Groundwater Budget for the Mountain Home Area, Irrigation Year 2023

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

In cooperation with the
Idaho Department of Water Resources

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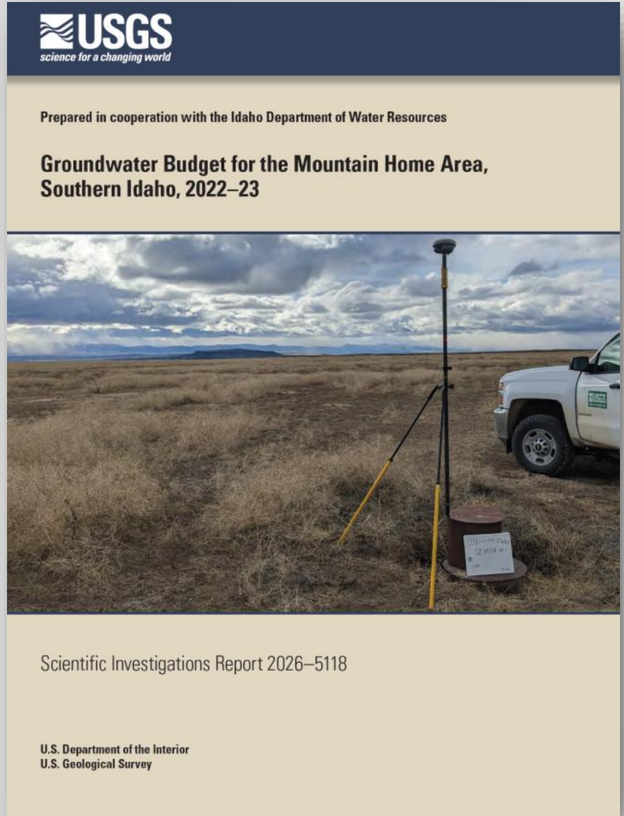
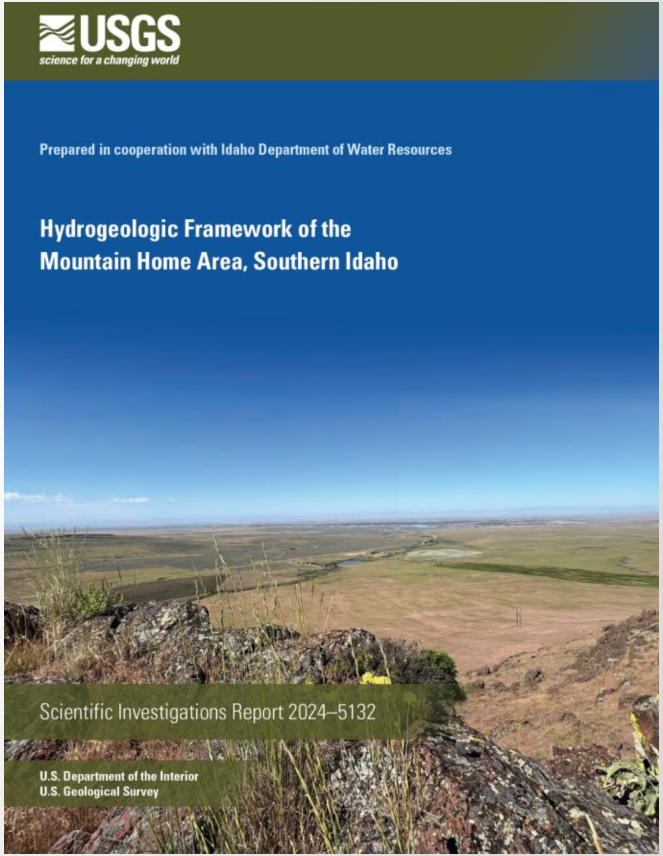


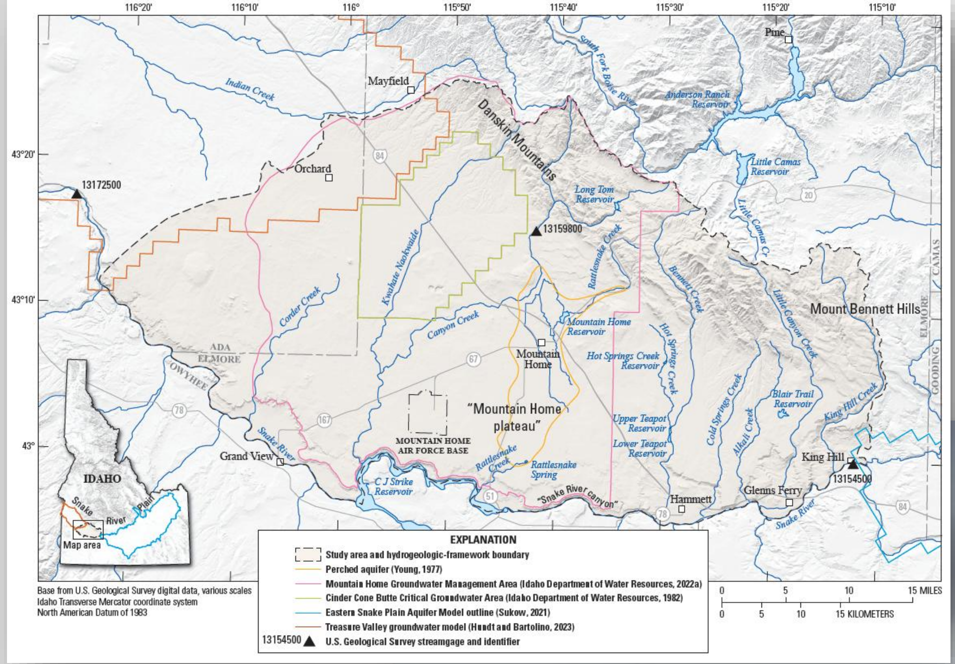
Source Material

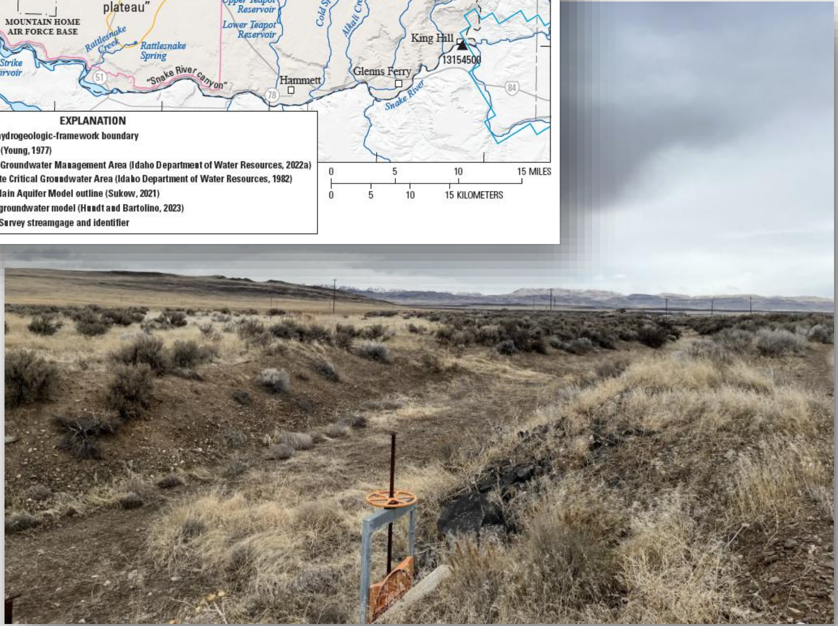
- SIR 2026-5118
- Paul Thomas

Additional Info

- SIR 2024-5132
- Lauren Zinsser & Scott Ducar







Motivation

- Surface water resources are limited
- Groundwater levels are declining

Goals

- Improve hydrogeologic understanding
- Inform water management
- Support current groundwater-flow modeling efforts

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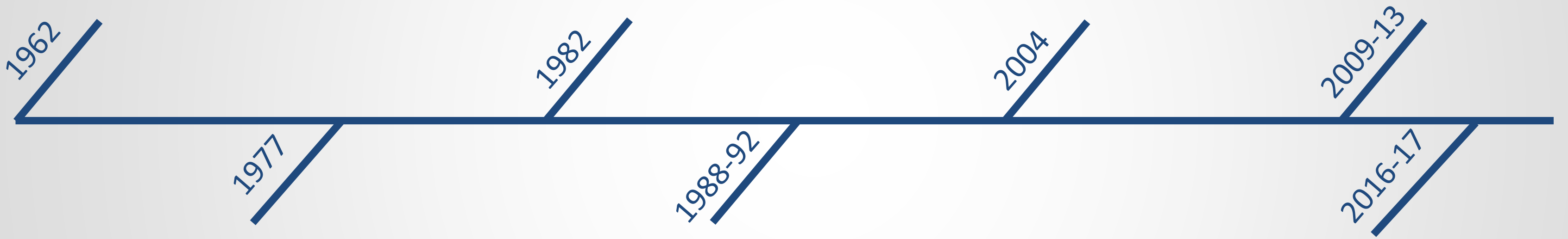
Previous Hydrogeologic Work

First extensive hydrogeologic investigation specific to Mountain Home:
- Ralston and Chapman, 1962

Review of hydrogeology around Cinder Cone Butte and included groundwater-levels:
- Norton and others, 1982

Update of groundwater budget for Mountain Home Plateau:
- Harrington, 2004

Mayfield studies:
- Aquifer recharge: Tesch and Vincent, 2009, Hopkins, 2013
- Geology: Phillips and others, 2012
- Hydrogeologic conditions: Welhan, 2012 and Tesch, 2013



Groundwater levels, delineated perched groundwater extent, and first to describe declining groundwater levels near Cinder Cone Butte:
- Young, 1977

Snake River Plain regional aquifer studies:
- GW-levels: Lindholm and others, 1988
- GW budget and flow model: Newton, 1991
- Geohydro Framework: Whitehead 1992

Water supply studies MHAFB and Elmore County:
- SPF, 2016
- SPF, 2017

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Approach

- Hydrogeologic framework, [Zinsser and Ducar (2025)]
    - Groundwater occurrence, movement, change
        - Hydrogeologic framework model
        - Groundwater-level synoptic
        - Long-term groundwater level monitoring
- Groundwater budget – [Thomas (2026)]
    - Single-year analysis **Nov. 2022 – Oct. 2023**
    - Three accounting zones
        - Cinder Cone Butte (CGWA)
        - Mountain Home (GWMA)
        - Rest of study area (RoSA)
    - Large positive residuals mostly due to exclusion of GW discharge to Snake River

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Groundwater Budget: Quantifying inflows and outflows

Methods & Approach

- **Remote sensing data:** Readily-available satellite imagery and data products to monitor environmental changes and map land use over time.
- **Field data:** Comparison to water levels, stream flows, diversions, pumping rates
- **Formalized mass balance equations:** Physically-based conceptual models
- **"Pro forma" results:** Calculations include assumptions, and individual components are compared to previous estimates, but no secondary interpretation/adjustment of budget results to align with prior assumptions based on expert knowledge
    - The product is in the approach – reproducible and adaptable.
    - **Residuals are presented as a record of uncertainty, not a proxy for excluded flow terms**

Groundwater Budget: Quantifying inflows and outflows

- **Focus Areas**
  - **Cinder Cone Butte Critical Groundwater Area** — **CGWA**
  - **Mountain Home Groundwater Management Area** — **GWMA**
  - **Rest of Study Area** — **RoSA**

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Groundwater Budget: Quantifying inflows and outflows

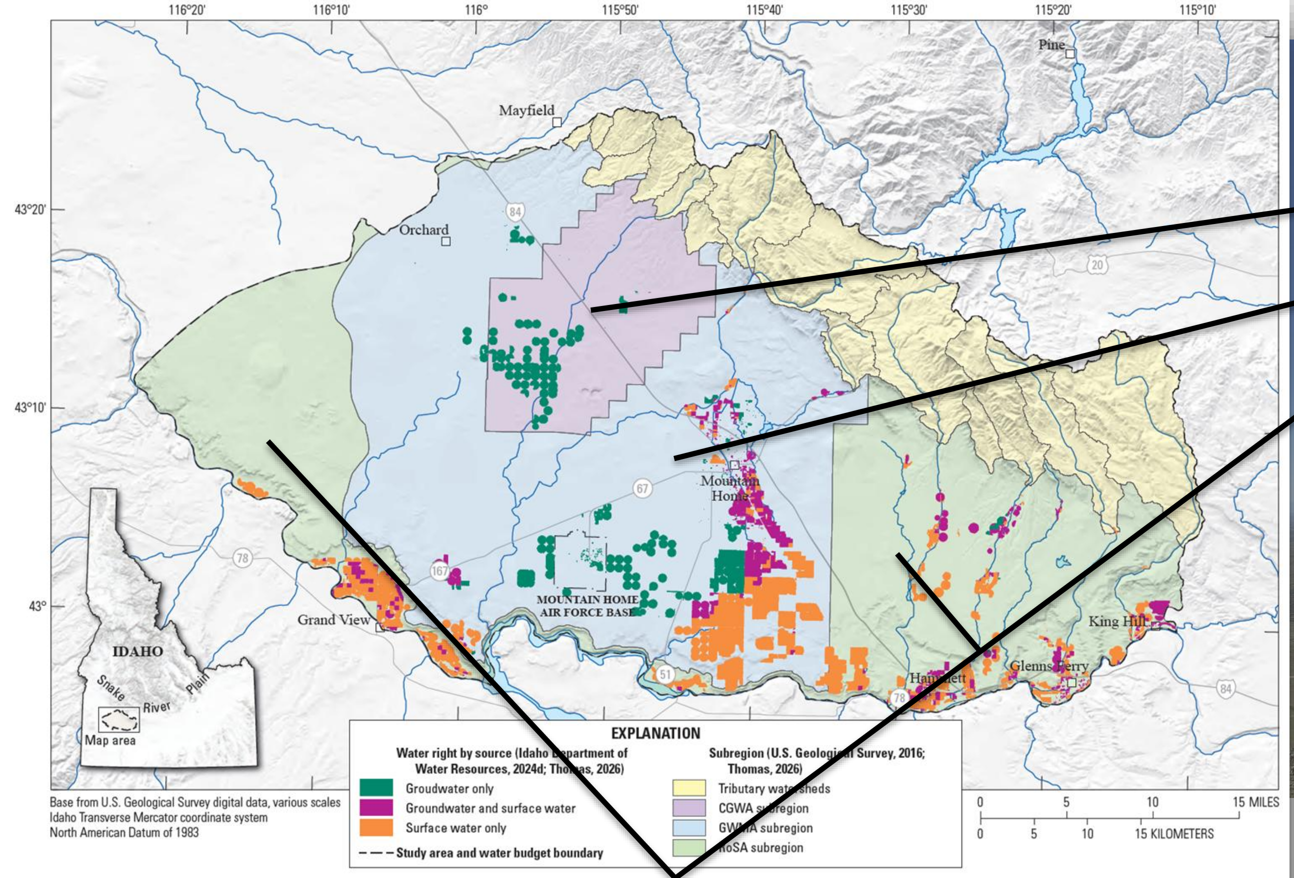
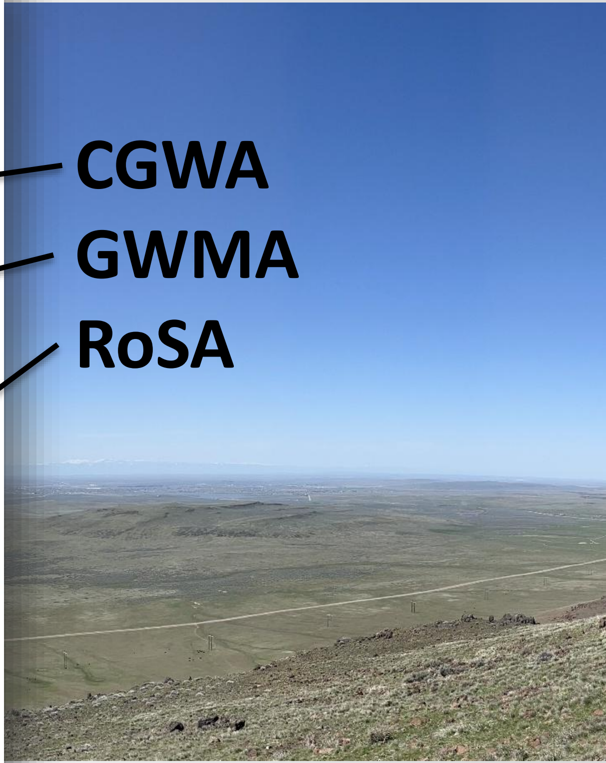


Figure 2. Map showing irrigated lands (intersected with water-right place of use), water budget subregions, and contributing tributary watersheds, Mountain Home area, southern Idaho. [CGWA, Cinder Cone Butte Critical Groundwater Area; GWMA, Mountain Home Groundwater Management Area; RoSA, rest of the study area]



Groundwater Budget: Quantifying inflows and outflows

- **Study Period**
  - **Irrigation <u>Year</u> 2023**
  - **Nov. 1, 2022 through Oct. 31, 2023**
  - **End of period aligns with groundwater synoptic study** (Zinsser & Ducar, 2025) **of Irrigation <u>Season</u> 2023**
  - **High data availability**
  - **Close to mean annual precipitation and Canyon Creek flow volume**

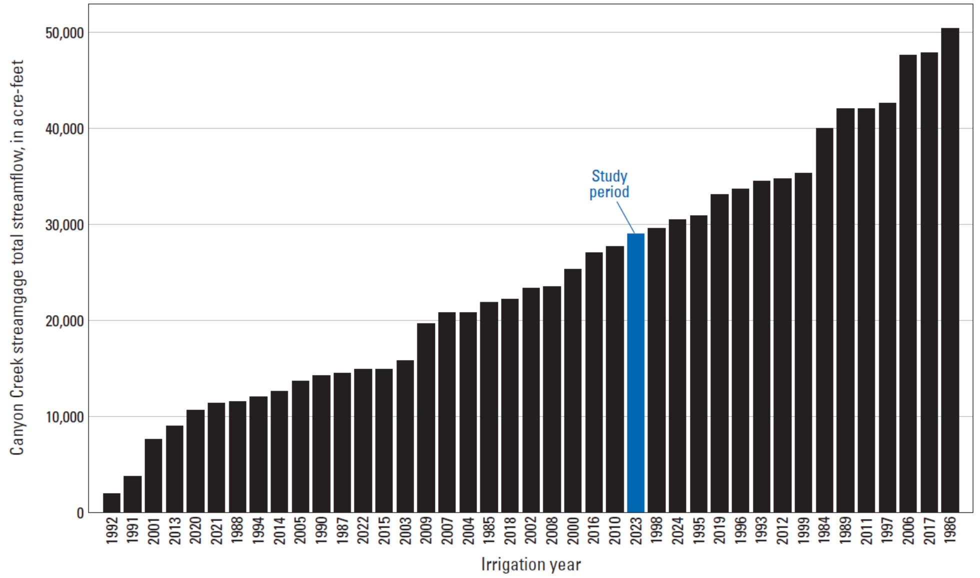


Figure 6. Graph showing total yields for Canyon Creek during irrigation years 1984–2023, Mountain Home area, southern Idaho. Data are from U.S. Geological Survey (2024). Bars are organized from smallest to largest annual yield. An irrigation year is the 12-month period from November 1 through October 31 of the following year and is designated by the calendar year in which it ends.

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Groundwater Budget: Inflow and Outflow Components 2023

- Inflows
  - Areal recharge
  - Recharge from tributary watersheds
  - Recharge of applied water
  - Mountain block recharge
- Outflows
  - Groundwater Pumping
  - Livestock operations
- Residuals
  - Discharge to Snake River
  - Other unmeasured flows
  - Uncertainties

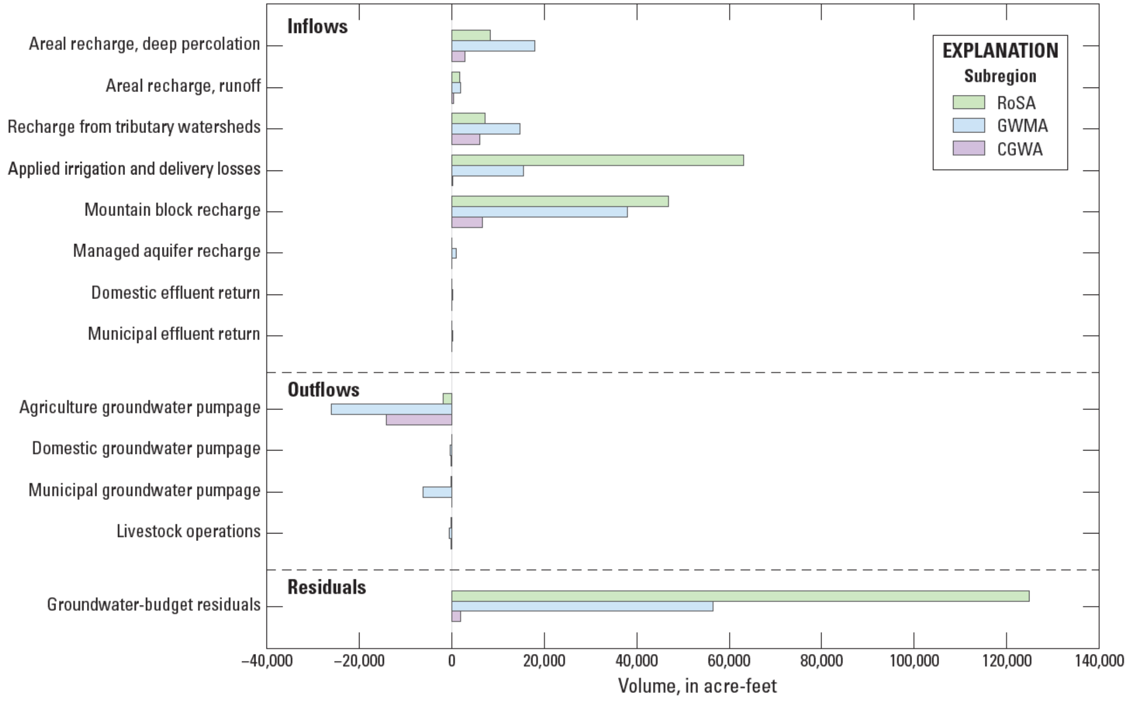

Figure 3. Bar graph of the inflows, outflows, and overall groundwater residuals (including change in storage, budget component uncertainty and errors, along with groundwater discharge to the Snake River) from the irrigation year 2023 water budget for the Mountain Home area, southern Idaho. Data are from Thomas (2026). An irrigation year is the 12-month period from November 1 through October 31 of the following year and is designated by the calendar year in which it ends. [CGWA, Cinder Cone Butte Critical Groundwater Area; GWMA, Mountain Home Groundwater Management Area; RoSA, rest of the study area]

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Inflows: Areal Recharge

- Source data:
  - ET-IDWR outputs 2008-2020
  - USDS Cropland Data Layer (CDL)
  - GridMET I.Y. 2023 precipitation
- Coverage:
  - Non-irrigated lands outside of tributary basins
  - Irrigated lands during non-irrigation season
- Method:
  - Deep percolation & runoff fractions of precipitation calculated from ET-IDWR data for each land type
  - Spatially averaged by area and over period 2008-2020
  - Fractions applied to total I.Y. 2023 GridMet precipitation volume

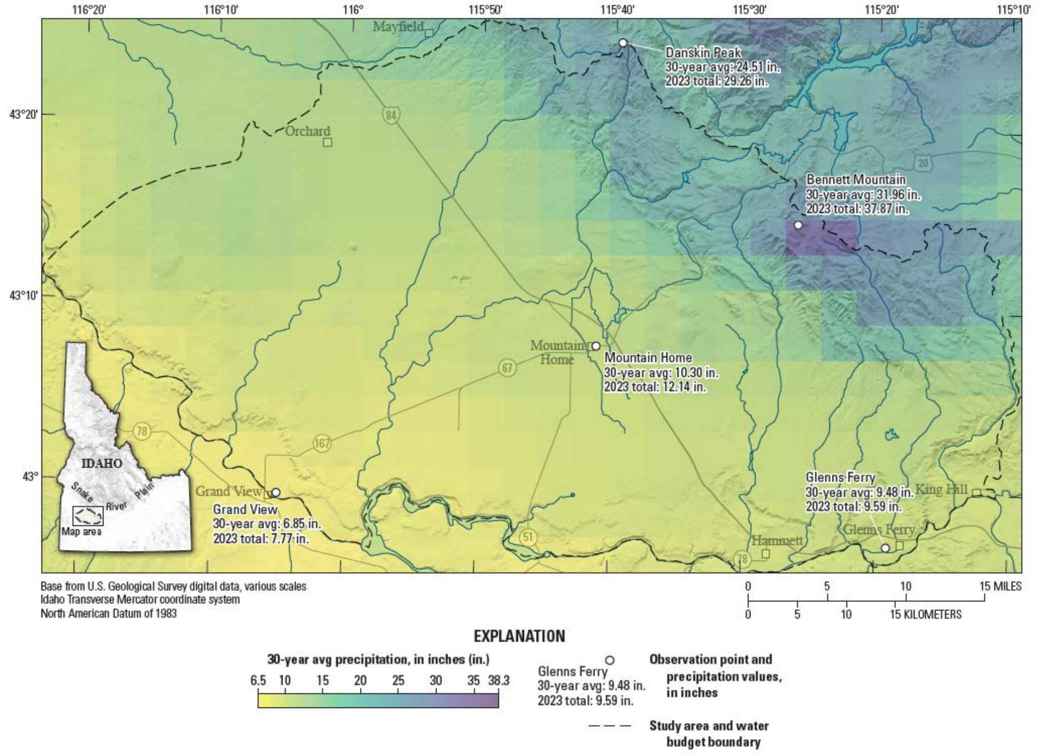

Figure 4. Map showing the average annual precipitation levels for irrigation years 1993–2022 (30-year average [avg]) and the total precipitation for irrigation year 2023 at select observation points, Mountain Home area, southern Idaho. Precipitation volumes estimated from gridMET (Abatzoglou, 2011, undated). An irrigation year is the 12-month period from November 1 through October 31 of the following year and is designated by the calendar year in which it ends.

Inflows: Areal Recharge

- Notes:
  - Both deep percolation and runoff are counted as recharge, with the assumption that runoff does not reach the Snake River.
  - A portion of simulated run-off could be lost to ET, lowering effective recharge

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Inflows				
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Areal recharge, deep percolation	2,874	18,028	8,276	29,178
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Applied irrigation and delivery losses	415	15,580	63,124	79,119
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Residuals[3]				
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Groundwater budget residuals	2,170	56,563	124,933	183,666

[1]Diversions and surface water loss to the Snake River are accounted for in each subregion's "Recharge from Tributary Watersheds" volumes.

[2]Streamflow loss to the Snake River based on historical data with outliers removed. Refer to the "Recharge from Tributary Watersheds" section for methodology.

[3]The residuals are large owing to limited data and assumptions regarding the budget components. For more information, refer to the following sections: "Budget Components," "Groundwater Budget Residuals," "Changes in Groundwater Storage," "Groundwater Discharge to Snake River," and "Uncertainty and Errors in the Groundwater Budget."

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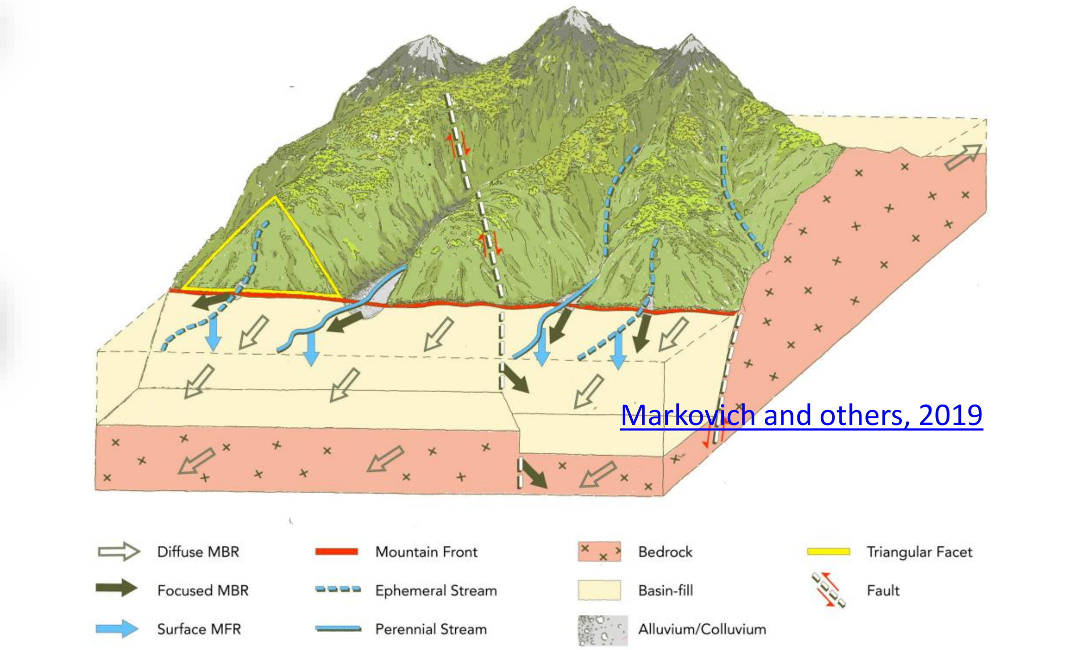
Inflows: Recharge from tributary watersheds

Definitions

- **Mountain Front Recharge**
  - Portion of tributary streamflow considered to infiltrate and recharge the aquifer within the study area

- **Mountain Block Recharge**
  - Deeper subsurface groundwater inflow to aquifer from adjacent mountain block



[Markovich and others, 2019]

Figure 2. Conceptual diagram showing two mountain fronts: a sedimentary contact (far side) between the mountain block and basin fill and a fault-controlled contact (near side). Different components of mountain-front recharge (MFR) and mountain-block recharge (MBR) are also shown, including surface MFR or infiltration through the basin fill from a mountain-sourced perennial or ephemeral stream; focused MBR, which occurs either through discrete faults and fracture zones or underneath mountain-sourced streams; and diffuse MBR, which occurs widely across the mountain front.

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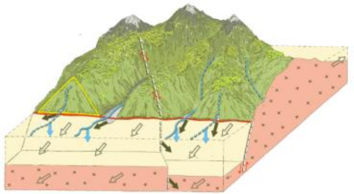
Inflows: Recharge from tributary watersheds



Calculations

- **Mountain Front Recharge** calculated as residual of surface flow produced by tributary basin, plus imports, minus diversions and flow reaching Snake River

Surface MFR

$$Q_{mfr} = Q_{streamflow\_out} + Q_{trib\_import} - Q_{diversions} - Q_{swsnakeriver}$$

- **Mountain Block Recharge** calculated as total precipitation minus sublimation & ET in tributary basin, minus surface flow leaving tributary basin

Diffuse MBR

Focused MBR

$$PR_{trib} - SB_{trib} - ET_{trib} = Q_{streamflow\_out} + Q_{mbr} + \Delta S_{trib}$$

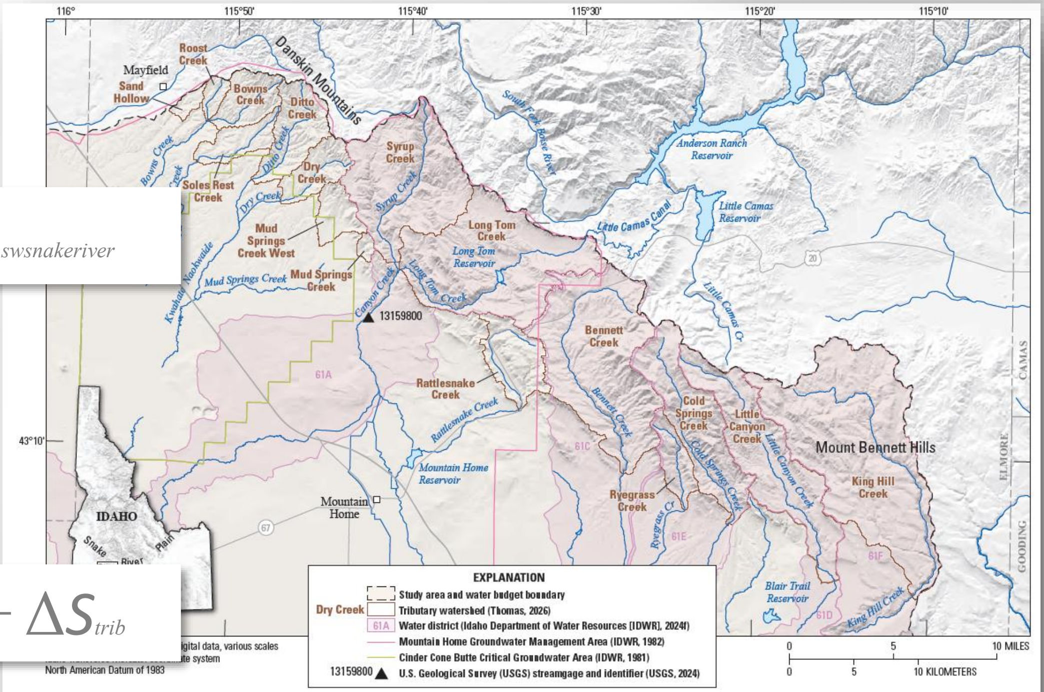


Figure 5. Map showing the tributary boundaries used to extract precipitation and evapotranspiration rates for calculating available precipitation for a tributary water budget, along with Little Camas Reservoir and Little Camas Canal, which serve as external sources of water that are transferred into the Mountain Home area, southern Idaho.

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Inflows: Recharge from tributary watersheds

- Notes
  - Mountain Front Recharge calculated as a quasi-stream loss calculation. Actual recharge to the aquifer could be delayed by years where depth to water table is deep.
  - Mountain Block Recharge is diffuse except along structure-controlled flow paths. Actual annual recharge volume will integrate the effects of several previous years.
  - Canyon creek gage relied on heavily as a proxy for determining streamflow from ungaged basins

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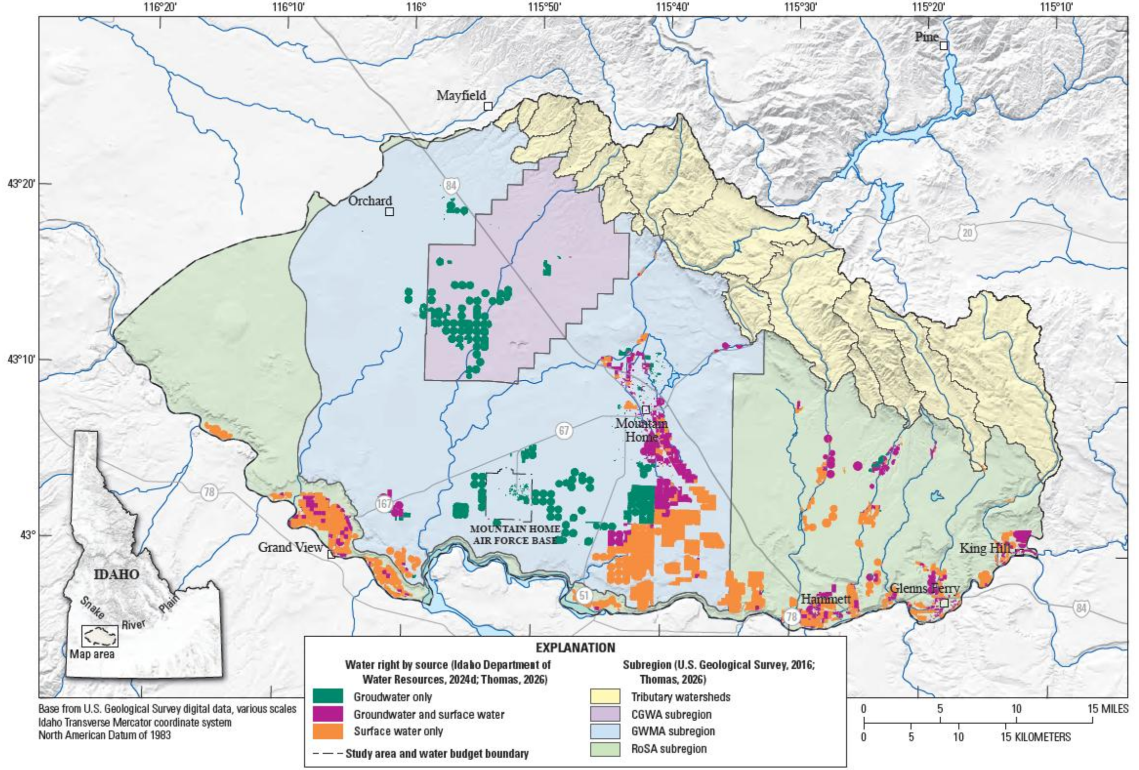
Inflows: Recharge from applied water

- Incidental recharge from:
  - **Irrigation**
- Also from:
  - Return flows
  - Canal seepage
  - Managed recharge
  - Septic system effluent
- CIR calculated as eeMETRIC ET minus gridMET precipitation
- Incidental recharge calculated as applied water minus CIR.

$$V_{losses} = (V_{applied\_gw} + V_{applied\_sw}) - CIR$$



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Inflows: Recharge from applied (irrigation) water

- Applied volumes determined based on water source: GW, SW, mixed
- Delivery volumes collected from WMIS, water master reports, local irrigation districts
- When unavailable, applied volume calculated from CIR and assumed efficiency (gw=0.9, sw=0.7)

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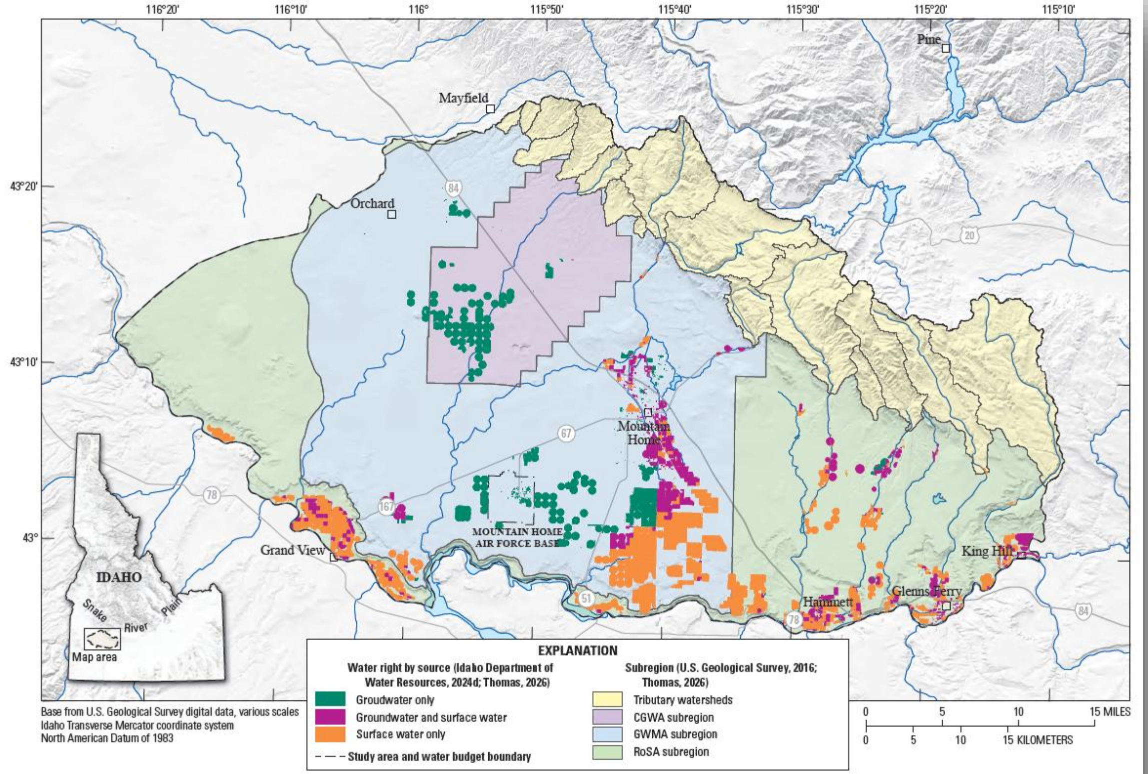

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Table 7. Crop irrigation requirements (CIR), surface water and groundwater diversions, and agricultural losses to the regional aquifer during irrigation and delivery for irrigation year 2023, Mountain Home area, southern Idaho.

[CGWA, Critical Groundwater Area; GWMA, Groundwater Management Area; RoSA, rest of the study area]

Subregion	Irrigated acres (acres)	CIR[1] (acre-foot)	Groundwater pumpage[2] (acre-foot)	Surface water applied[3] (acre-foot)	Losses (incidental recharge) (acre-foot)	Consumptive use[4] (acre-feet per acre)
CGWA	6,829	14,029	14,444	0	415	2.05
GWMA	32,730	73,252	25,793	62,813	15,580	2.24
RoSA	23,237	52,346	1,880	113,590	63,124	2.25
Total	62,797	139,627	42,117	176,404	78,894	NA

[1]Evapotranspiration rates estimated from rasters obtained from OpenET (2024).

[2]Groundwater pumpage rates from Idaho Department of Water Resources (2024g).

[3]Surface water diversions from water district diversion records for 2023 (Idaho Department of Water Resources, 2024h).

[4]Consumptive use calculated as CIR divided by irrigated acres. Refer to the "Recharge from Applied Irrigation" section for more details.

Outflows: Groundwater Pumping

- Pumping for:
  - **Irrigation**
- Also for:
  - Municipal supply
  - Livestock operations
  - Domestic supply
- Taken from WMIS data when/where available,
- Or derived from calculated CIR using assumptions on efficiency of delivery & application.

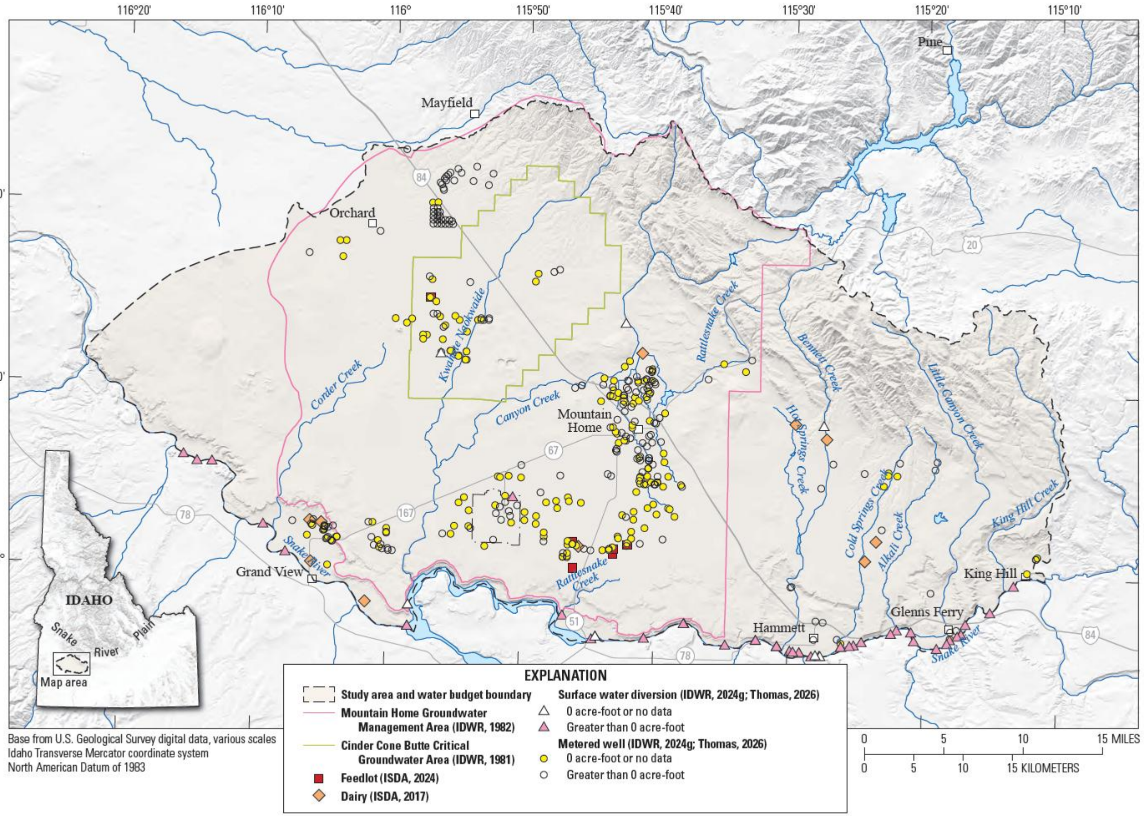

Figure 7. Map showing metered wells and surface water diversions from the Idaho Department of Water Resources (IDWR) Water Management Information System and dairy and feedlot locations from the Idaho State Department of Agriculture (ISDA), Mountain Home area, southern Idaho, for irrigation year 2023. An irrigation year is the 12-month period from November 1 through October 31 of the following year and is designated by the calendar year in which it ends.

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Outflows/Residual: Discharge to Snake River

- Likely a substantial portion of total groundwater outflow from WSRP aquifer
- Difficult to measure because seepage is small relative to streamflow
- Seepage estimates exist **but combine seepage to river from North and South.**
  - King Hill – Murphy

    Model simulation (Newton, 1991): 334k AFY
  - King Hill – CJ Strike

    Seepage Calculation (Woods, 2014): 300k AFY +/- 164k AFY

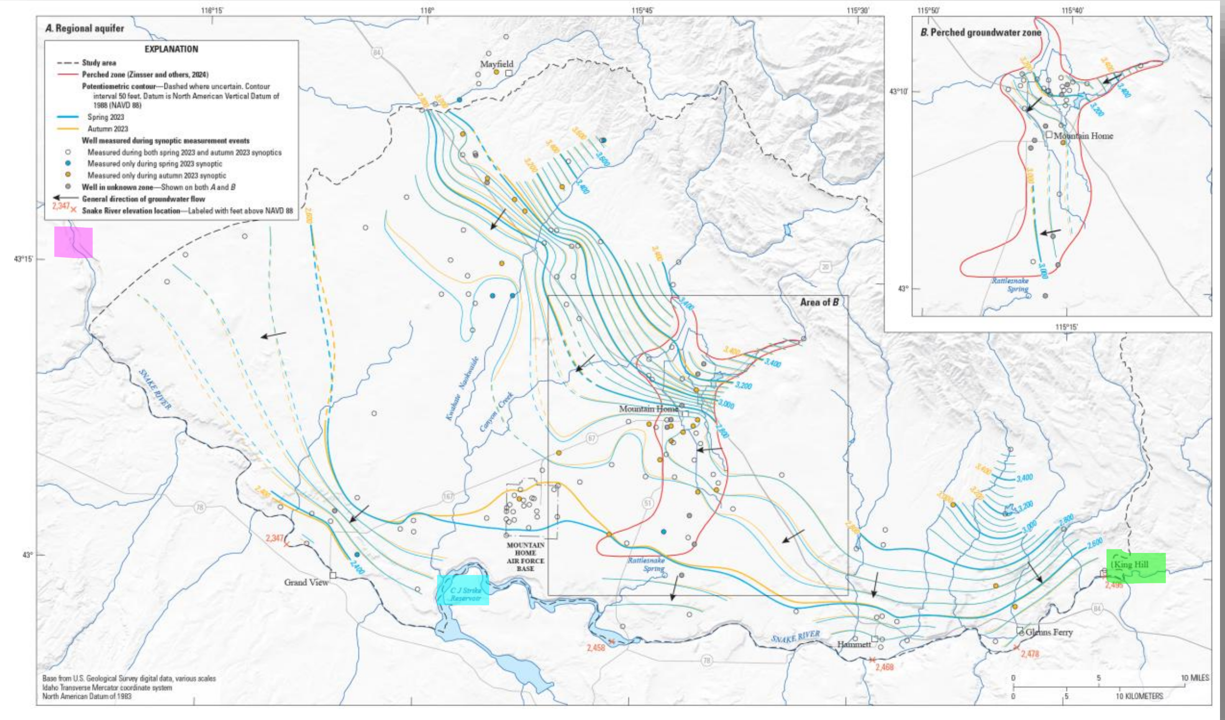

Figure 13. Water-table contours in March and November 2023 for (A), the regional aquifer and (B) the perched groundwater zone, Mountain Home area, southern Idaho (Idaho Department of Water Resources, 2024a; U.S. Geological Survey, 2024; Zinsser and others, 2024).

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Residuals: Inflows minus Outflows = R = ΔS + error

$$Q_{inflow} - Q_{outflow} = R = \Delta S + (\varepsilon_{assumptions} + \varepsilon_{data} + \varepsilon_{temporal} + \varepsilon_{omissions})$$

- Groundwater storage change omitted due to temporal mismatch (“meta” $\varepsilon_{omission}$)
- Exclusion of discharge to Snake River ($\varepsilon_{omission}$)
- Other unmeasured flows ($\varepsilon_{omission}$)
- Uncertainty and error in existing budget items (ε_{data} , $\varepsilon_{temporal}$)
- “Residual” is a budgeting term, not a proxy for physical hydrologic fluxes

Table 2. Water budget for irrigation year 2023 comparing inflows and outflows within the Mountain Home area, southern Idaho.

[Data are from Thomas (2026) and Idaho Department of Water Resources (2023a). All values are given in acre-feet. An irrigation year is the 12-month period from November 1 through October 31 of the following year and is designated by the calendar year in which it ends. CGWA, Critical Groundwater Area; GWMA, Groundwater Management Area; RoSA, rest of the study area ; undet., undetermined]

Budget component	Subregion			Component total
	CGWA	GWMA	RoSA	
Inflows				
Recharge from tributary watersheds[1,2]	6,127	14,740	7,150	28,017
Mountain block recharge	6,689	38,074	46,916	91,679
Areal recharge, deep percolation	2,874	18,028	8,276	29,178
Areal recharge, runoff	385	1,927	1,633	3,945
Applied irrigation and delivery losses	415	15,580	63,124	79,119
Managed aquifer recharge	0	910	0	910
Domestic effluent return	60	247	49	356
Municipal effluent return	0	131	0	131
Total inflows	16,550	89,637	127,148	233,335
Outflows				
Agriculture groundwater pumpage	14,229	26,018	1,880	42,128
Domestic groundwater pumpage	75	309	62	445
Municipal groundwater pumpage	0	6,126	90	6,216
Livestock operations	76	621	182	879
Total outflows	14,380	33,074	2,214	49,669
Residuals[3]				
Storage change	undet.	undet.	undet.	undet.
Groundwater discharge to Snake River	undet.	undet.	undet.	undet.
Groundwater budget uncertainty and errors	undet.	undet.	undet.	undet.
Groundwater budget residuals	2,170	56,563	124,933	183,666

[1]Diversions and surface water loss to the Snake River are accounted for in each subregion’s “Recharge from Tributary Watersheds” volumes.

[2]Streamflow loss to the Snake River based on historical data with outliers removed. Refer to the “Recharge from Tributary Watersheds” section for methodology.

[3]The residuals are large owing to limited data and assumptions regarding the budget components. For more information, refer to the following sections: “Budget Components,” “Groundwater Budget Residuals,” “Changes in Groundwater Storage,” “Groundwater Discharge to Snake River,” and “Uncertainty and Errors in the Groundwater Budget.”

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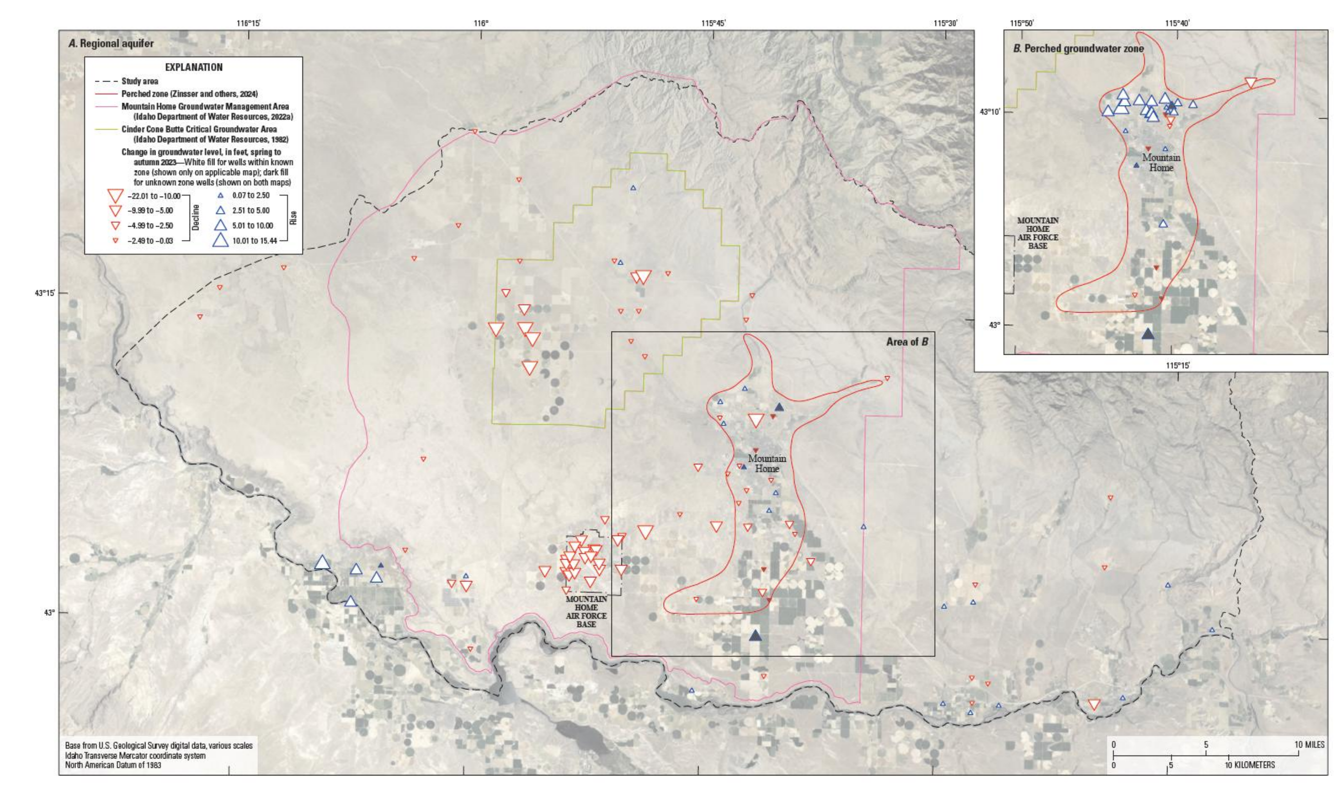
Water Level Change: Spring to Autumn 2023

- Declines in Cinder Cone Butte CGWA and near MHAFB
- Less change east of Mountain Home and far west
- Rise in Snake River canyon
- Rise in perched area with variability related to heterogeneity, groundwater use, and surface water recharge



USGS

Groundwater Storage Change: Spring to Autumn 2023

- Developed groundwater level change raster
- Intersected autumn 2023 water level with 3D model to calculate unit volume
- Estimated storage change using feet of water level change and unit storativity
- Storage change is consistent with annual withdrawal estimates (43,000 acre-ft SPF, 2017) and an annual water-budget deficit (30,900 acre-ft Harrington, 2004)

Table 6. Estimated change in groundwater storage between spring and autumn 2023, Mountain Home area, southern Idaho.

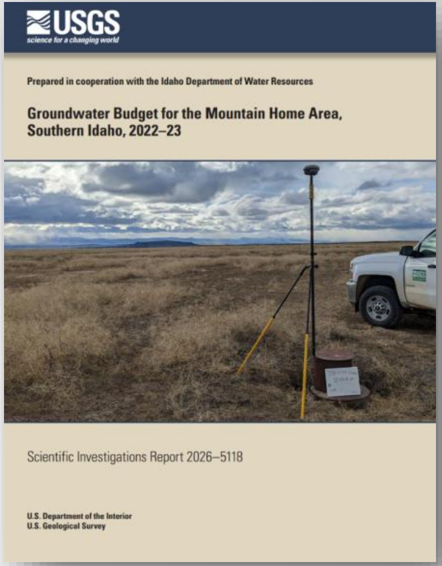
[Data are from Zinsser and others, 2024]

Area	Storage change: Estimated using the storativity presented in table 2		Storage change: Estimated using uniform specific yield of 0.1	Area (acres)
	Total change (acre-feet)	Change range (acre-feet)	Total change (acre-feet)	
Cinder Cone Butte Critical Groundwater Area	–13,620	–3,620 to –23,250	–10,080	80,080
Mountain Home Groundwater Management Area	–23,690	–5,240 to –41,680	–18,910	359,120
Combined groundwater management areas	–37,310	–8,860 to –64,930	–28,990	439,200
Regional aquifer excluding the combined groundwater management areas	4,810	1,230 to 10,670	2,550	265,140
Perched groundwater zone	6,390	1,410 to 11,690	4,820	34,020

USGS

Conclusions

Read all about it!



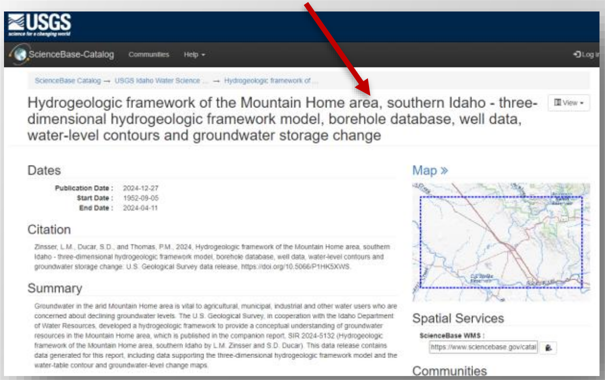
- **Dominant Water Drivers:** Mountain block recharge and applied surface water irrigation were identified as the primary inflows, while groundwater pumping for agriculture was the largest outflow.

- **Positive Budget Residuals:** Positive budget residuals are a formalization of uncertainty, not an indication of surplus water. They are driven primarily by exclusion of discharge to Snake River and/or lateral groundwater flow between focus areas.

- **Significant Uncertainties:** Aside from omission of unknown lateral groundwater flow & discharge to the Snake River, budget accuracy is limited by errors associated with remote sensing precision, and spatial & temporal interpolation.

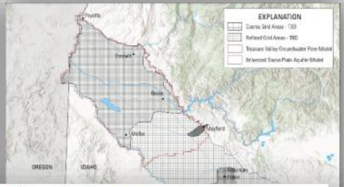
- **Implications for WeSPAM Model:** Several budget components map directly to GW Model inputs. Methods will be reproduced on same/similar data sources over simulation period. Other budget components align with model outputs and can be used as targets to inform parameter selection.

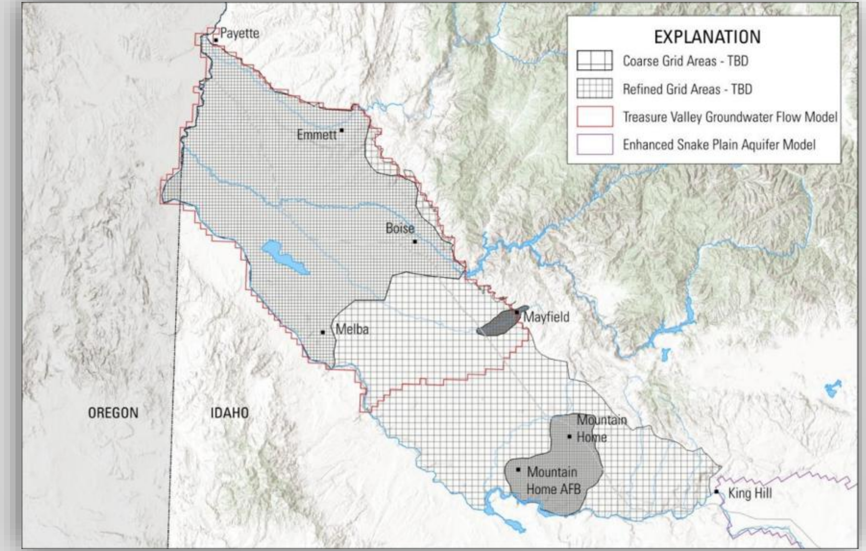
Check out the data!



Implication for WeSPAM

- Budget components → model input
- Budget components ≈→ model input
- Budget components ↔ model output





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Questions?

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