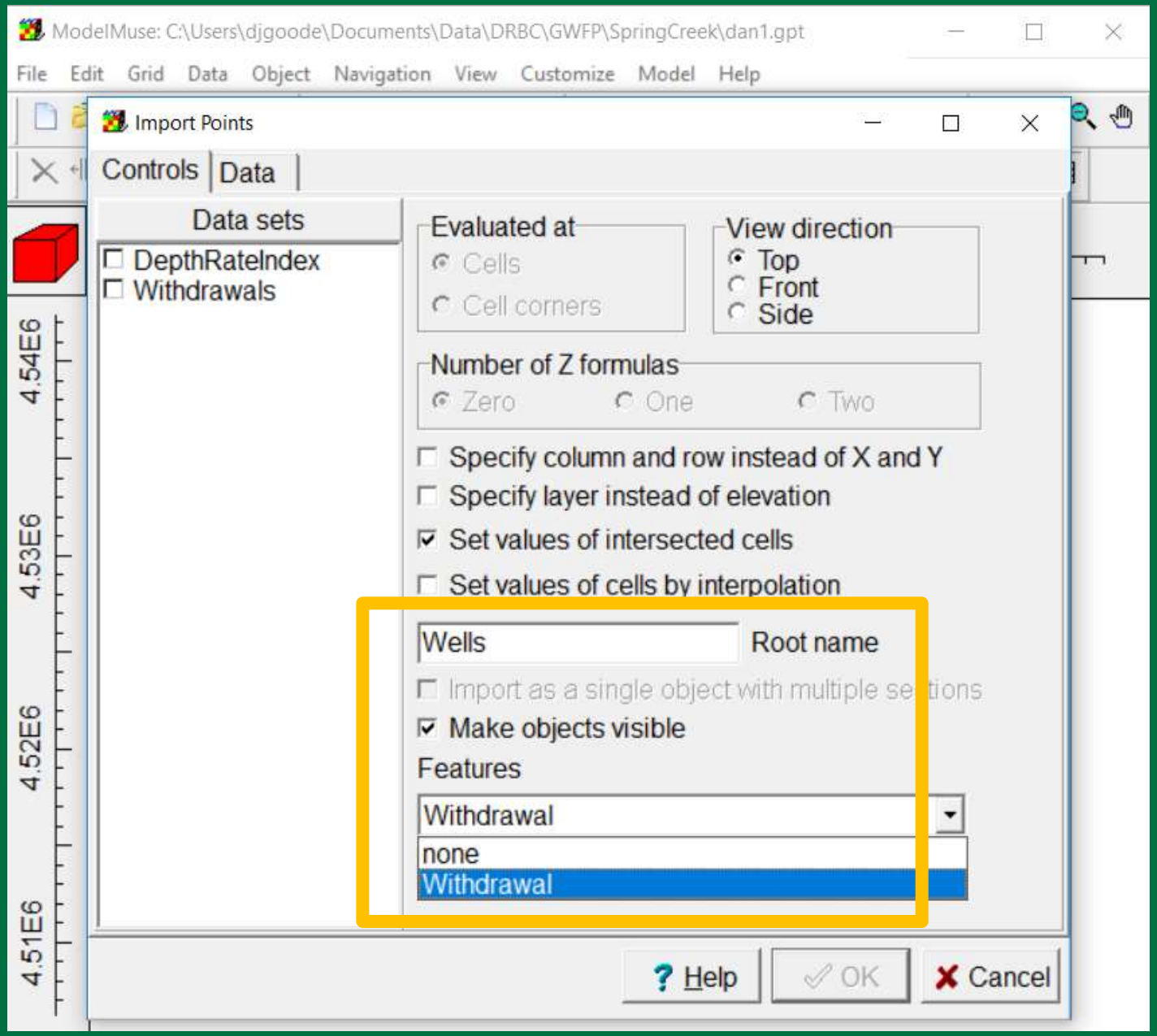
Well Data



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Wells_Demo.xlsx

File Home Insert Page Layout Form

Paste Clipboard Font Alignment

A2 2622

	A	B	C
1	x-coord (utm-18N, NAD83)	y-coord (utm-18N, NAD83)	PUMP RATE (CUBIC METERS PER YEAR)
2	262	4521	1132595
3	274	4522	29565
4	274	4522	297475
5	263	4524	282145
6	261	4522	1265820
7	271	4529	1692140
8	272	4530	2685305
9	271	4535	1527890
10	260	4522	542025
11	260	4522	329230
12	260	4522	66065
13	260	4516	27375
14	260	4516	15695
15	248	4519	379965
16	249	4519	379965

ModelMuse

File Edit Grid Data Object Navigation View Customize Model Help

Import Points

Controls Data

X	Y	Withdrawal	Object name (optional)
262	4521	1132595	CE162_LEMONT
274	4522	29565	CENTRE_HALL_WELL_8
274	4522	297475	CENTRE_HALL_WELL_9
263	4524	282145	COLLEGE_TWP_ROGERS_SHILO
261	4522	1265820	COLLEGE_TWP_SP_CR_WELL
271	4529	1692140	DEEP_MINE
272	4530	2685305	GENTZEL_QUARRY
271	4535	1527890	HRI_-_CURTIN_GAP_QUARRY
260	4522	542025	PS33
260	4522	329230	PS34
260	4522	66065	PS35
260	4516	27375	scbwa11

45 Rows Open file

Help OK Cancel

4.44E6 4.43E6 4.42E6 4.41E6 4.4E6

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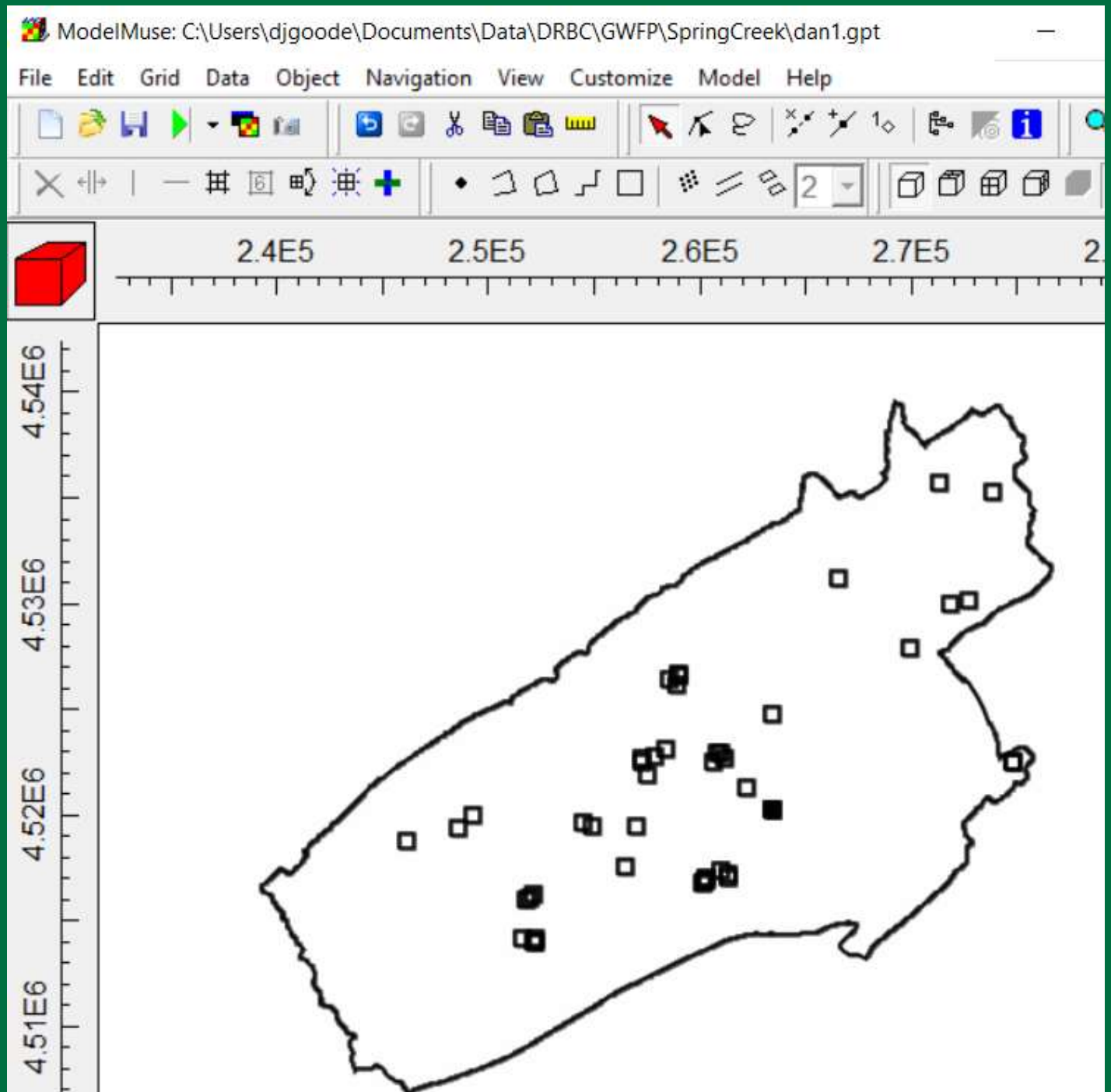
Well Data



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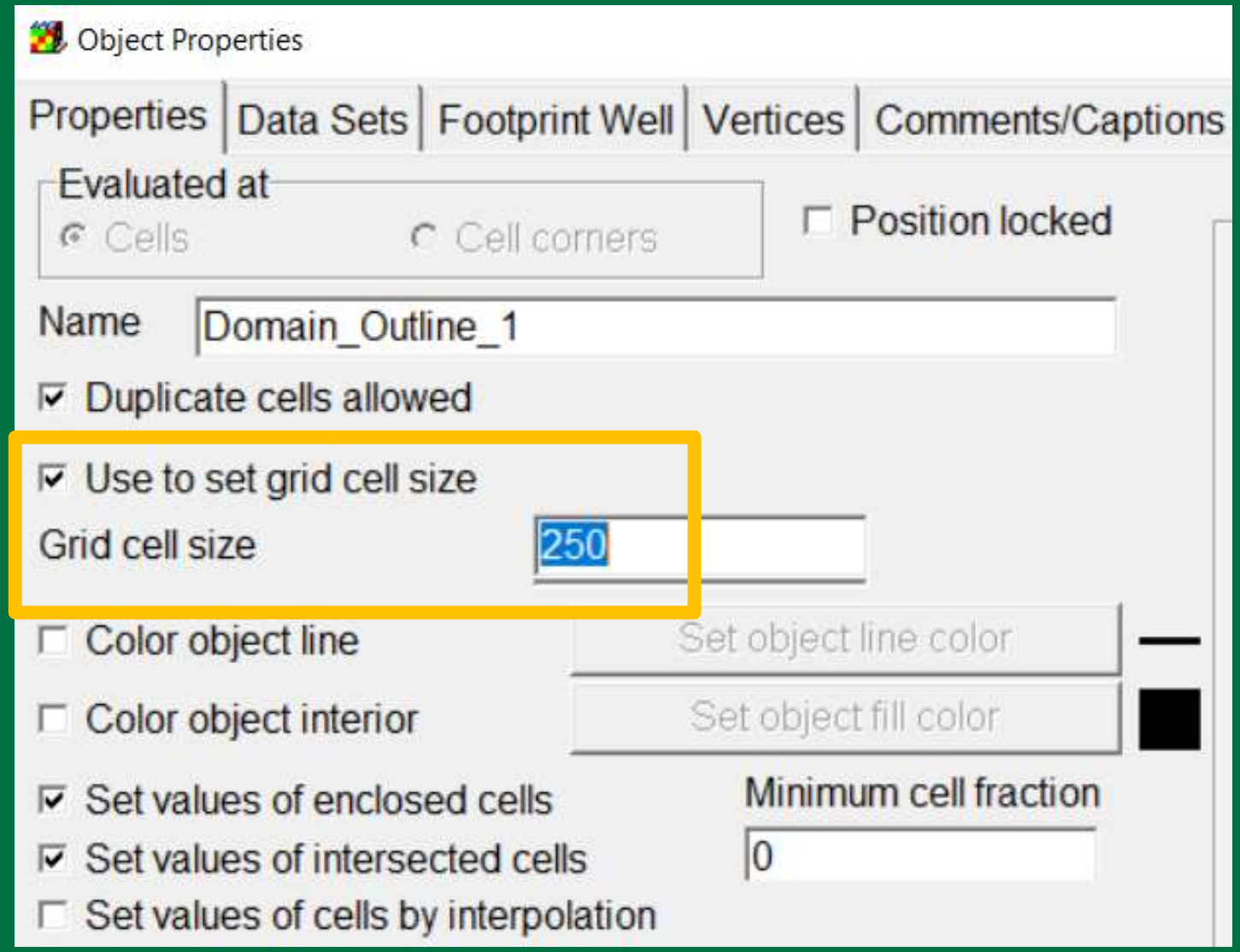
Define Grid



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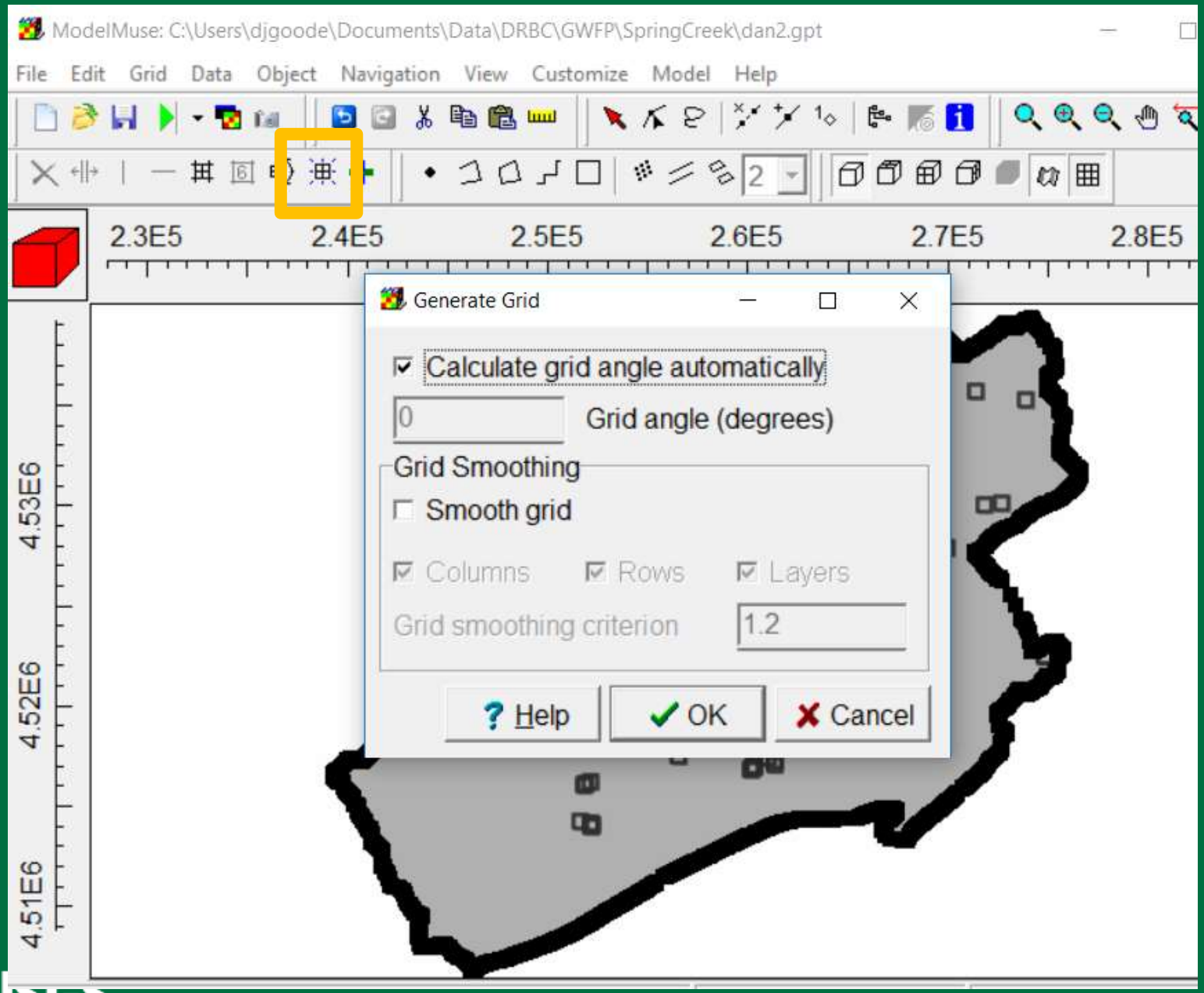
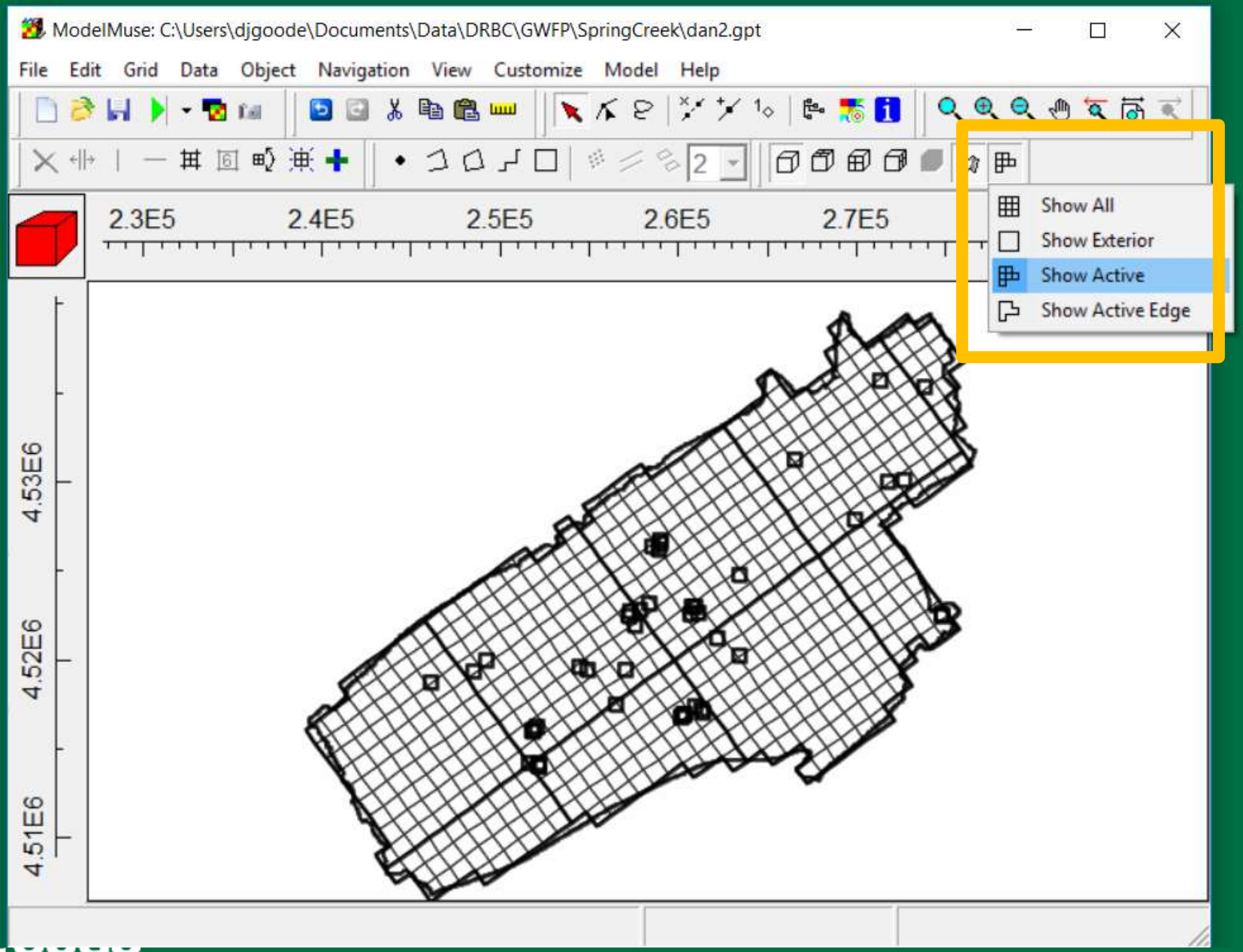

ModelMuse: C:\Users\djgoode\Documents\Data\DRBC\GWFP\SpringCreek\dan2.gpt
File Edit Grid Data Object Navigation View Customize Model Help
2.3E5
2.4E5
2.5E5
2.6E5
2.7E5
2.8E5
4.53E6
4.52E6
4.51E6
Generate Grid
Calculate grid angle automatically
0
Grid angle (degrees)
Grid Smoothing
Smooth grid
Columns
Rows
Layers
Grid smoothing criterion
1.2
Help
OK
Cancel


ModelMuse: C:\Users\djgoode\Documents\Data\DRBC\GWFP\SpringCreek\dan2.gpt
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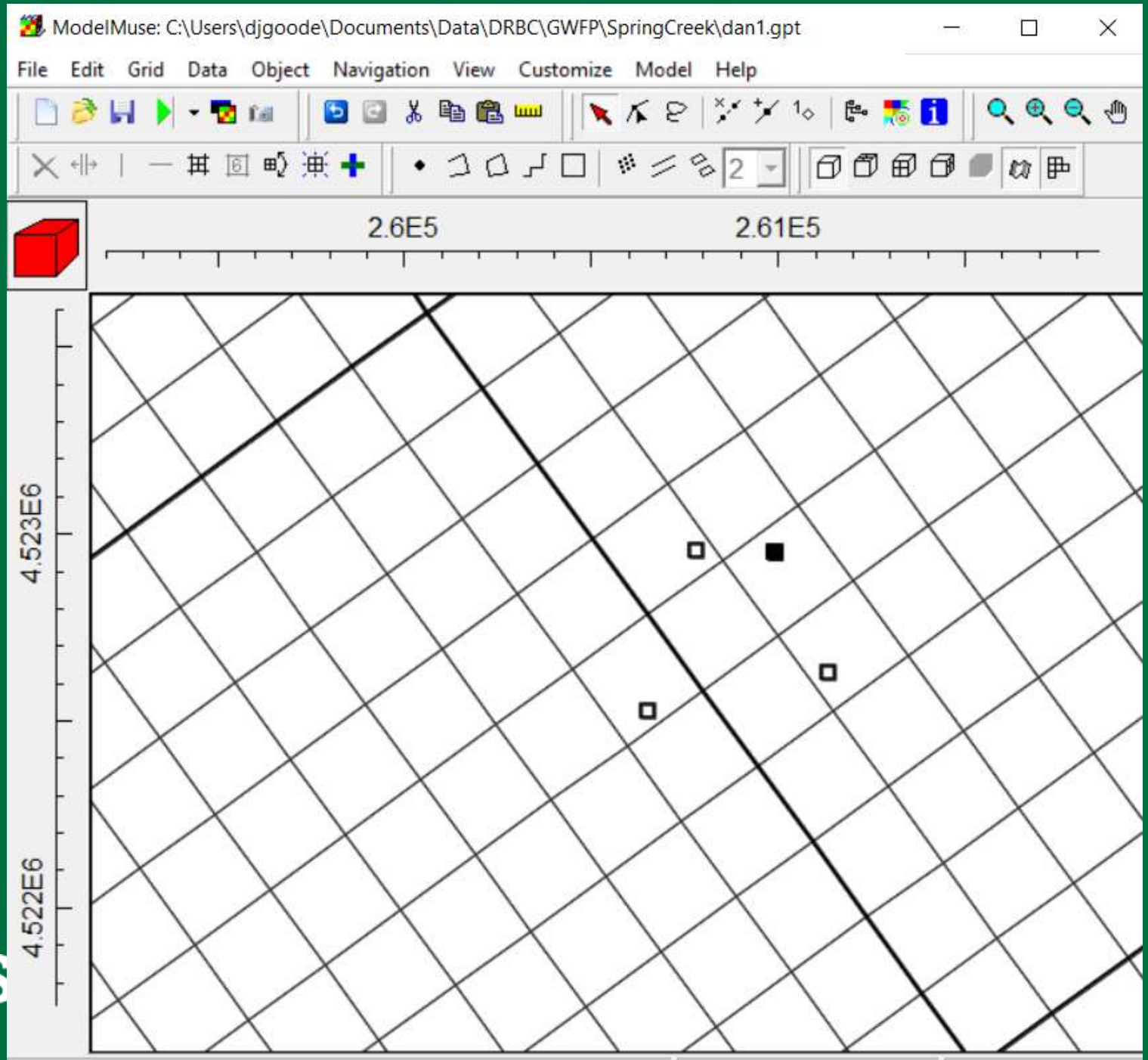
View
Customize
Model
Help
2.3E5
2.4E5
2.5E5
2.6E5
2.7E5
4.53E6
4.52E6
4.51E6
Show All
Show Exterior
Show Active
Show Active Edge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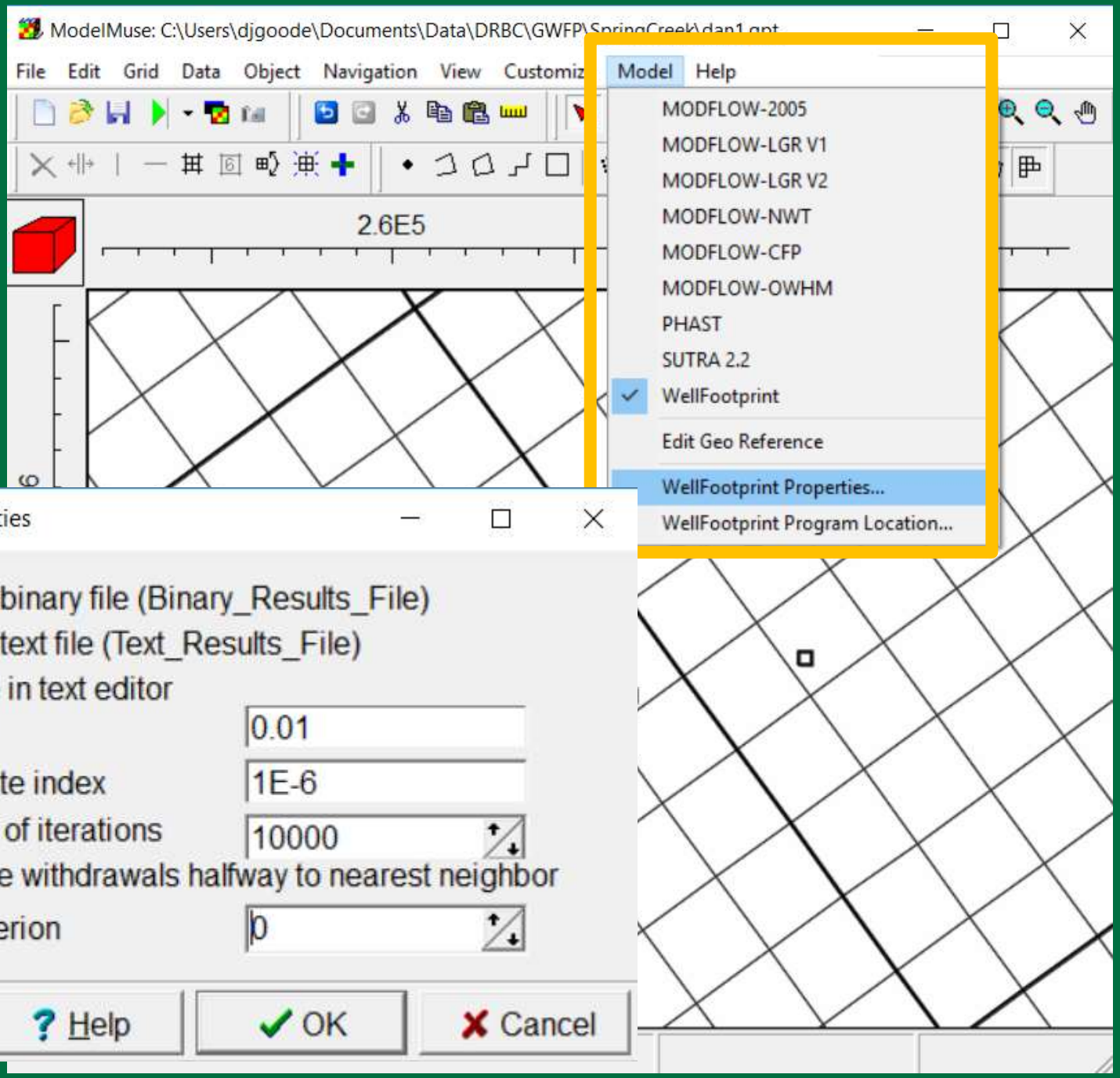
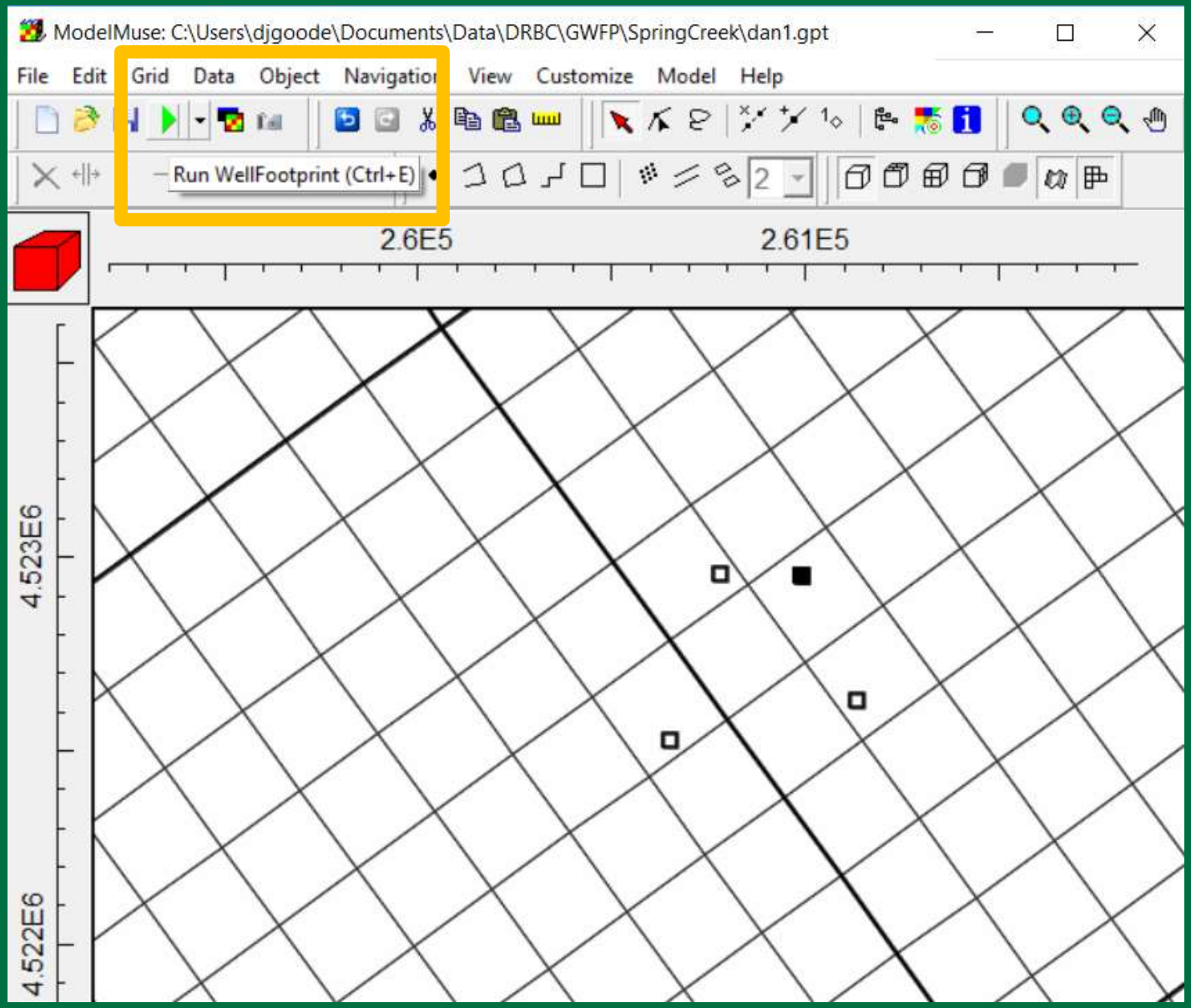
Help
2
2.6E5
2.61E5
4.523E6
4.522E6

Options


ModelMuse: C:\Users\djgoode\Documents\Data\DRBC\GWFP\SpringCreek\dan1.gpt
File Edit Grid Data Object Navigation View Customiz
Model Help
MODFLOW-2005
MODFLOW-LGR V1
MODFLOW-LGR V2
MODFLOW-NWT
MODFLOW-CFP
MODFLOW-OWHM
PHAST
SUTRA 2.2
WellFootprint
Edit Geo Reference
WellFootprint Properties...
WellFootprint Program Location...
2.6E5
WellFootprint Properties
Save results to binary file (Binary_Results_File)
Save results to text file (Text_Results_File)
Open listing file in text editor
Closure criterion
0.01
Minimum depth-rate index
1E-6
Maximum number of iterations
10000
Initially distribute withdrawals halfway to nearest neighbor
Redistribution criterion
0
Help
OK
Cancel

Go!


ModelMuse: C:\Users\djgoode\Documents\Data\DRBC\GWFP\SpringCreek\dan1.gpt
File
Edit
Grid
Data
Object
Navigation
View
Customize
Model
Help
Run WellFootprint (Ctrl+E)
2
2.6E5
2.61E5
4.523E6
4.522E6

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C:\Windows\system32\cmd.exe

```
C:\Users\djgoode\Documents\Data\DRBC\GWFP\SpringCreek>C:\WRDAPP\WellFootprint.1_0\bin\
WellFootprint.exe dan2.fpi

WellFootprint Version 1.0.0.0

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Normal termination

C:\Users\djgoode\Documents\Data

C:\Users\djgoode\Documents\Data
Press any key to continue . . .
```

dan2.fplst - Notepad

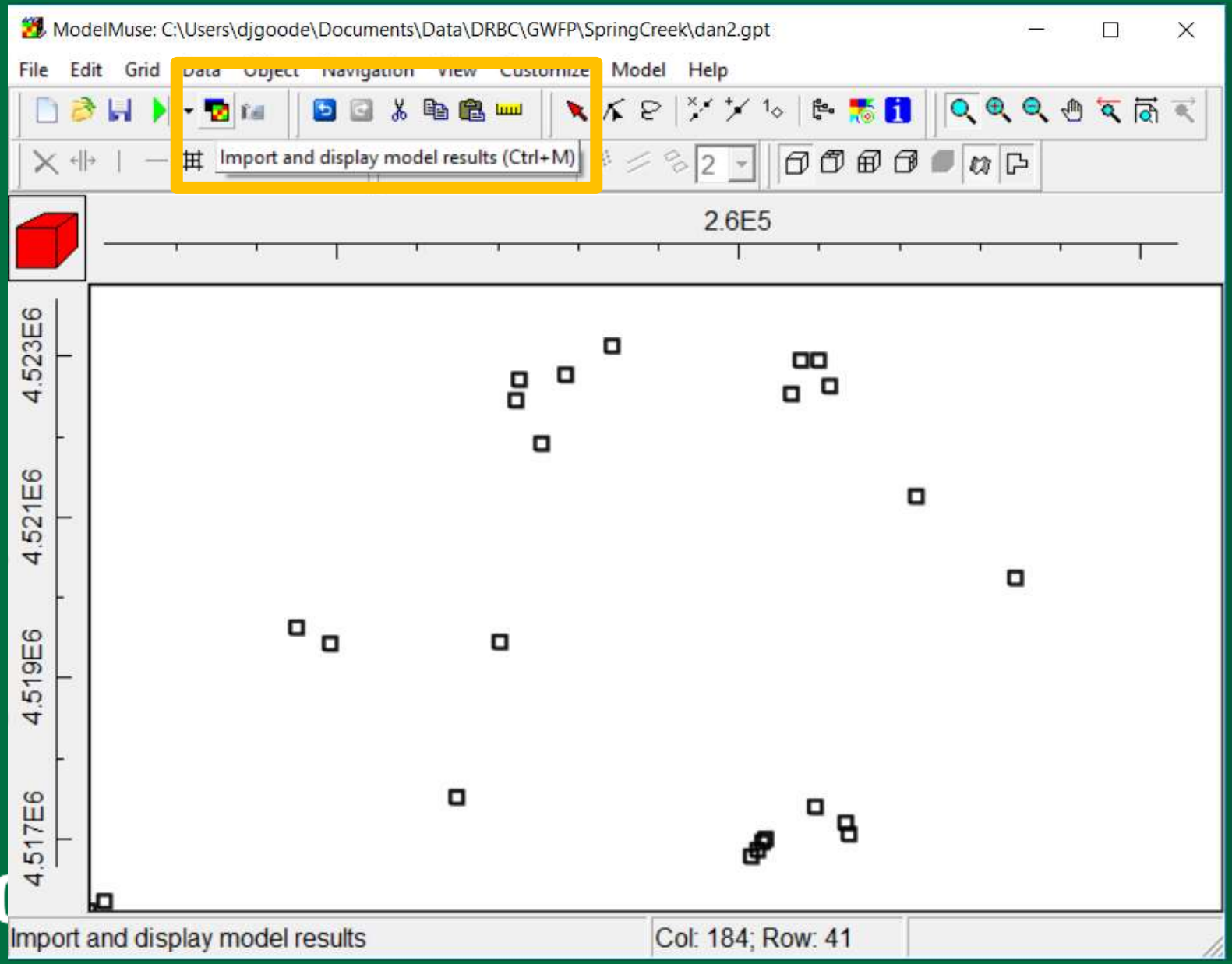
File Edit Format View Help

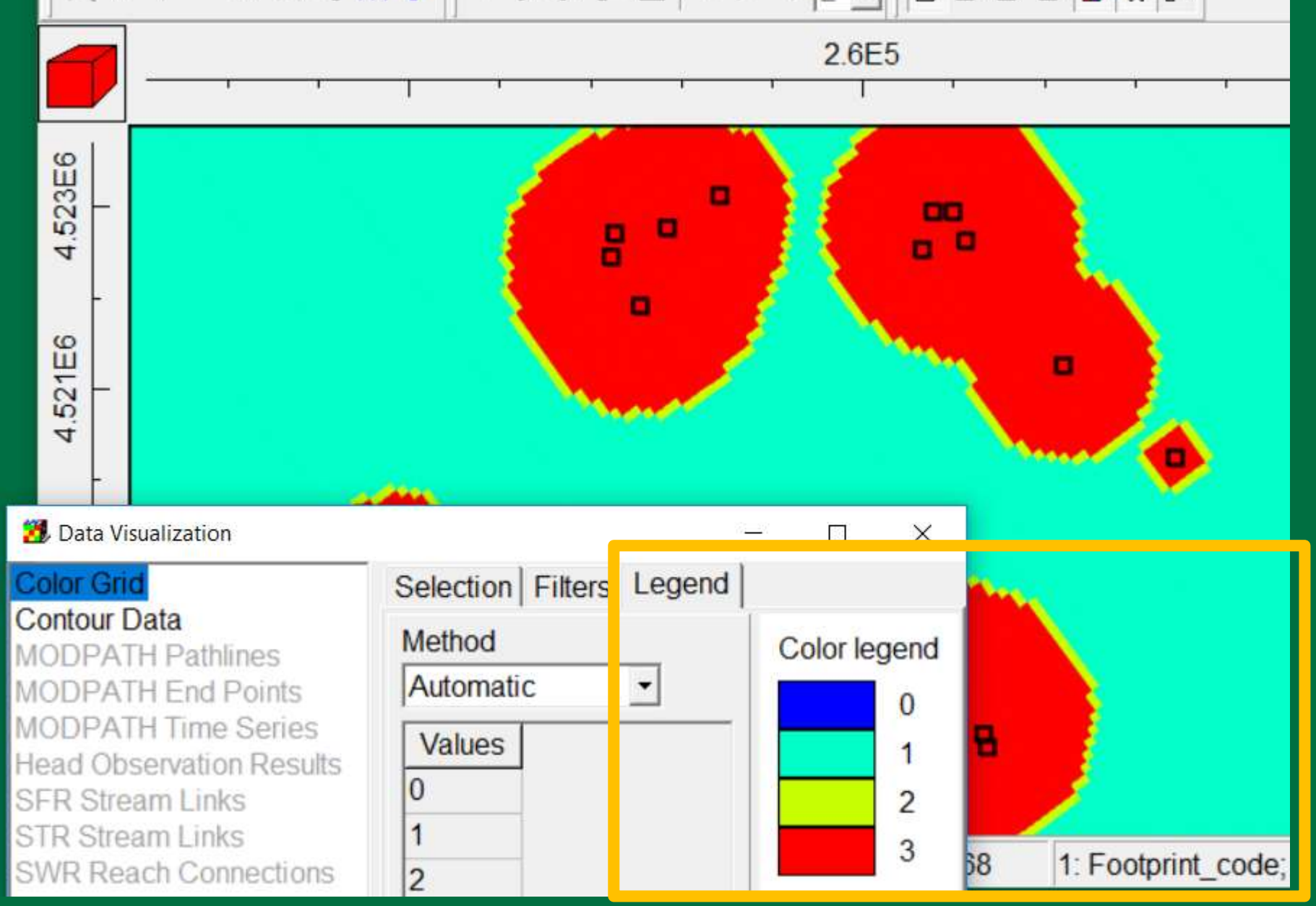
```
Redistributing excess pumpage to edges of groups on iteration 336
Redistributing excess pumpage to edges of groups on iteration 337
Redistributing excess pumpage to edges of groups on iteration 338
Redistributing excess pumpage to edges of groups on iteration 339

Number of iterations = 340
Maximum excess fraction = 0.0082514165196641
normal termination
```

4.517E6

Col: 179; Row: 105

Display Results




2.6E5
4.523E6
4.521E6
Data Visualization
Color Grid
Contour Data
MODPATH Pathlines
MODPATH End Points
MODPATH Time Series
Head Observation Results
SFR Stream Links
STR Stream Links
SWR Reach Connections
Selection
Filters
Legend
Method
Automatic
Values
0
1
2
Color legend
0
1
2
3
1: Footprint_code;

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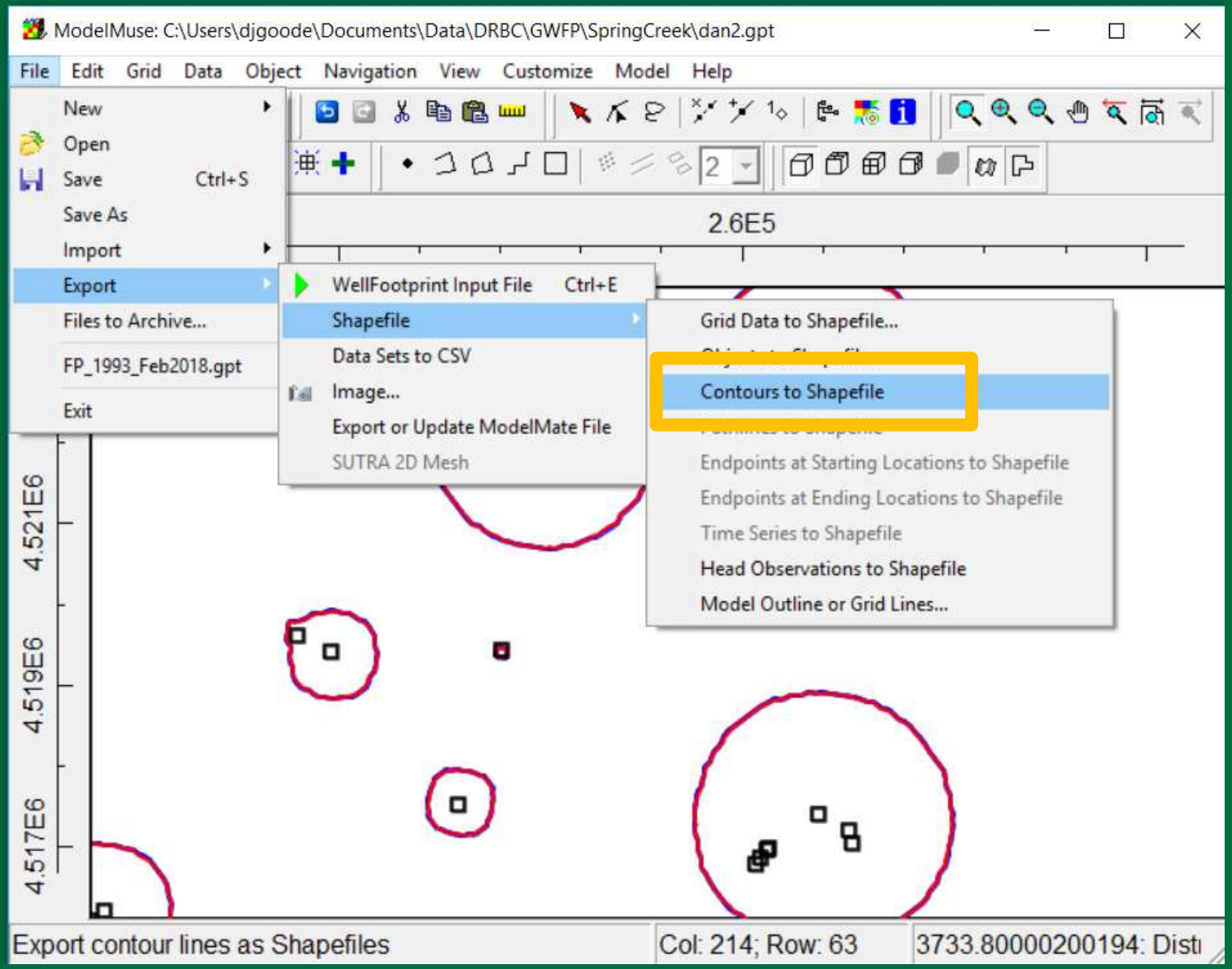
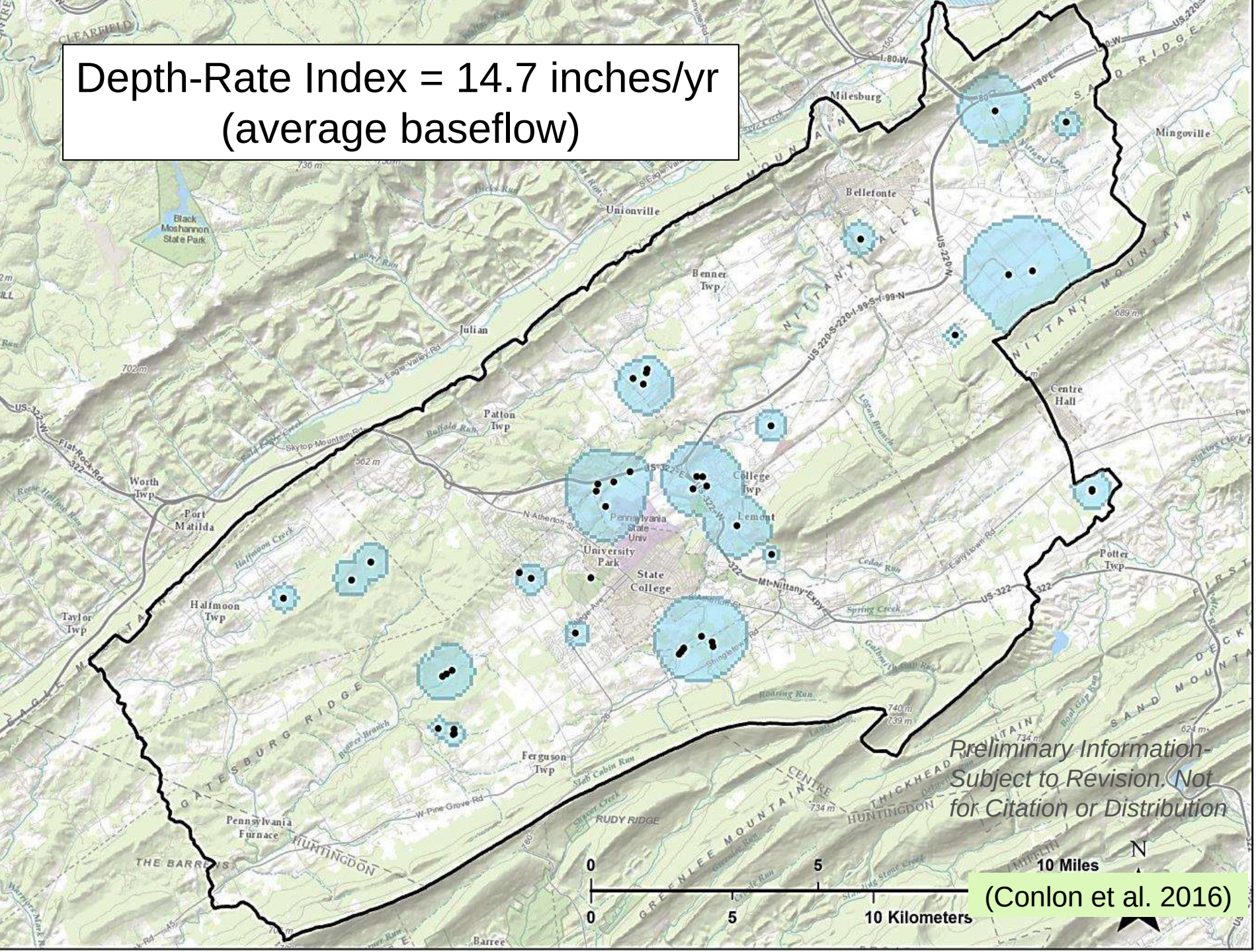
Export for Map Display



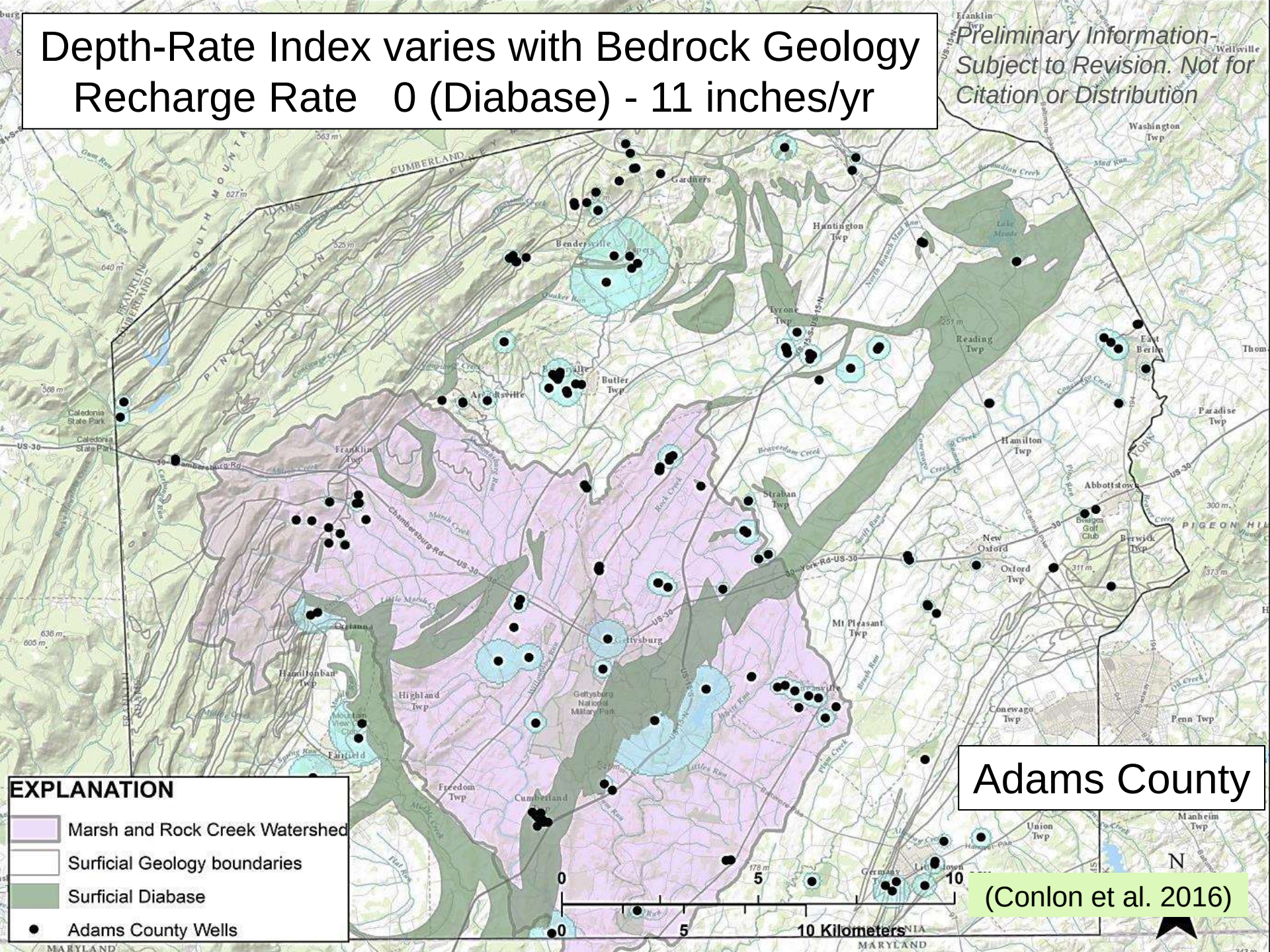
Depth-Rate Index = 14.7 inches/yr (average baseflow)

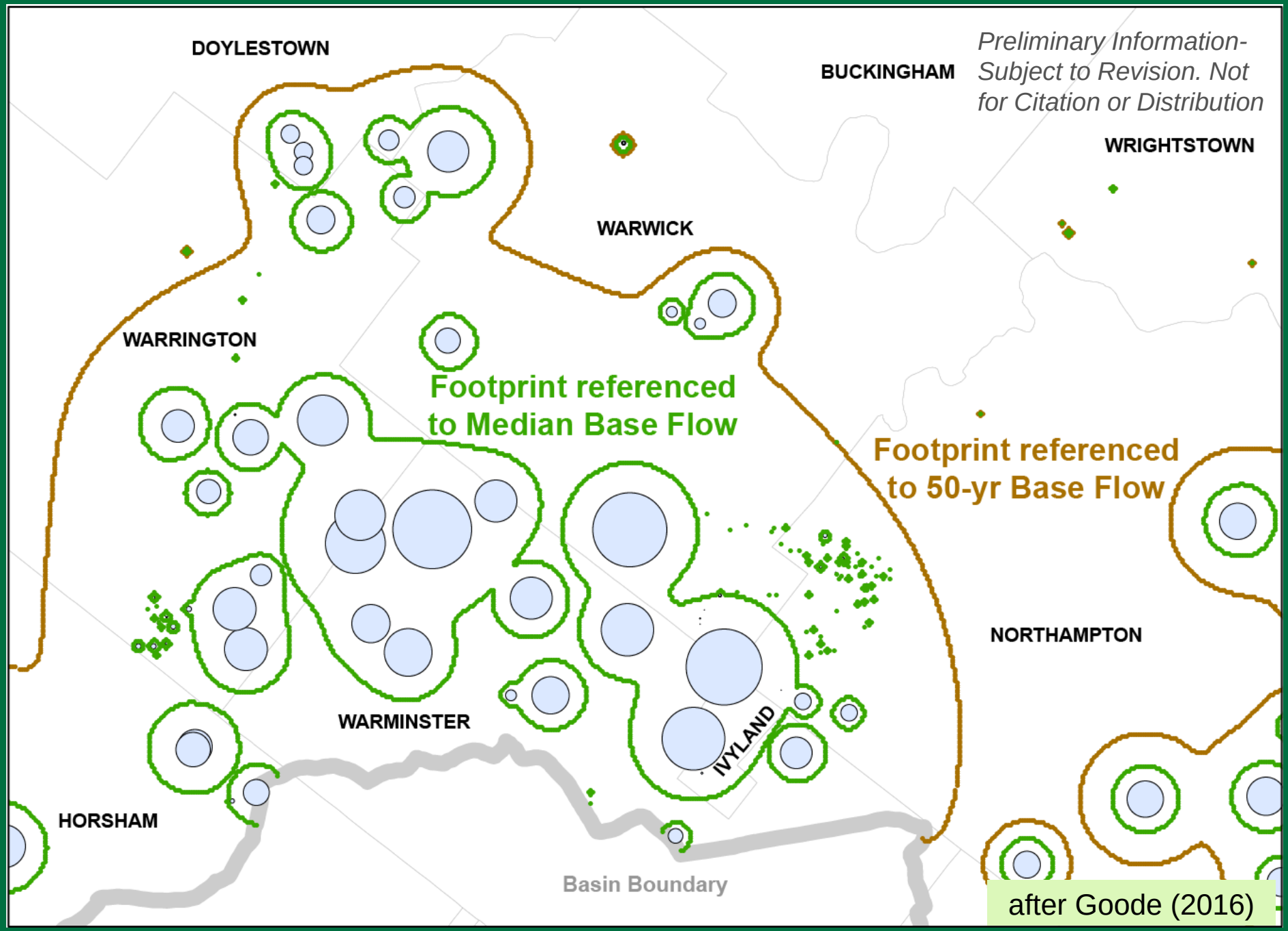


(Conlon et al. 2016)

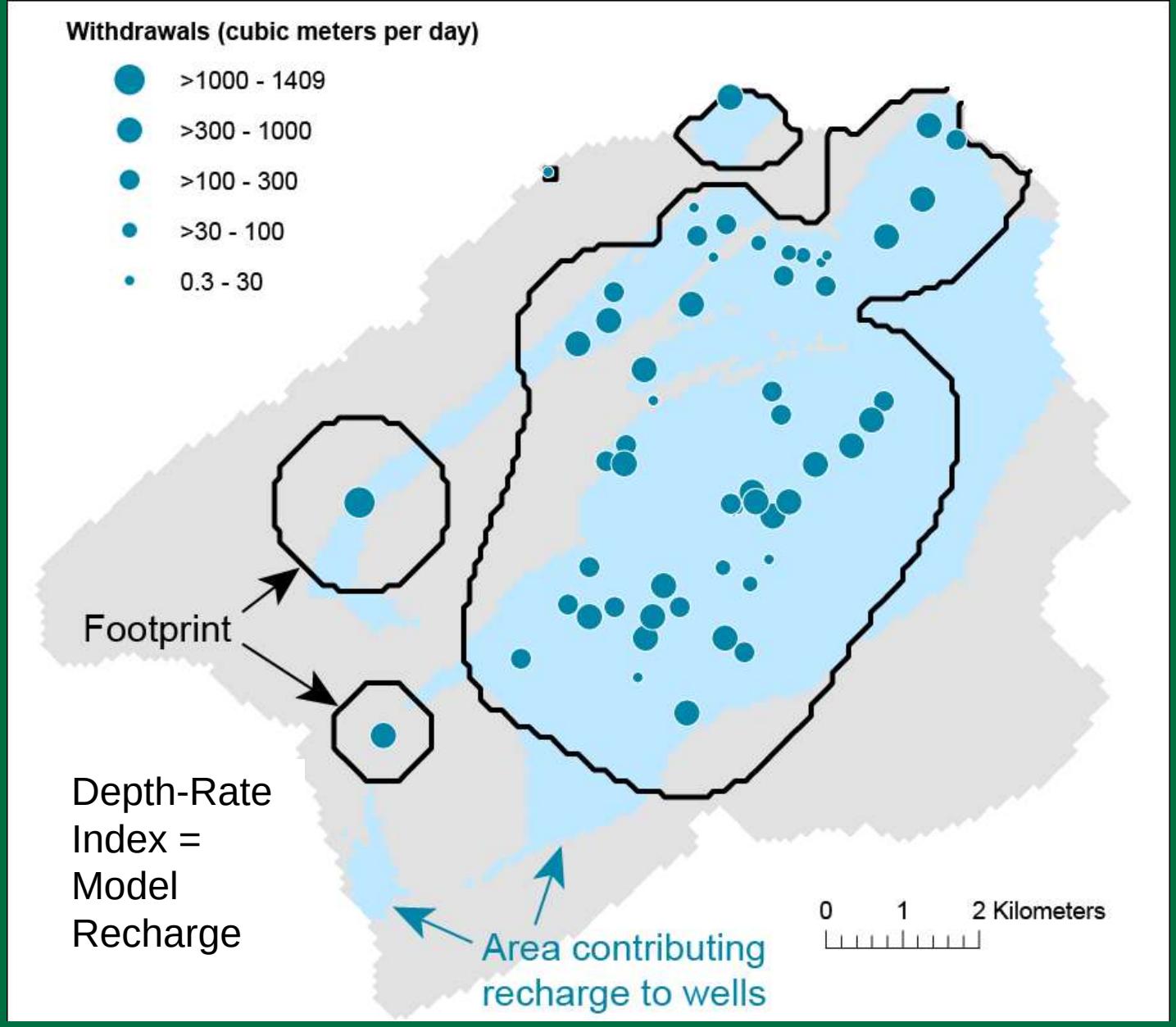
Depth-Rate Index varies with Bedrock Geology
Recharge Rate 0 (Diabase) - 11 inches/yr

Preliminary Information- Subject to Revision. Not for Citation or Distribution



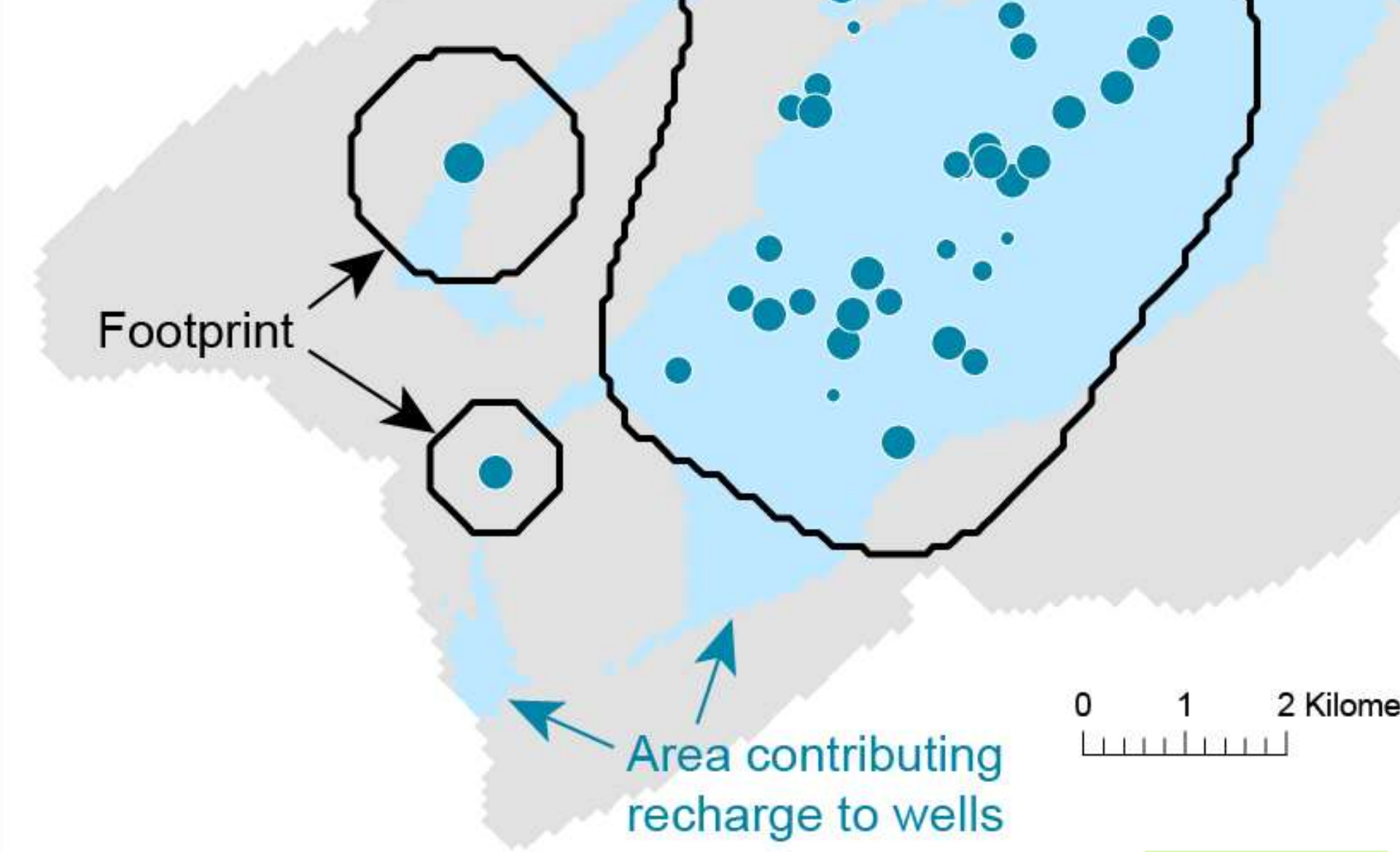


after Goode (2016)



Groundwater-Flow Model
Lansdale, Montgomery County

(Goode 2016)

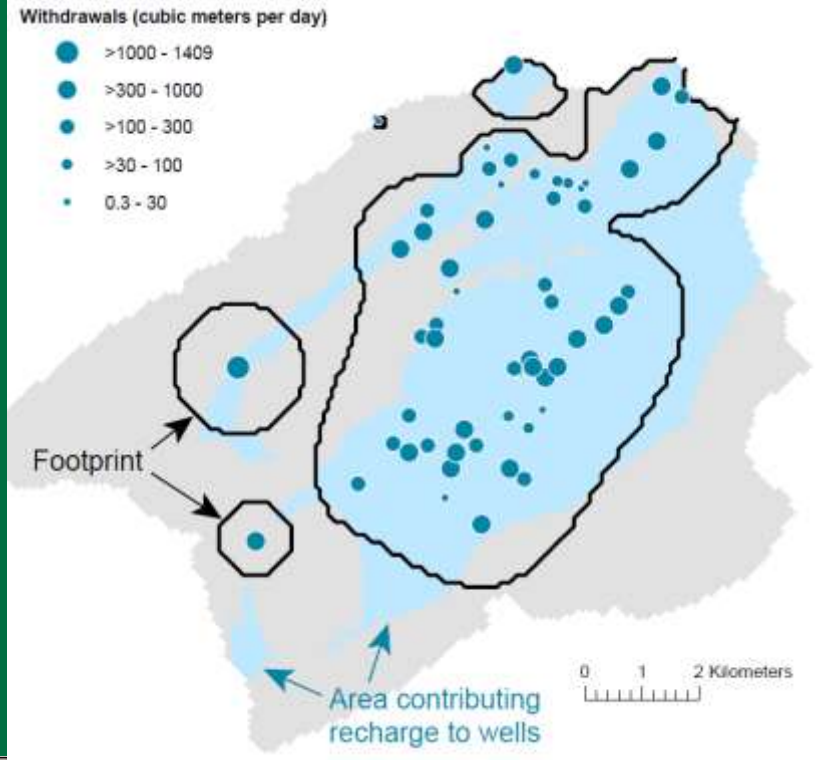


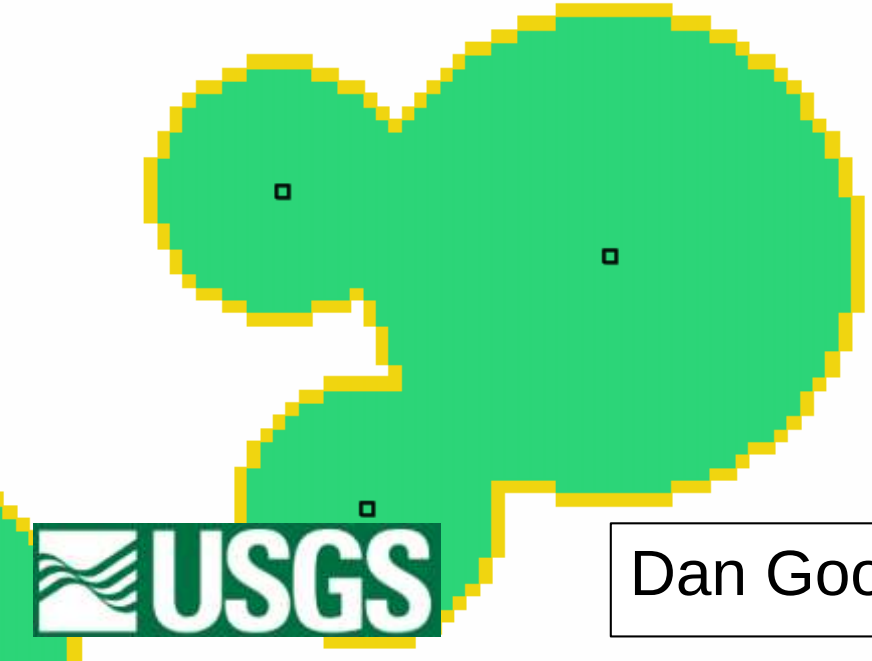
(Goode 2016)

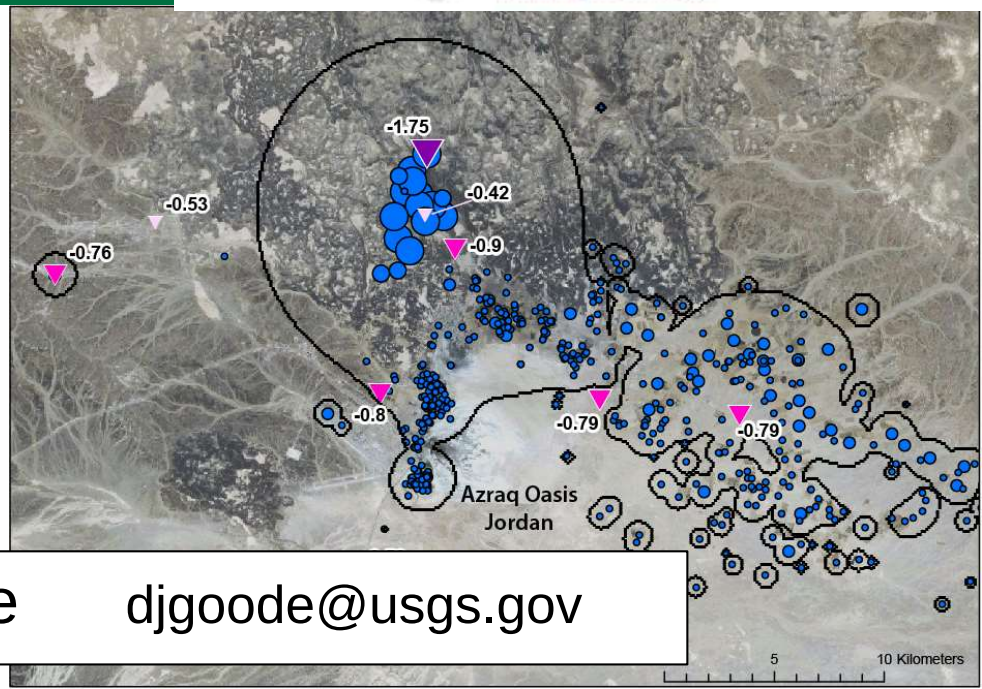
The Footprint is NOT a Capture Zone!

WellFootprint and ModelMuse

A New Map App for Visualizing the Magnitude of Pumping







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The following reference and background slides were not shown during the live presentation at the Symposium.

References

Baldwin, H.L., and C.L.McGuinness (1963) A primer on ground water. US Geol Surv General Interest Pub, 26 pp, http://pubs.usgs.gov/gip/7000056/report.pdf

Conlon, M.D., D.J. Goode, R.B. Winston, and D.W. Risser, 2016, Visualizing the "footprint" of Groundwater withdrawals in parts of Centre and Adams Counties, Pennsylvania: (abs.) Pennsylvania State University, Pennsylvania Groundwater Symposium, May, 2016.

Goode, D.J., 2016, Map visualization of groundwater withdrawals at the sub-basin scale: *Hydrogeology Journal*, v. 24, no. 4, p. 1057-1065.

Winston, R.B., 2009, ModelMuse - A graphical user interface for MODFLOW-2005 and PHAST: U.S. Geological Survey Techniques and Methods 6-A29, 52 p.

Winston, R.B., 2014, Modifications made to ModelMuse to add support for the Saturated-Unsaturated Transport model (SUTRA): USGS Techniques & Methods, book 6, chap. A49, 6 p.

Software available from:
https://water.usgs.gov/nrp/gwsoftware/WellFootprint/WellFootprint.html

USGS

A Primer on Ground Water
(Baldwin and McGuinness, 1963)

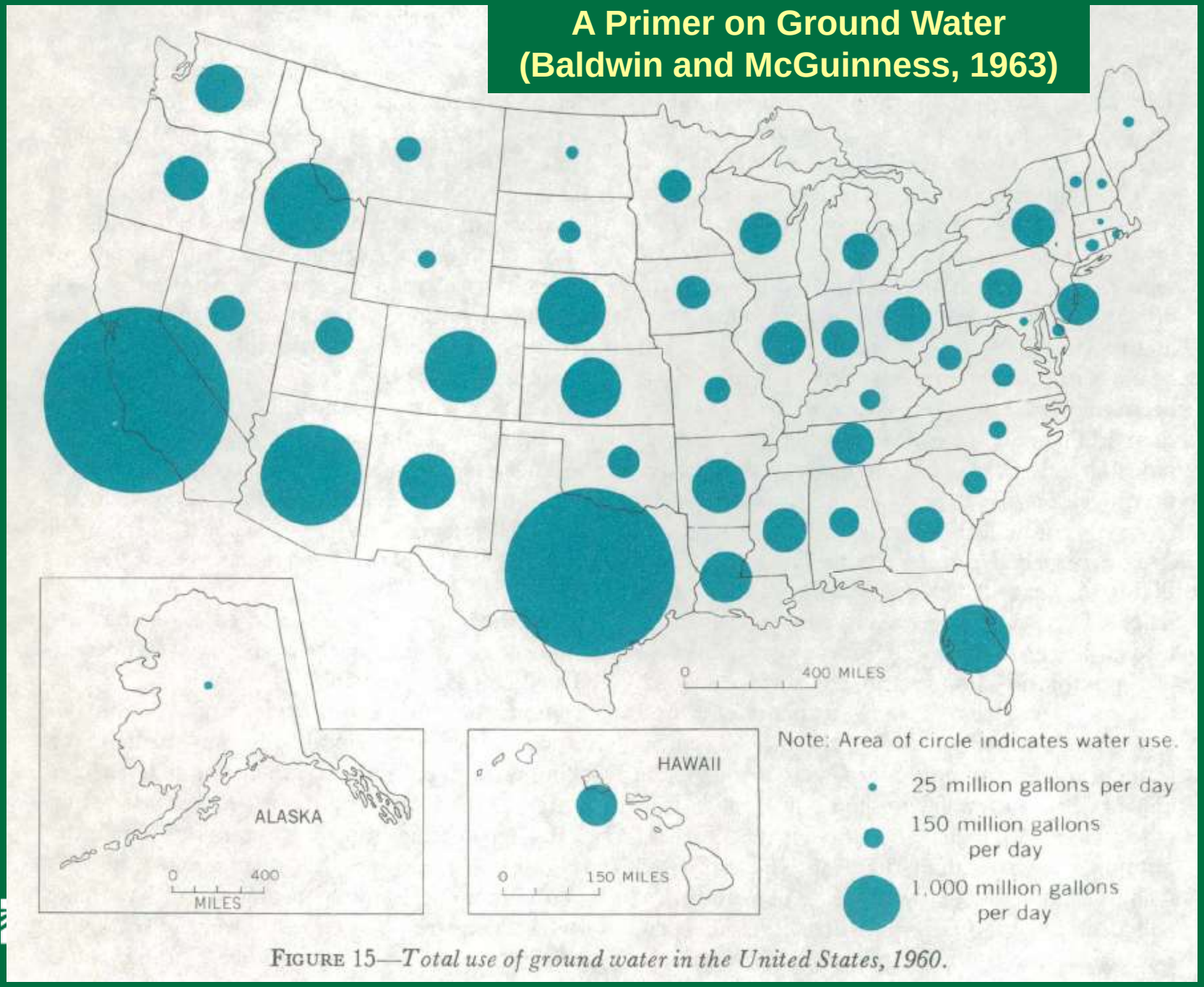
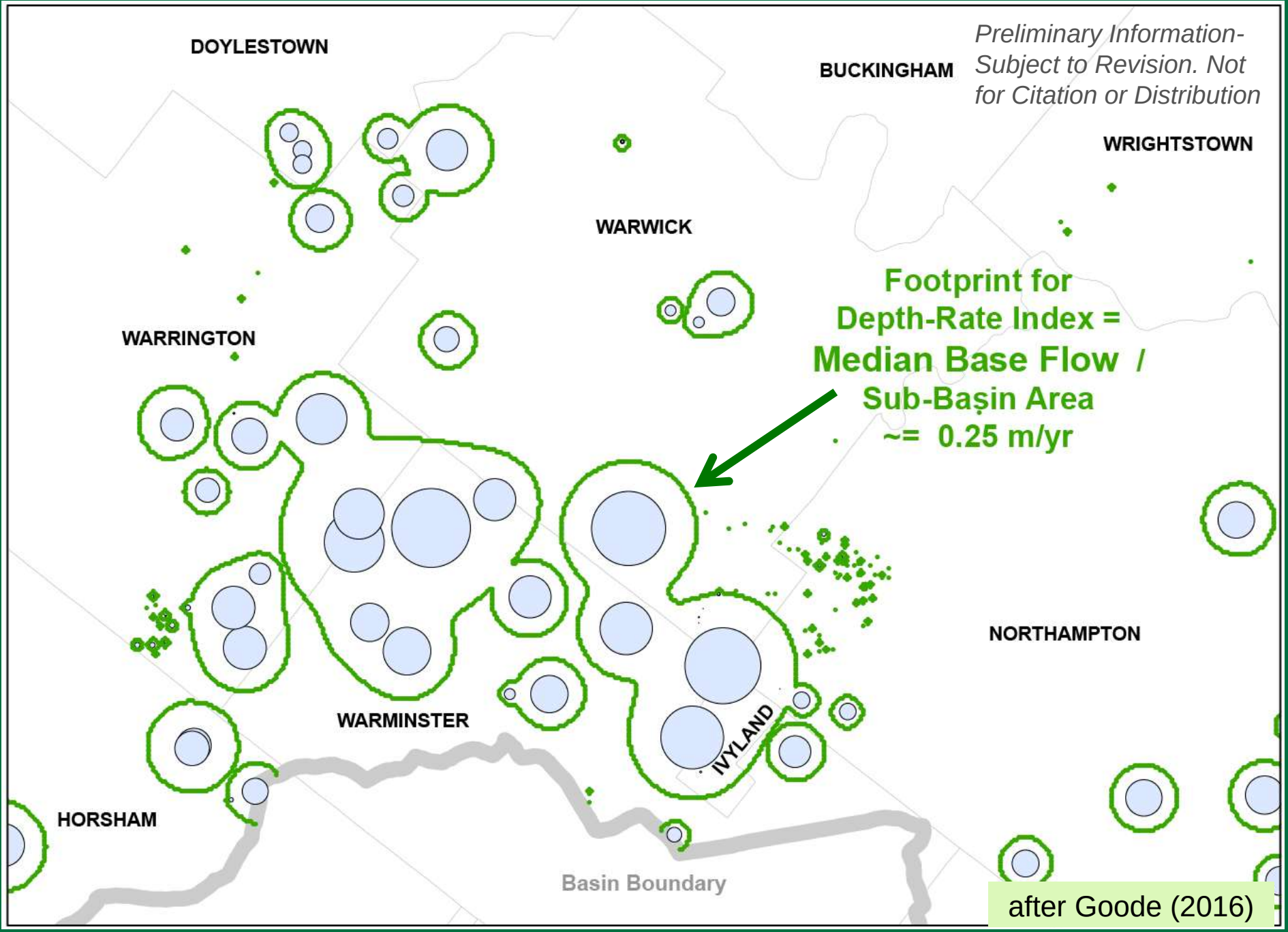
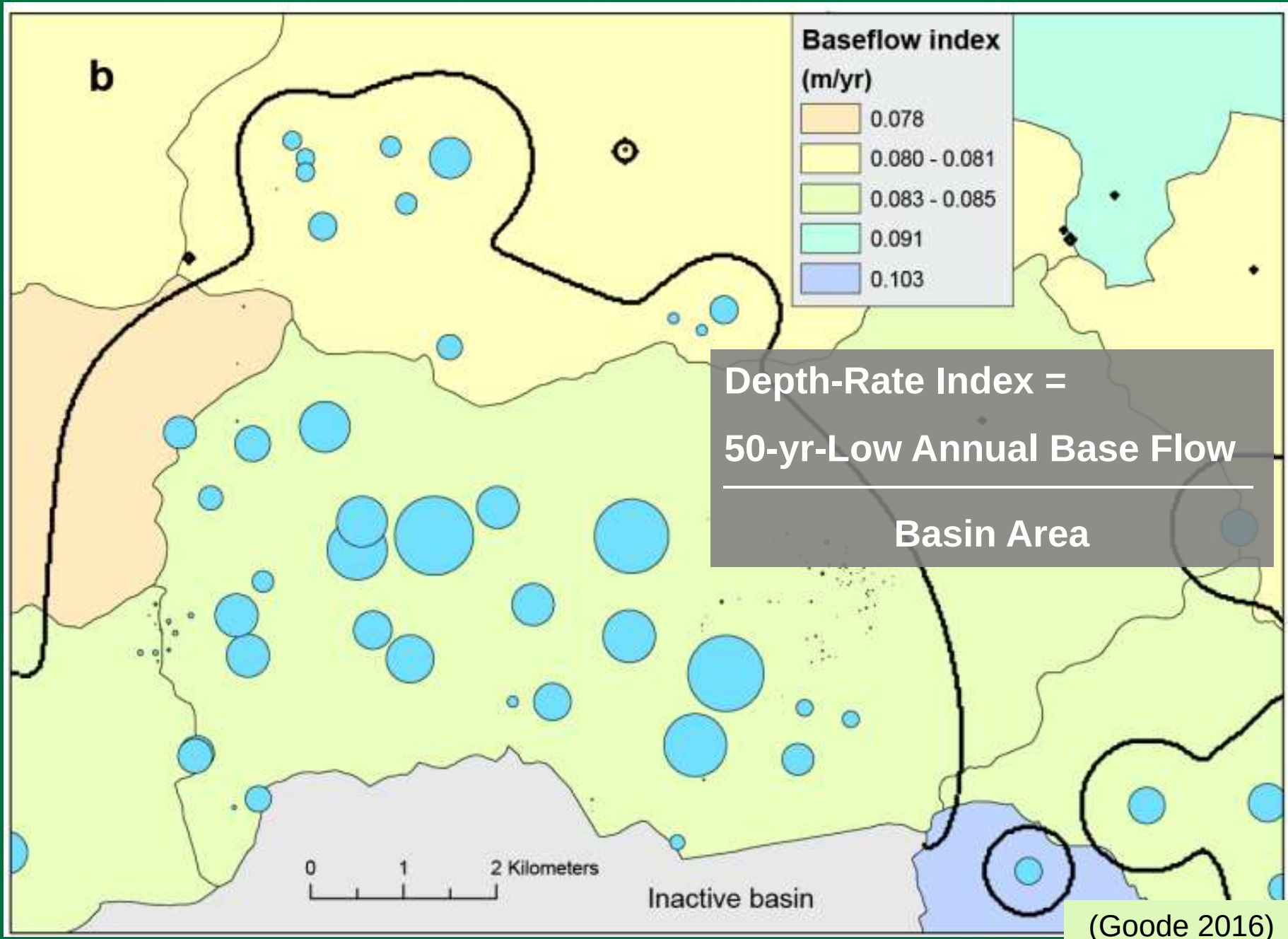


FIGURE 15—*Total use of ground water in the United States, 1960.*



after Goode (2016)



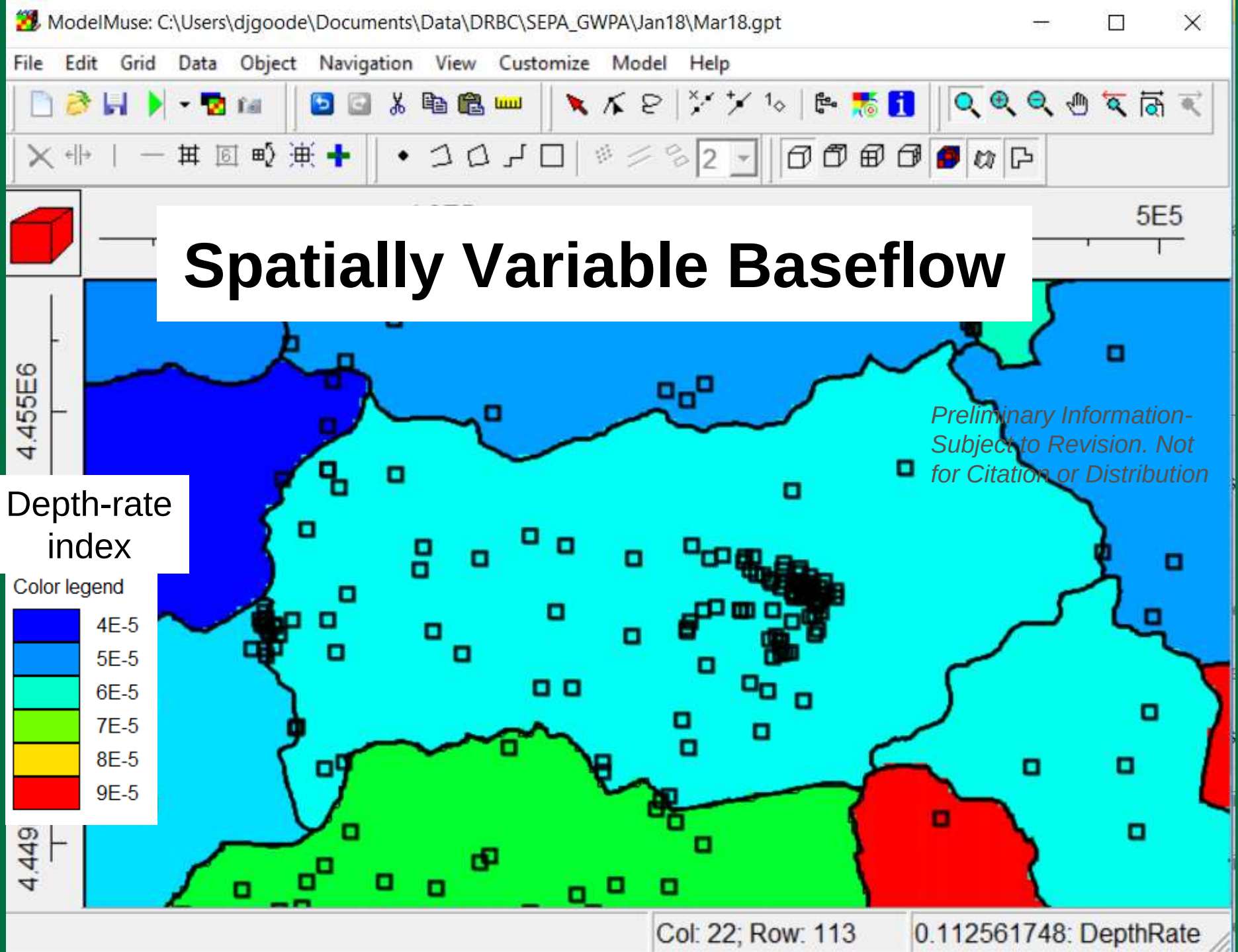
Depth-Rate Index =

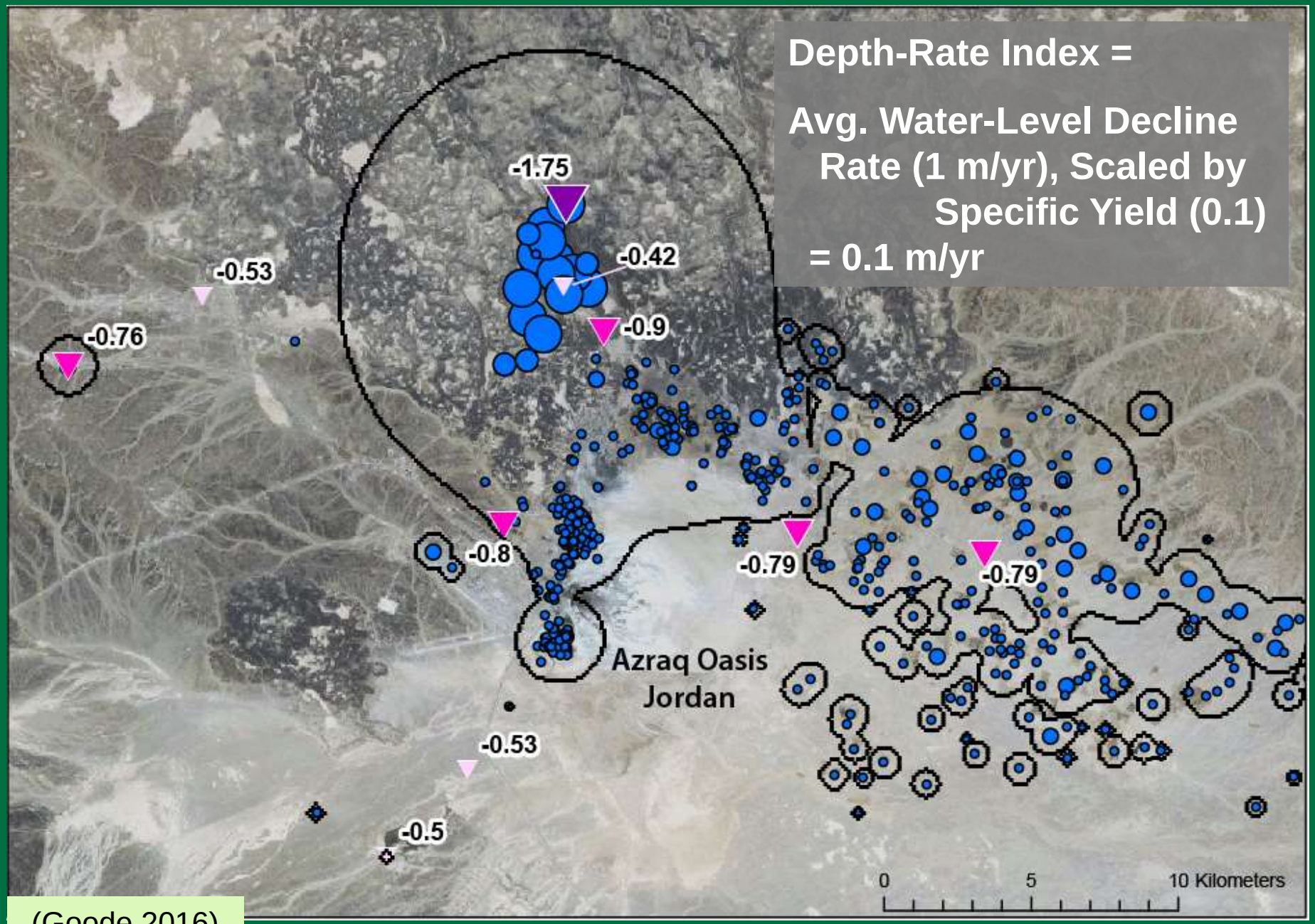
50-yr-Low Annual Base Flow

Basin Area

(Goode 2016)

Spatially Variable Baseflow




Depth-Rate Index =
Avg. Water-Level Decline Rate (1 m/yr), Scaled by Specific Yield (0.1)
= 0.1 m/yr
-1.75
-0.42
-0.53
-0.76
-0.9
-0.8
-0.79
-0.79
-0.53
-0.5
Azraq Oasis
Jordan
0
5
10 Kilometers

(Goode 2016)