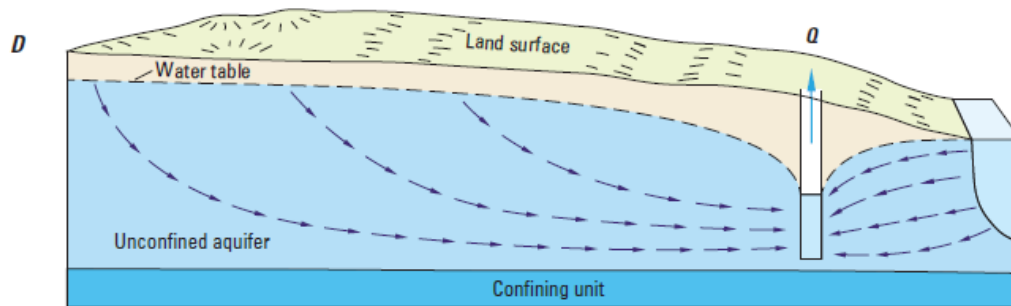
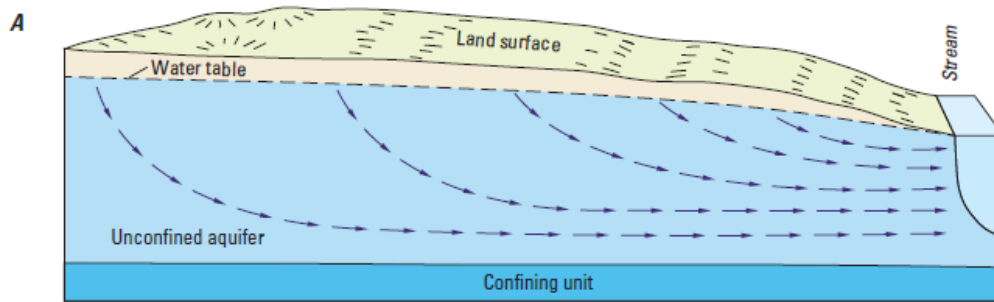


A Graphical Interface to Quantify and Visualize Streamflow Depletion



*Jessica D. Rogers, Ph.D.,
Gilbert Barth, Ph.D. and Doug Hayes
S. S. Papadopoulos & Associates, Inc.
2021 Sustaining Colorado Watersheds Conference
October 5, 2021*

Stream Depletion

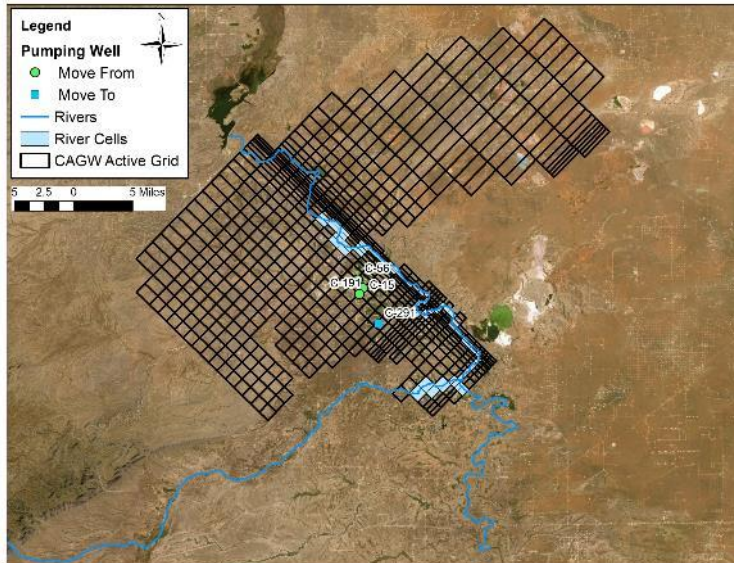


From Barlow and Leake, 2012



Quantification of Rates, Location, Timing

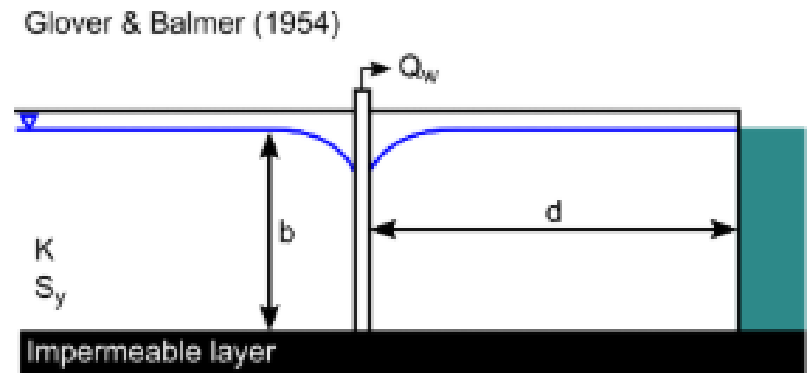
Numerical Modeling



Pro: Accuracy (heterogeneity, complex geometry), spatial resolution, flexibility

Con: Requires large amount of input data, time for construction and calibration, significant hydrological and modeling expertise, expensive

Analytical Estimates

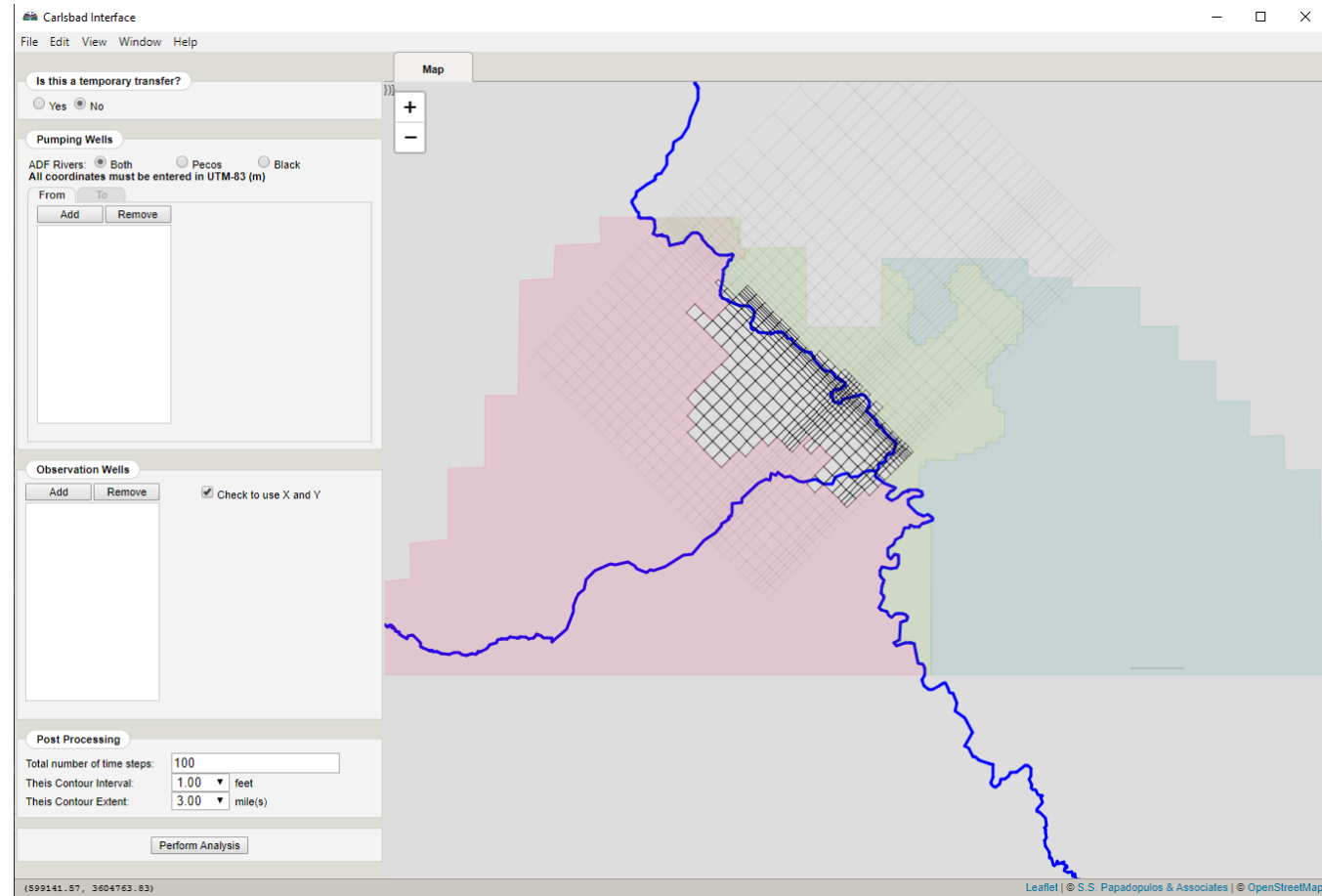


Pro: Rapid, do not require significant input data, cost-effective

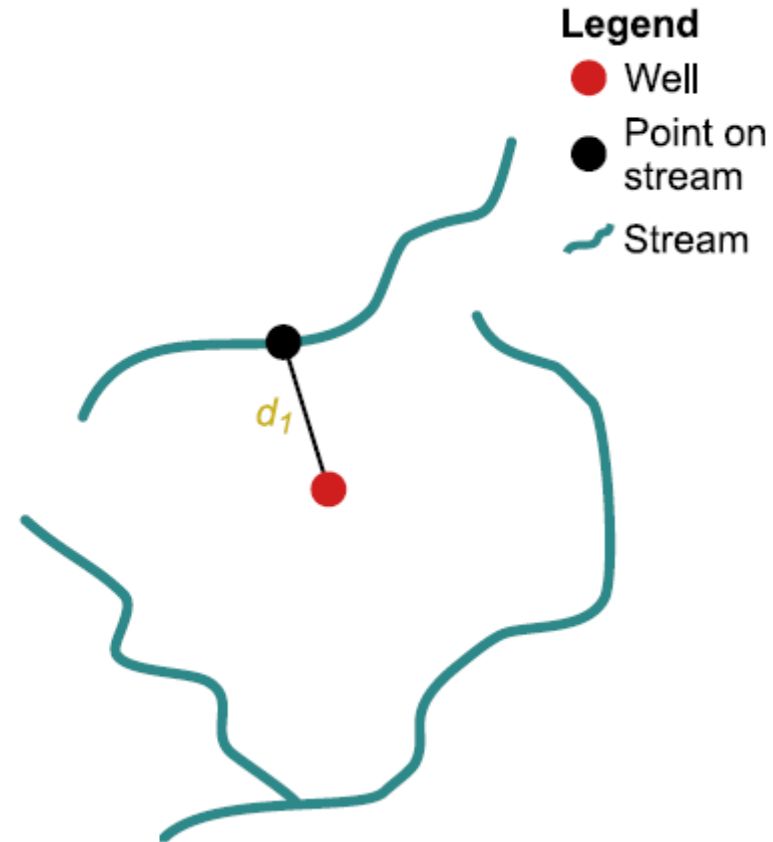
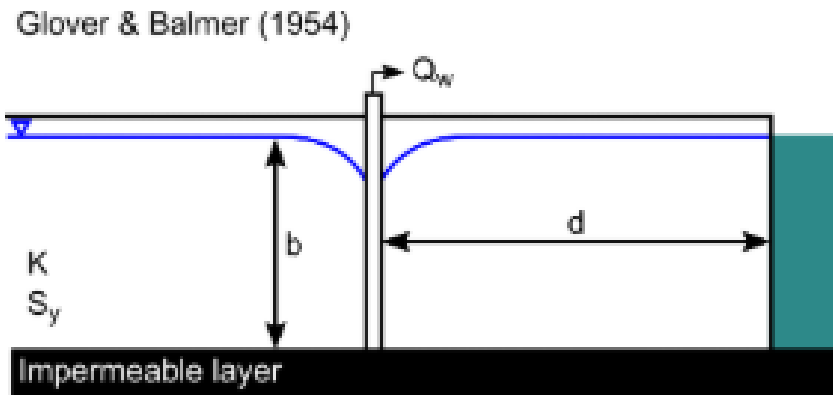
Con: Simplified assumptions (homogenous, idealized aquifer and stream geometry) lead to greater uncertainty in estimates

User-Friendly, Hybrid Approach: Graphical User Interface (GUI)

- ✓ Use numerical model (if desired or available) and/or analytical method.
- ✓ Refined analytical streamflow depletion approximations via Analytical Depletion Function (ADF).
- ✓ Readily accessible to a broad variety of stakeholders.

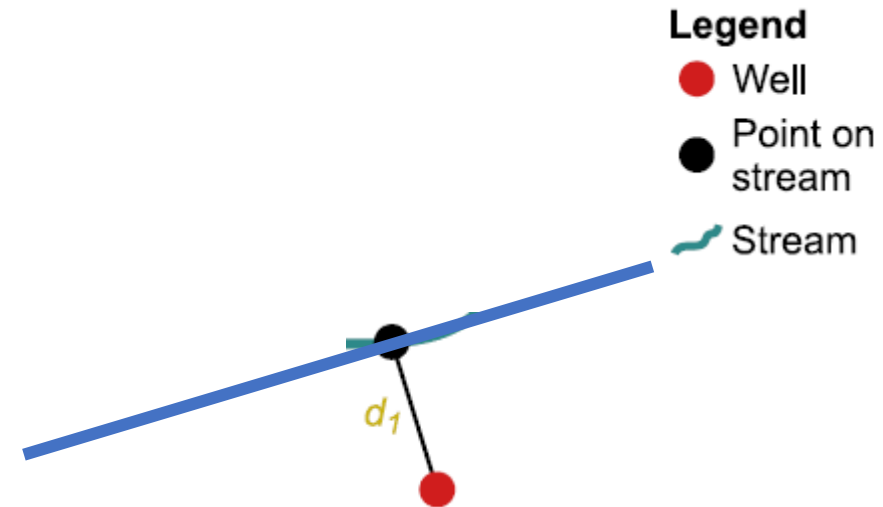
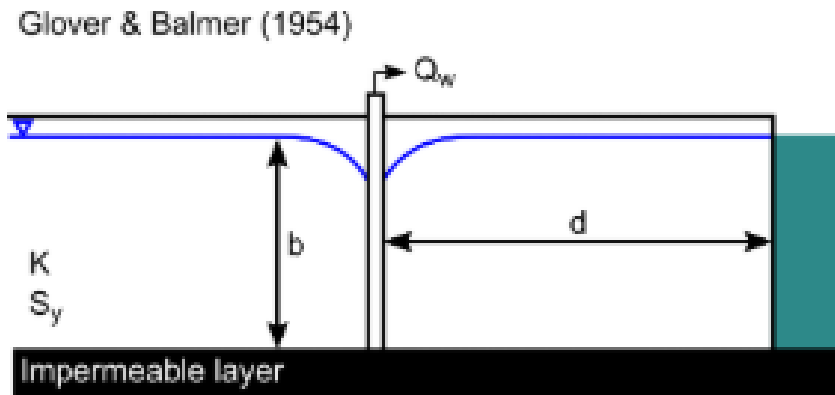


Analytical Stream Depletion Estimates



d_1 = shortest distance to a stream

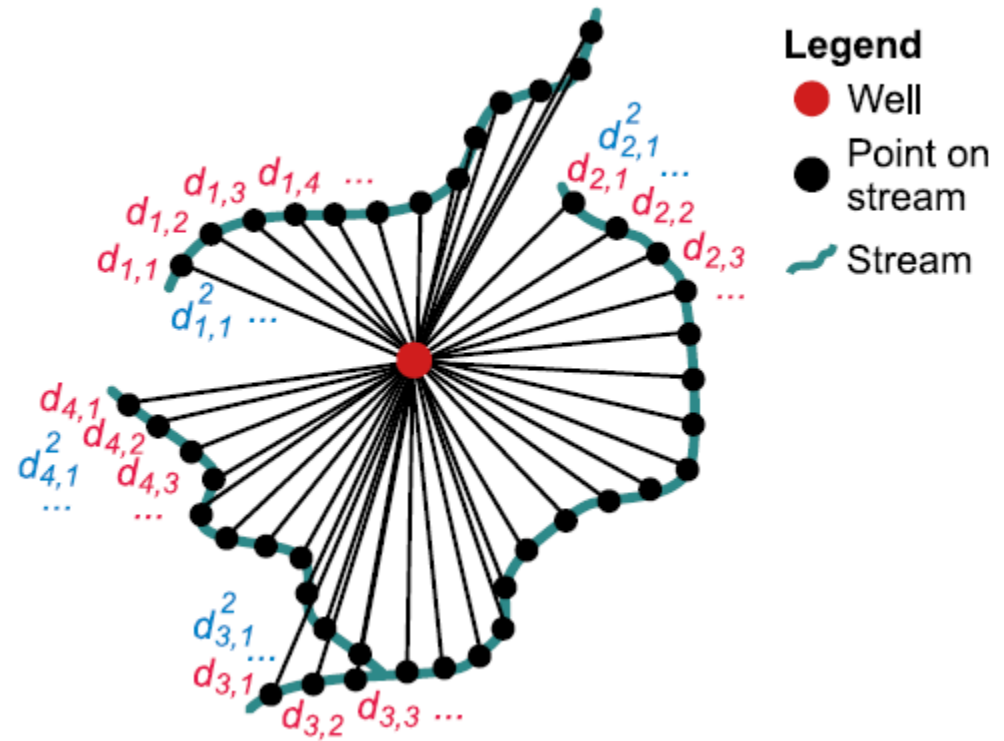
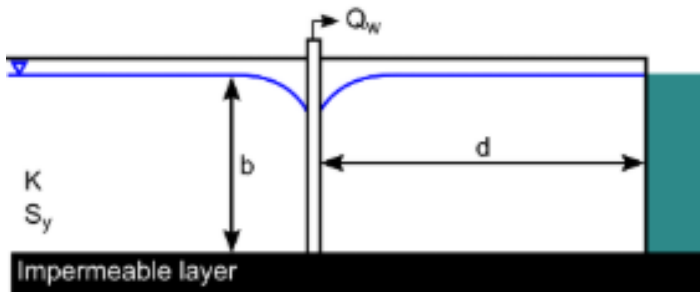
Analytical Stream Depletion Estimates



d_1 = shortest distance to a stream

Analytical Stream Depletion Estimates

Glover & Balmer (1954)



Zipper, S. C. et al, 2019. Rapid and Accurate Estimates of Streamflow Depletion Caused by Groundwater Pumping using Analytical Depletion Functions, *Water Resources Research*, 55, 5807-5829.

Analytical Depletion Function (ADF)

ADF Components (Zipper et al, 2019)

Proximity criteria:

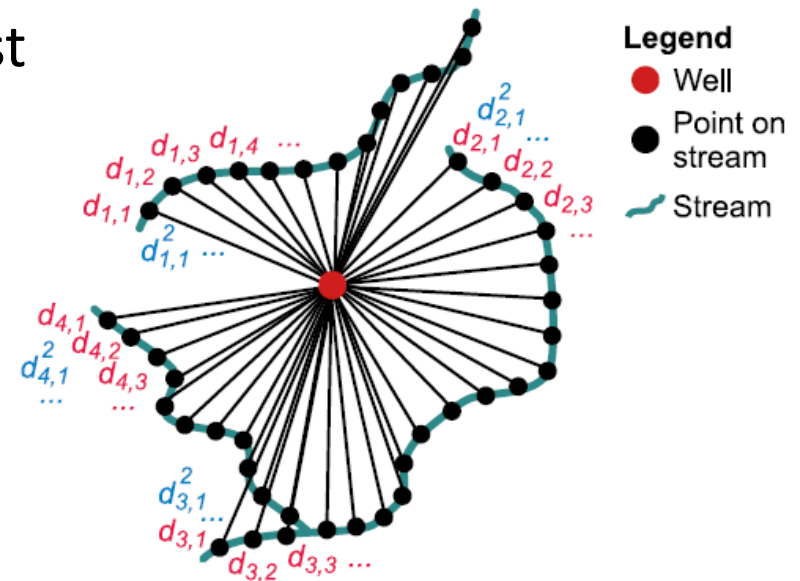
Identify segments within a network most significantly affected by pumping well

Depletion Apportionment:

Estimate fraction of total depletion attributed to each segment

Analytical Model:

Estimate streamflow depletion at each segment selected by proximity criteria



Zipper, S. C. et al, 2019. Rapid and Accurate Estimates of Streamflow Depletion Caused by Groundwater Pumping using Analytical Depletion Functions, *Water Resources Research*, 55, 5807-5829.

CBI Implementation

Proximity criteria:

“Adjacent and Expanding”: 0.25 mile uniform segments with depletion $\geq 1\%$, annual time step (capped at 100 segments, 25 river miles)

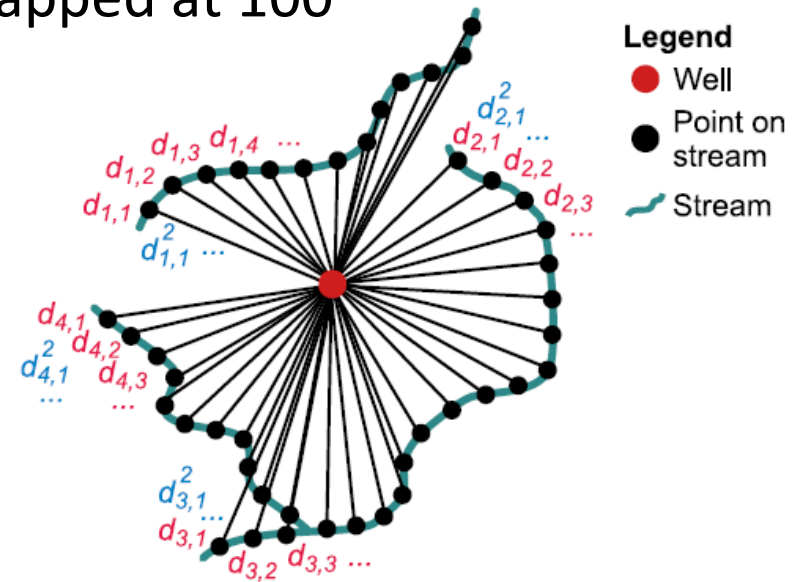
Depletion Apportionment:

Web Squared

Analytical Model:

Glover Balmer

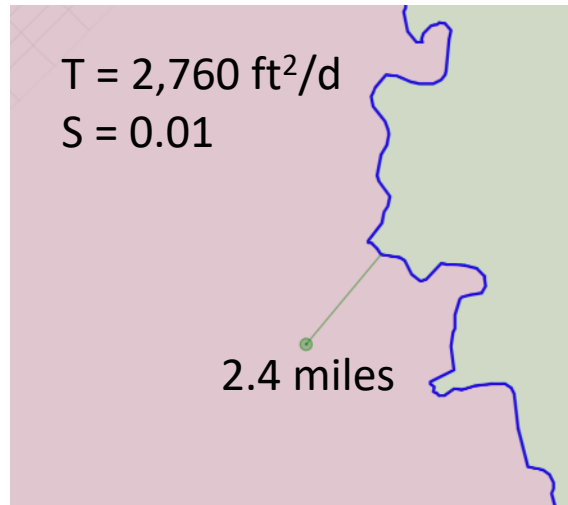
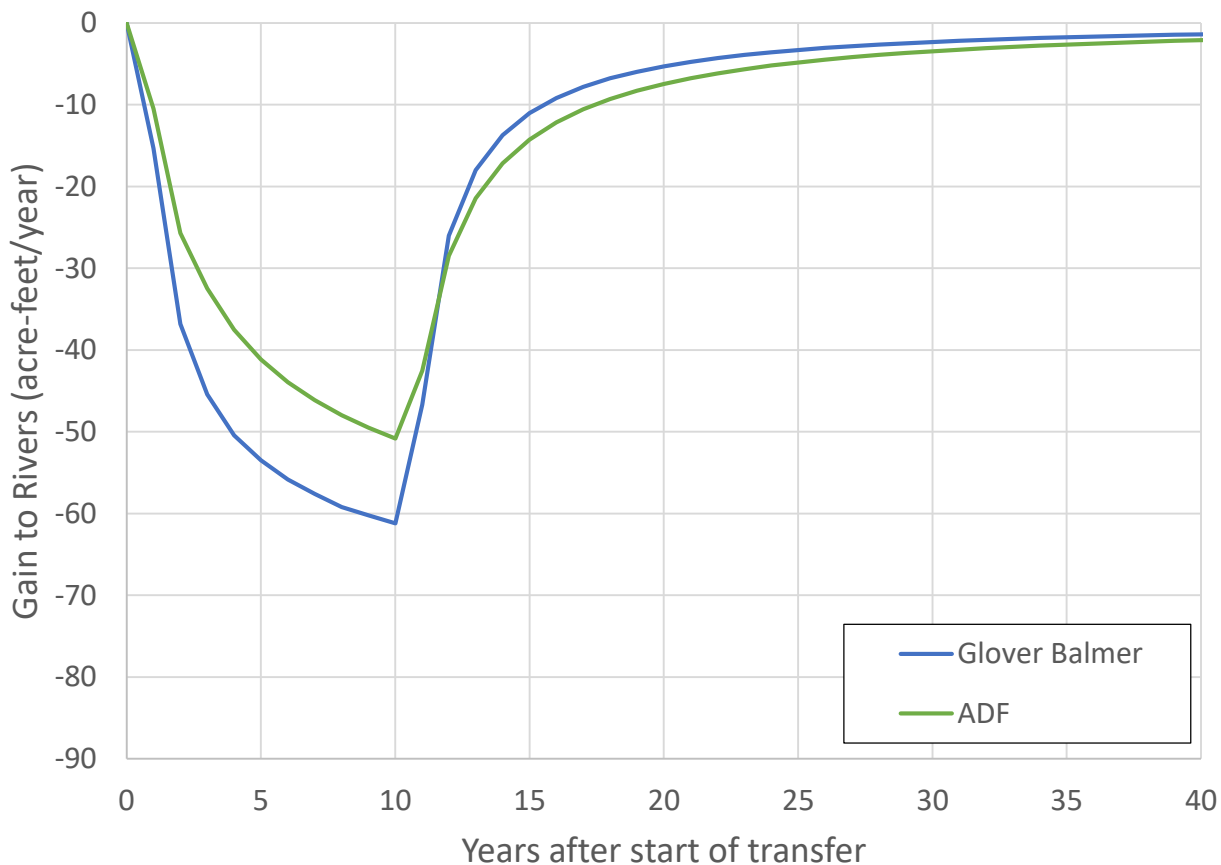
Integration: Scale depletion computed at each segment by depletion apportionment attributed to segment



- Legend**
- Well
 - Point on stream
 - Stream

Example Results

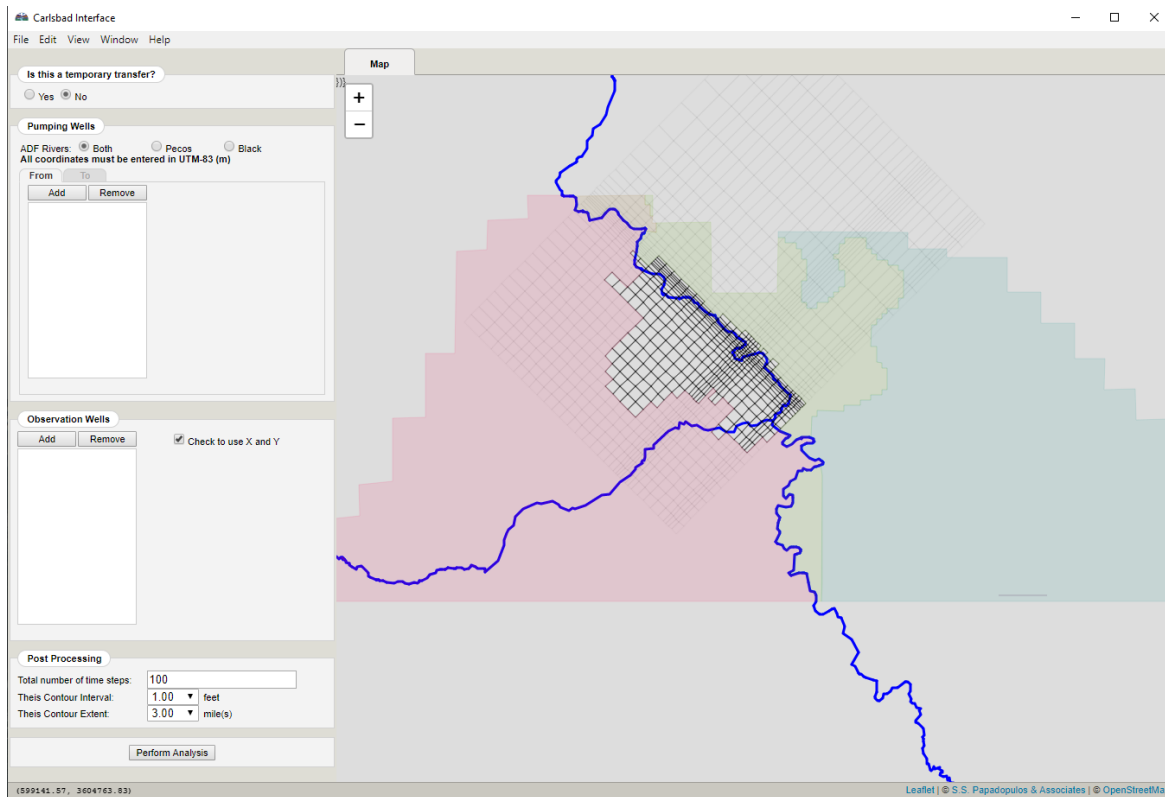
Estimated River Depletion by Pumping



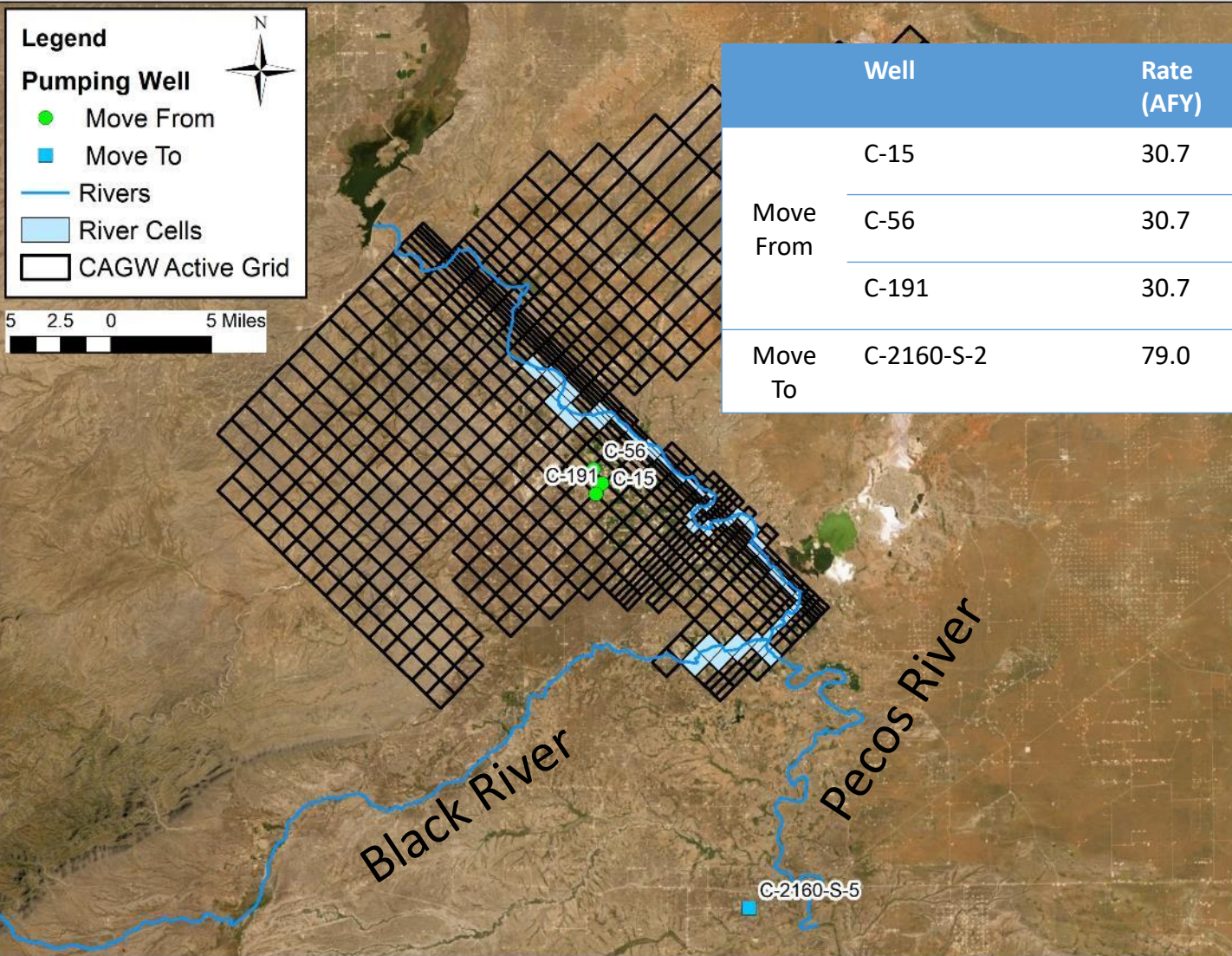
$Q = 79$ acre-feet/year
Pumping for 10 years

Desktop GUI: Carlsbad Interface (CBI)

- Superposition numerical model (MODFLOW)
- Outside numerical model extents:
 - Analytical Depletion Function (ADF, Zipper et al, 2019) for depletion
 - Theis for drawdown
- All output consolidated into a single xlsx
- Accessible user interface:
 - Interactive map
 - Save/load input
 - Plots results
 - Exports tabulated results to workbook



CBI Demo: Example Transfer



	Well	Rate (AFY)	T (ft ² /d)	S	Within CAGW?
Move From	C-15	30.7	[model]	[model]	Inside
	C-56	30.7	[model]	[model]	Inside
	C-191	30.7	[model]	[model]	Inside
Move To	C-2160-S-2	79.0	2,760	0.01	Outside

Questions?



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