Groundwater model for the Harney Basin, Oregon

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Harney County Community Center, Burns, OR

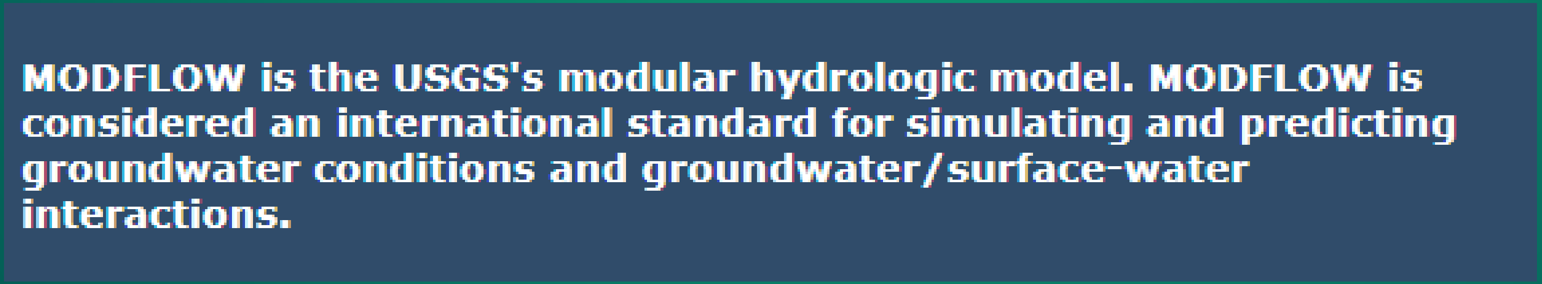
U.S. Department of the Interior
U.S. Geological Survey

Harney Basin Groundwater Model (HBGM)

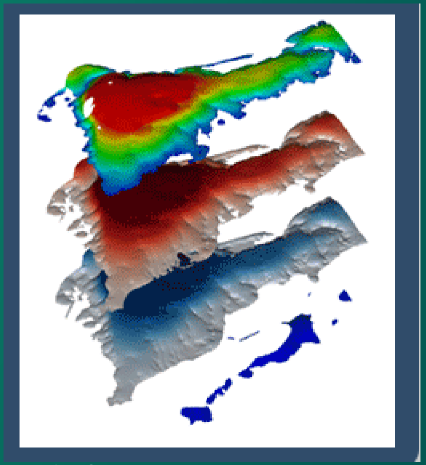
- What is a groundwater model?
- Harney Basin model development
- What can we learn about the basin hydrologic system?
- Example future scenarios

Why a groundwater model?

- Common method to understand complex physical processes using equations that describe the physics of the process
- Numerical modeling used in many applications: aerodynamics of planes, weather forecasting, smoke-plume drift, mining, heating, etc.
- Used to test systems that can't be built in a laboratory
- Can be used to estimate flows and aquifer characteristics for which direct measurements are not available
- Ideal for evaluating various future scenarios



MODFLOW is the USGS's modular hydrologic model. MODFLOW is considered an international standard for simulating and predicting groundwater conditions and groundwater/surface-water interactions.

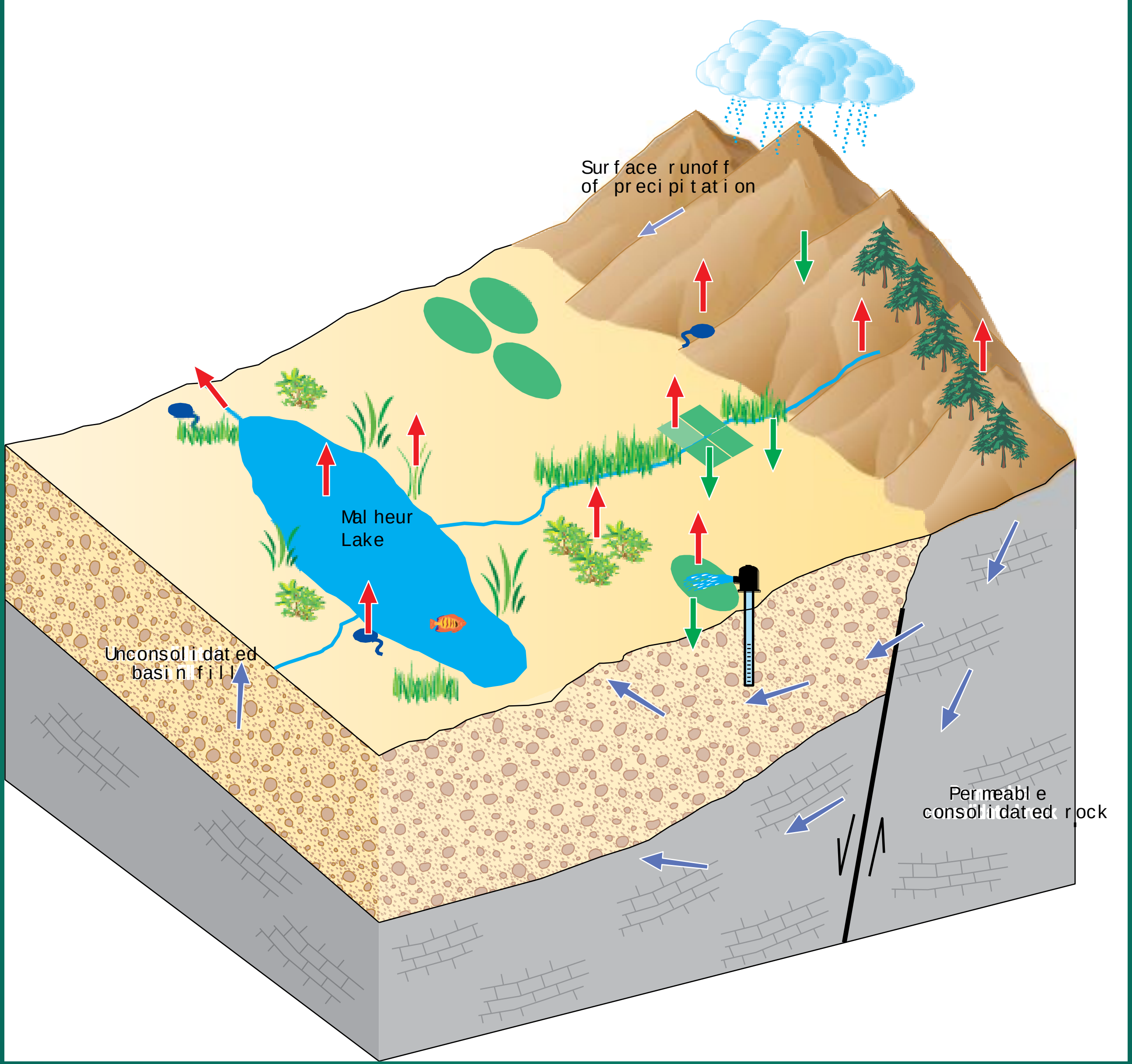


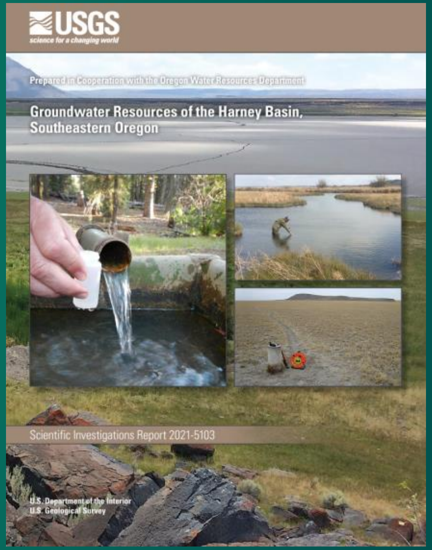
https://www.usgs.gov/software/modflow-6-usgs-modular-hydrologic-model

Some important concepts

- Aquifer--a geologic formation(s) that is water bearing; a geological formation or structure that stores and/or transmits water, such as to wells and springs.
- Transmissivity, hydraulic conductivity, permeability--the capacity of a porous rock, sediment, or soil for transmitting a groundwater (different precise definitions but I may interchange them today).
- Recharge—Water reaching the groundwater system (rain/snow melt/stream infiltration, irrigation return…)
- Discharge—Water leaving the groundwater system (springs/streams/evapotranspiration/pumping…)
- Steady state—Recharge equals discharge in a groundwater system; no change in storage and no long-term water-level changes

Start with a hydrostratigraphic framework

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Prepared in Cooperation with the Oregon Water Resources Department

Groundwater Resources of the Harney Basin, Southeastern Oregon

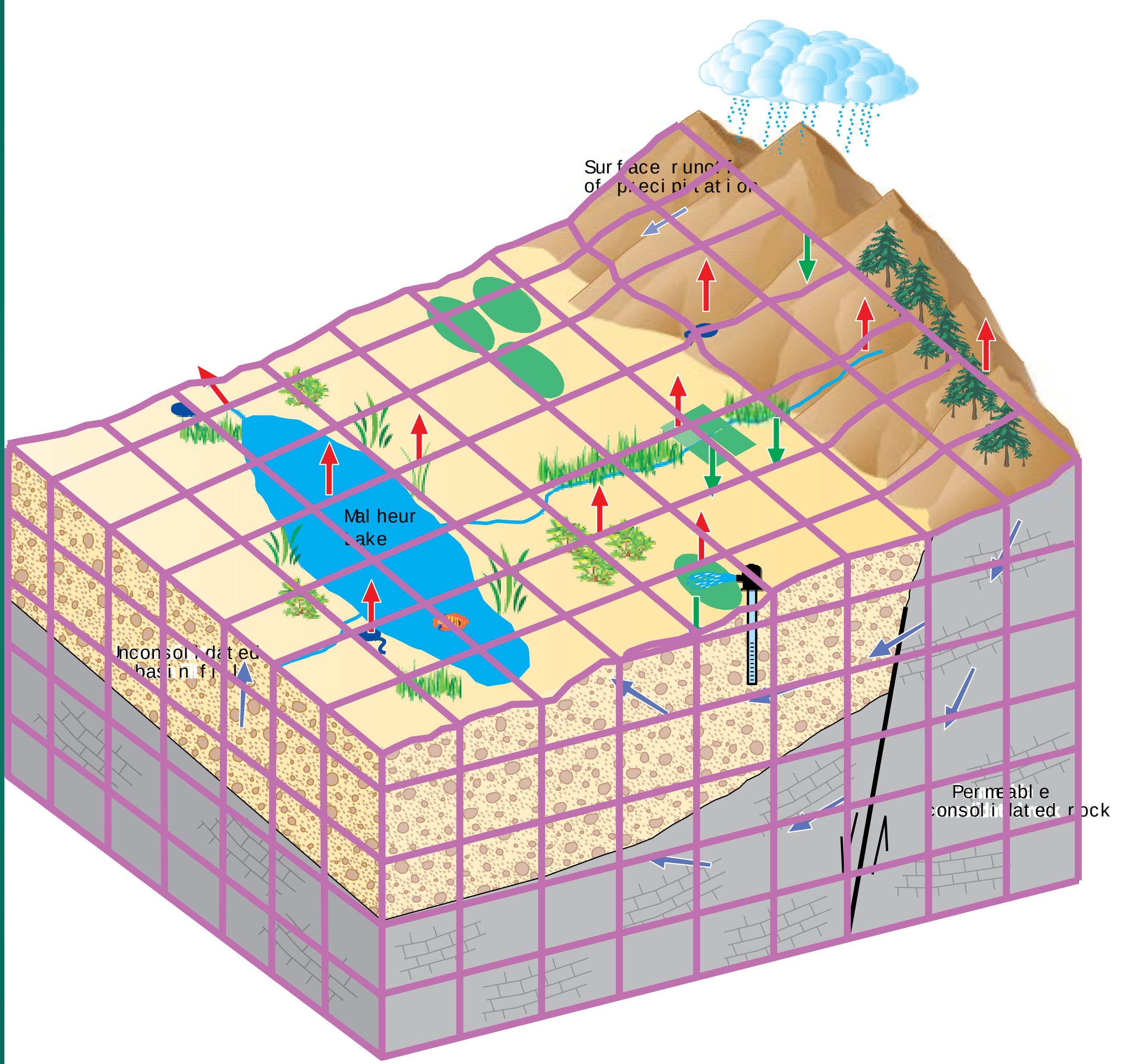
Scientific Investigations Report 2021-5103

U.S. Department of the Interior
U.S. Geological Survey

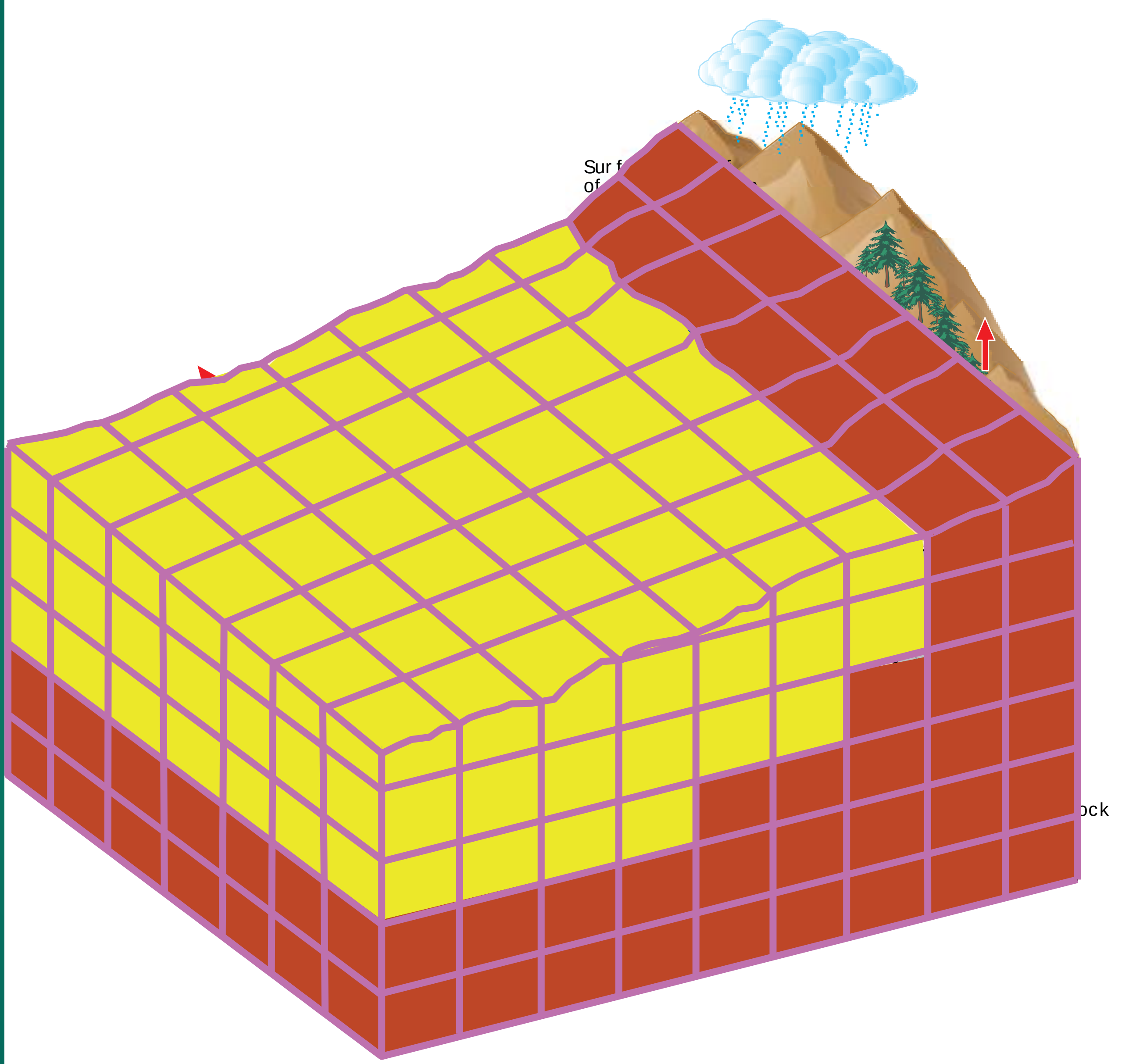
Described in here

Modified from Masbruch and others (2010)

Divide the area into a uniform grid



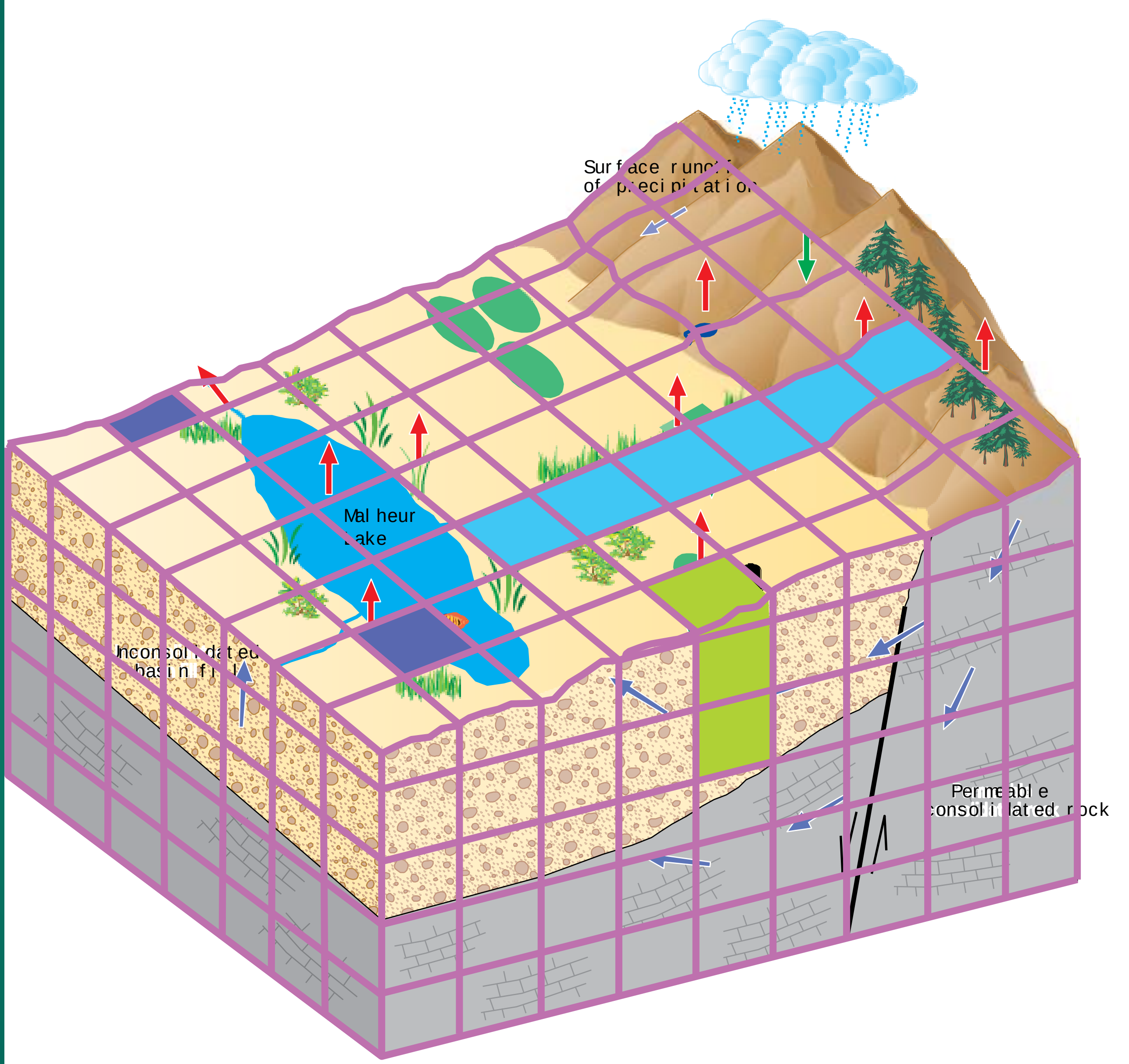
Assign hydrologic properties

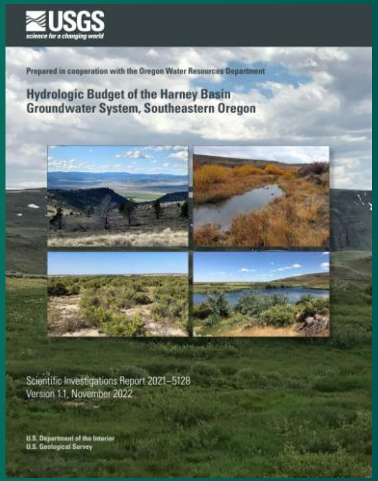


Represent hydrologic features

Recharge: rain/snowmelt, stream infiltration

Discharge: streams, springs, wells, evapotranspiration




Prepared in cooperation with the Oregon Water Resources Department

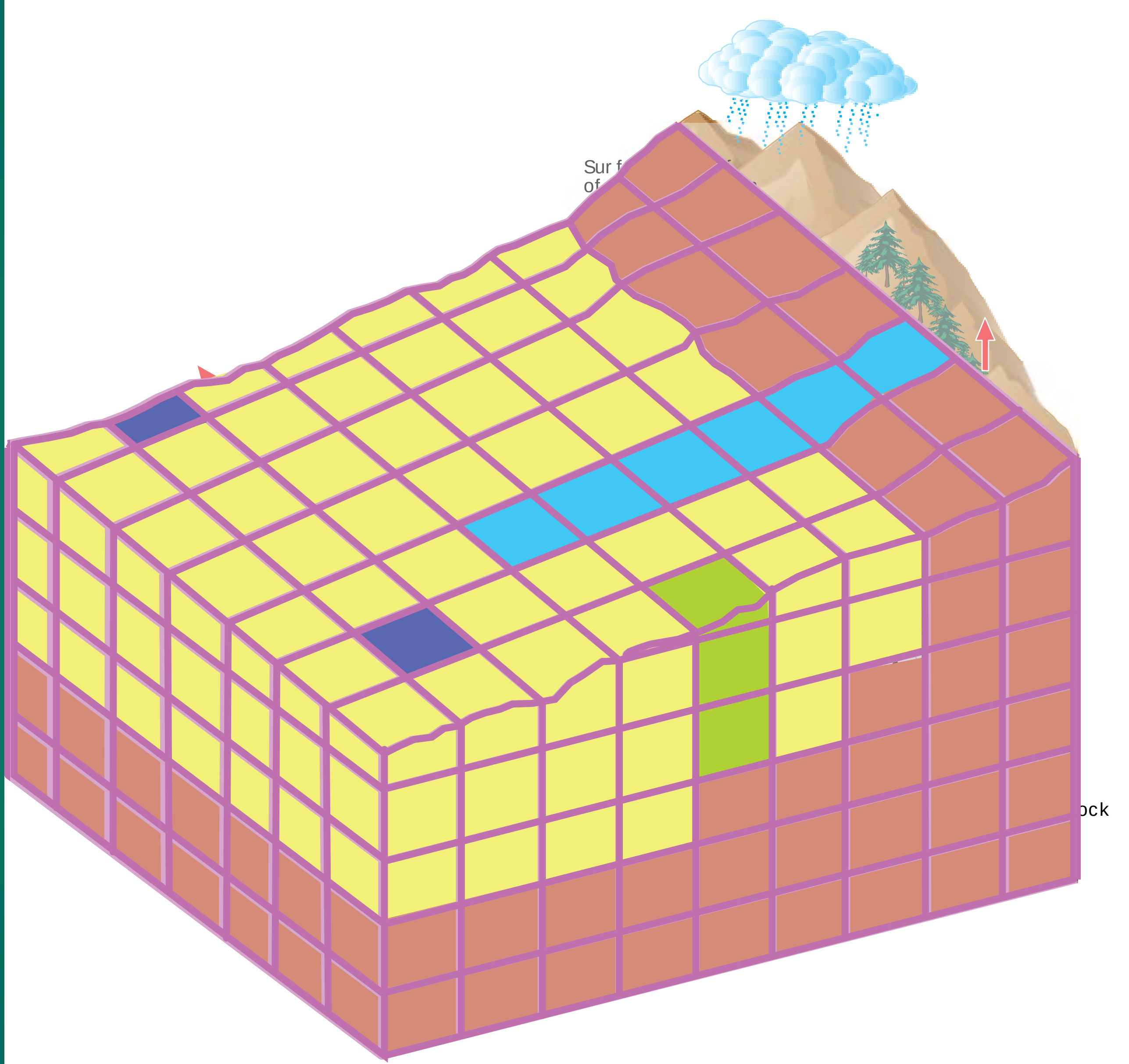
Hydrologic Budget of the Harney Basin Groundwater System, Southeastern Oregon

Scientific Investigations Report 2021–5128
Version 1.1, November 2022

U.S. Department of the Interior
U.S. Geological Survey

Described in here

Complete model representing the physics of the hydrologic system



Harney Basin Groundwater Model (HBGM)

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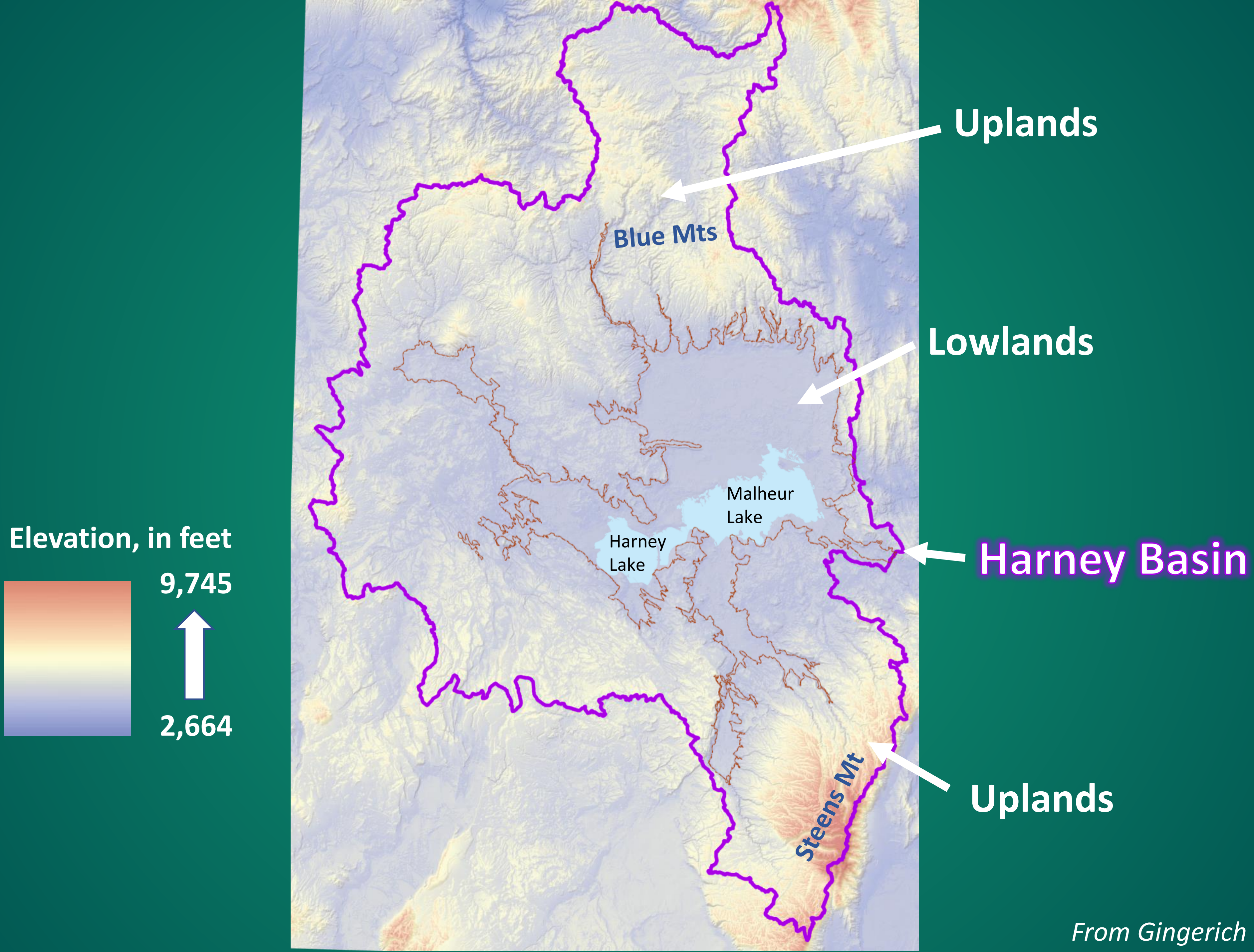
- What can we learn about the basin hydrologic system?
- Example future scenarios



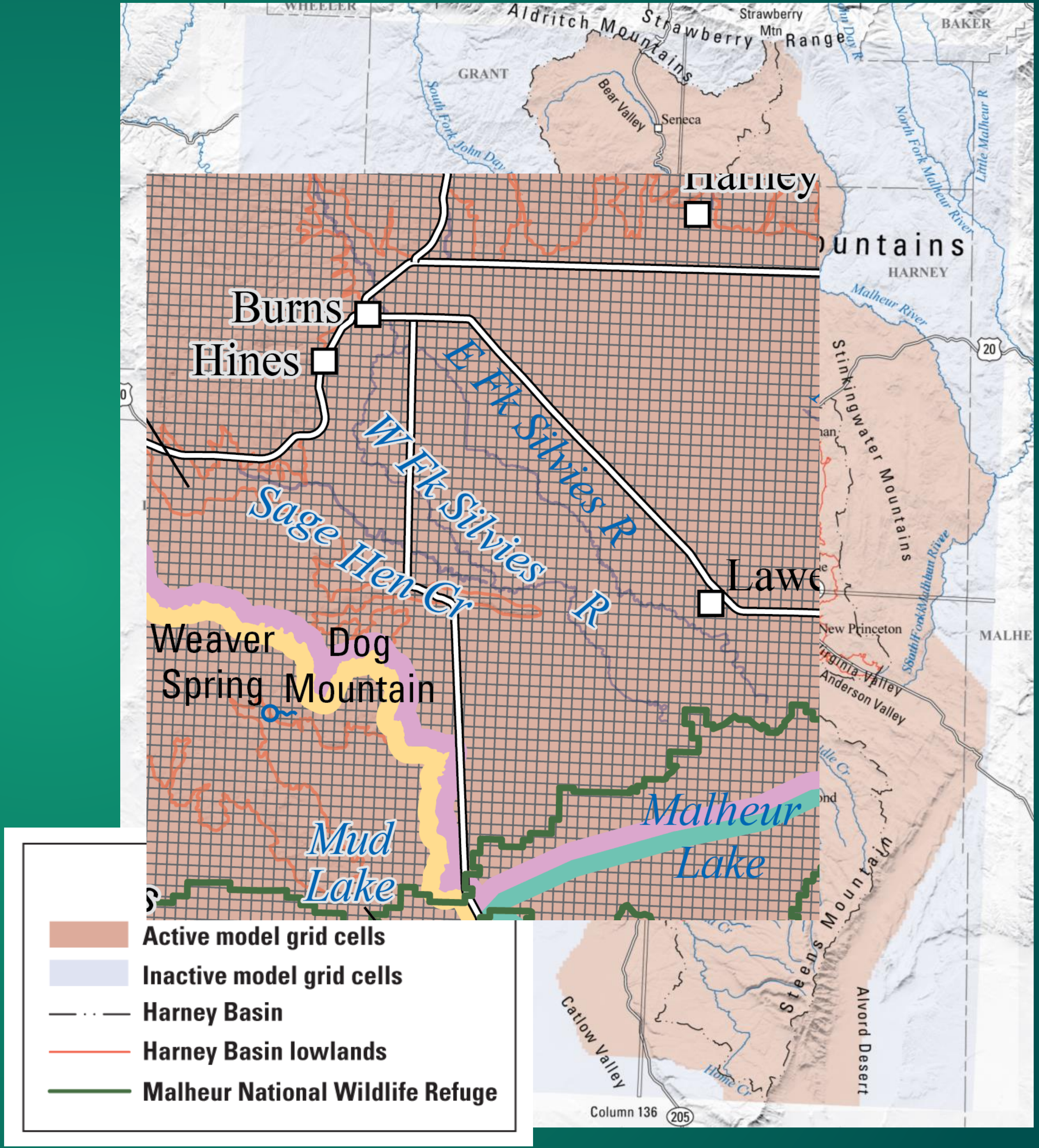
From Gingerich and others (2022)

MODFLOW 6 model grid

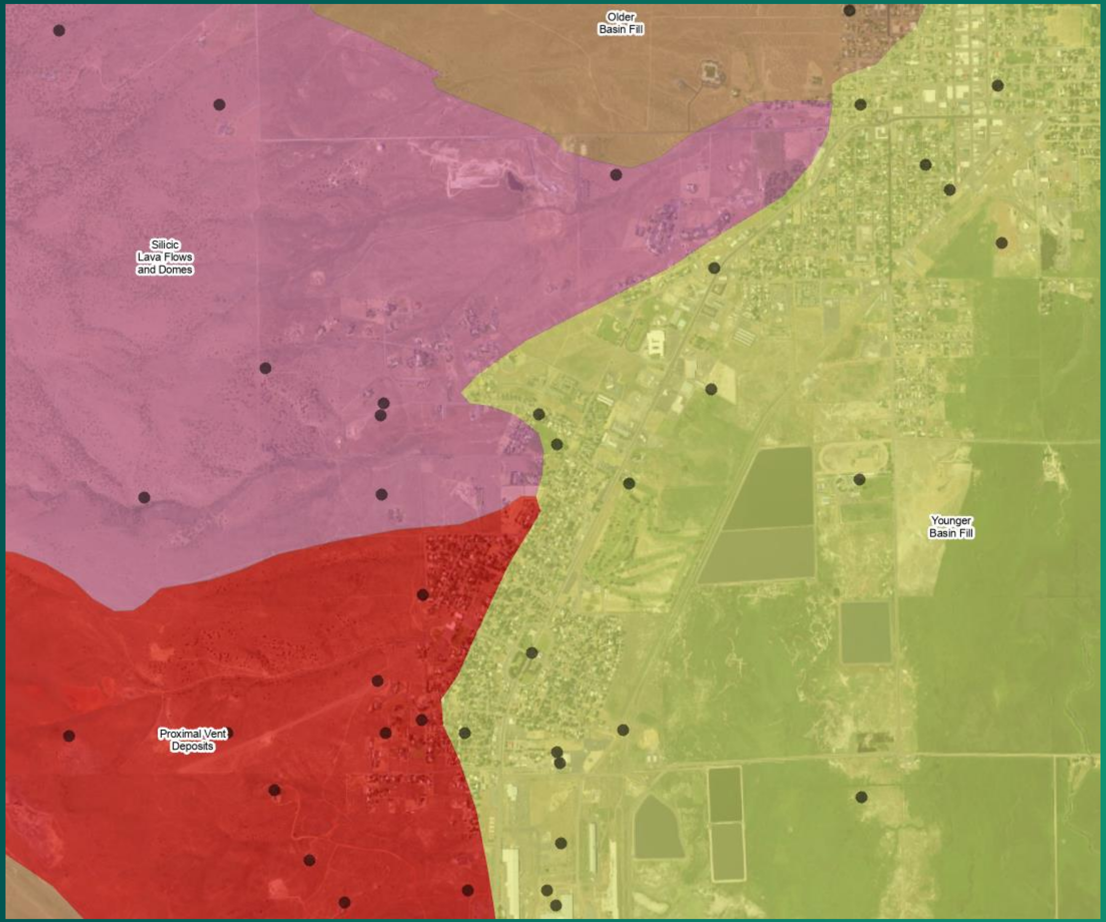
each cell about 2,000 ft per side

74,840 cells x 10 layers→740,840 total cells

480,016 cells are active in the model



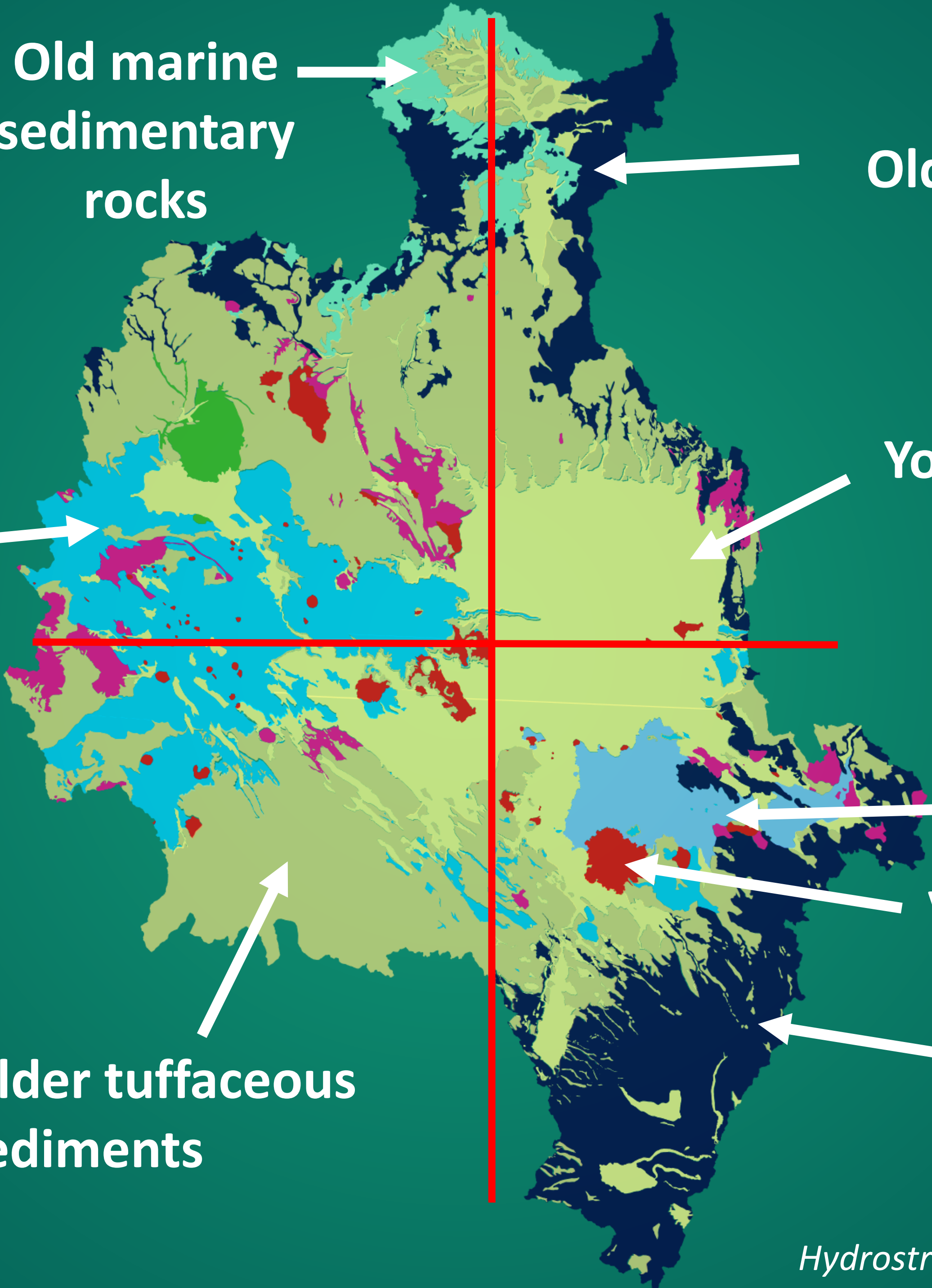
Hydrostratigraphic units and well locations are generalized



Reality

Model

Generalized surface hydrostratigraphy



Old marine sedimentary rocks

Old volcanics

Younger alluvial fill

Lava flows

Youngest lava flows

Volcanic vent deposits

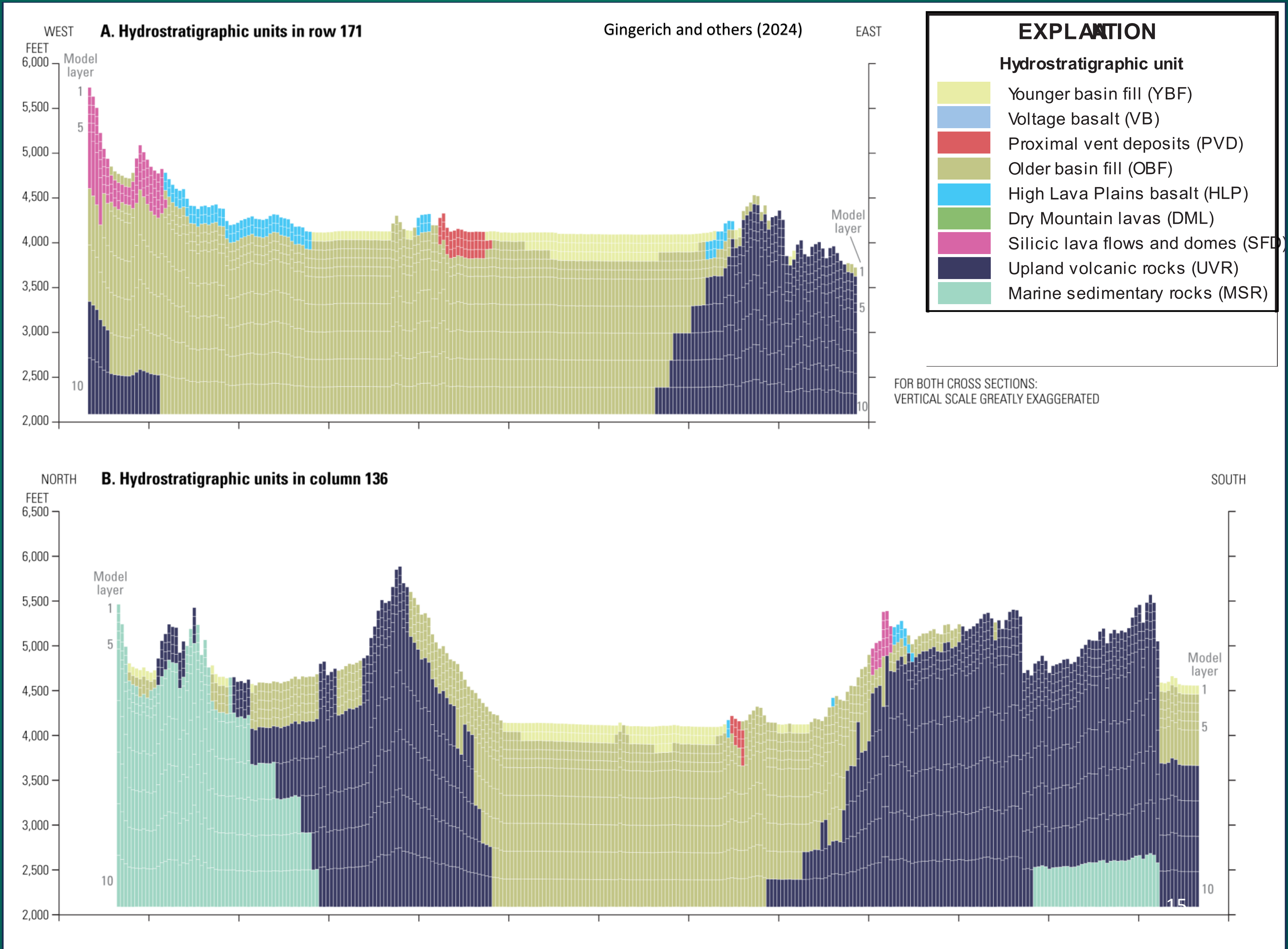
Old volcanics

Older tuffaceous sediments

Hydrostratigraphy from Grondin and others (2021)

MODFLOW 6 model grid

10 layers
each 100–1,400 feet thick



USGS

Generalized surface hydrostratigra

Youngish lava

l fill

va flows

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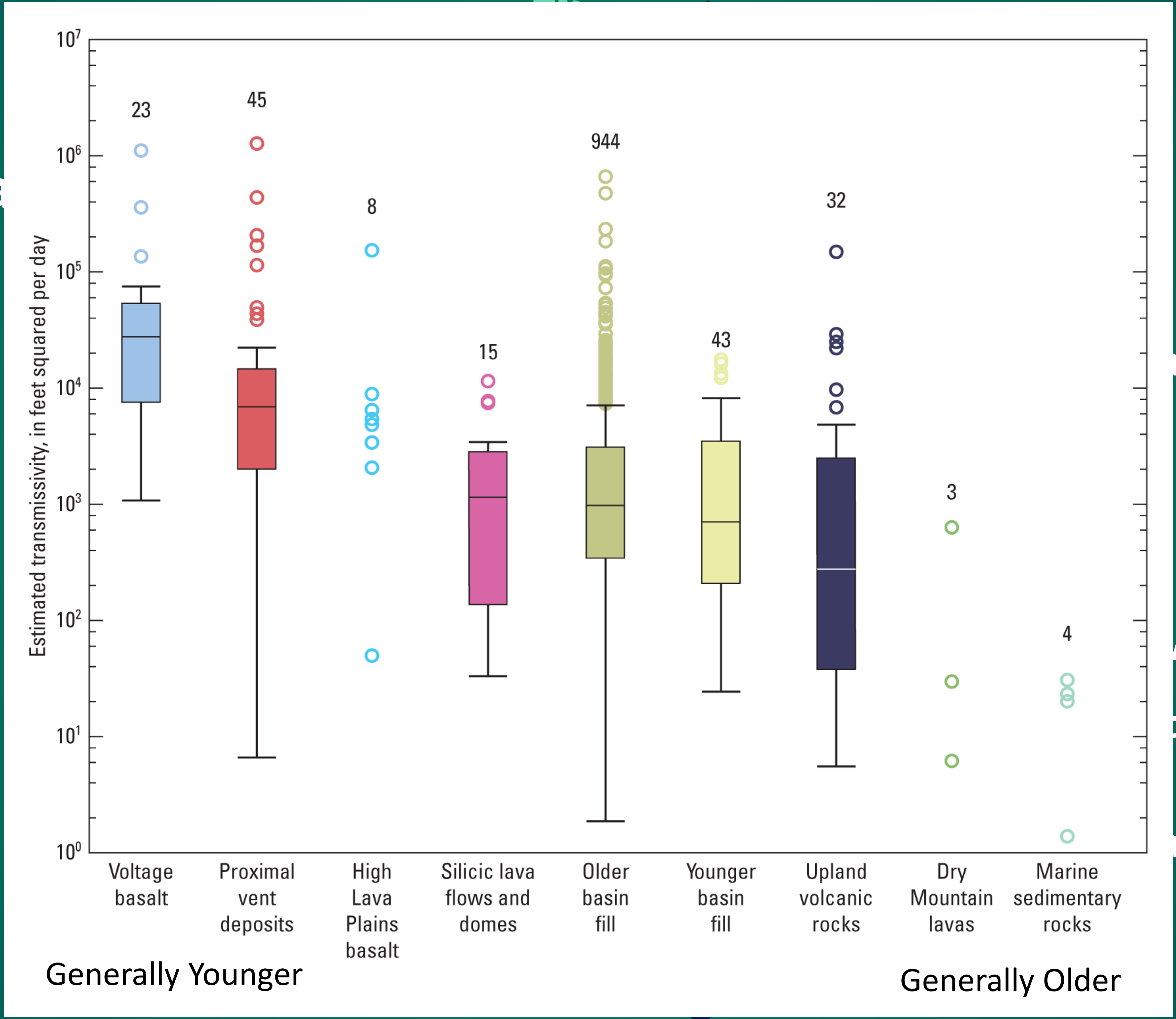


Hydrostratigraphy from Grondin and others (2021)

Hydraulic conductivity is highly variable

Old marine sedimentary rocks

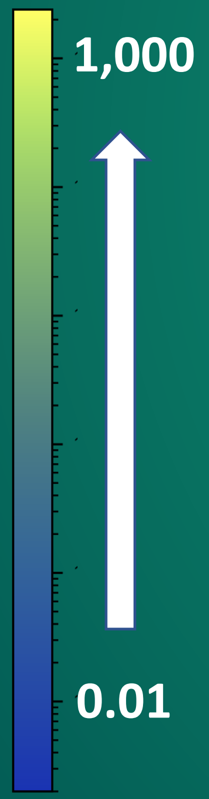
ranges from
0.002 to 4,790 ft/d in layer 1

Older volcanics

Youngish lava flows

Younger alluvial fill

Hydraulic conductivity, ft/d



Youngest lava flows

Volcanic vent deposits

Older volcanics

Older tuffaceous sediments

Hydraulic conductivity distribution from Gingerich and others (2024)

Hydraulic conductivity is highly variable

Old marine sedimentary rocks

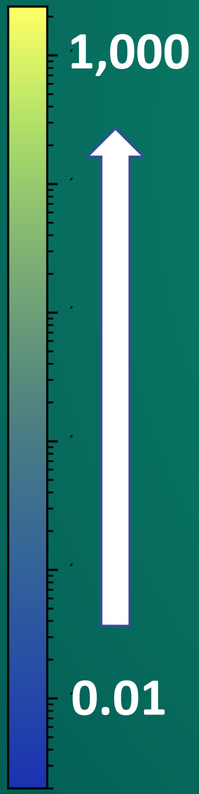
ranges from
0.002 to 400 ft/d in layer 5

Older volcanics

Western permeable zone

Older alluvial fill

Hydraulic conductivity, ft/d



Virginia/Andersen Valley permeable zone

Older volcanics

Older tuffaceous sediments

Hydraulic conductivity distribution from Gingerich and others (2024)

Hydraulic conductivity is highly variable

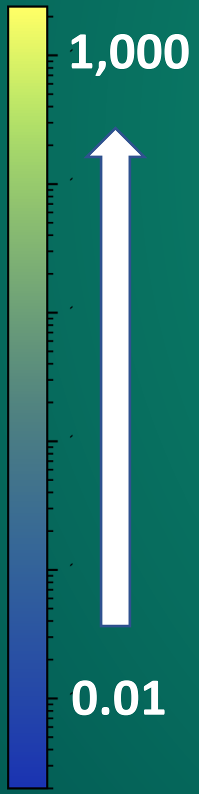
Old marine sedimentary rocks →

ranges from
0.002 to 0.060 ft/d in layer 10

← Older volcanics

← Pre-Steens Basalt unit

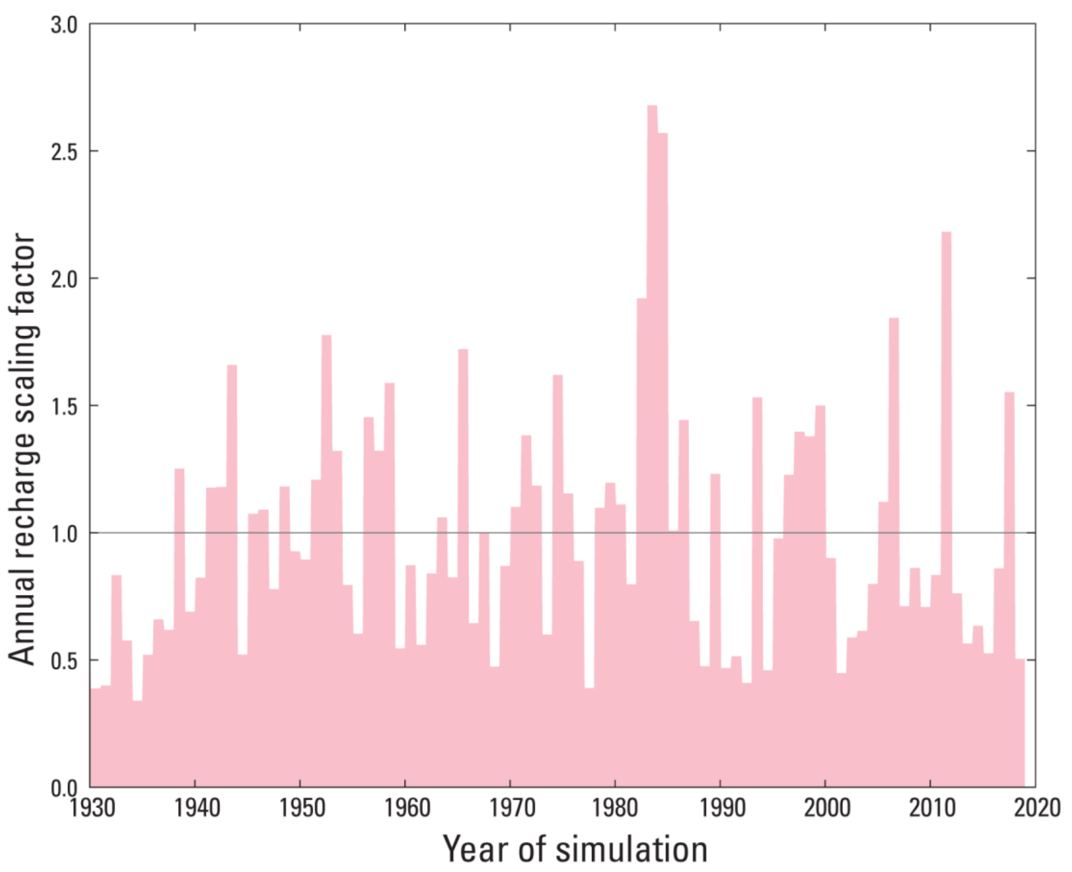
Hydraulic conductivity, ft/d

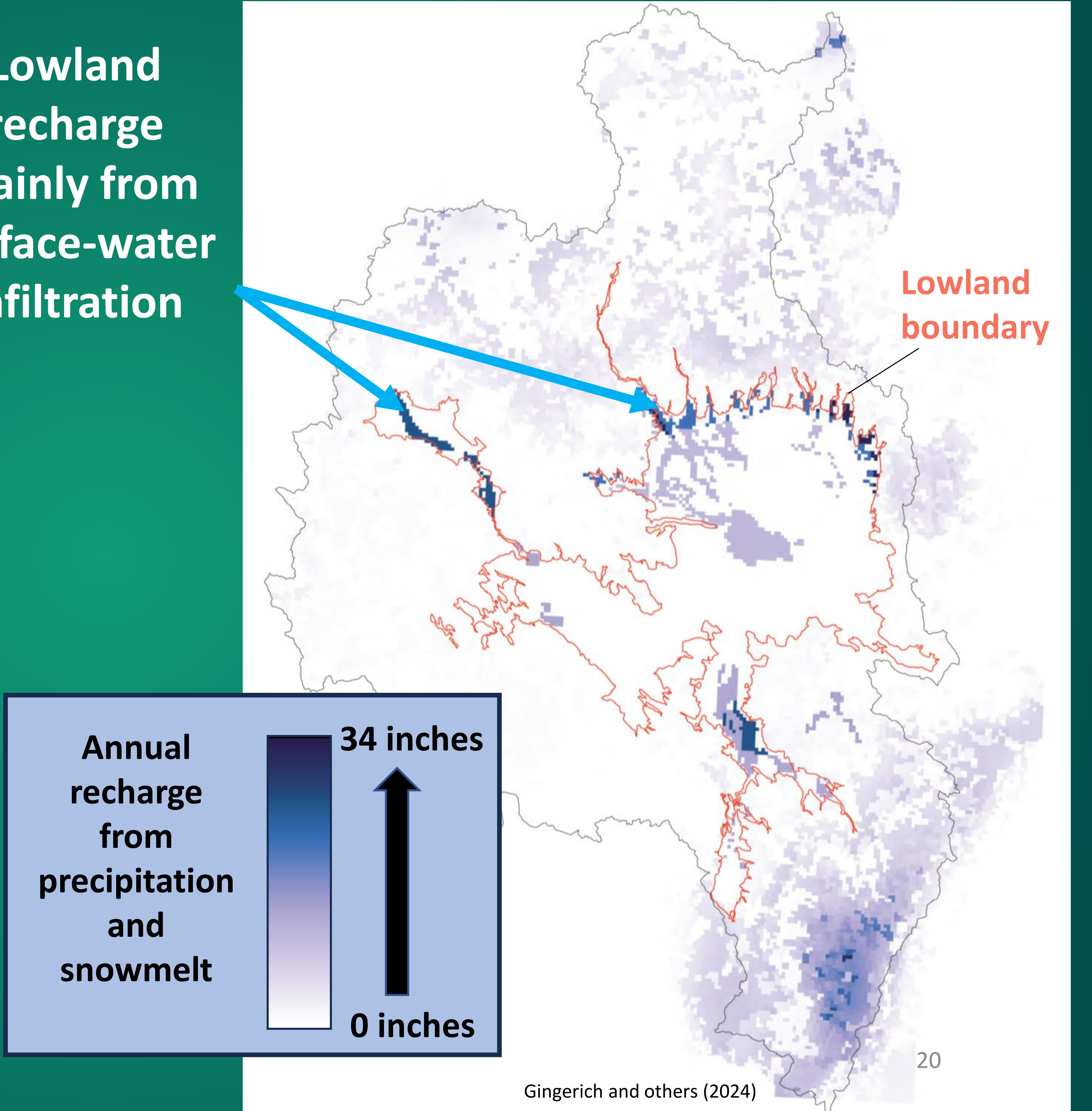


Hydraulic conductivity distribution from Gingerich and others (2024)

Recharge during 1982–2016

Uplands – 288,000 acre-ft/yr
Lowlands – 116,000 acre-ft/yr
(*estimated in Garcia and others [2022]*)





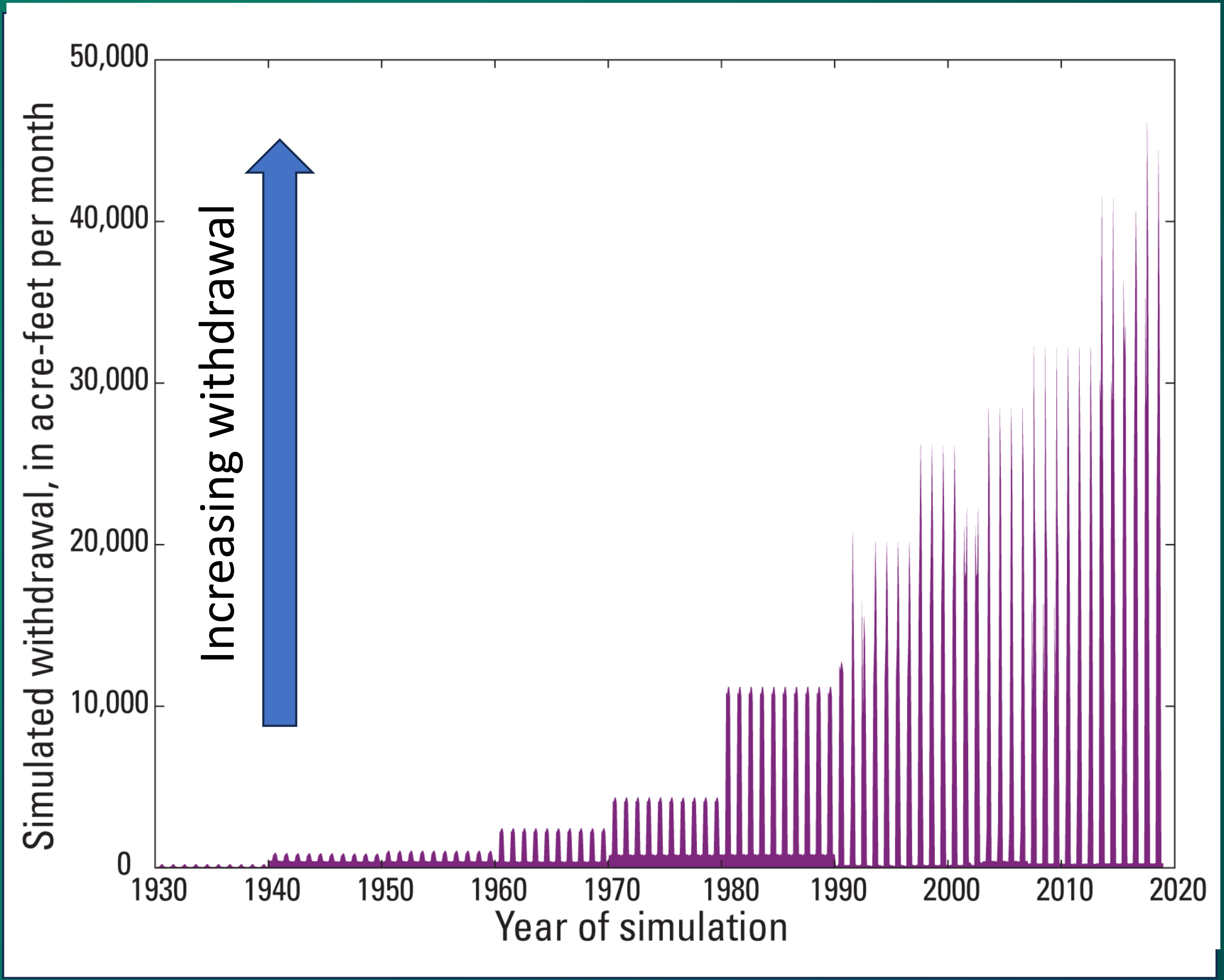
Gingerich and others (2024)

Discharge

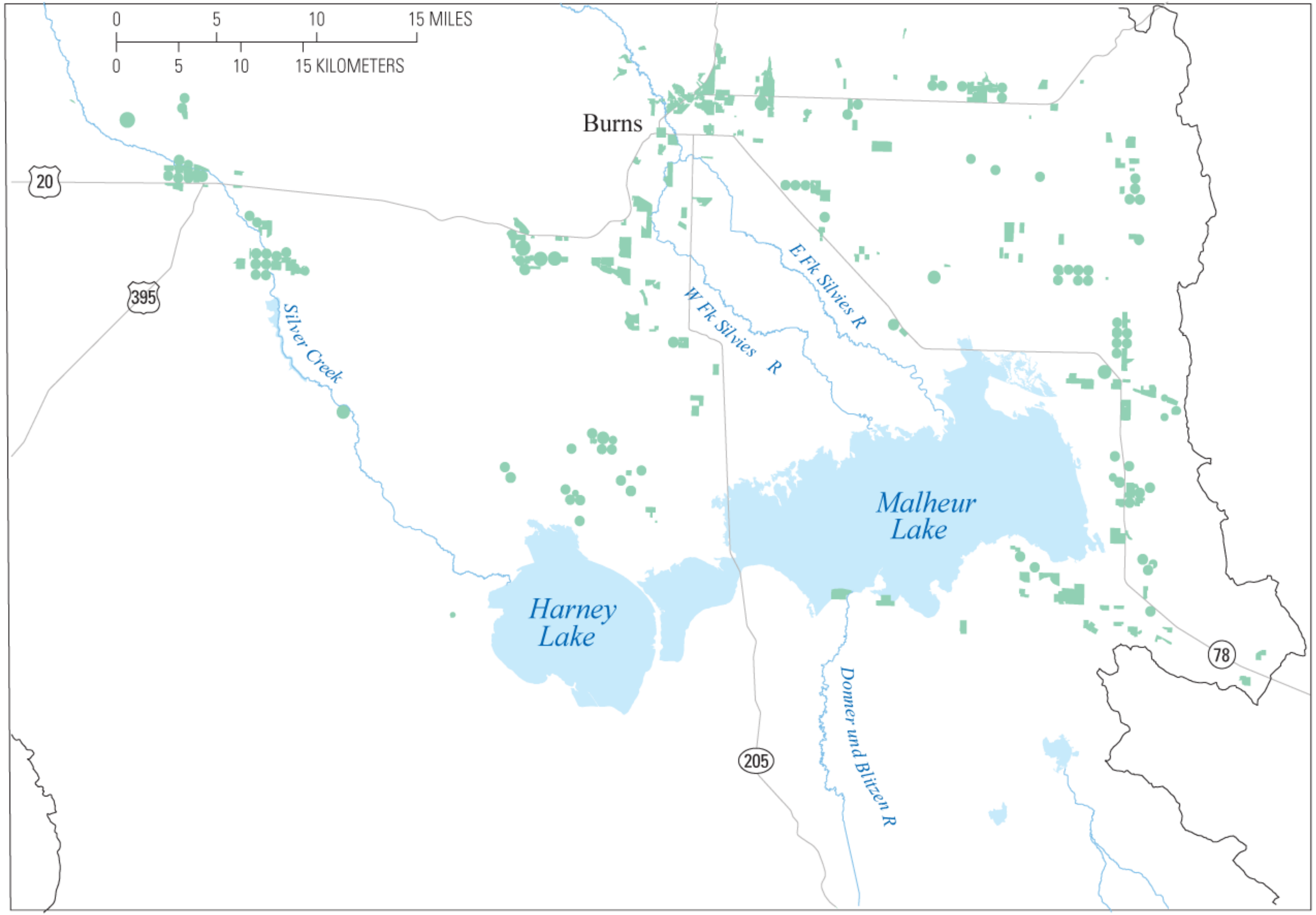
Groundwater withdrawal tripled during 1990–2018
(from Schibel and Grondin, 2023)

2017 annual withdrawal was 149,000 acre-ft

Irrigation withdrawals are about 95 percent of total basin withdrawal



Gingerich and others (2024)



Base map modified from U.S. Geological Survey and other digital data, various scales. Projection: UTM Zone 1 North American Datum of 1983

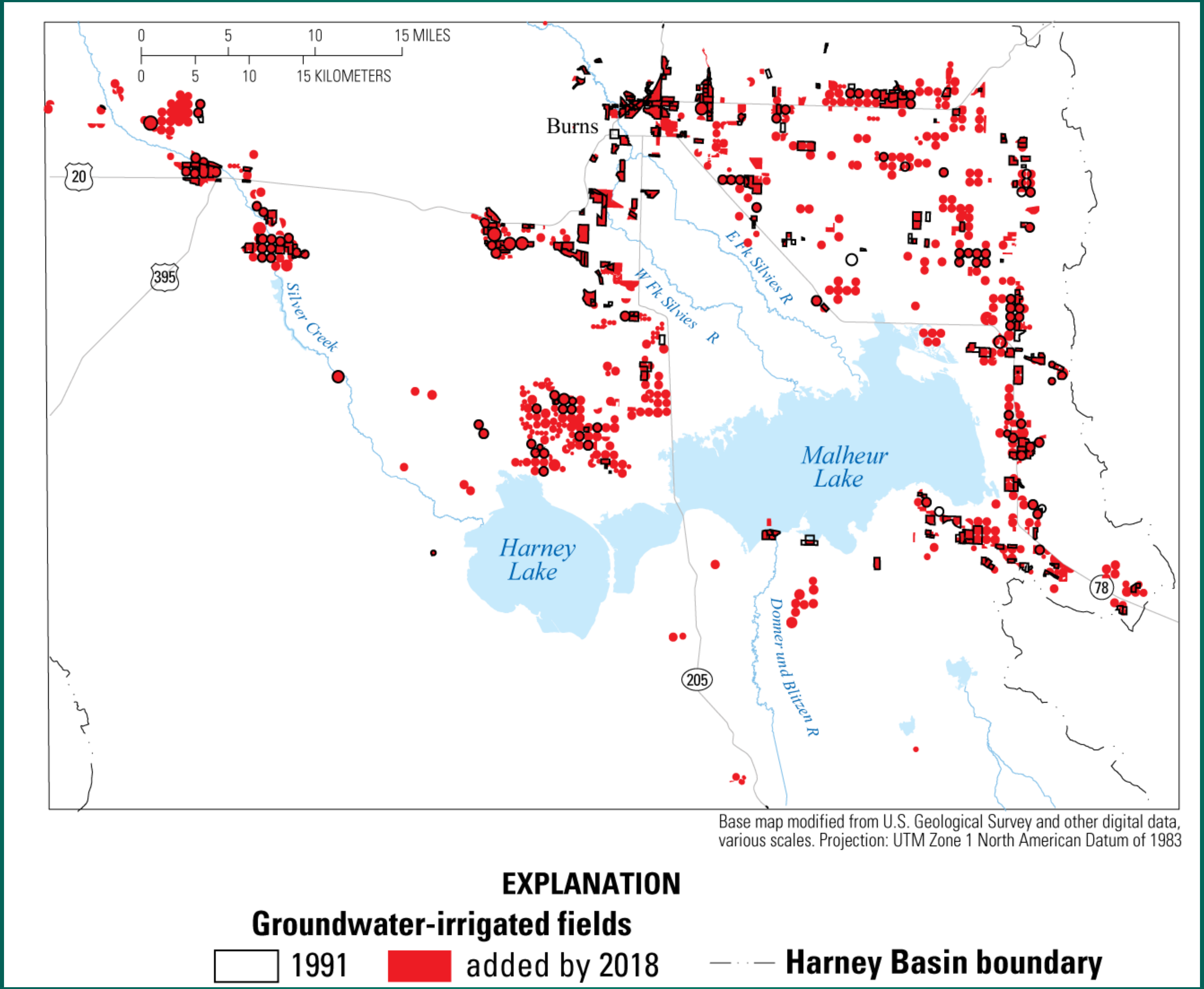
EXPLANATION

Groundwater-irrigated fields

🟩 1991

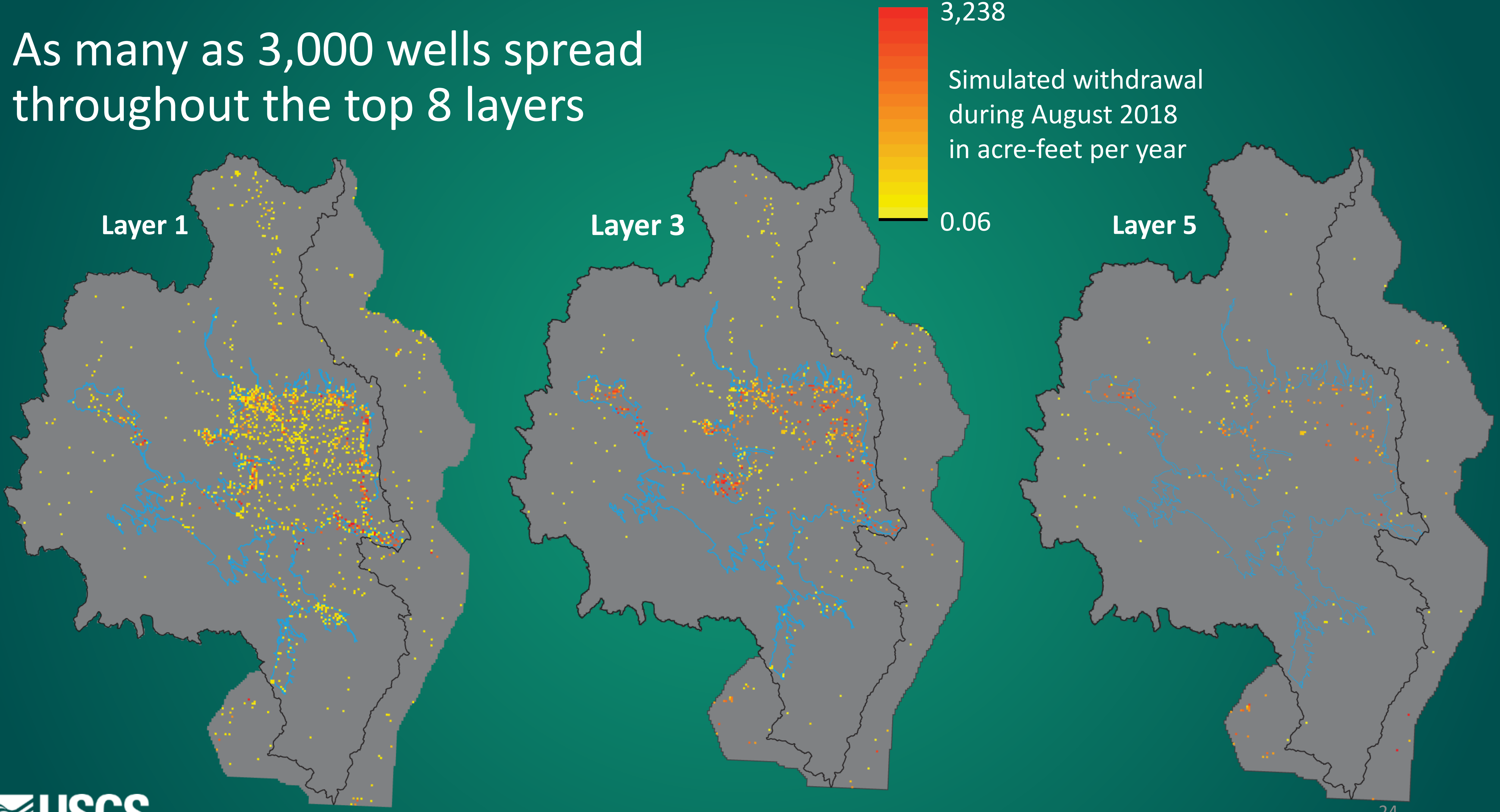
—·—·— **Harney Basin boundary**

Gingerich and others (2022)



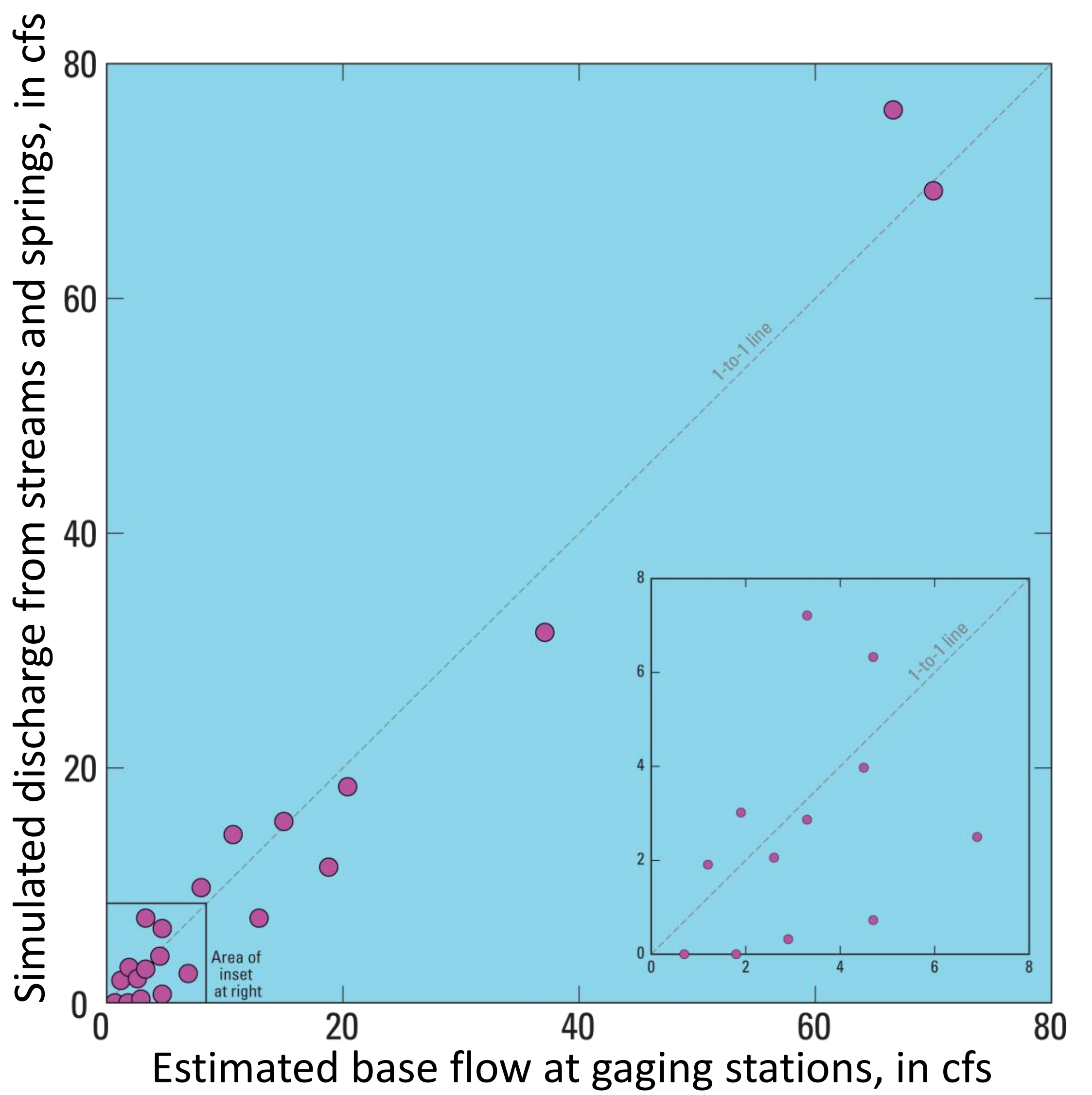
Gingerich and others (2022)

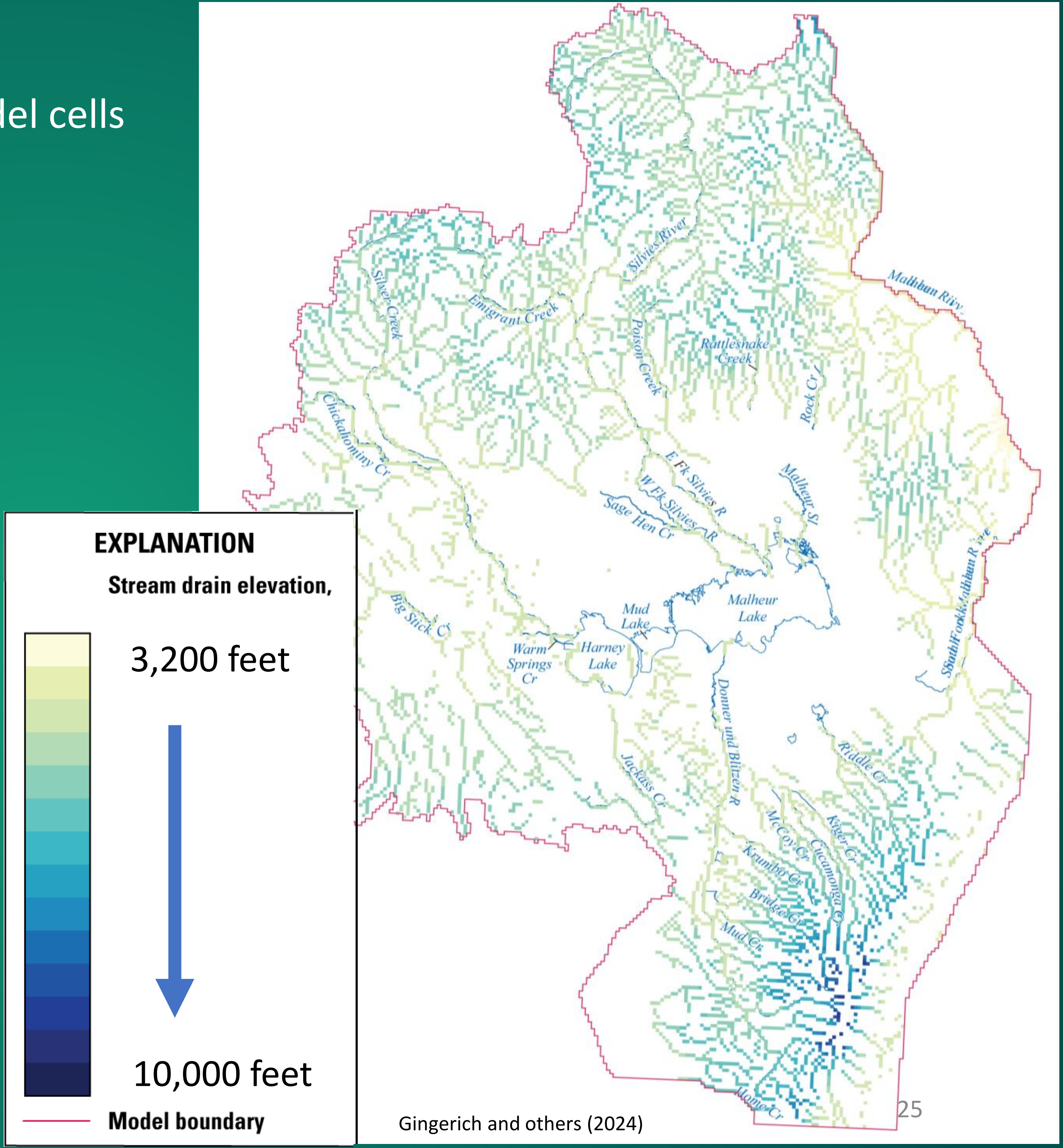
As many as 3,000 wells spread throughout the top 8 layers



Discharge

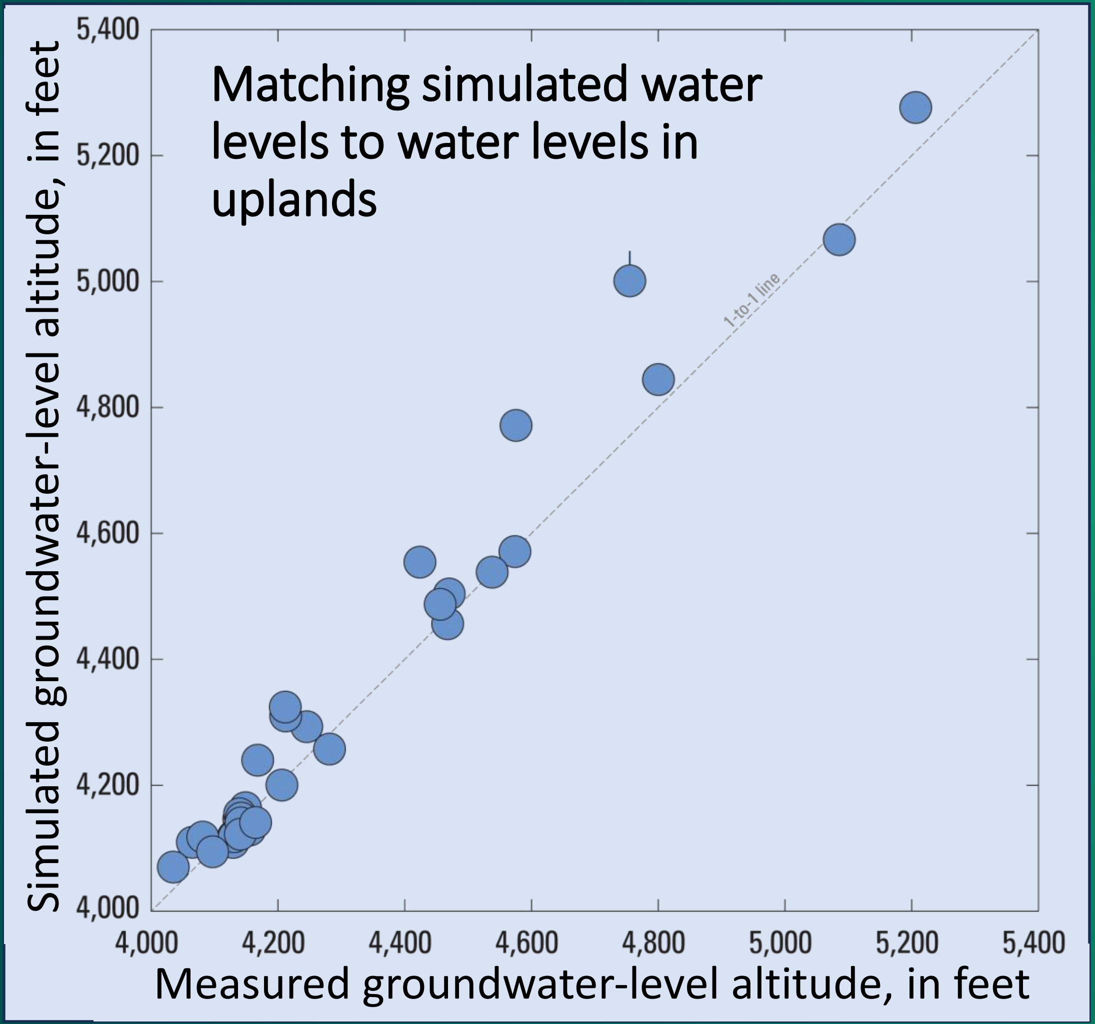
Stream network represented by more than 9,000 model cells

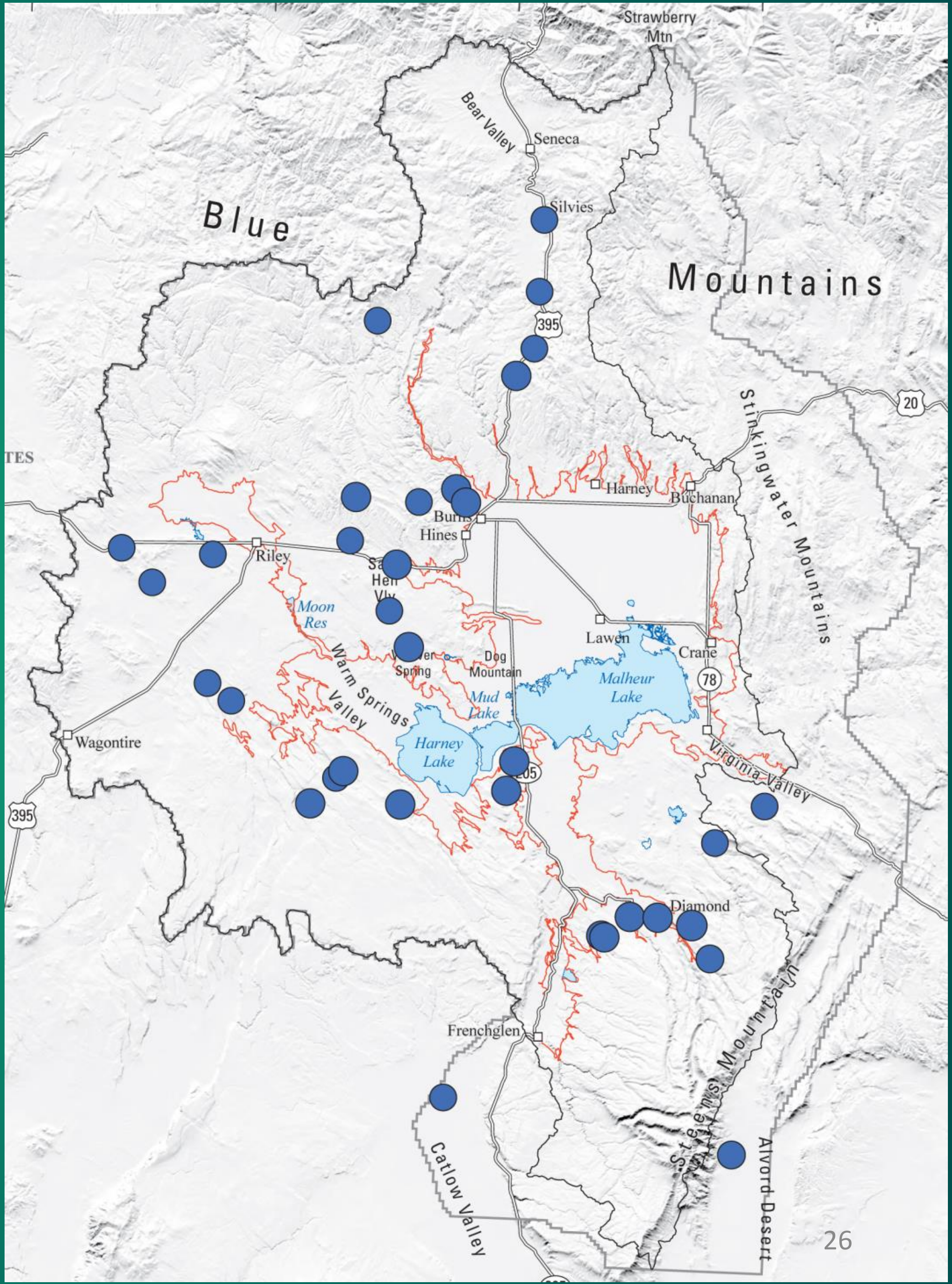




Gingerich and others (2024)

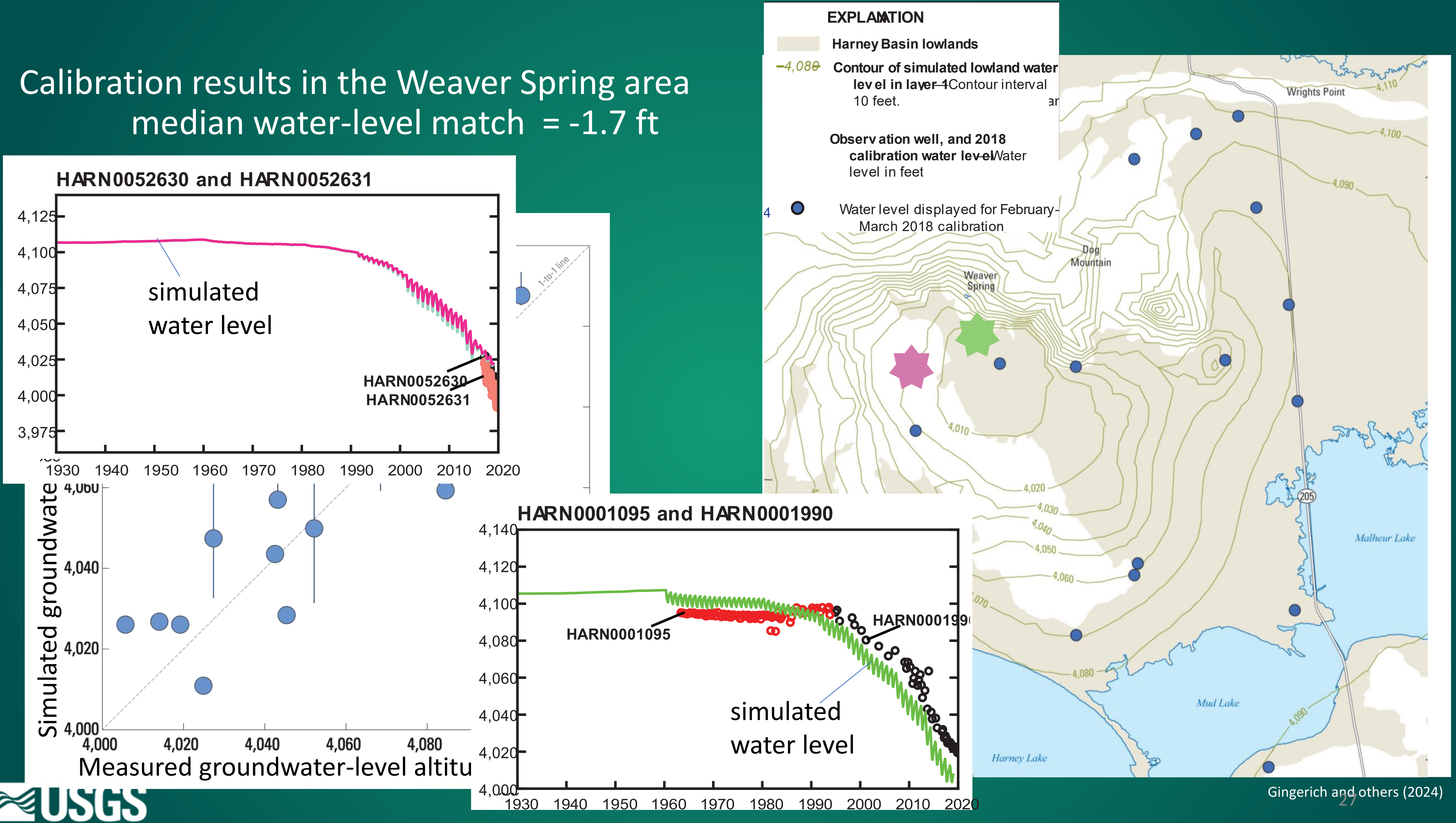
Upland monitoring wells used for calibration to 2018 water-level conditions


Matching simulated water levels to water levels in uplands



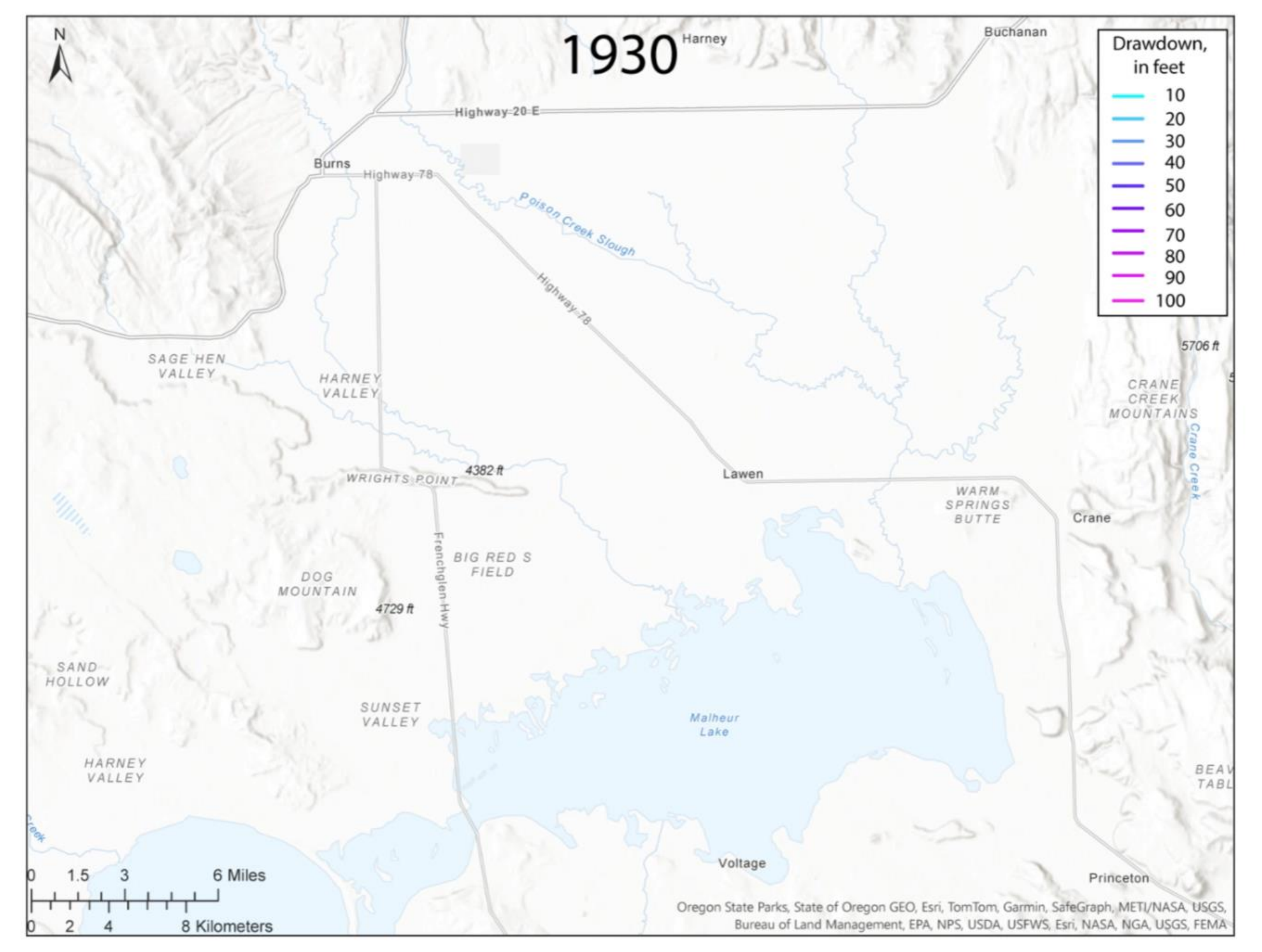
Gingerich and others (2024)

Calibration results in the Weaver Spring area
median water-level match = -1.7 ft



Gingerich and others (2024)

Drawdown at the water table during 1930–2018



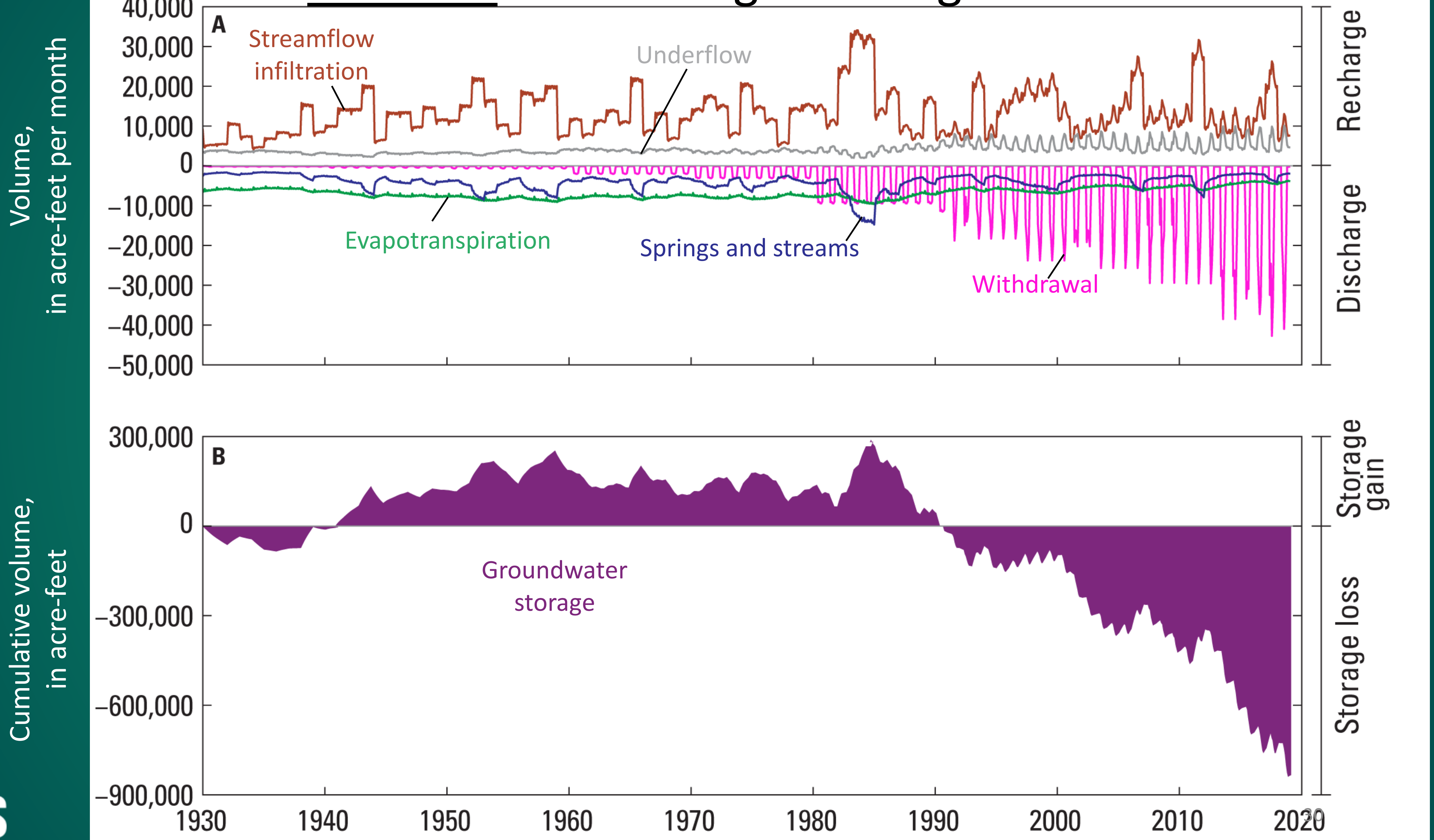
Oregon State Parks, State of Oregon GEO, Esri, TomTom, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA, USFWS, Esri, NASA, NGA, USGS, FEMA

We now have a calibrated model……So what can we learn about the hydrologic system?

- Components of the water budget
- Effects of historic withdrawal
- What if we continue current stresses?
- How quickly can the system recover?

Lowland water budget through time

Gingerich and others (2024)



Decrease in stream and spring discharge from 1988–92 through 2014–18

(example of a hydrologic condition that can be difficult or impossible to measure)

Decrease in discharge

↓

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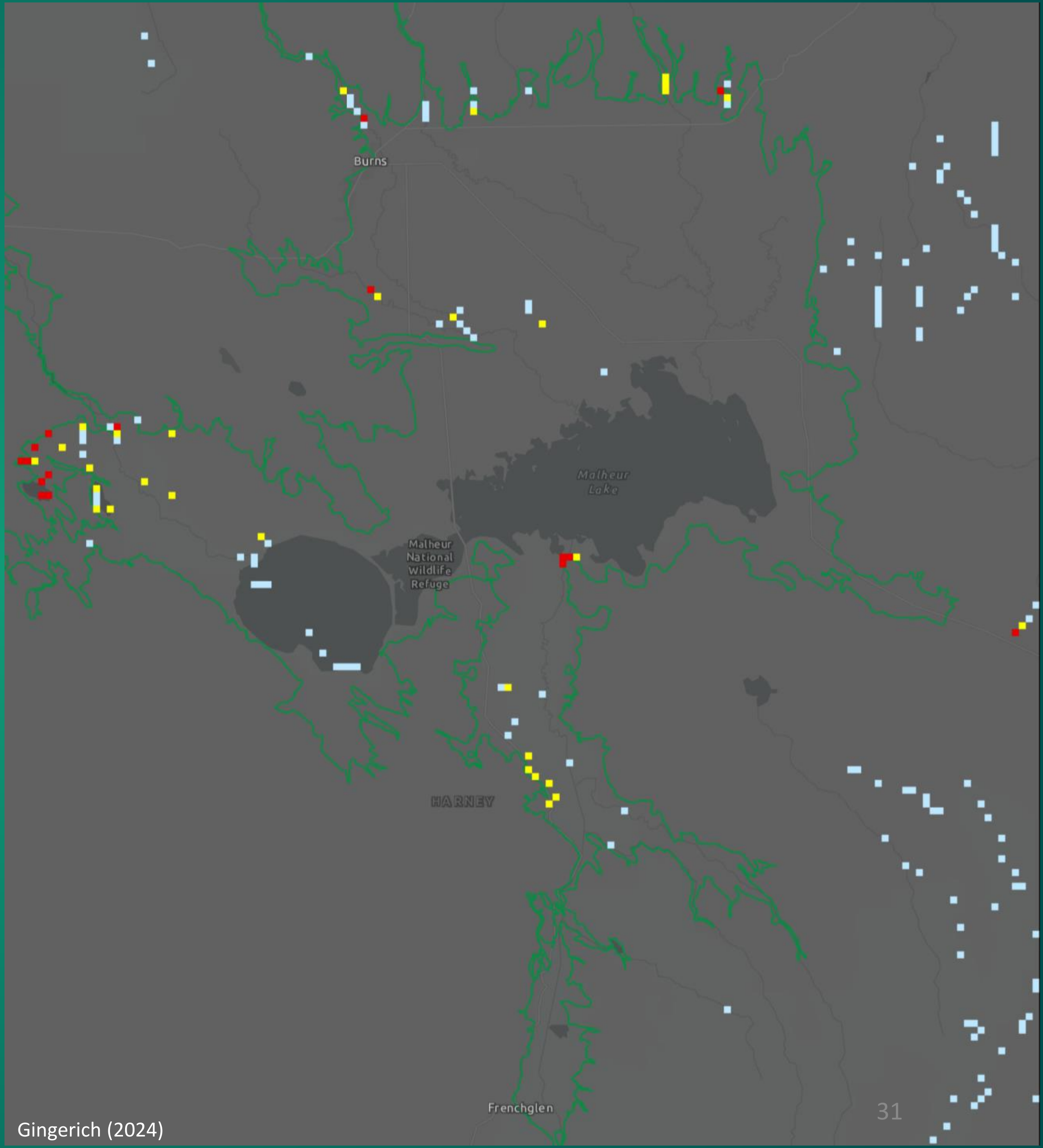
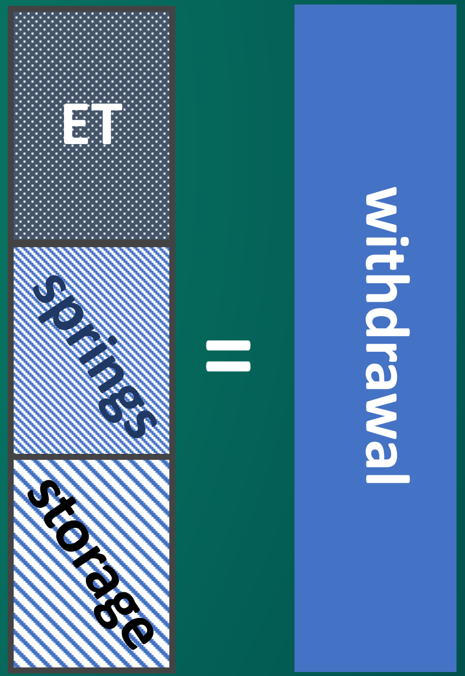
🟥



Gingerich (2024)

When you pump groundwater from the system, what happens to the other types of discharge?

- Simulation using 1930–2018 water budget but no withdrawal
  - 3,400,00 acre-ft of water not withdrawn from groundwater system is balanced by:
  - 1,200,000 acre-ft of increased lowland evapotranspiration (35%)
  - 1,100,000 acre-ft of increased stream and spring discharge (32%)
  - 1,100,000 acre-ft of additional groundwater storage (32%)



Gingerich and others (2024)

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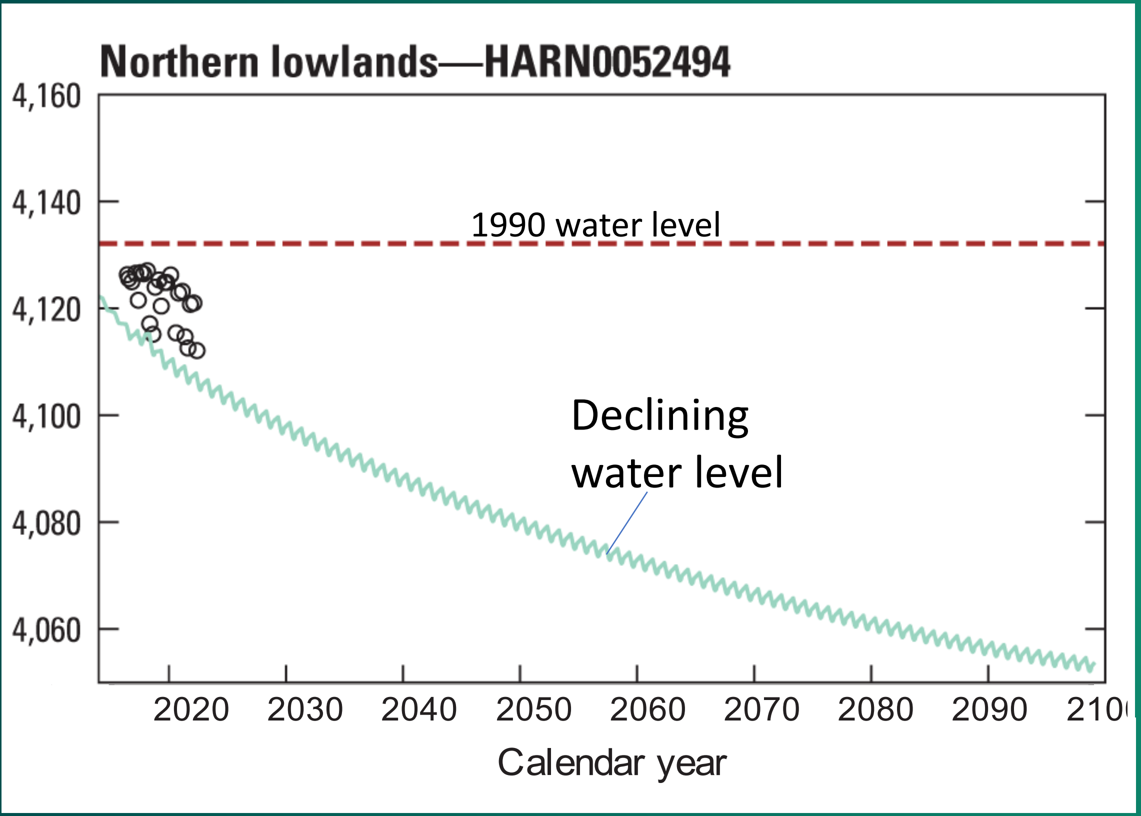
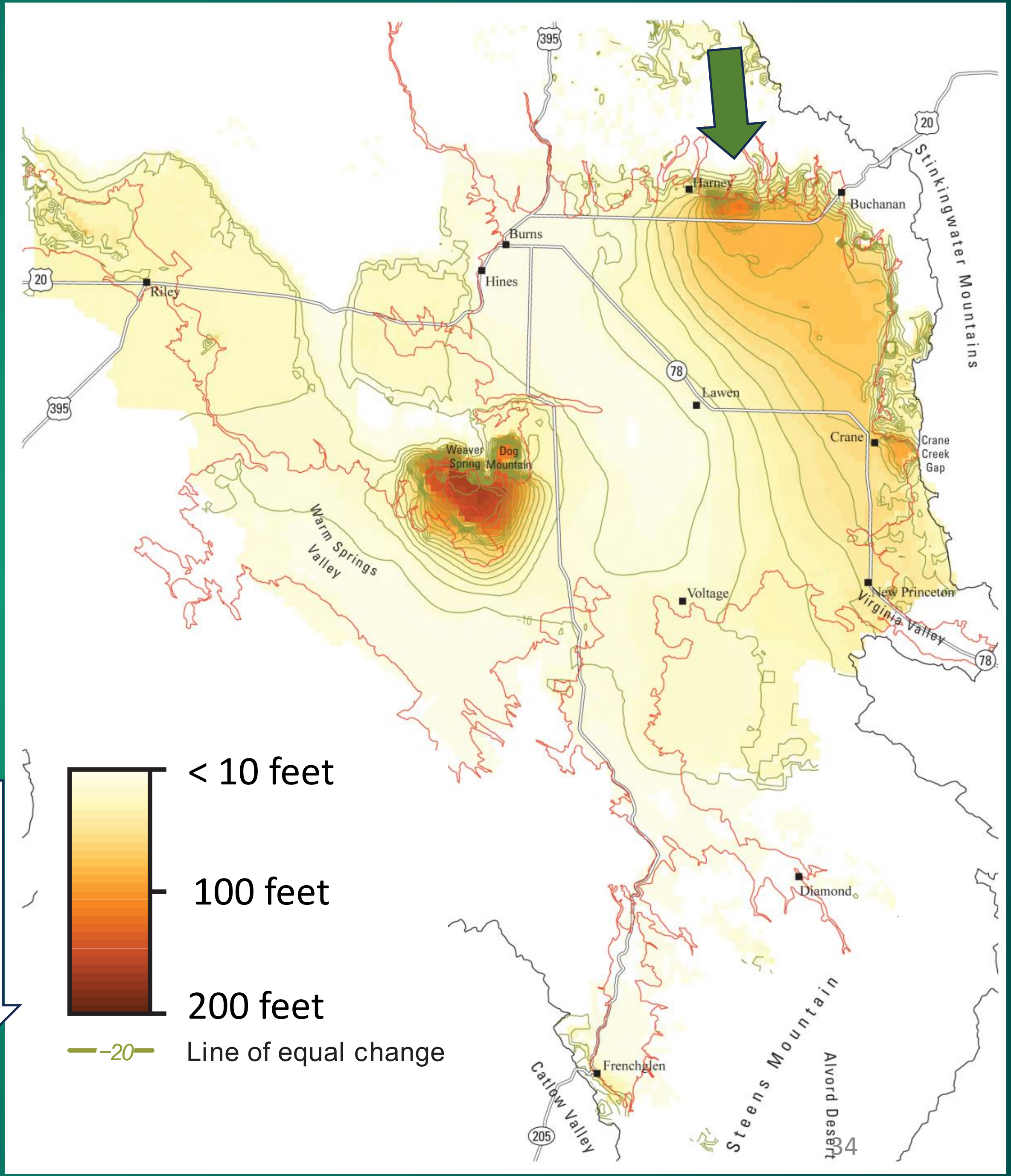
Future Scenario 1: continue 2018 pumpage until 2100



Increasing drawdown



Gingerich and others (2024)

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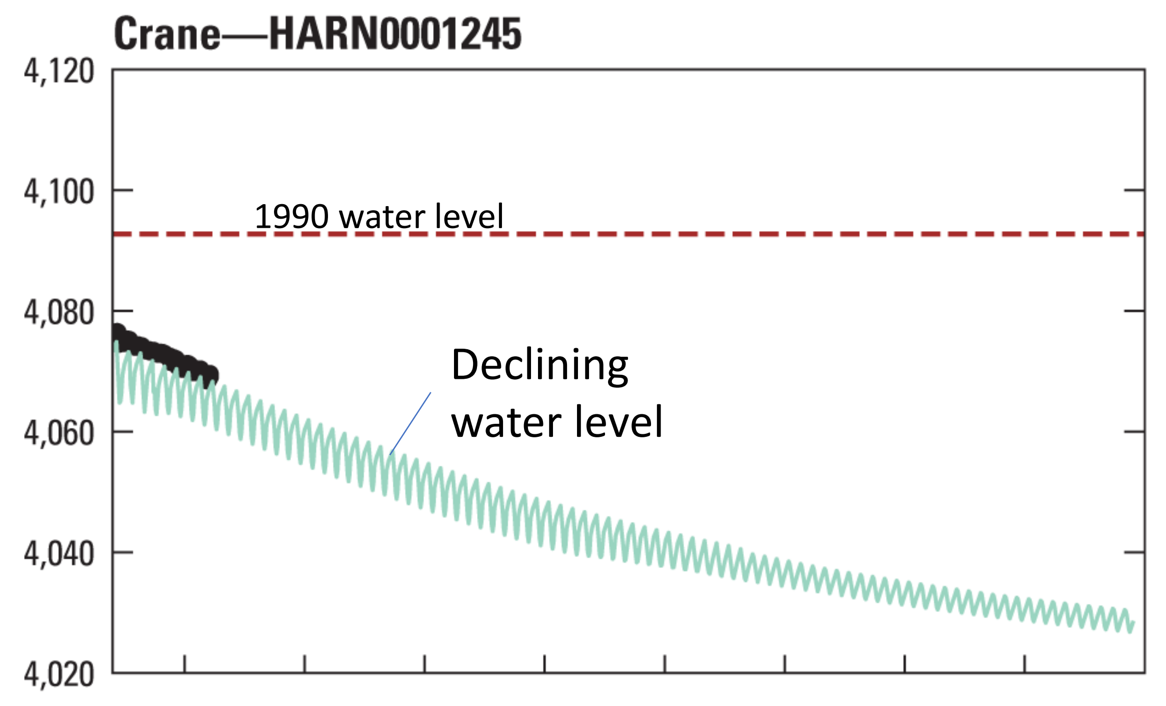
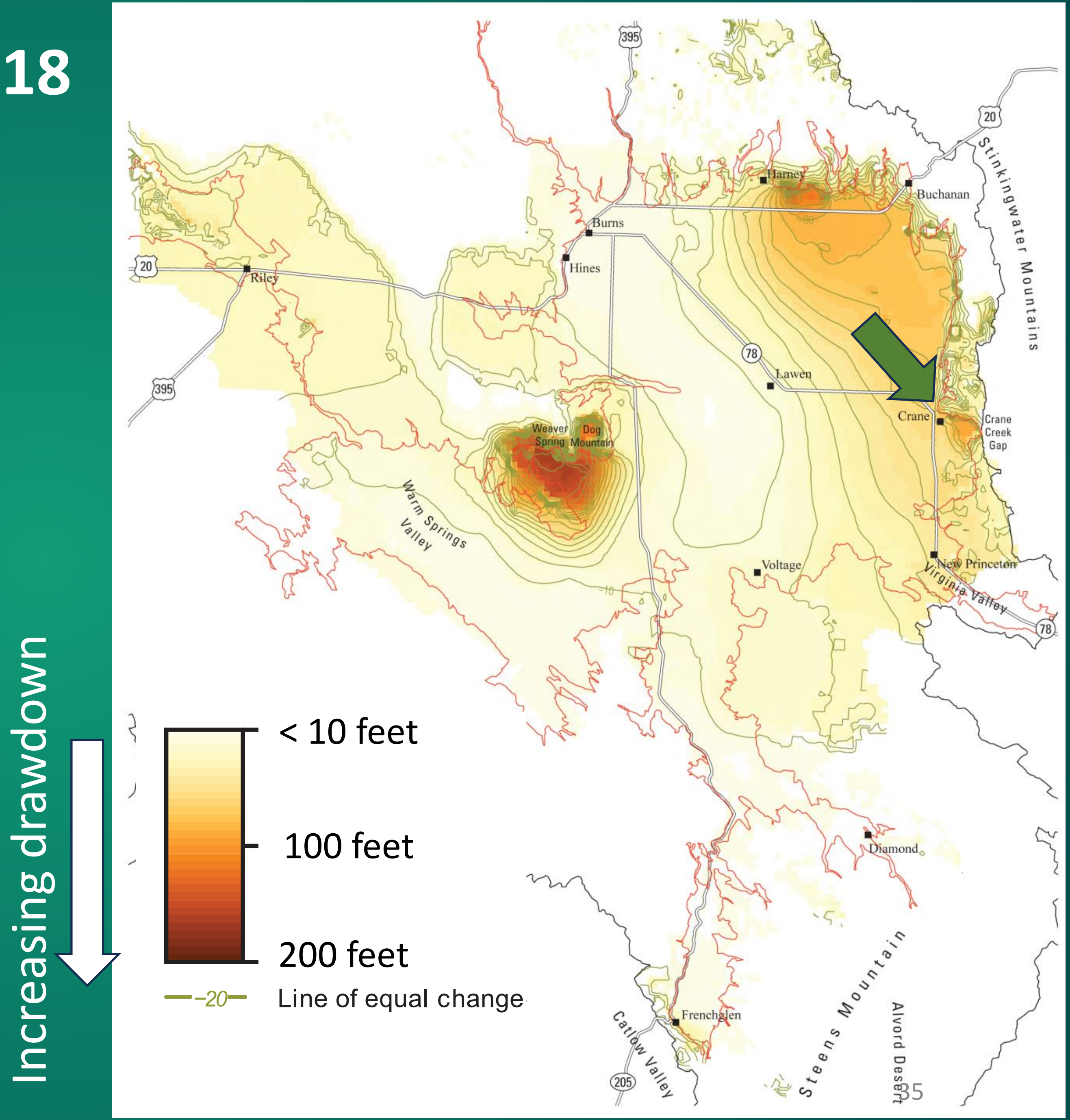
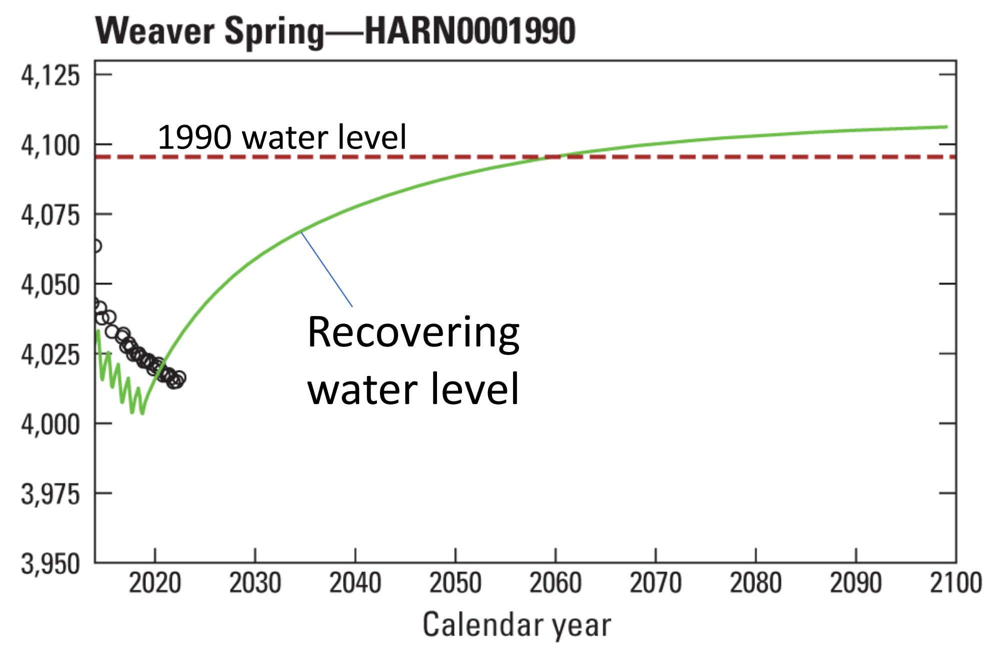


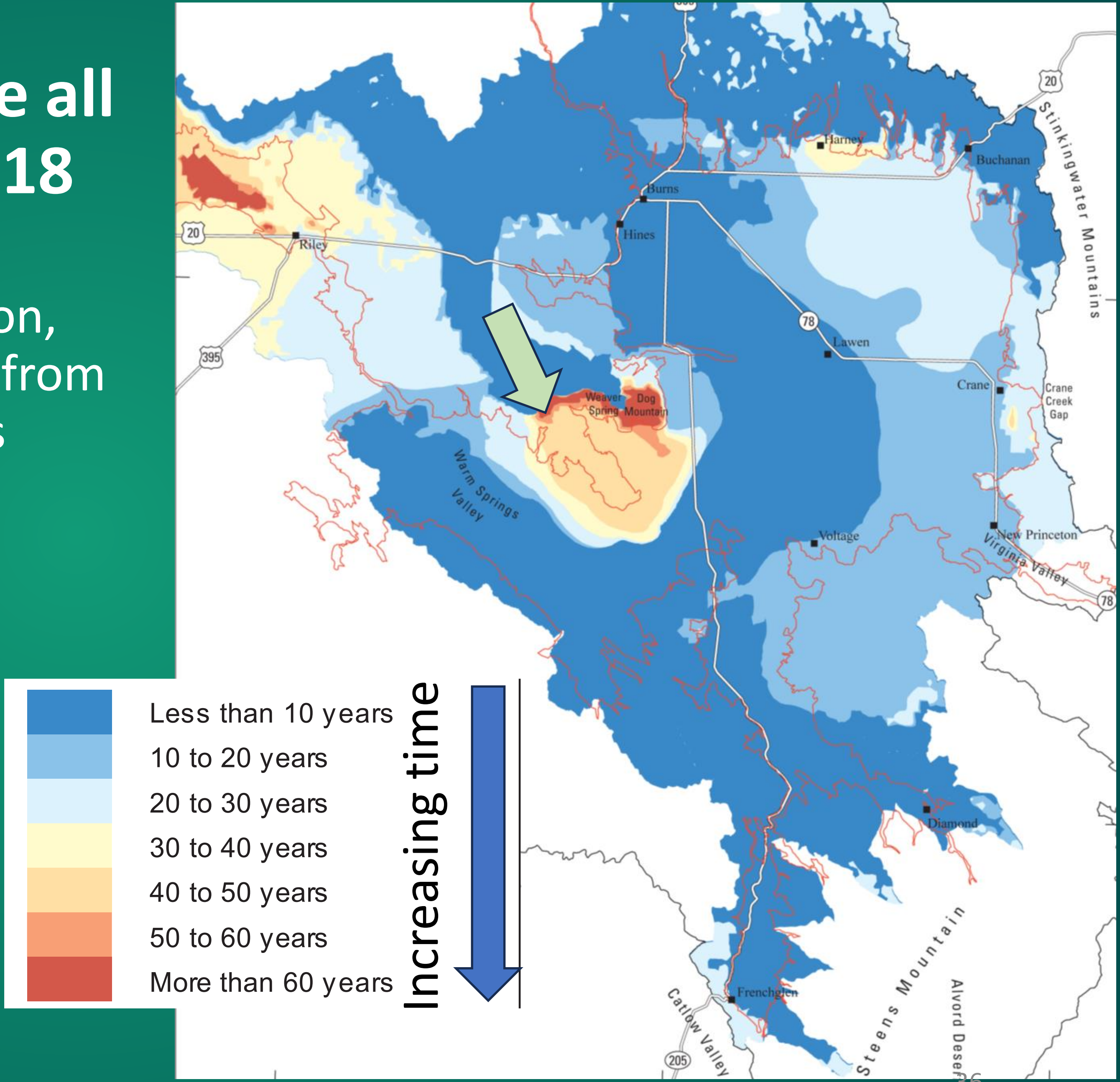


Gingerich and others (2024)

Future Scenario 2: discontinue all irrigation withdrawal after 2018

Water table will recover to 1990 condition, depending on location, in times ranging from less than 10 years to more than 60 years





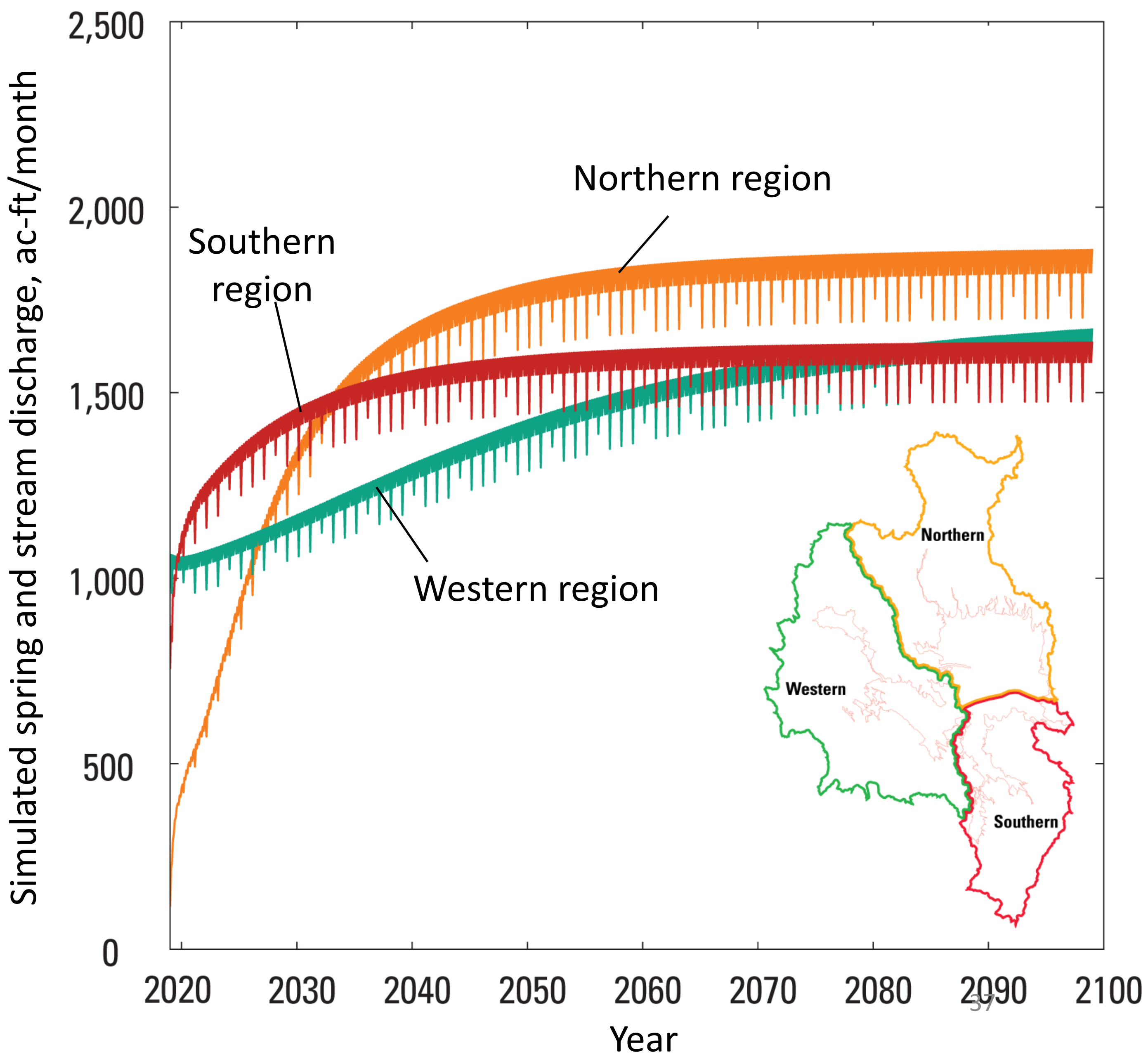
Gingerich and others (2024)

Future Scenario 2: discontinue all irrigation withdrawal after 2018

Spring and stream discharge in the Western region is still recovering 80 years after withdrawal stops

The Northern region recovers the most

The Southern region recovers the fastest



Gingerich and others (2024)

Future Scenario 2: discontinue all irrigation withdrawal after 2018

Increase in stream and spring discharge by 2100

Increase in discharge ↑

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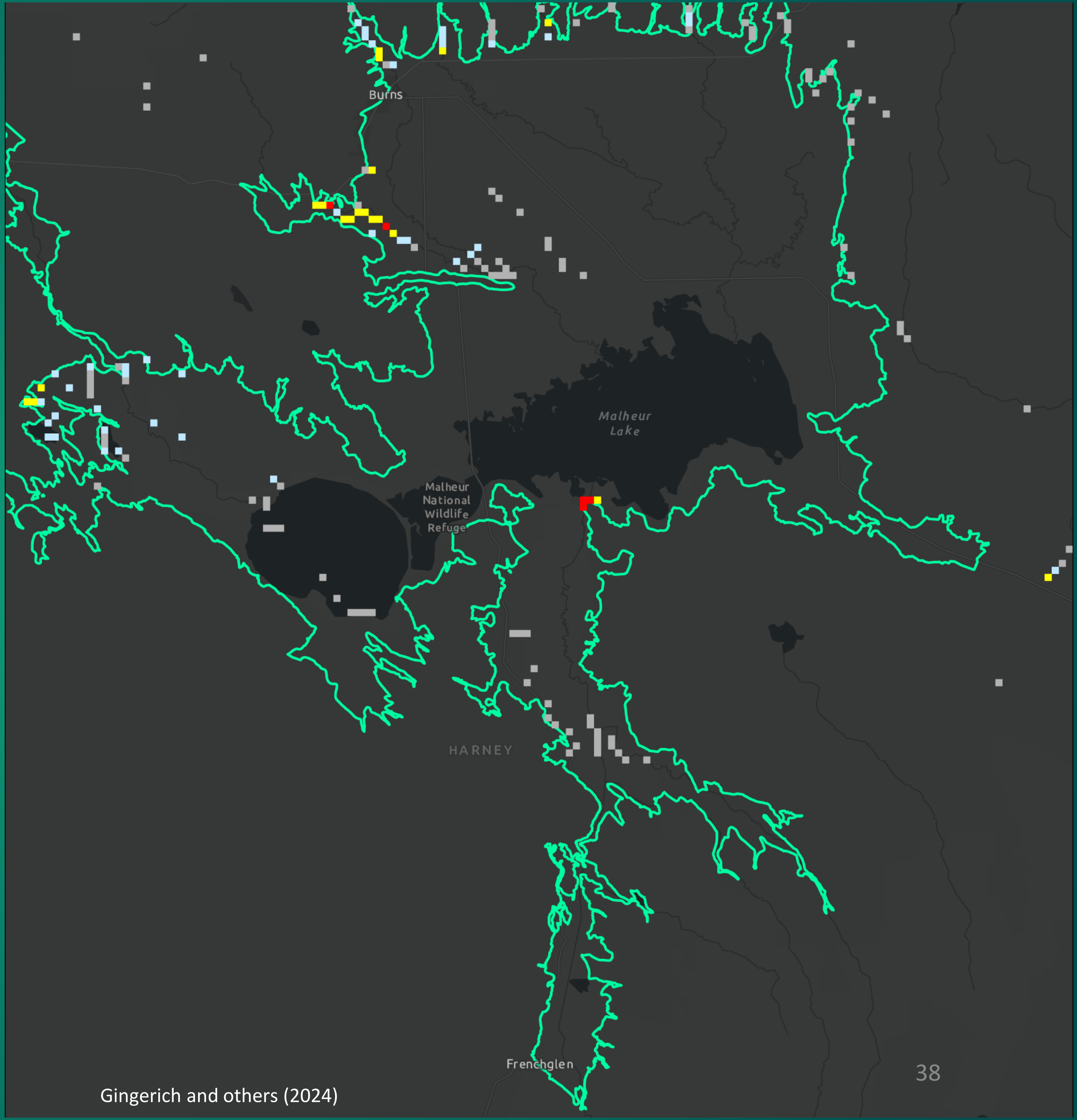


Gingerich and others (2024)

Take home messages

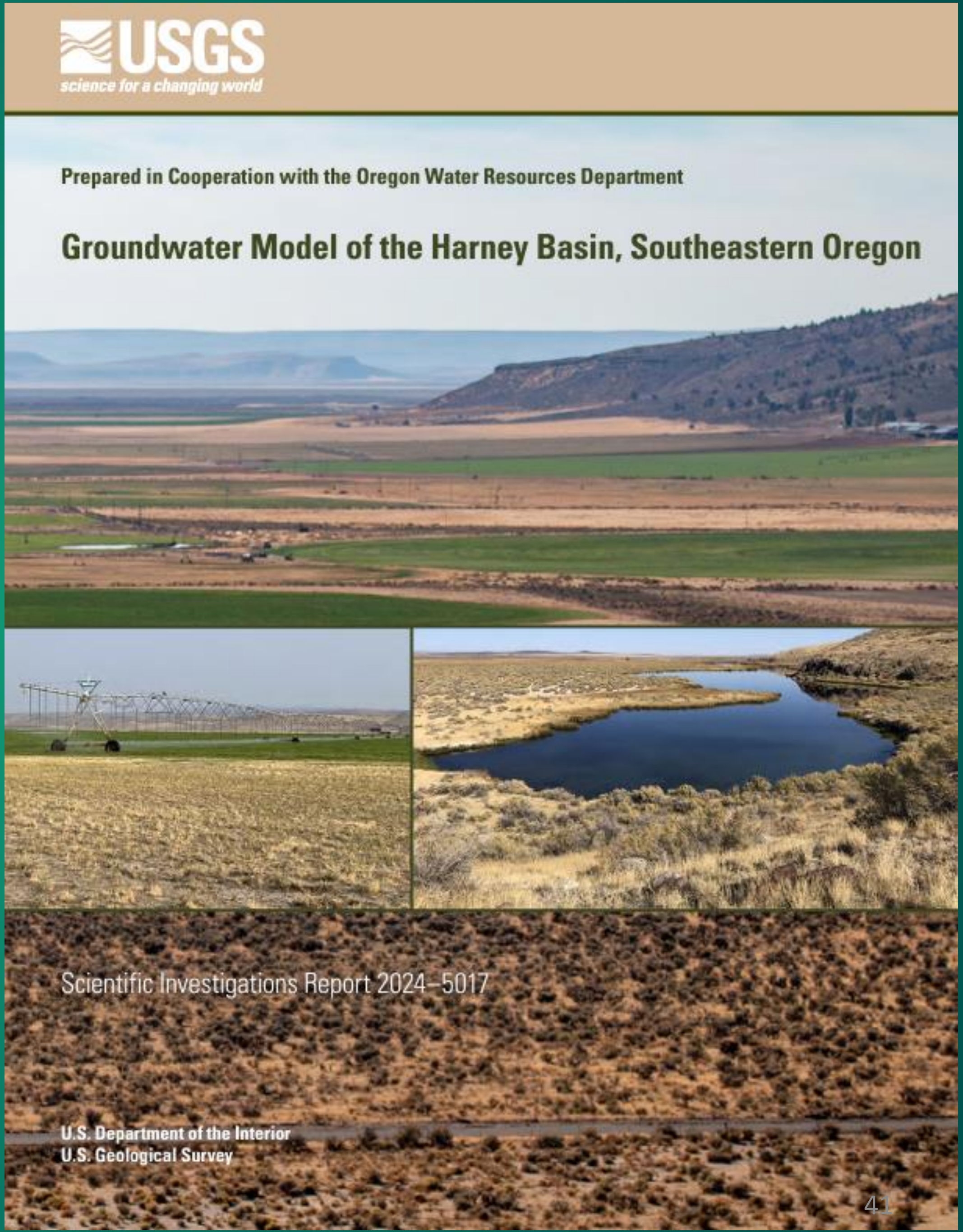
- The Harney Basin Groundwater Model is able to match 80 years of historic measurements of upland base flow and lowland water-level decline
- Historic withdrawal captured natural discharge and reduced storage:
  - Evapotranspiration (35%),
  - Stream and spring discharge (32%),
  - Groundwater storage (32%)
- Continued withdrawal at 2018 rates will lead to deeper and more widespread declines
- If all irrigation pumping stops, timing of water-table recovery varies spatially
  - At least 60 years to recover in areas with heavy pumping and little recharge
  - 10 years in areas under recharge sources

Coming Soon!

- The Harney Basin Hydro-Economic model: linking the dynamics of the groundwater system with crop irrigation decisions and farm economic outcomes
- Collaboration between USGS and OSU Dept. of Applied Economics (Bill Jaeger, John Antle, Dan Bigelow)
- We simulate 30-yr future scenarios using alternative management choices

Questions?

Check out the new report for more details



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Groundwater Model of the Harney Basin, Southeastern Oregon

Scientific Investigations Report 2024–5017

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U.S. Geological Survey

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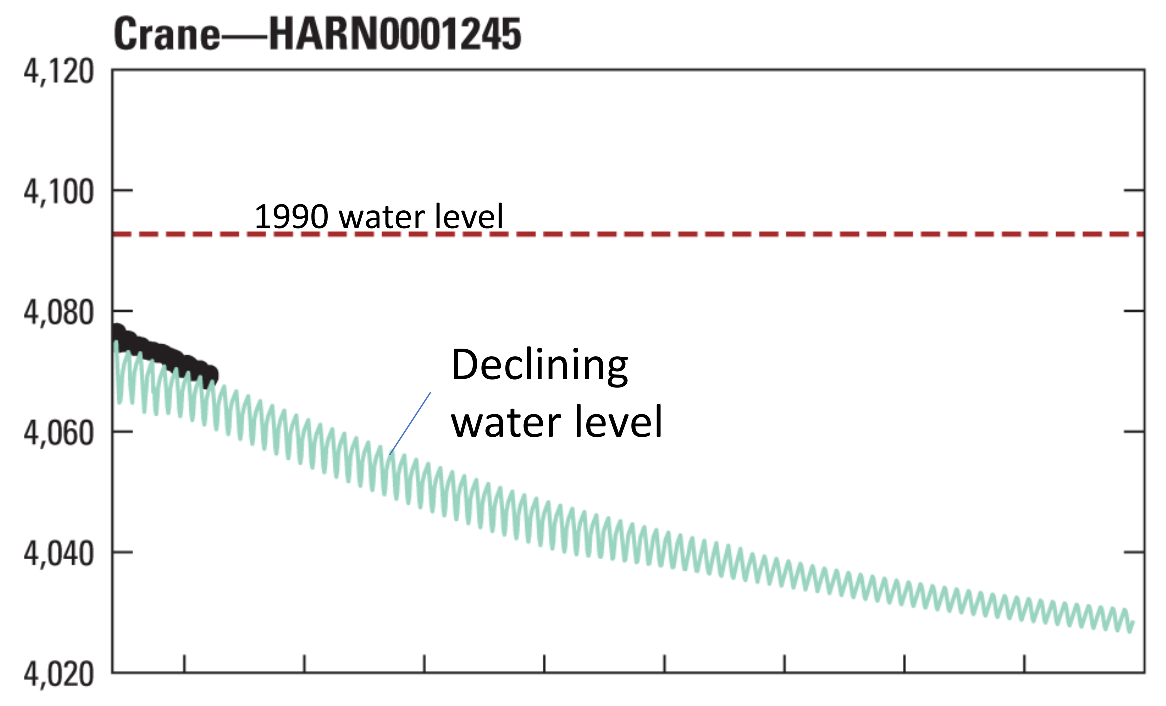
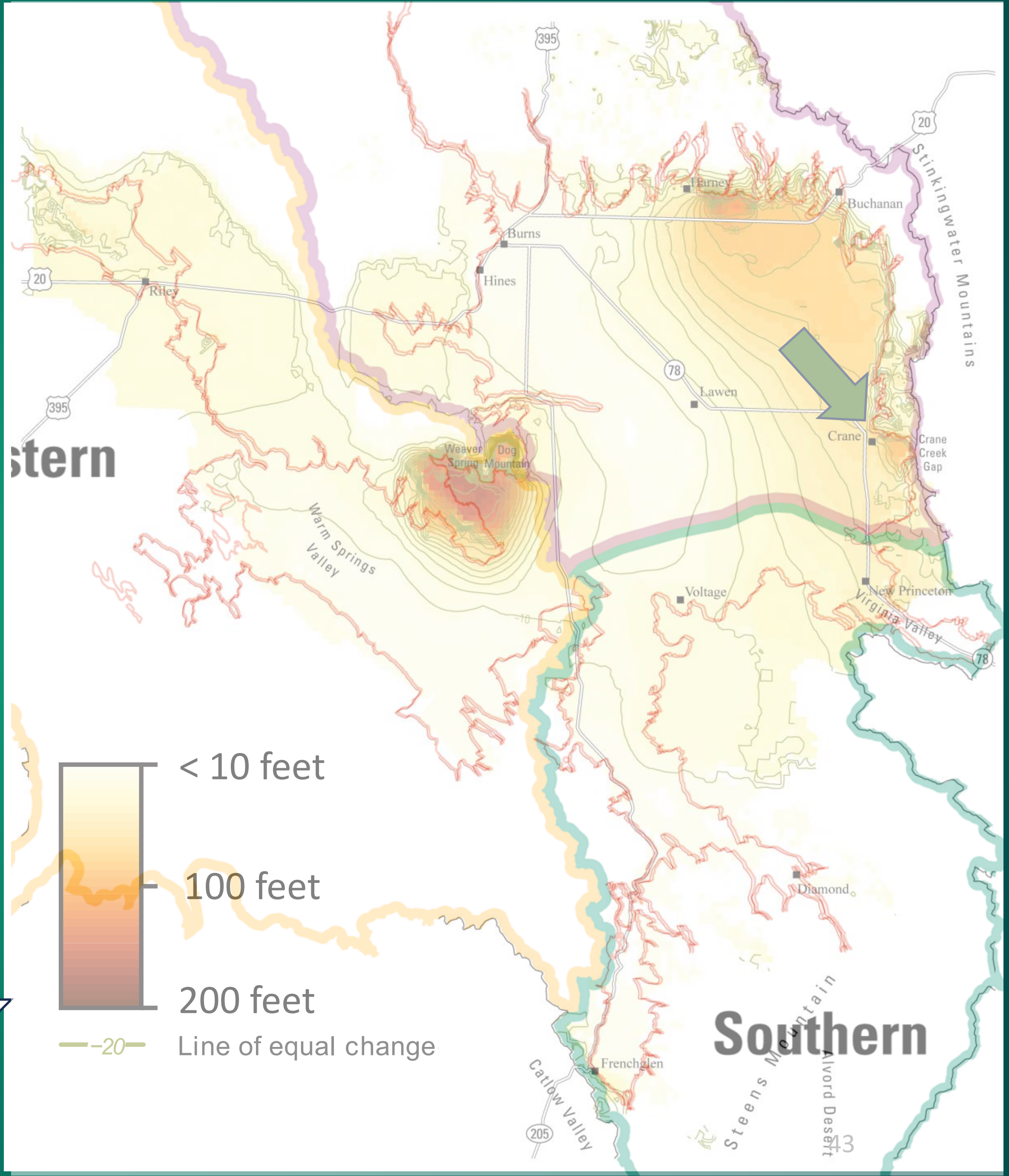
Future Scenario 1: continue 2018 withdrawal until 2100



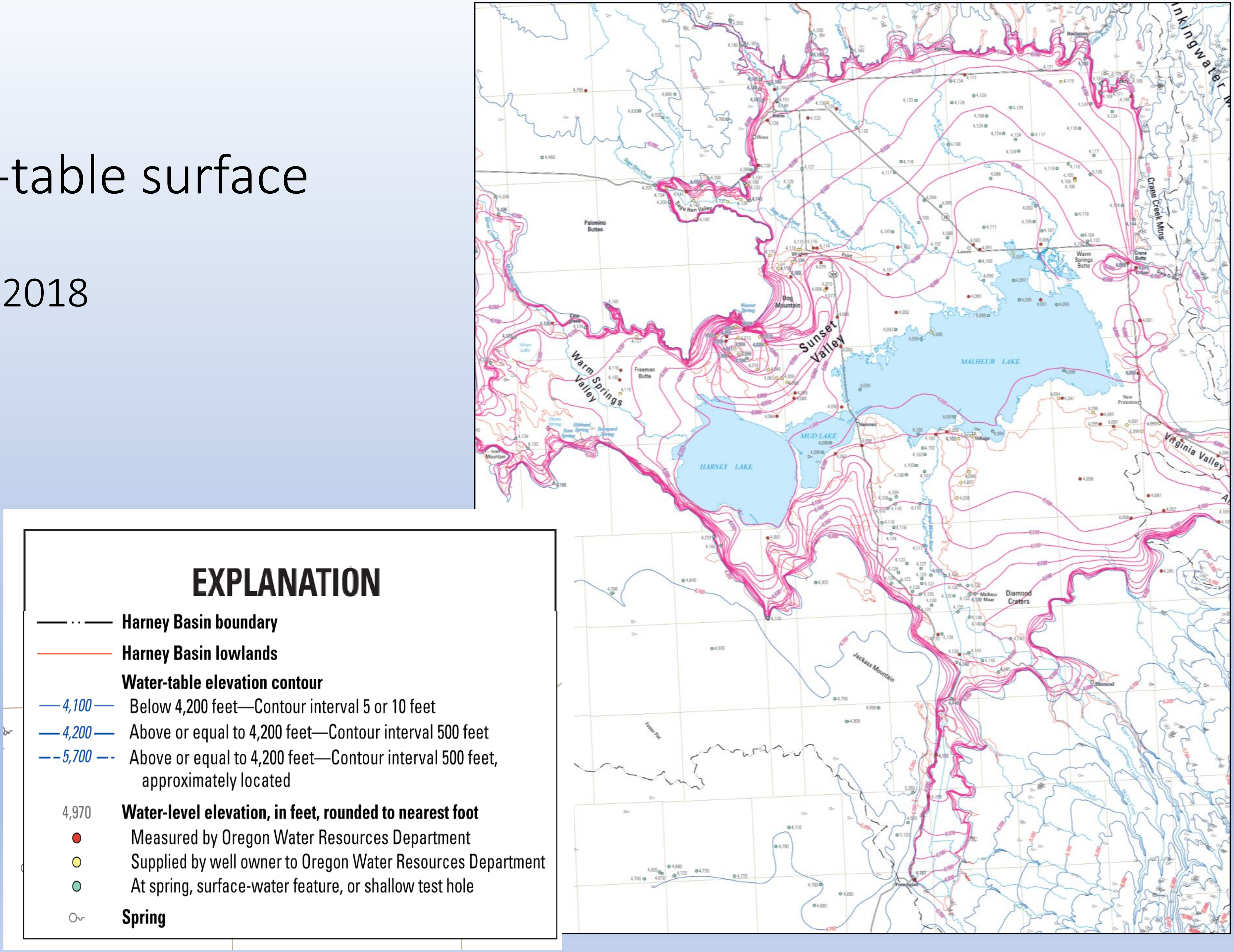
Increasing drawdown



Gingerich and others (2024)

Lowland water-table surface

Winter 2018



EXPLANATION

—·-— **Harney Basin boundary**

—— **Harney Basin lowlands**

Water-table elevation contour

- 4,100 — Below 4,200 feet—Contour interval 5 or 10 feet
- 4,200 — Above or equal to 4,200 feet—Contour interval 500 feet
- 5,700 - - Above or equal to 4,200 feet—Contour interval 500 feet, approximately located

4,970 **Water-level elevation, in feet, rounded to nearest foot**

- ● Measured by Oregon Water Resources Department
- ● Supplied by well owner to Oregon Water Resources Department
- ● At spring, surface-water feature, or shallow test hole

O~ **Spring**