Observation Datasets

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USGS
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Goal of this talk

Briefly introduce role of observation data

Give overview of different observation data sources and processing steps

Present seepage calculations and ask for feedback about approach

Role of observation data in the model

‘Reality Check’

Observation data:

- *Not* for defining model structure
- *Not* for defining boundary conditions
- History-matching (calibration)
- Some are used formally, others informally to constrain parameters

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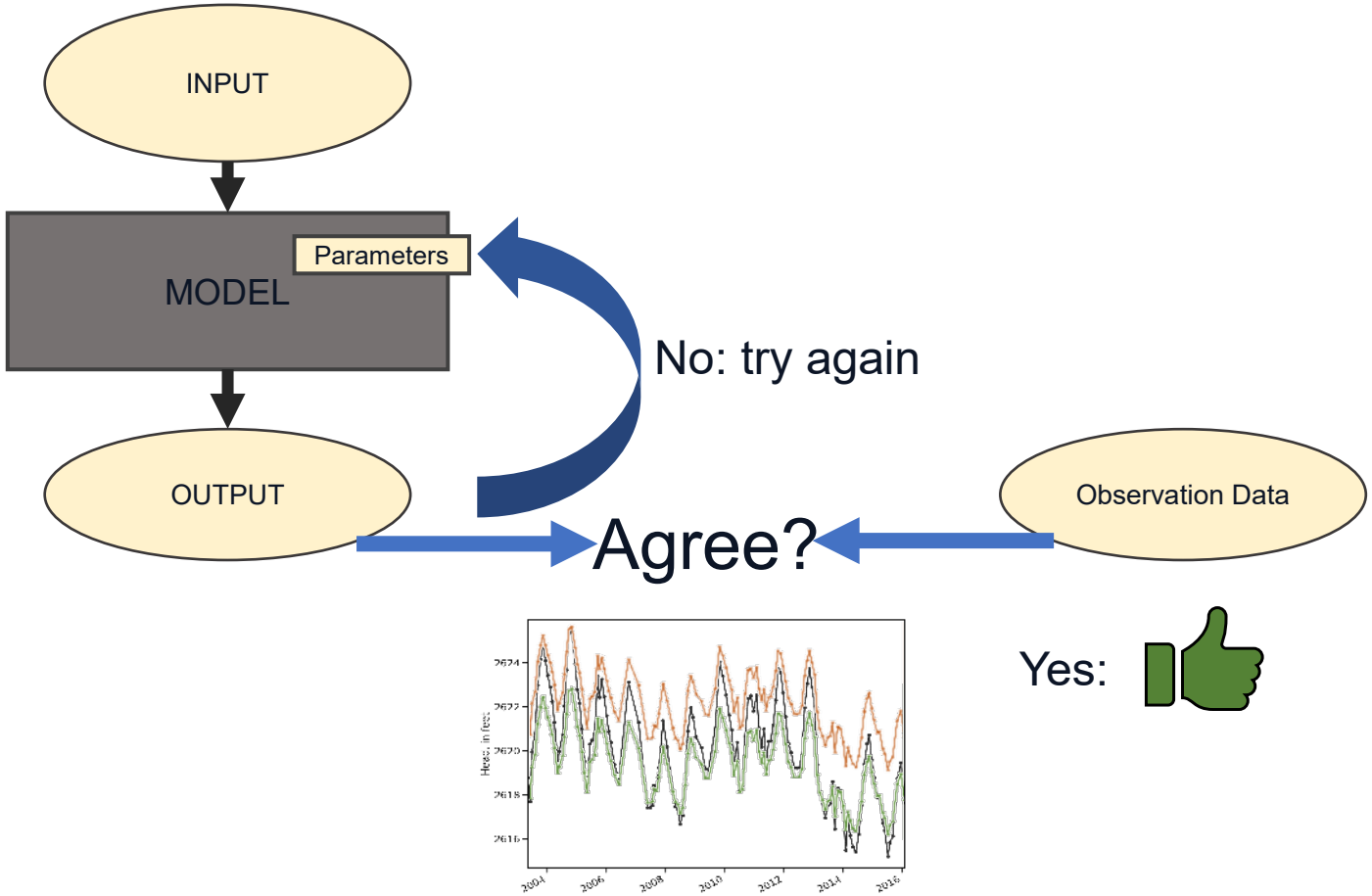


Value of Different Types

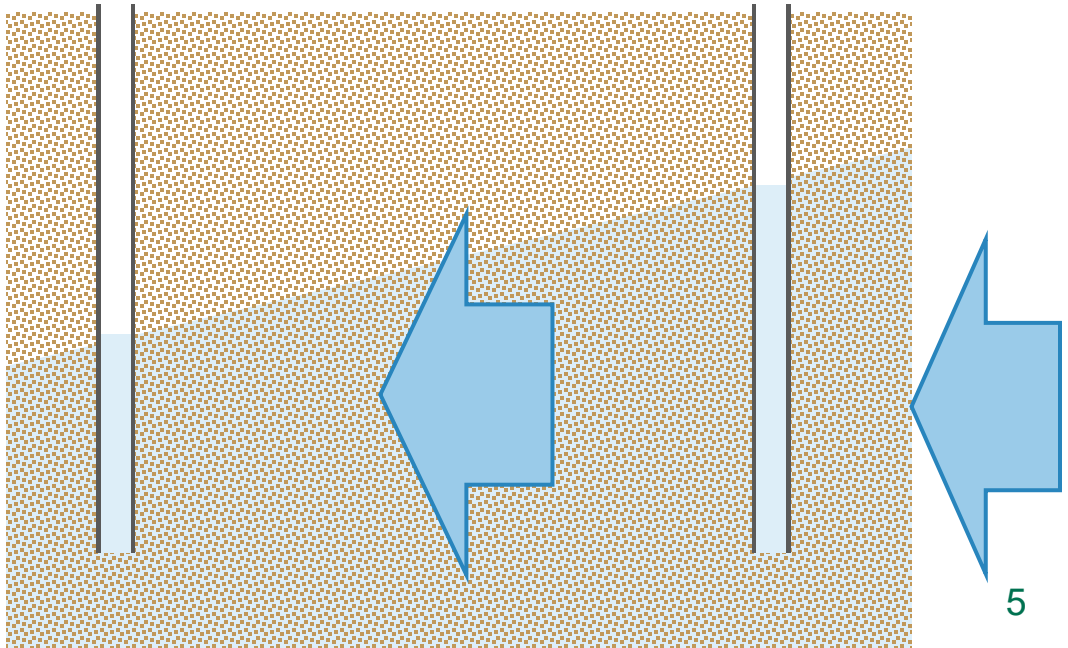
- **Parameter correlation and non-uniqueness**

f(parameter)

$$Q = K\frac{\Delta H}{L}$$

observation

parameter



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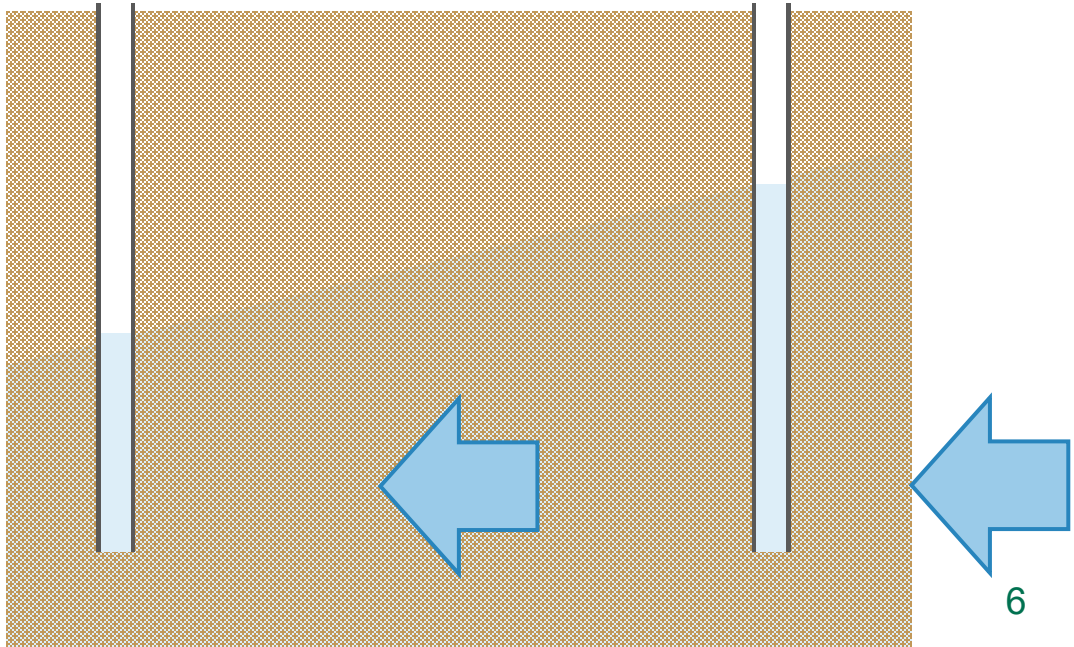

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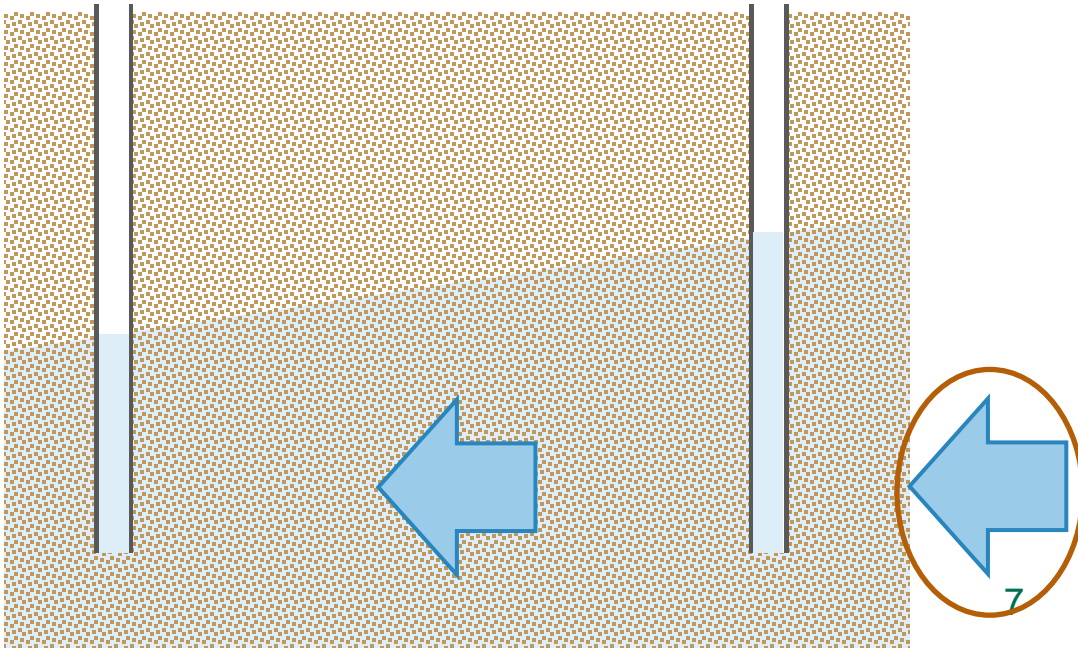

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Value of Different Types

- **Parameter correlation and non-uniqueness**
- **Improved confidence in multi-use model**

Model Objectives

1. **Simulate interactions between surface water and groundwater**
   - Big Lost River modelled as SFR. Model simulating flow and seepage.
   - Relatively small (100's of meters) grid
   - *Maybe* other surface water bodies represented explicitly
2. **Provide a more accurate estimate of discharge to ESPA**
   - Ability to do uncertainty and sensitivity analysis for this output
   - Probably won't deviate much from Clark (2022), but will assimilate more information
   - Monthly and annual variations
3. **Be a tool for water rights administration**
   - Will the location of actual pumping wells (PODs) in the model
   - Future users can develop administration scenarios with the wells and
4. **Ability to simulate subregional impacts of pumping (and MAR)**
   - Well to well impacts are too specific for the model
   - The impacts of well or groups of wells on collection of cells (resolution of 100's of meters, rather than at a single specific well)
5. **Ability to simulate how pumping and consumptive use in the upper valley impacts Mackay**
   - Pumping → Groundwater levels → Stream gains → Mackay inflow → Downstream water availability

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Observation datasets for Big Lost groundwater flow model

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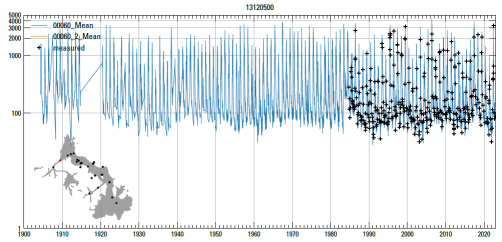
Observation Data

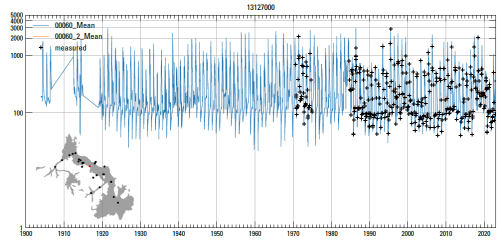
Name	Type	Locations	Form	Derived from
Groundwater levels	state	Throughout model area	continuous & manual measurements	N/A
Streamflow	flux	A few points on Big Lost River	continuous & manual measurements	N/A (stage)
Stream seepage	flux	A few large reaches on Big Lost River	calculated time-series	streamflow, diversions & returns
Volume in Mackay reservoir	state	Mackay reservoir	continuous measurements	N/A (stage)
Inflow (sw + gw) to Mackay reservoir	flux	Upper valley cumulative outflow (less flow under Mackay)	calculated time-series	ET, streamflow, lake stage, bathymetry
1,000 spring discharge	flux	A point on stream	calculated time-series	Streamflow, ET
Seepage survey(s)	flux	Smaller reaches on Big Lost River below Mackay	Manual measurements	Streamflow
Groundwater level synoptic	state	Throughout model area	Manual measurements	N/A
Water budget estimates	flux	Three subbasins of model area	Calculated annual	A lot
Pumping measurements	flux	Throughout model area	Irrigation season total	N/A

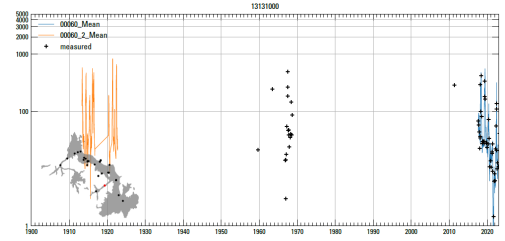
Streamflow In/Out

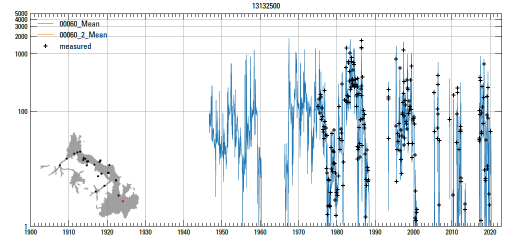
- **Source:** USGS NWIS streamgaging network

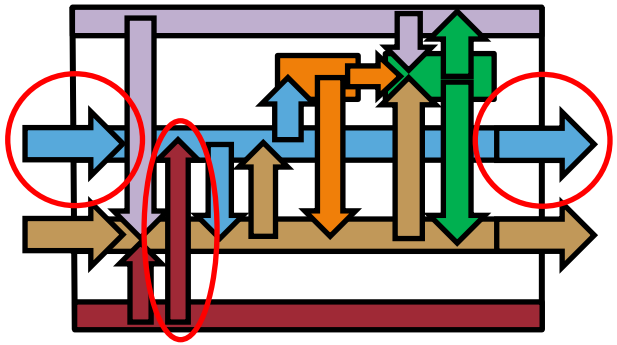
- **Temporal coverage:** Good
- **Spatial coverage:** Good
- **Reliability:** Excellent
- **Important Gaps:** Antelope Creek before2018; 4 gages upstream of Mackay Reservoir after 1920-1960;







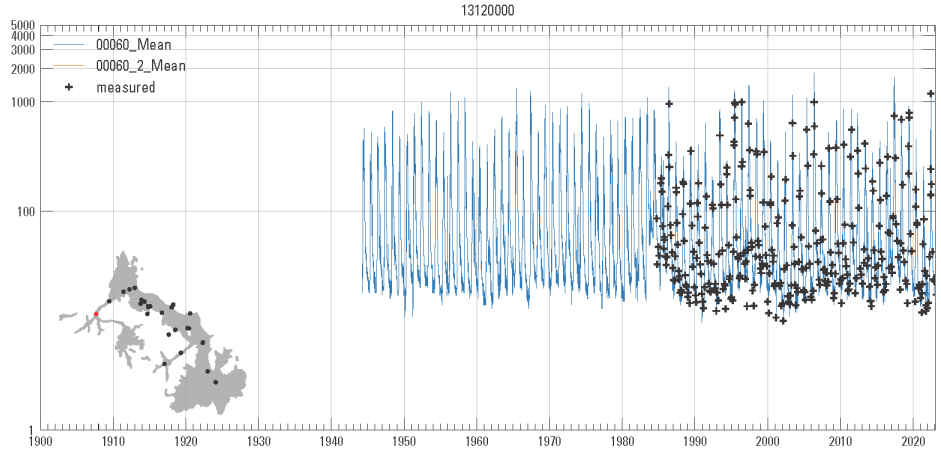


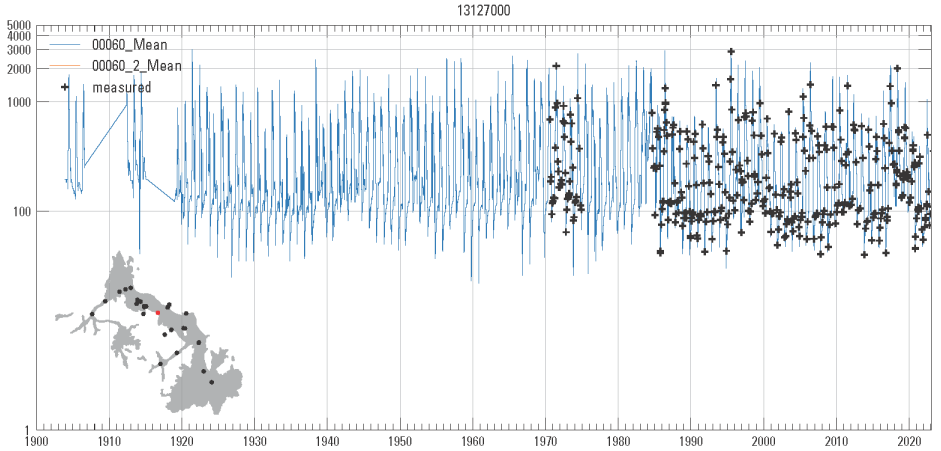


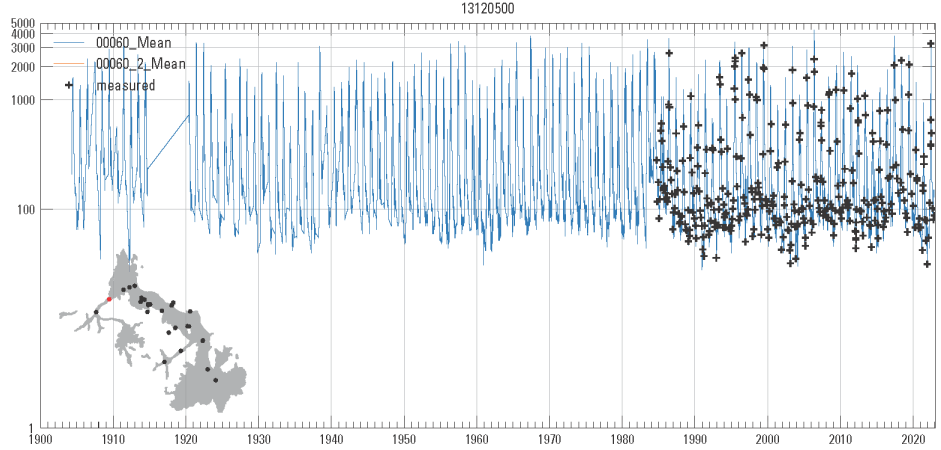
Streamflow Observations

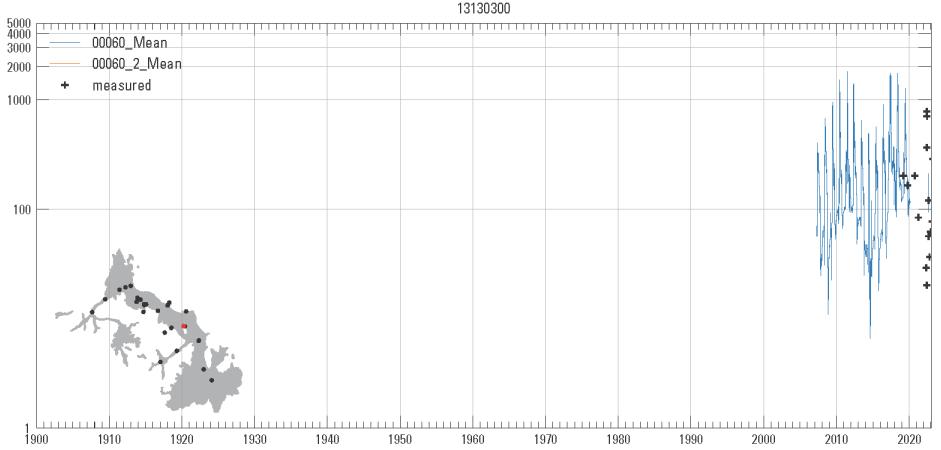
Gages on the Big Lost downstream of Howell, excluding Mackay Res

Related, but different than seepage









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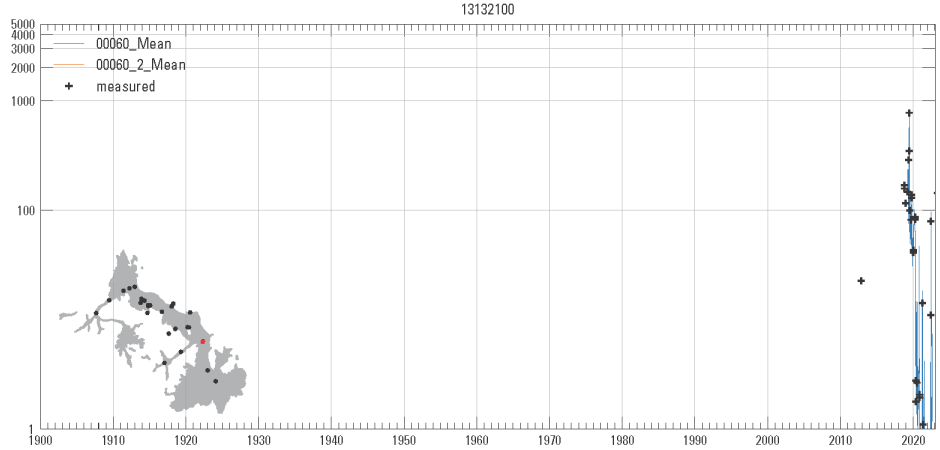

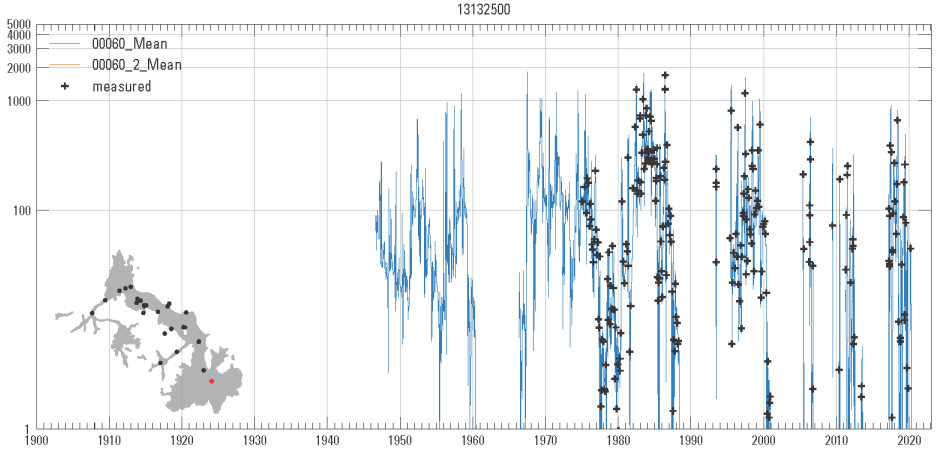

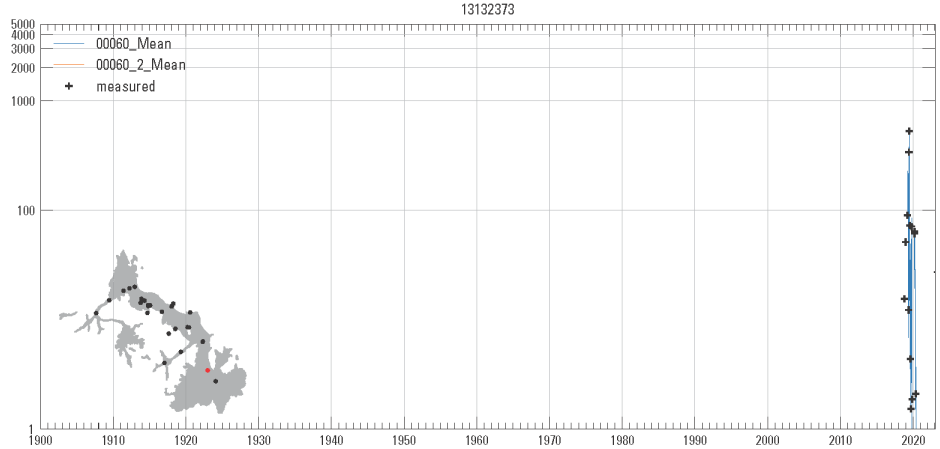

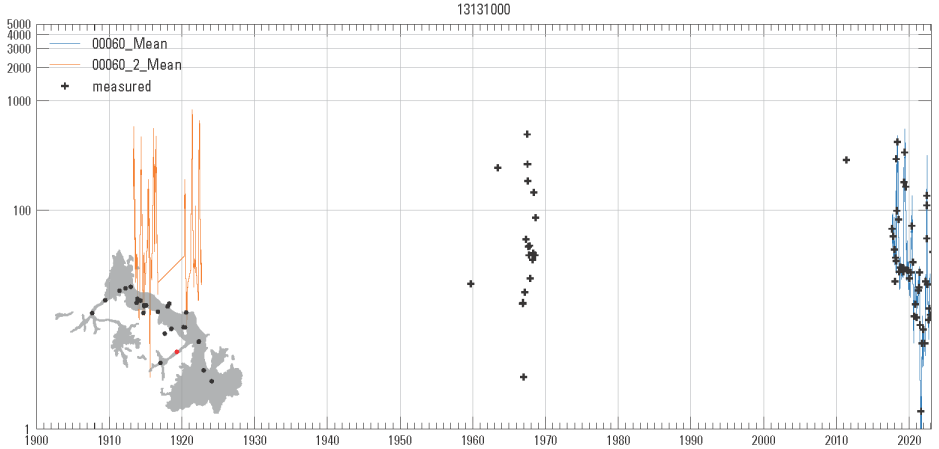

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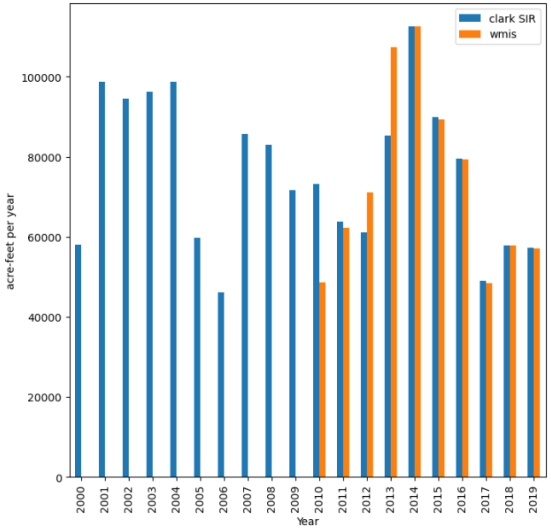
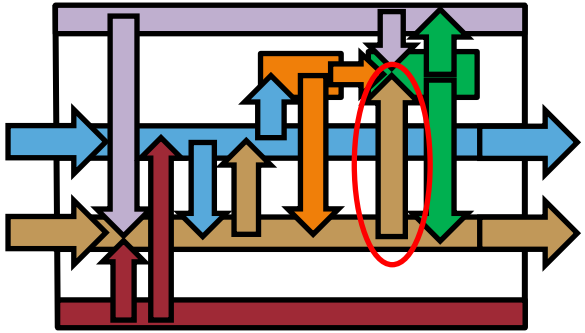
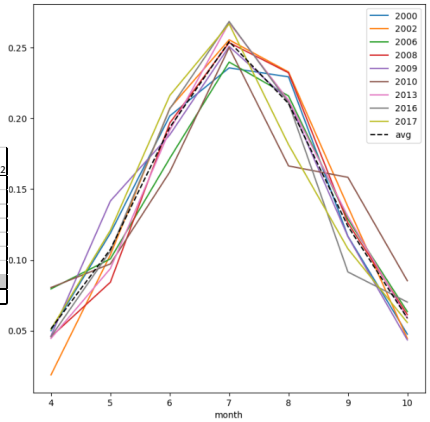
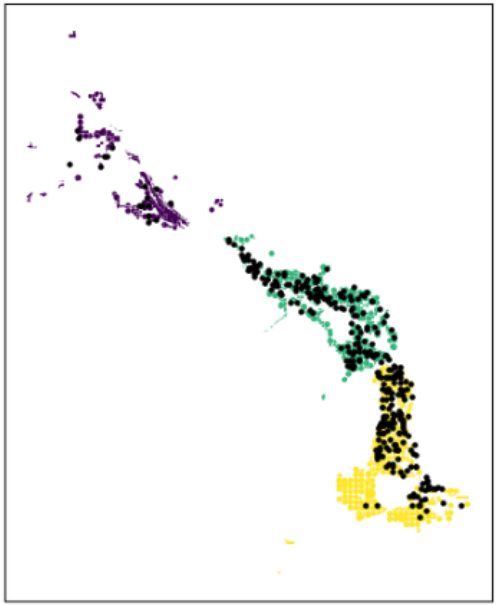
Groundwater pumping

- **Source:** IDWR Water Management Information System database
- **Temporal coverage:** annual since 2010
- **Spatial coverage:**
- **Reliability:** Very good
- **Important Gaps:** Must upscale annual to monthly via proxy (EVT, SW div?); must backfill to simulation start









	Temporal Resolution	Source	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Diversion Records	daily	IDWR																							
Pumping Records	annual	IDWR																							
Irrigated Lands Shapefile	yearly	IDWR																							
Metric EVT	monthly (Apr-Oct)	IDWR																							
ssebop/NDVI	monthly (?)	USGS																							
Water Budget Report	yearly	IGS																							
Reitz Recharge Arrays	monthly	USGS																							
Prism Precipitation Arrays	monthly	PRISM																							

tentative simulation period

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Annual Budget Values

- Much of this info – or associated info is used as inputs
- Some will probably be used as informal or qualitative targets – QA checks
- Some may be quantitative targets

Table 4. Estimated annual groundwater budgets for the Big Lost River Basin, south-central Idaho, for average conditions during 2000–19, 2014 (dry), and 2017 (wet).

[All values in acre feet per year (acre-ft/yr) are rounded up or down to the nearest 100]

Budget component	Entire basin			Above Mackay Dam			Below Mackay Dam		
	2000–19	2014	2017	2000–19	2014	2017	2000–19	2014	2017
Tributary canyon underflow	88,700	87,900	124,200	50,900	49,800	72,100	37,800	38,100	52,100
Areal recharge	99,700	116,200	146,800	36,800	44,200	62,500	62,900	72,000	84,300
Applied irrigation recharge	46,900	15,800	71,700	16,600	5,300	20,700	30,300	10,500	51,000
Canal seepage	55,300	43,000	70,800	19,000	18,600	23,000	36,300	24,400	47,800
Managed recharge (winter)	1,900	0	6,100	100	0	400	1,800	0	5,700
Septic system effluent	200	100	300	0	0	0	200	100	300
Losing river reaches	144,800	109,600	339,900	6,600	0	70,500	138,200	109,600	269,400
Mackay Reservoir seepage	1,600	1,300	2,300	1,600	1,300	2,300	0	0	0
Groundwater inflow (above dam residual)	0	0	0	0	0	0	100,400	96,700	248,300
Groundwater pumpage to canals	8,300	22,400	2,900	0	0	0	8,300	22,400	2,900
Irrigation pumpage	76,000	112,700	49,000	4,200	4,700	3,100	71,800	108,000	45,900
Domestic supply pumpage	500	400	800	100	100	100	400	300	700
Municipal supply pumpage	600	300	700	0	0	0	600	300	700
Gaining river reaches	26,900	17,700	0	26,900	17,700	0	0	0	0
Total inflow (recharge)	439,100	373,900	762,100	131,600	119,200	251,500	407,900	351,400	758,900
Total outflow (discharge)	112,300	153,500	53,400	31,200	22,500	3,200	81,100	131,000	50,200
Difference (residual)	326,800	220,400	708,700	100,400	96,700	248,300	326,800	220,400	708,700

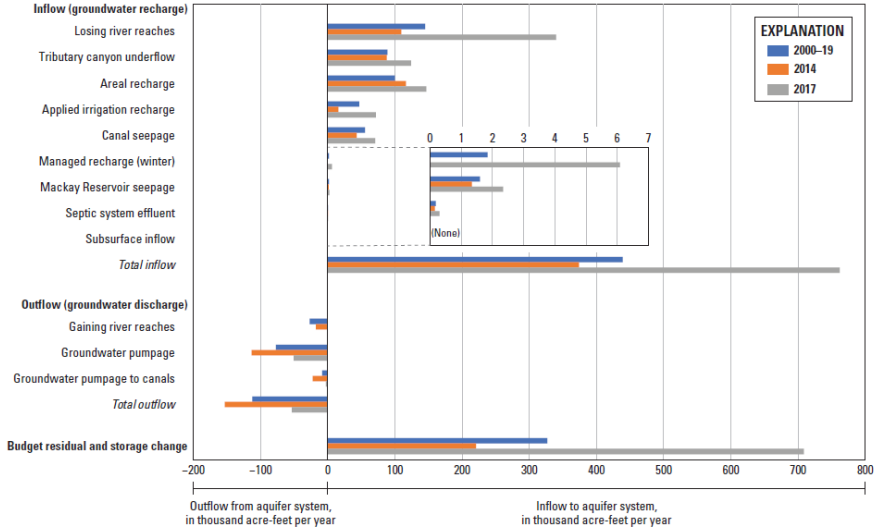


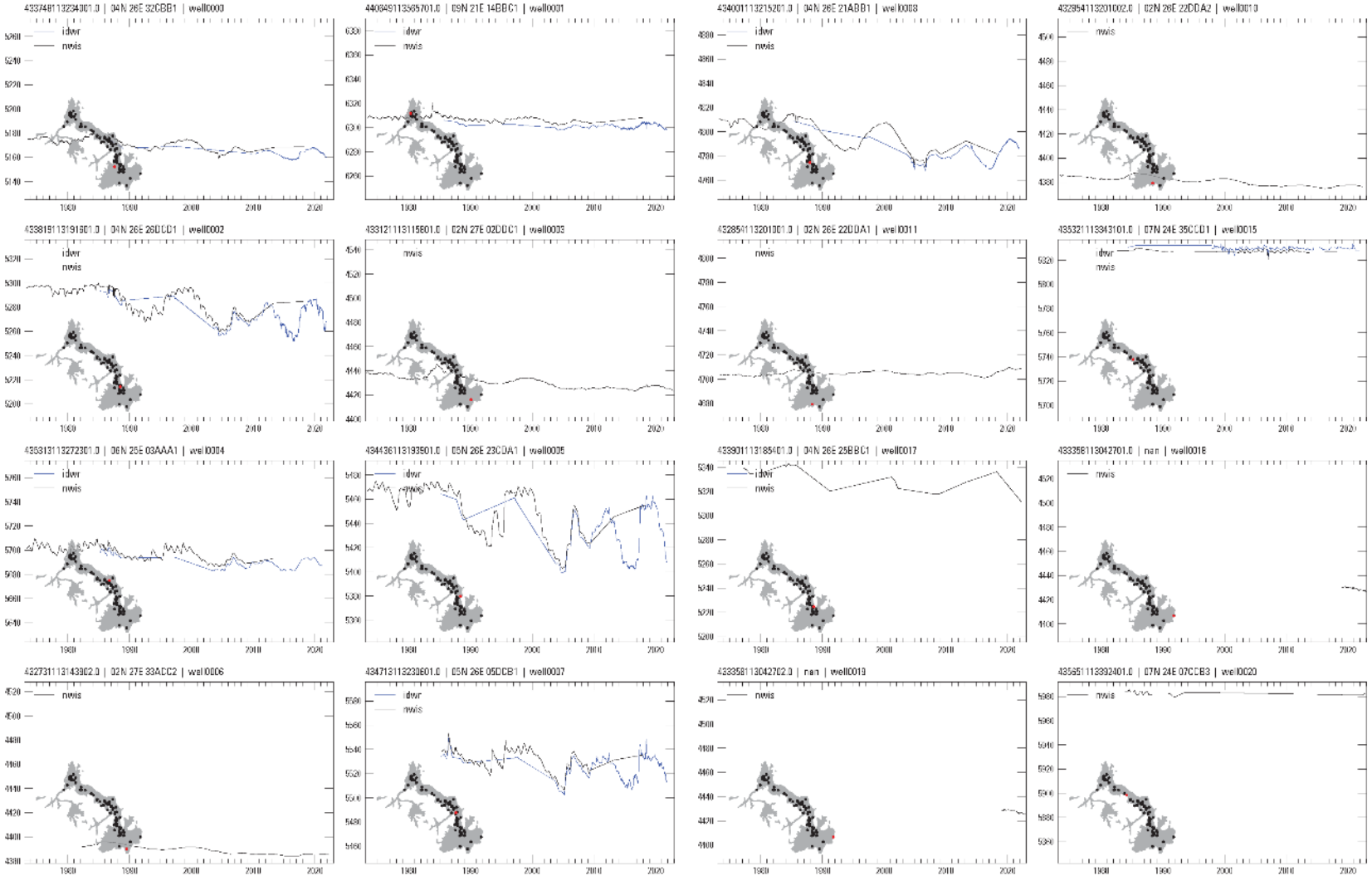
Figure 5. Average groundwater-budget components, as calculated in this report, for the Big Lost River Basin, south-central Idaho, 2000–19, 2014, and 2017. See table 4 for data.

Groundwater Level Observations

Groundwater Levels are throughout the valley

Requires some processing

- Get end-of month values
- Cluster wells



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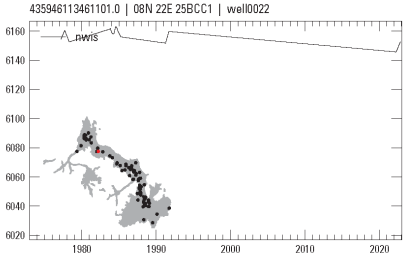

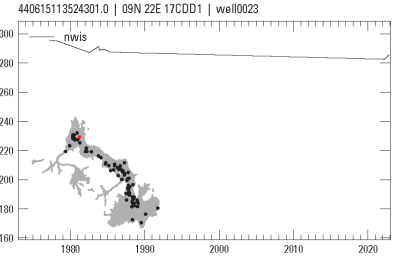

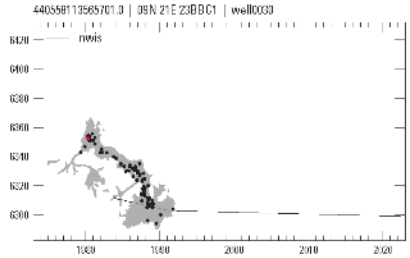

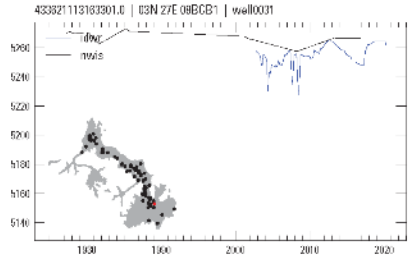

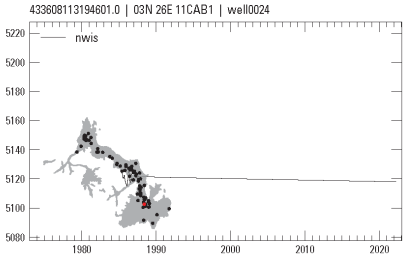

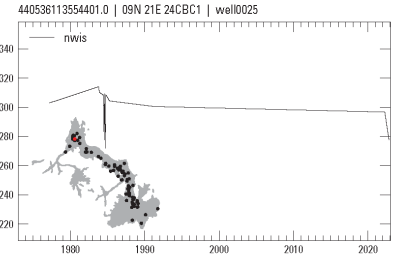

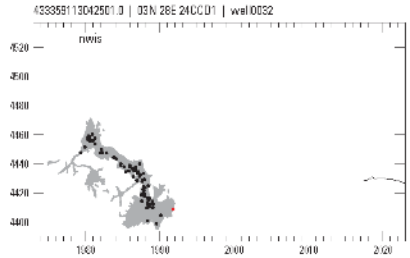

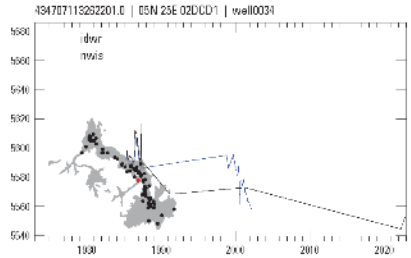

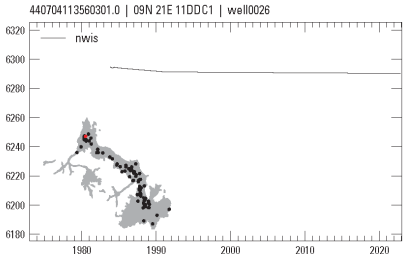

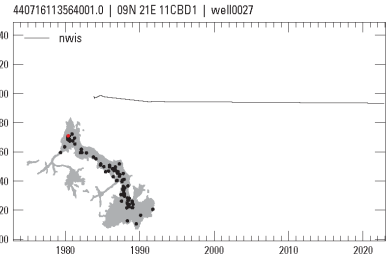

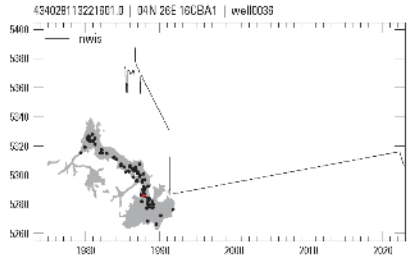

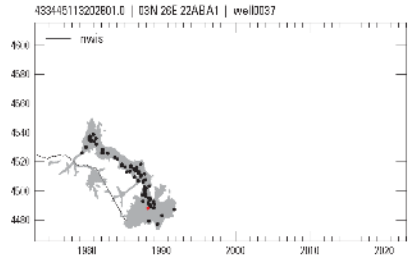

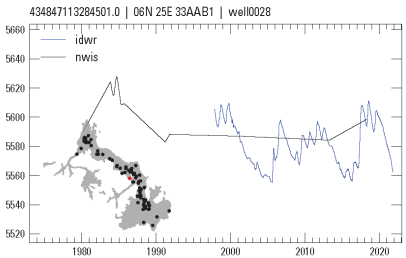

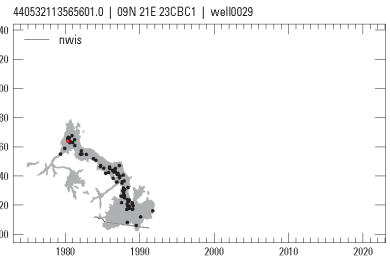

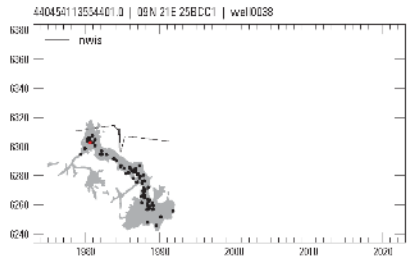

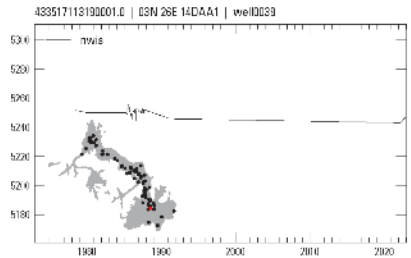

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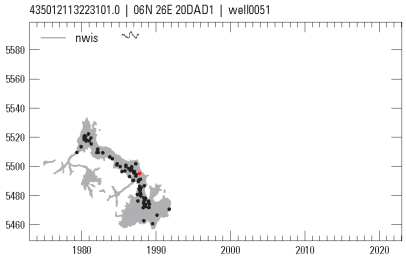

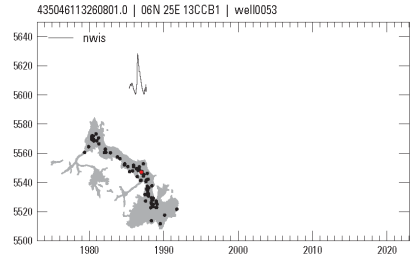

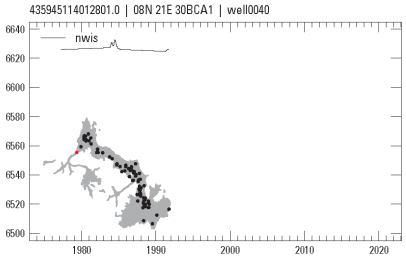

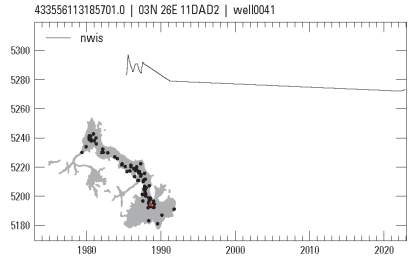

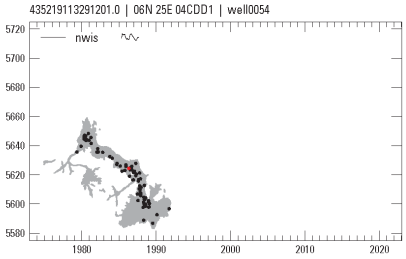

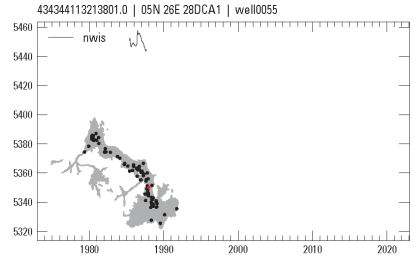

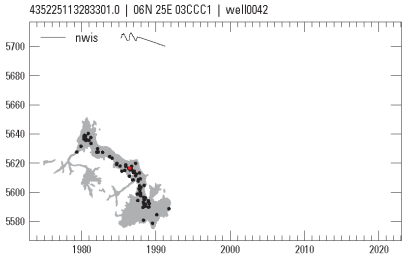

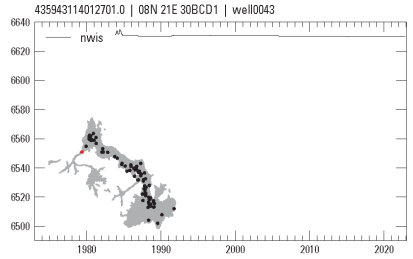

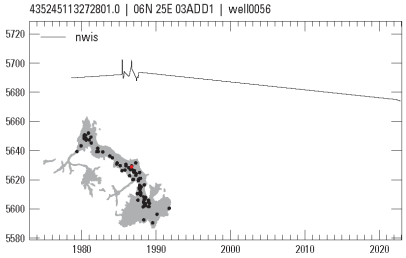

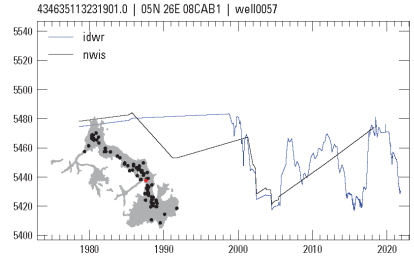

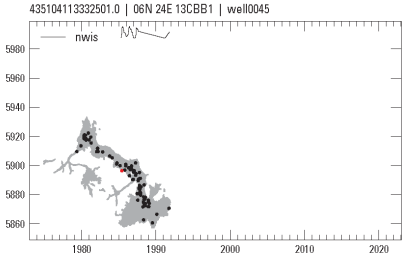

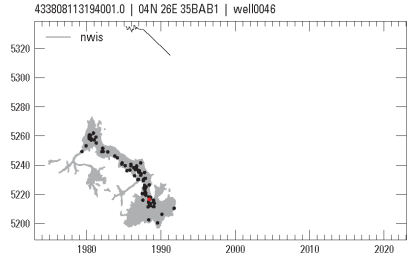

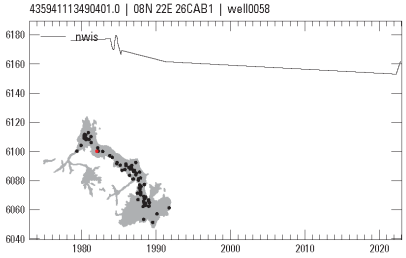

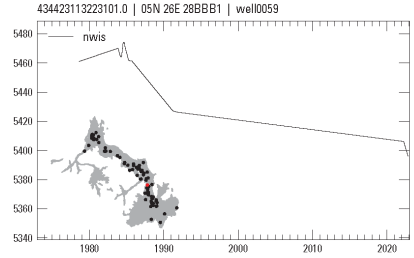

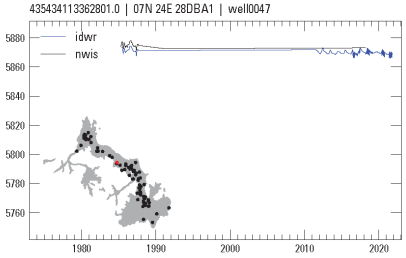

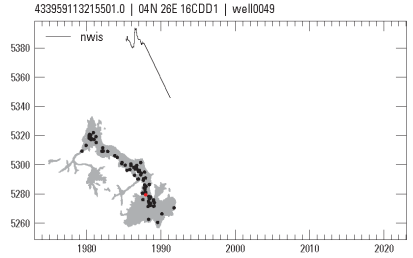

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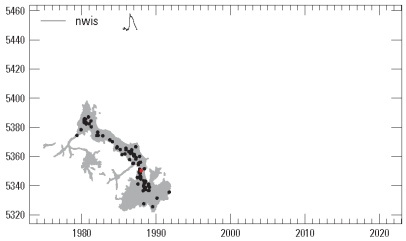

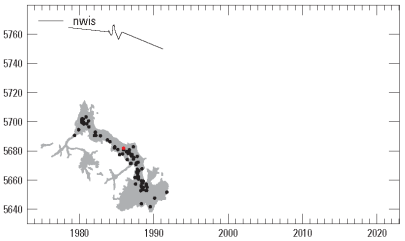

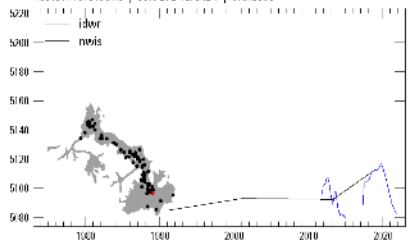

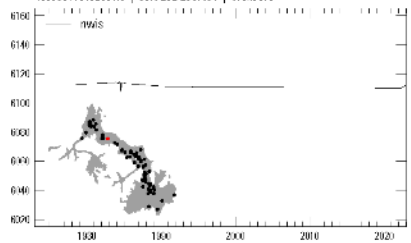

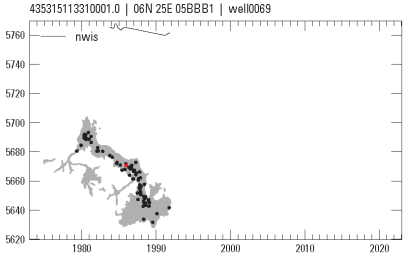

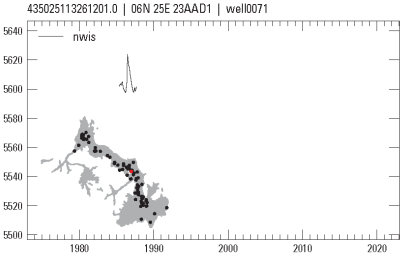

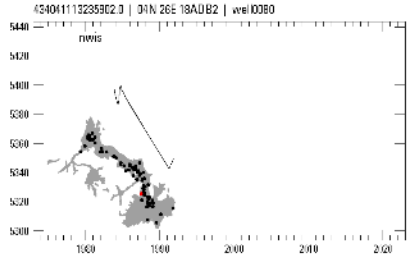

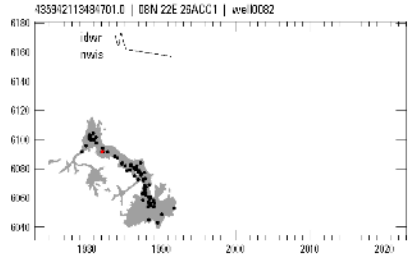

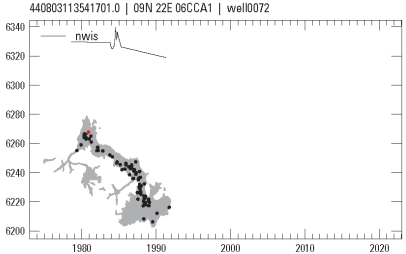

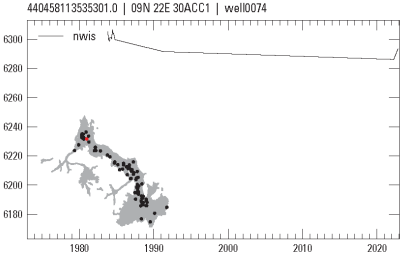

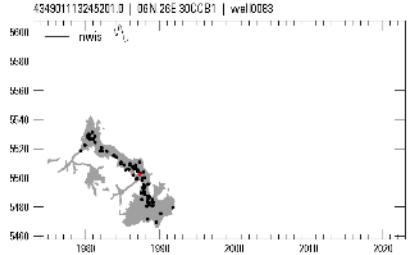

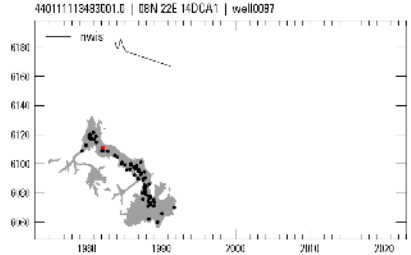

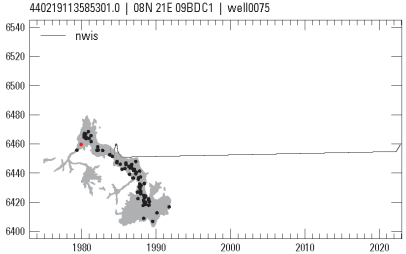

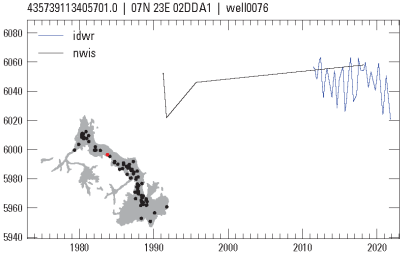

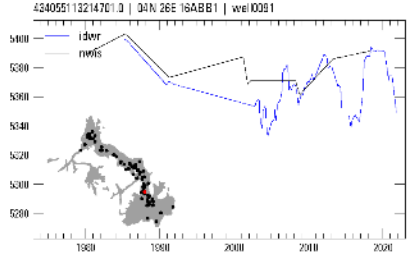

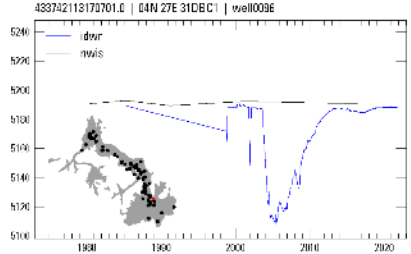

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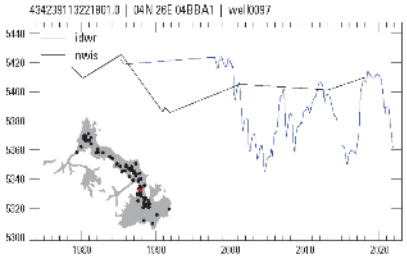

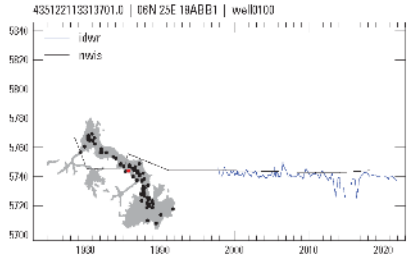

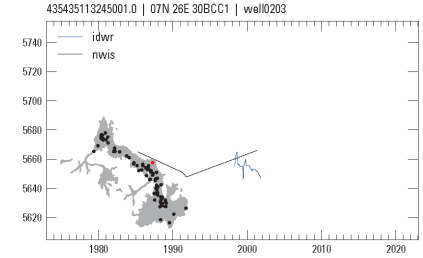

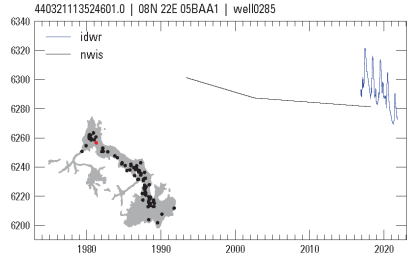

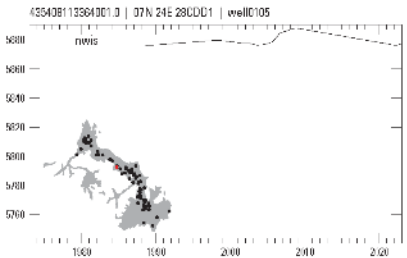

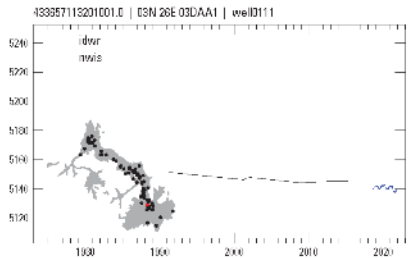

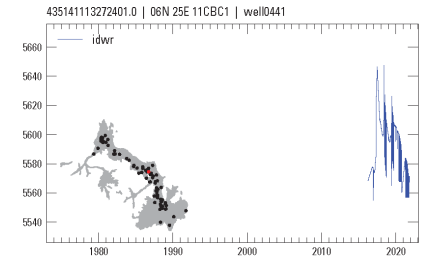

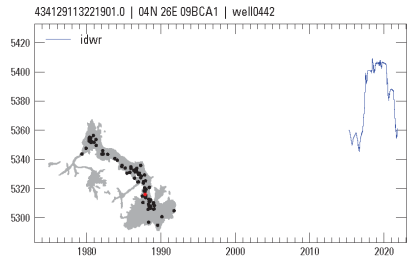

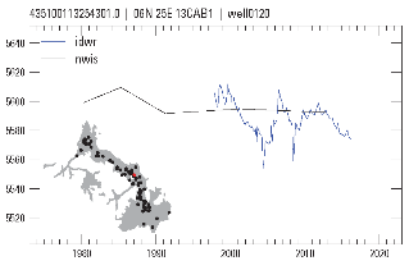

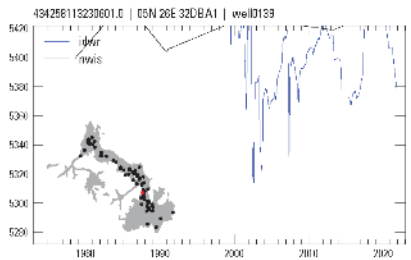

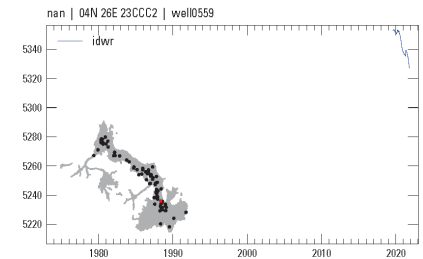

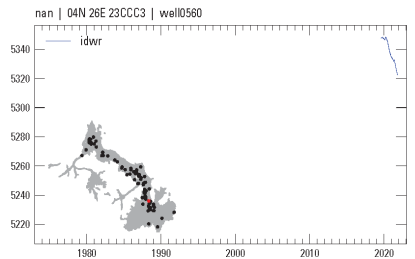

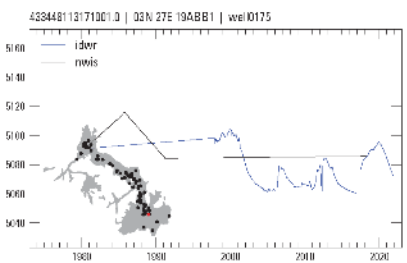

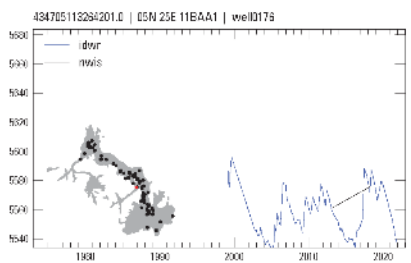

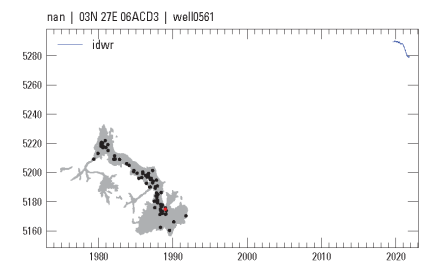

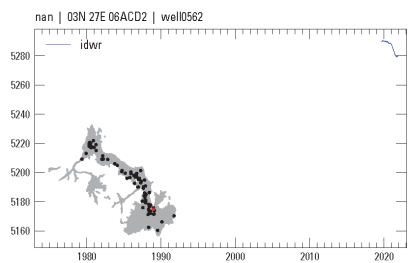

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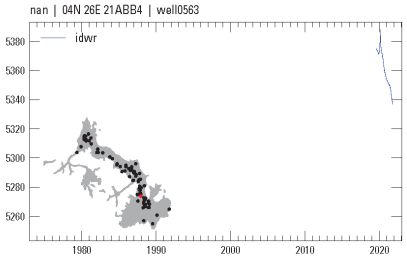

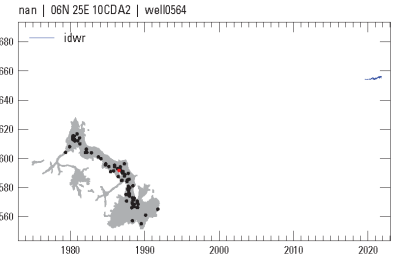

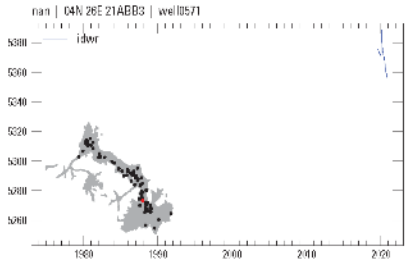

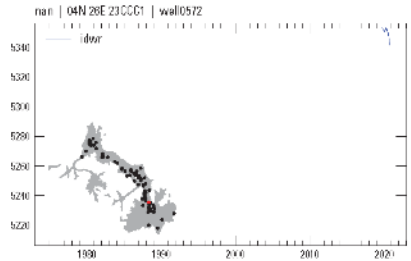

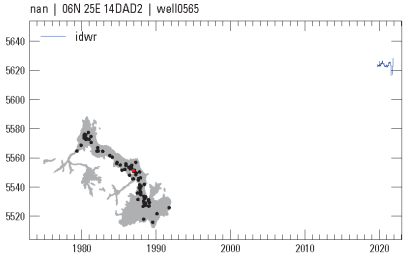

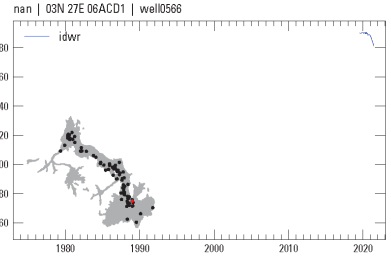

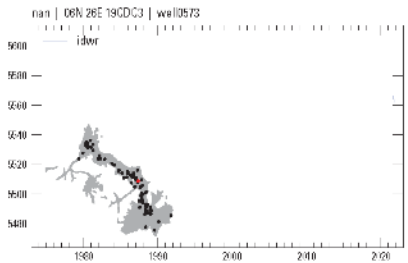

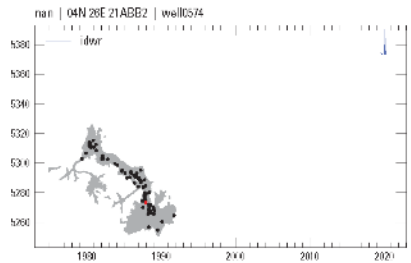

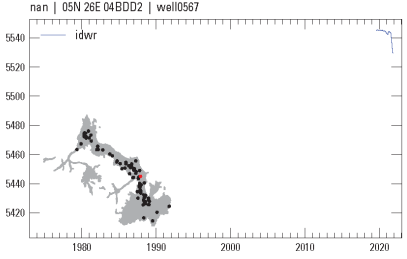

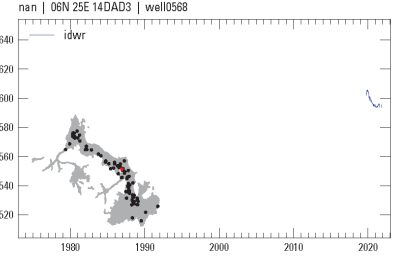

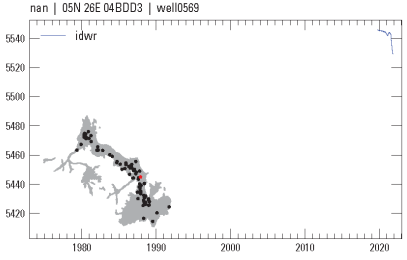

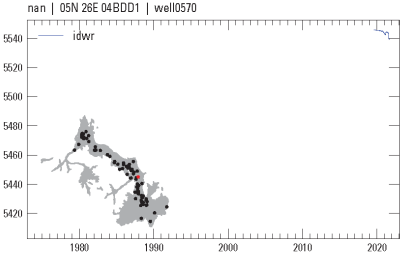

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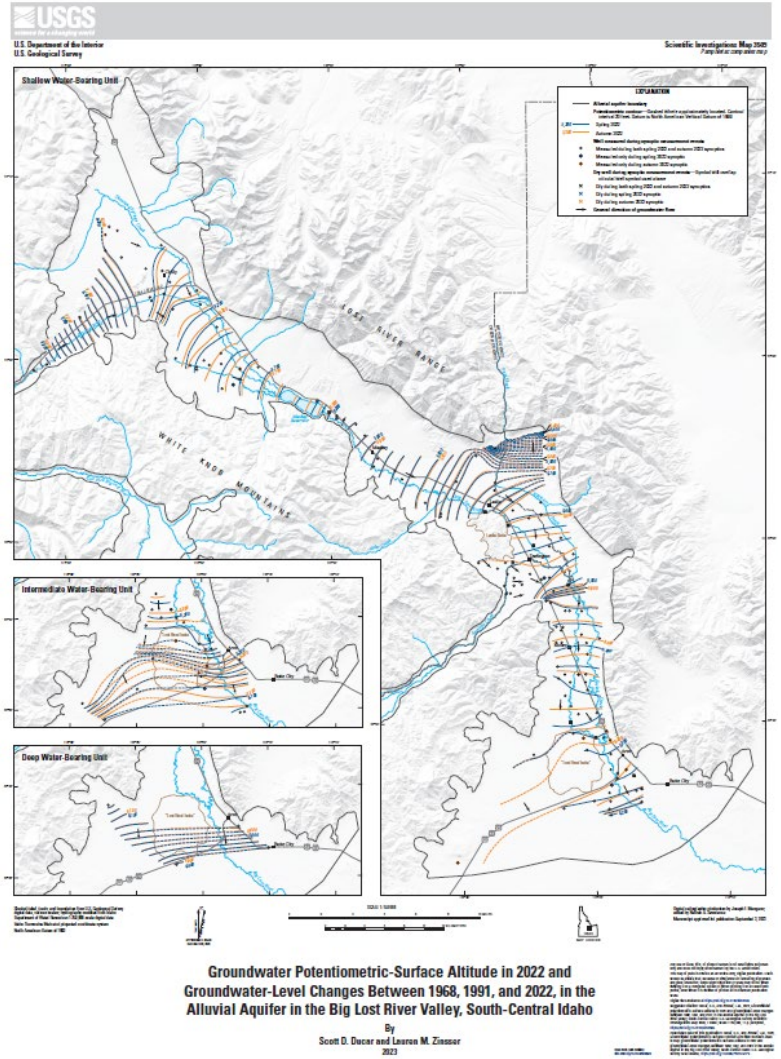
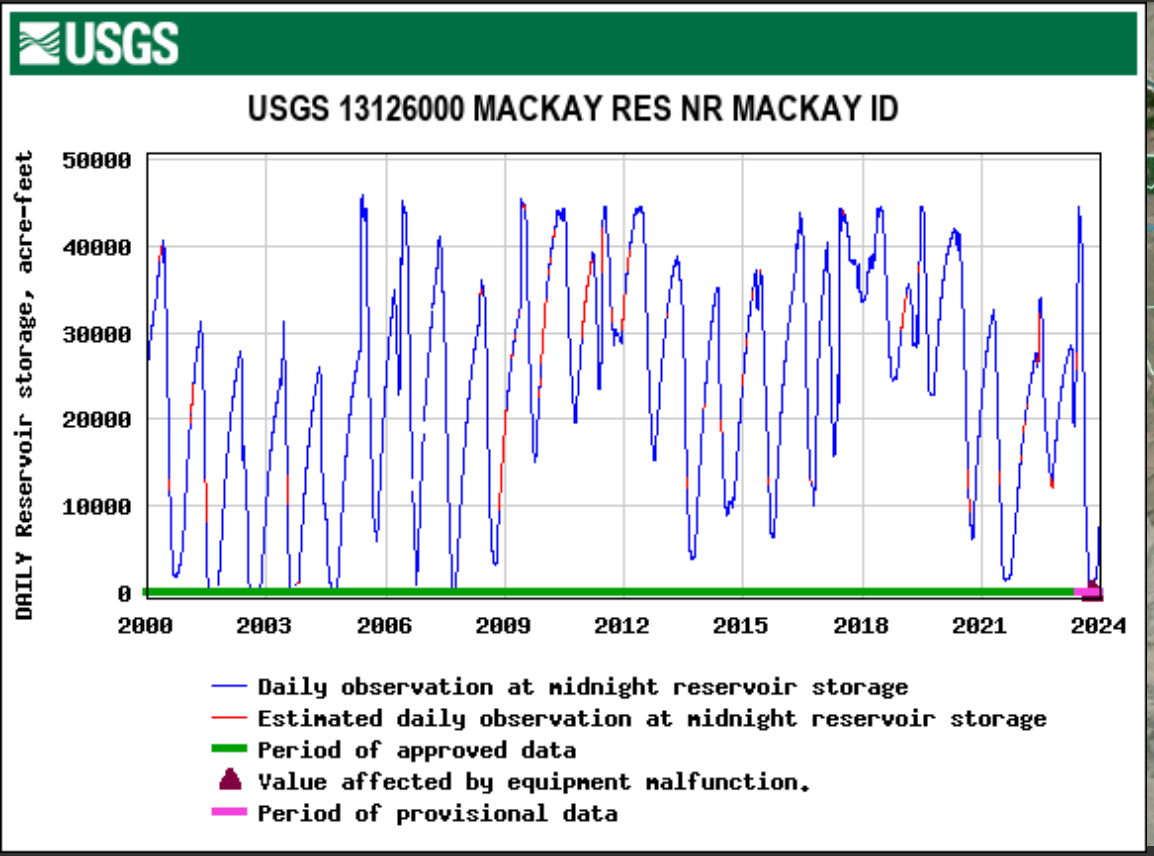
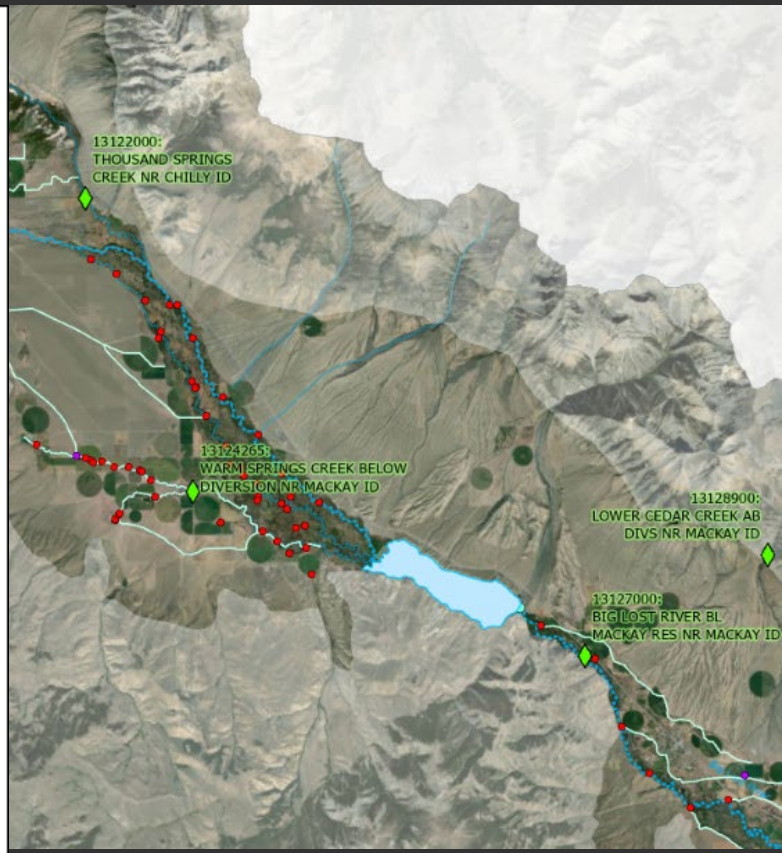
Groundwater Level Observations - Synoptic



Mackay Volume

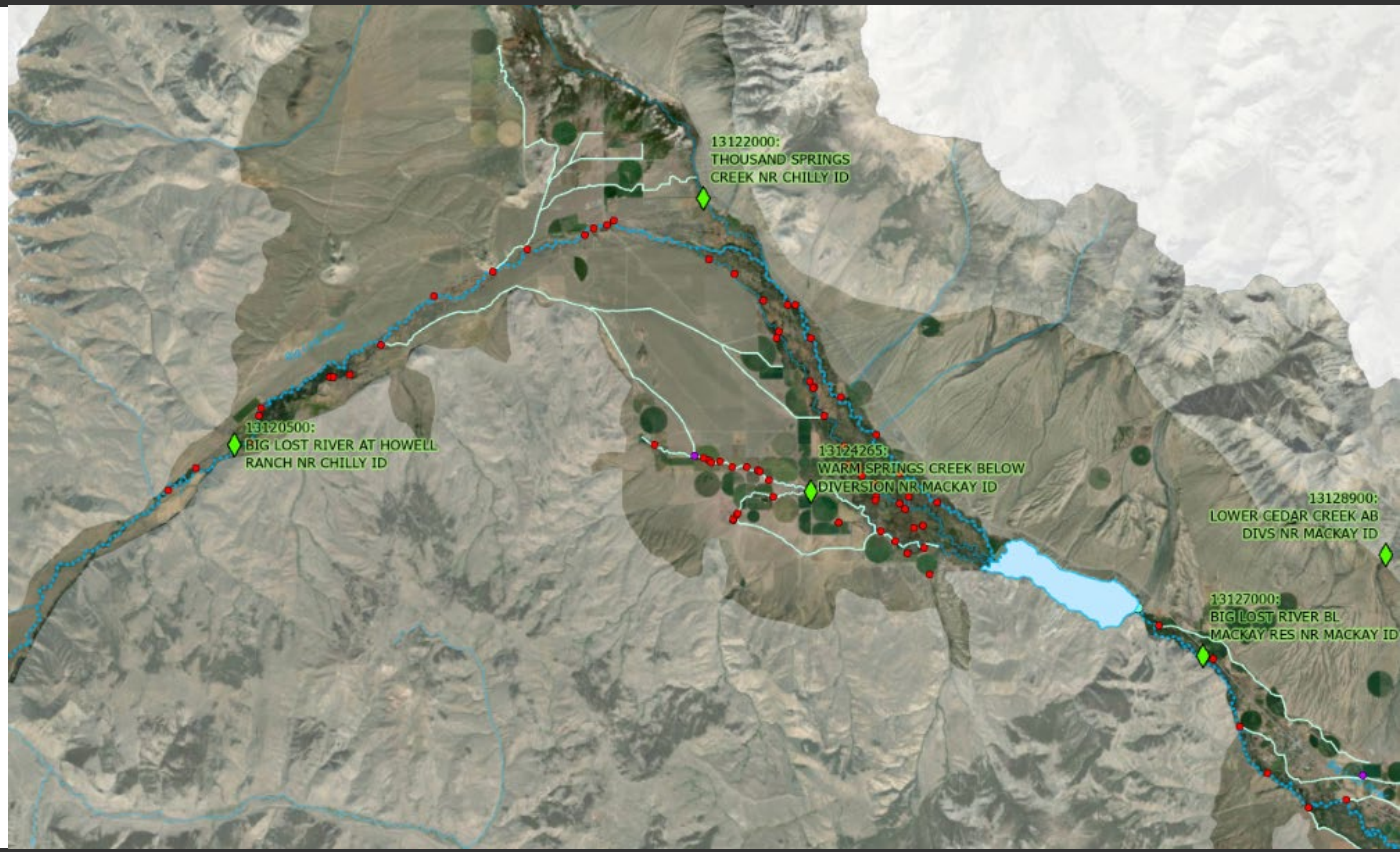




Mackay Inflow

We don't have enough data to parse out GW versus SW outflow (and their interchange)

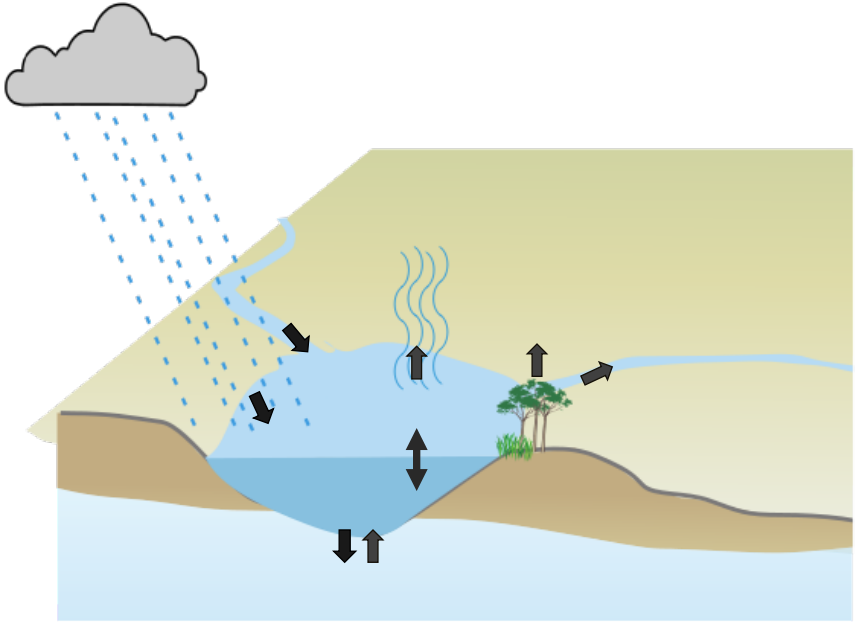
We have change in volume and measured outflow from reservoir



Mackay Inflow

- A.K.A – net outflow of SW and GW from upper valley

In	–	Out	=	±ΔStorage
inflow from streams		discharge to streams		Δ lake volume
inflow from canals		discharge to canals		
inflow from direct precipitation		evaporation		
inflow from groundwater		transpiration of lakeside plants		
		leakage to groundwater		

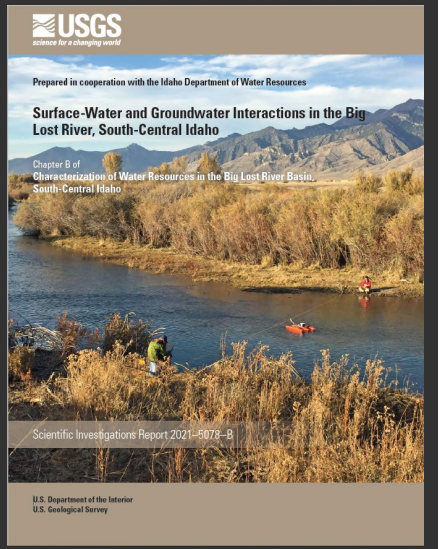


(modified from Faunt, 2009)

Mackay Reservoir

Seepage Survey

- Points in time, but high quality and high spatial resolution



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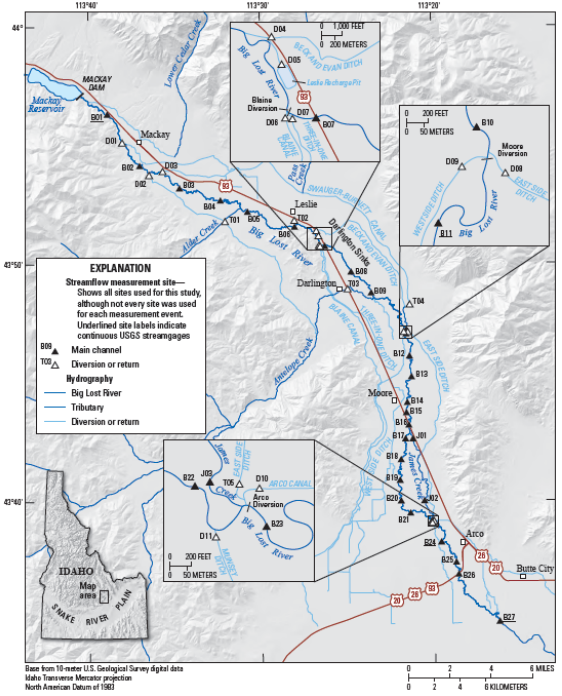


Figure 1. Streamflow measurement sites, communities, and other features in the Big Lost River Basin, south-central Idaho. USGS, U.S. Geological Survey.

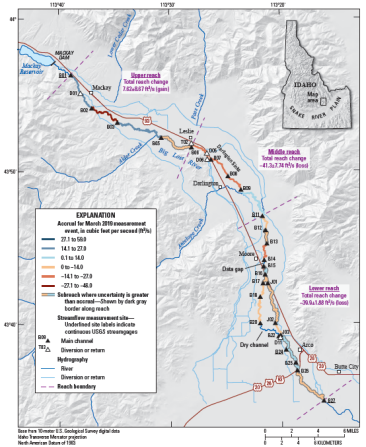


Figure 2. Gaining and losing reaches and subreaches on the Big Lost River, south-central Idaho, March 2019. USGS, U.S. Geological Survey; ±, plus or minus.

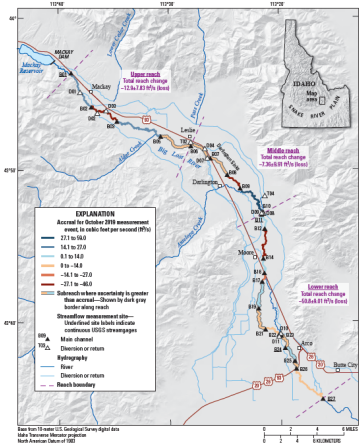


Figure 3. Gaining and losing reaches and subreaches on the Big Lost River, south-central Idaho, October 2019. USGS, U.S. Geological Survey; ±, plus or minus.

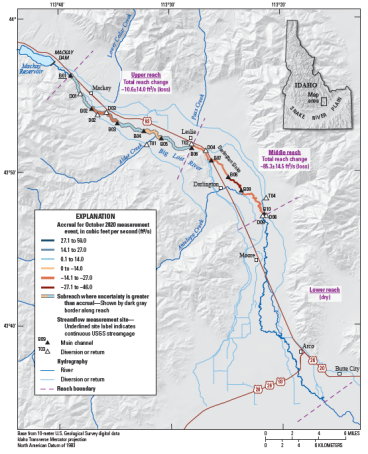


Figure 4. Gaining and losing reaches and subreaches on the Big Lost River, south-central Idaho, October 2020. USGS, U.S. Geological Survey; ±, plus or minus.

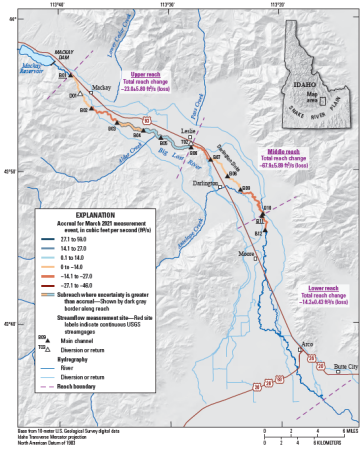


Figure 5. Gaining and losing reaches and subreaches on the Big Lost River, south-central Idaho, March 2021. USGS, U.S. Geological Survey; ±, plus or minus.

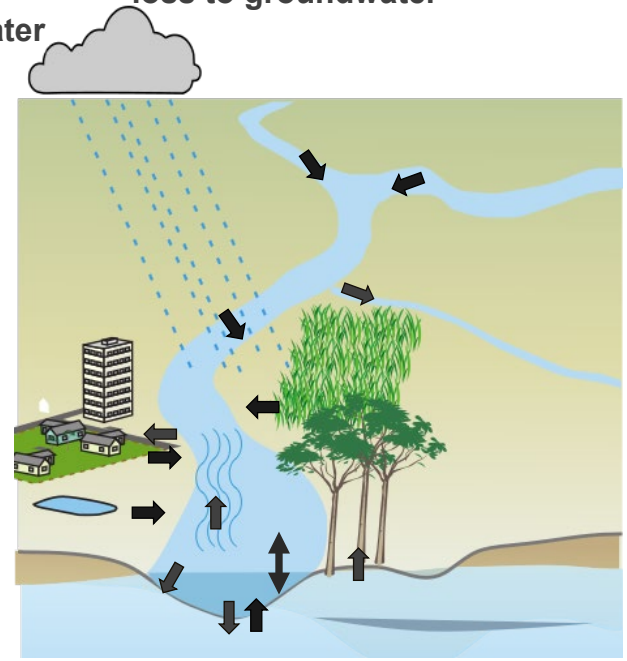
Big Lost River seepage calculations

Streamflow Seepage

- SW-GW interactions in Big Lost is important in management and for model objectives
- We have a heterogeneous dataset of streamflow, diversions, & returns

In – **Out** = **±ΔStorage**

In	Out	±ΔStorage
upstream inflow	downstream outflow	Δ instream volume (negligible)
tributary inflow	diversions (ag, urban)	
runoff (urban, ag, native veg)	transpiration from riparian vegetation	
treated wastewater	evaporation	
precipitation	**loss to groundwater**	
gain from groundwater		

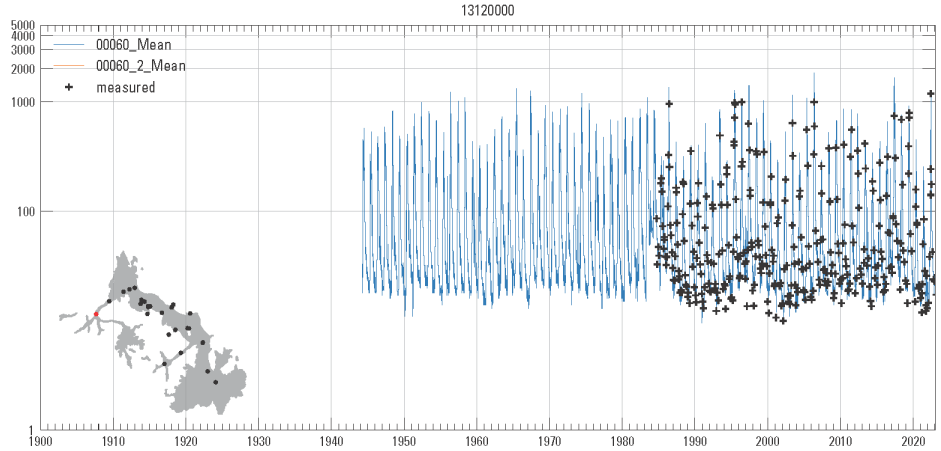


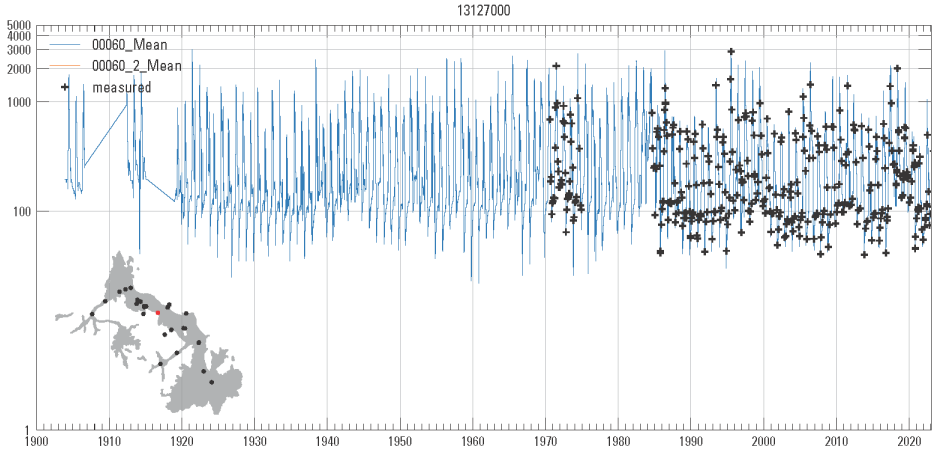
Rivers

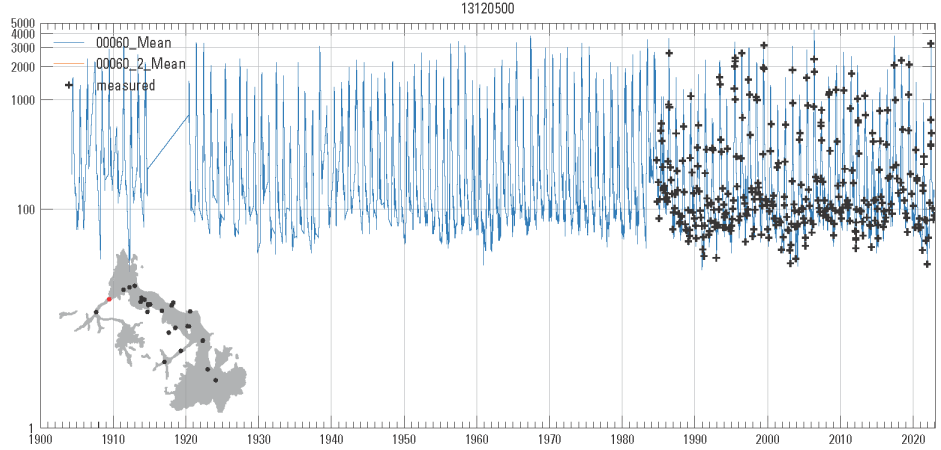
(modified from Faunt, 2009)

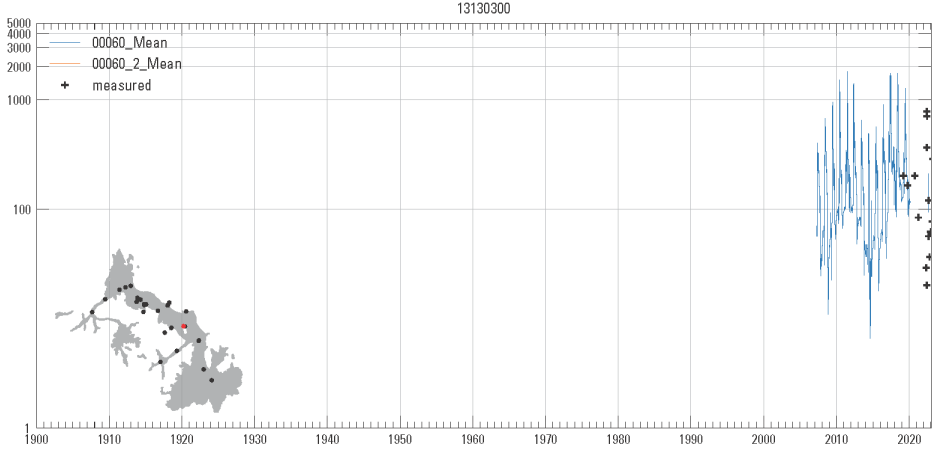
Stream Seepage in Big Lost

We have streamflow observations for different periods at different locations









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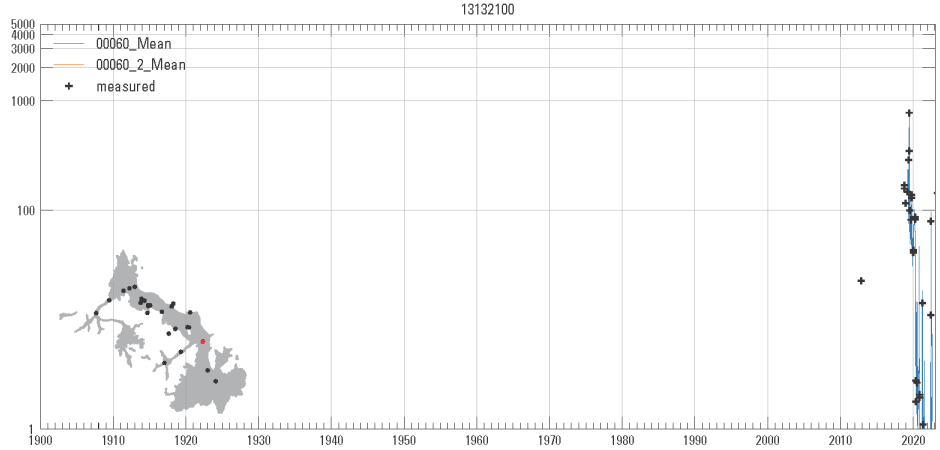

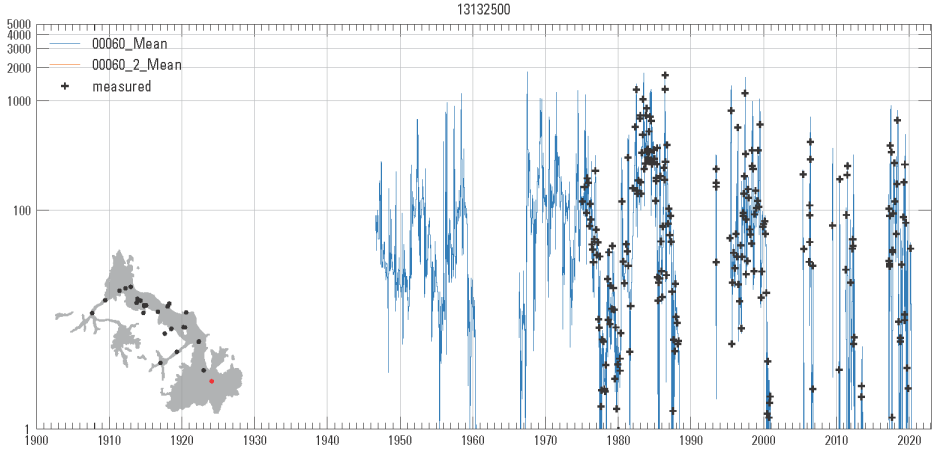

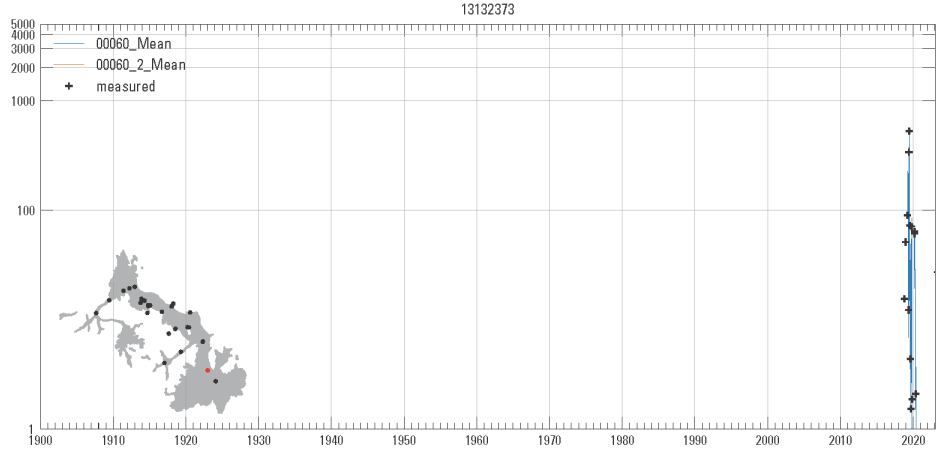

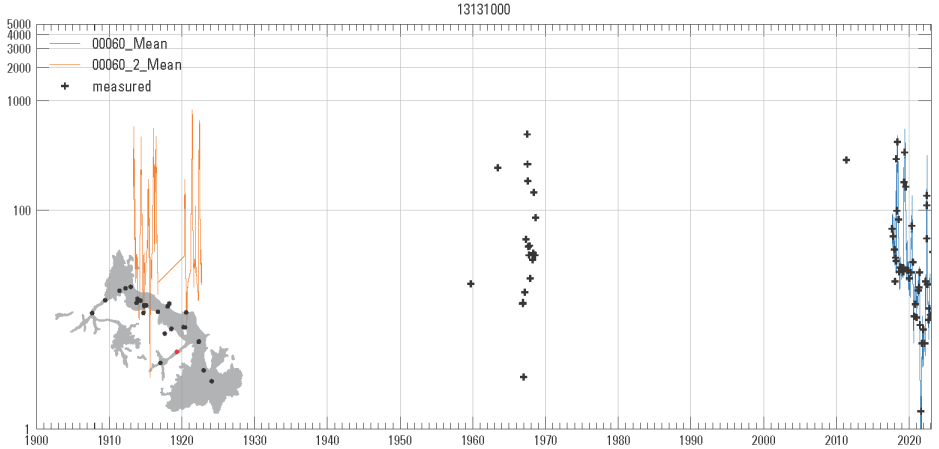

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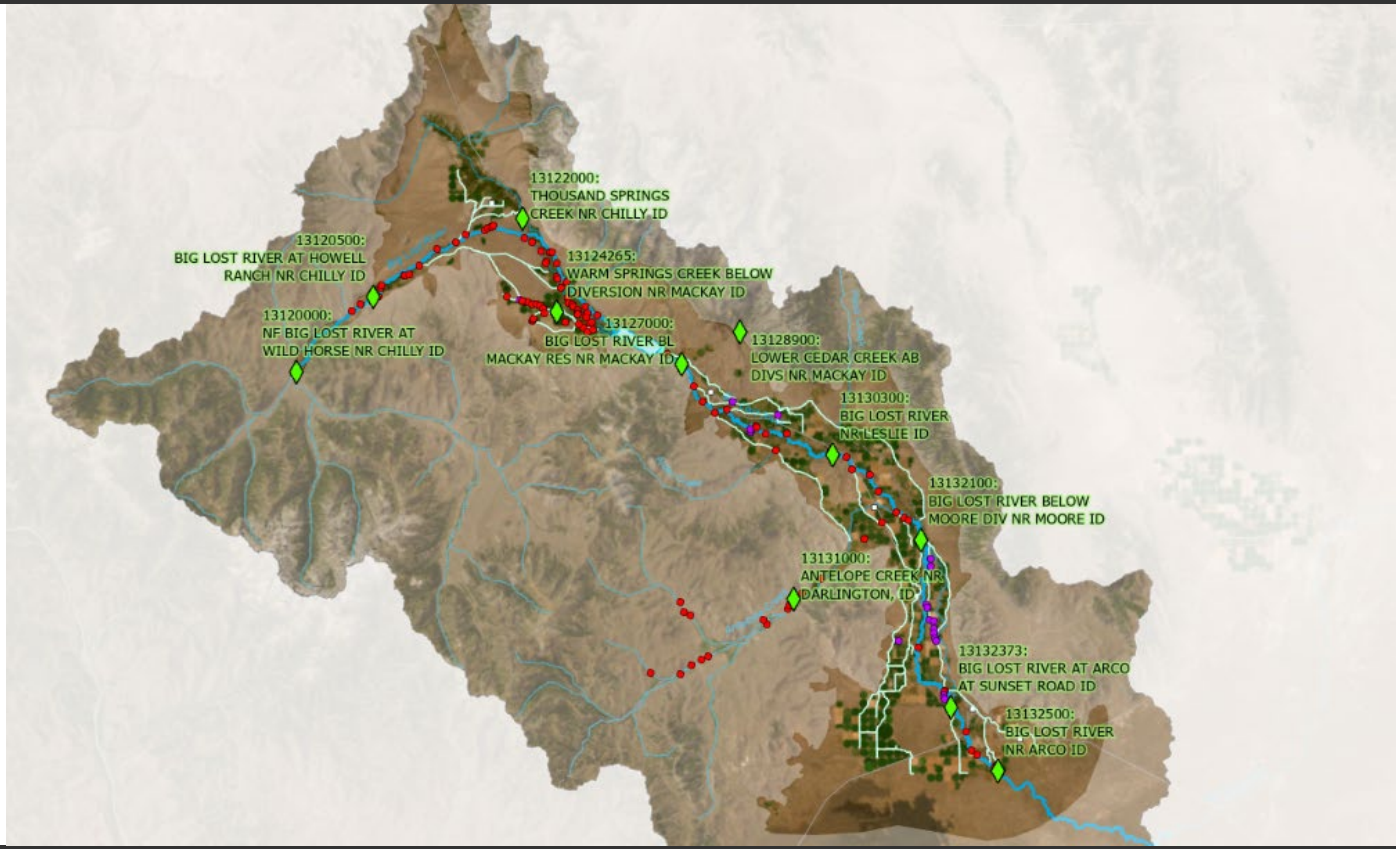
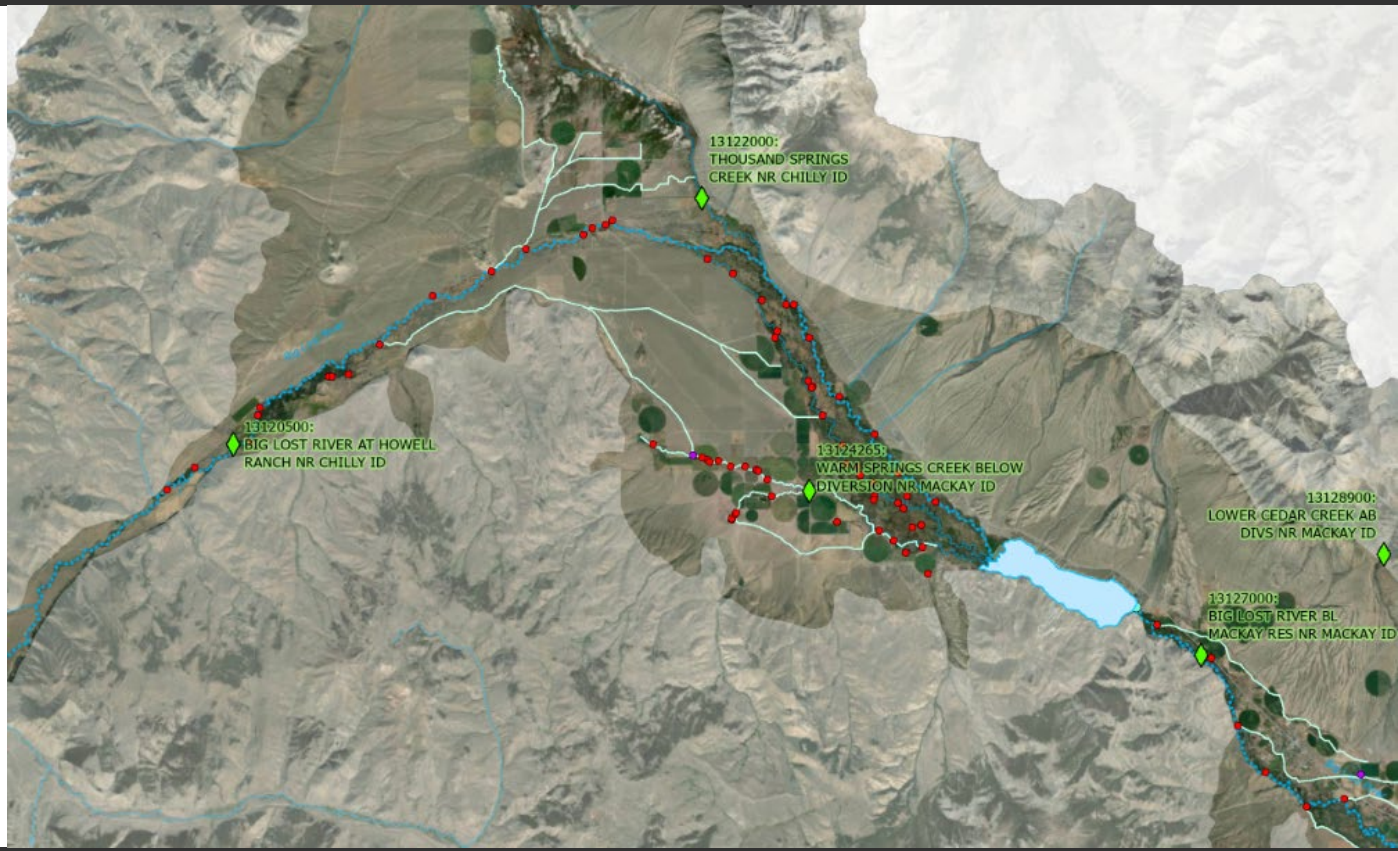
Stream Seepage in Big Lost

We have diversion and return locations and data from 2003 onward



Stream Seepage in Big Lost – Upper

Don’t have great data for calculating seepage in upper basin on monthly basis at a sub-reach scale



Stream Seepage in Big Lost – Middle & Lower

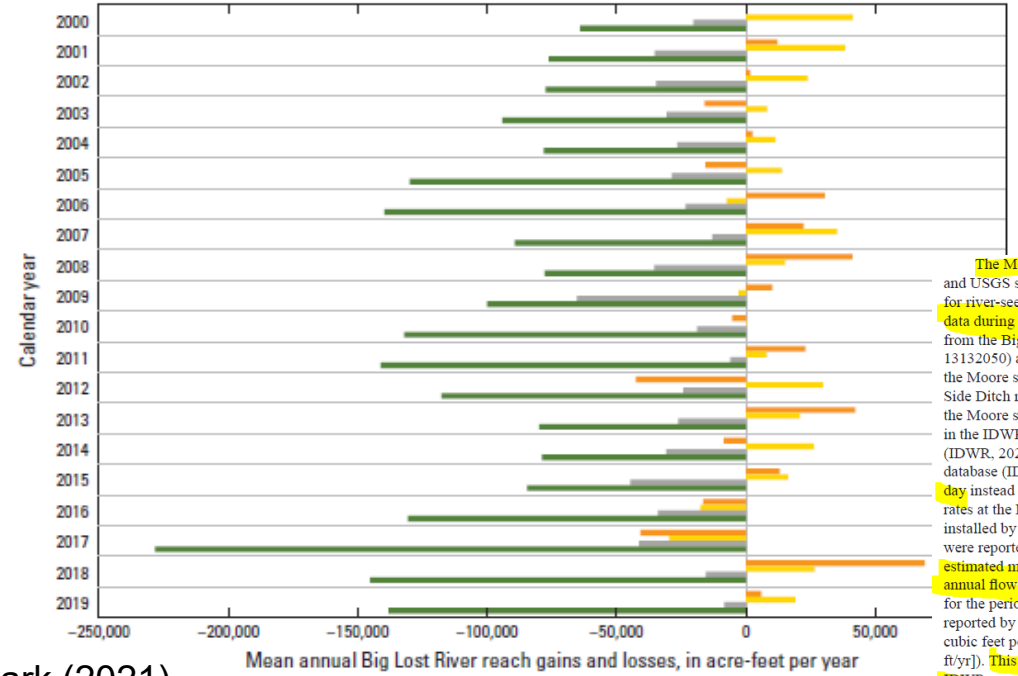
Much better for middle and lower valley

Biggest source of uncertainty is unmeasured tributary inflow – especially Antelope Creek

Stream Seepage in Big Lost – Middle & Lower

IDWR accounting model has multiple reaches

Clark (2021) has two reaches



Clark (2021)

Figure 16. Mean annual estimated gains and losses in reaches of Big Lost River, south-cent
indicate a loss from the river and a gain to the aquifer. Positive values indicate a gain to the r
tables 9.1–9.4 in appendix 9 ("River Reach Gain and Loss Assumptions") for source datasets

The Moore streamgage location (IDWR site 13132100 and USGS streamgage 13132100) ultimately was not selected for river-seepage analysis because of insufficient available data during the study period. Substantial flow was diverted from the Big Lost River to the Moore Canal (IDWR site 13132050) and East Side Ditch (IDWR site 13132060) above the Moore streamgage location. The Moore Canal and East Side Ditch measured diversions and estimated streamflow at the Moore streamgage (IDWR site 13132100)[2] were reported in the IDWR Water District surface-water diversion database (IDWR, 2020d) and in the IDWR water rights accounting database (IDWR, 2020e) in diversion units of cubic feet per day instead of in flow units of cubic feet per second. Flow rates at the Moore streamgage (USGS streamgage 13132100) installed by the USGS in 2019 (U.S. Geological Survey, 2020) were reported in cubic feet per second, resulting in different estimated mean flows for 2019 when compared to the total annual flow in the diversion database[3]. The mean streamflow for the period from March 25, 2019, to December 31, 2019, reported by the USGS at the Moore streamgage, was 135.6 cubic feet per second (ft^3/s; 98,200 acre feet per year [acre-ft/yr]). This flow was substantially greater than reported in IDWR records during prior years at IDWR site 13132100. Before streamgage instrumentation in 2019, data reported for the Moore location typically reflected the irrigation season but not other times when flow might occur. Records indicate that values were either measured, estimated, or interpolated. Estimates of Big Lost River flows at Moore were not reported for 2006, 2007, 2011, and 2015. Some flow likely occurred during wet years such as 2006 and 2011 or outside the irrigation season. Measured flow at the downstream USGS Arco streamgage (13132500) in wet years suggests that unmeasured flow likely occurred at Moore during wet years and non-irrigation periods.

Stream Seepage in Big Lost – Unmeasured Tributaries?

Still not sure what to do about unmeasured tributary inflow

- **Ignore**

- Only use months with likely little flow

- Estimate inflow
  - Mutliple linear regression
  - Index gage

- Only use months when we have USGS gage + diversions + Pivotrac for Antelope

Table 9.3. Estimated seepage, below Mackay Reservoir (USGS streamgage 13127000) to Leslie (Idaho Power streamgage 13130500), in the Big Lost River below Mackay Dam, south-central Idaho, 2000–19.

[All values in ***bold italics*** are estimated. Groundwater budget includes seepage using tributary flows. All values in the table are in acre-feet per year. Negative seepage values indicate a losing reach condition and positive values indicate a gaining reach condition. **Abbreviations:** USGS, U.S. Geological Survey; IDWR, Idaho Department of Water Resources]

Year	Leslie streamgage[1]	Below Mackay Reservoir streamgage[2]	Diversions[3]	Groundwater pumpage to canals[3]	Alder Creek	Seepage without Alder Creek	Seepage with Alder Creek
2000	***117,288***	166,785	35,191	958	***5,219***	***–15,025***	***–20,244***
2001	***77,737***	125,025	16,383	664	***3,818***	***–31,376***	***–35,194***
2002	***79,811***	127,215	17,886	1,070	***4,432***	***–30,278***	***–34,709***
2003	***88,380***	136,262	24,362	0	***7,072***	***–23,520***	***–30,592***
2004	***71,726***	118,678	25,989	0	***5,488***	***–20,963***	***–26,450***
2005	***142,102***	192,984	33,289	0	***11,022***	***–17,594***	***–28,616***
2006	***226,970***	282,593	43,284	0	***10,899***	***–12,340***	***–23,239***
2007	109,766	146,563	29,242	1,716	***4,141***	***–8,824***	***–12,965***
2008	101,714	158,050	26,774	1,595	***4,524***	***–30,743***	***–35,267***
2009	126,101	214,110	33,161	502	***10,047***	***–55,229***	***–65,275***
2010	158,010	197,374	30,865	451	***9,937***	***–8,837***	***–18,774***
2011	197,177	226,776	32,448	0	***8,857***	***2,849***	***–6,008***
2012	154,033	203,830	36,036	687	***9,935***	***–14,283***	***–24,217***
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2014	66,380	117,527	27,271	2,269	***5,287***	***–25,533***	***–30,820***
2015	85,869	147,272	23,316	1,561	***5,391***	***–39,226***	***–44,617***
2016	124,927	175,586	27,330	307	***10,301***	***–23,554***	***–33,854***
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2018	230,369	279,410	41,606	69	***7,967***	***–7,483***	***–15,450***
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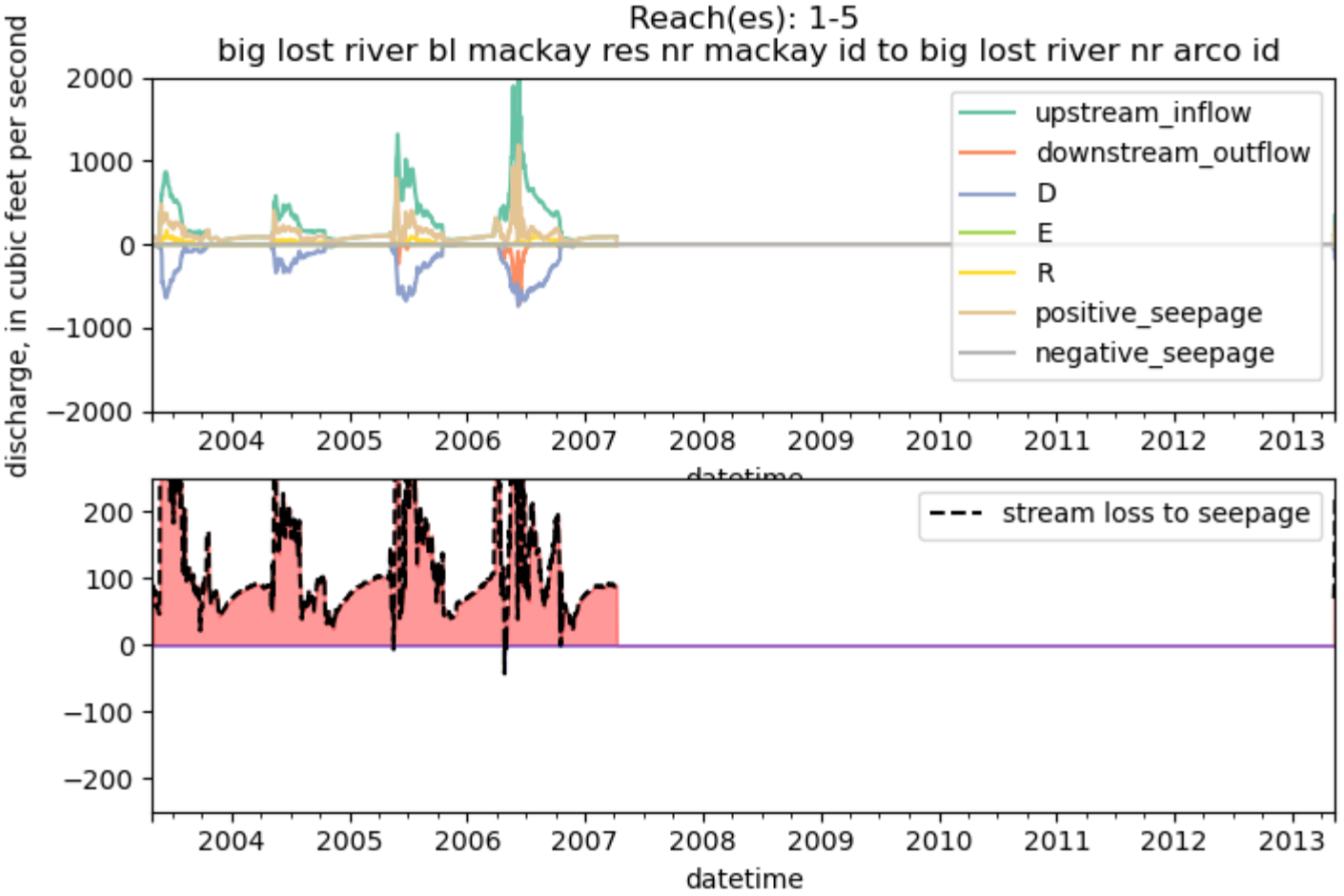
Mean	139,161	189,868	31,112	746	***7,953***	***–20,143***	***–28,096***

[1]Streamflow datasets were accessed from Idaho Power (2020).

[2]Streamflow datasets were accessed from U.S. Geological Survey (2020).

[3]Surface-water diversion and groundwater pumpage datasets were accessed from IDWR (2020d).

Clark (2021)



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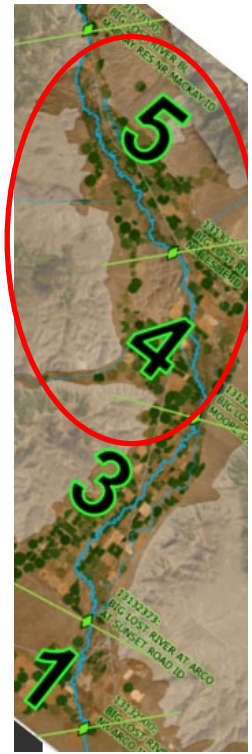

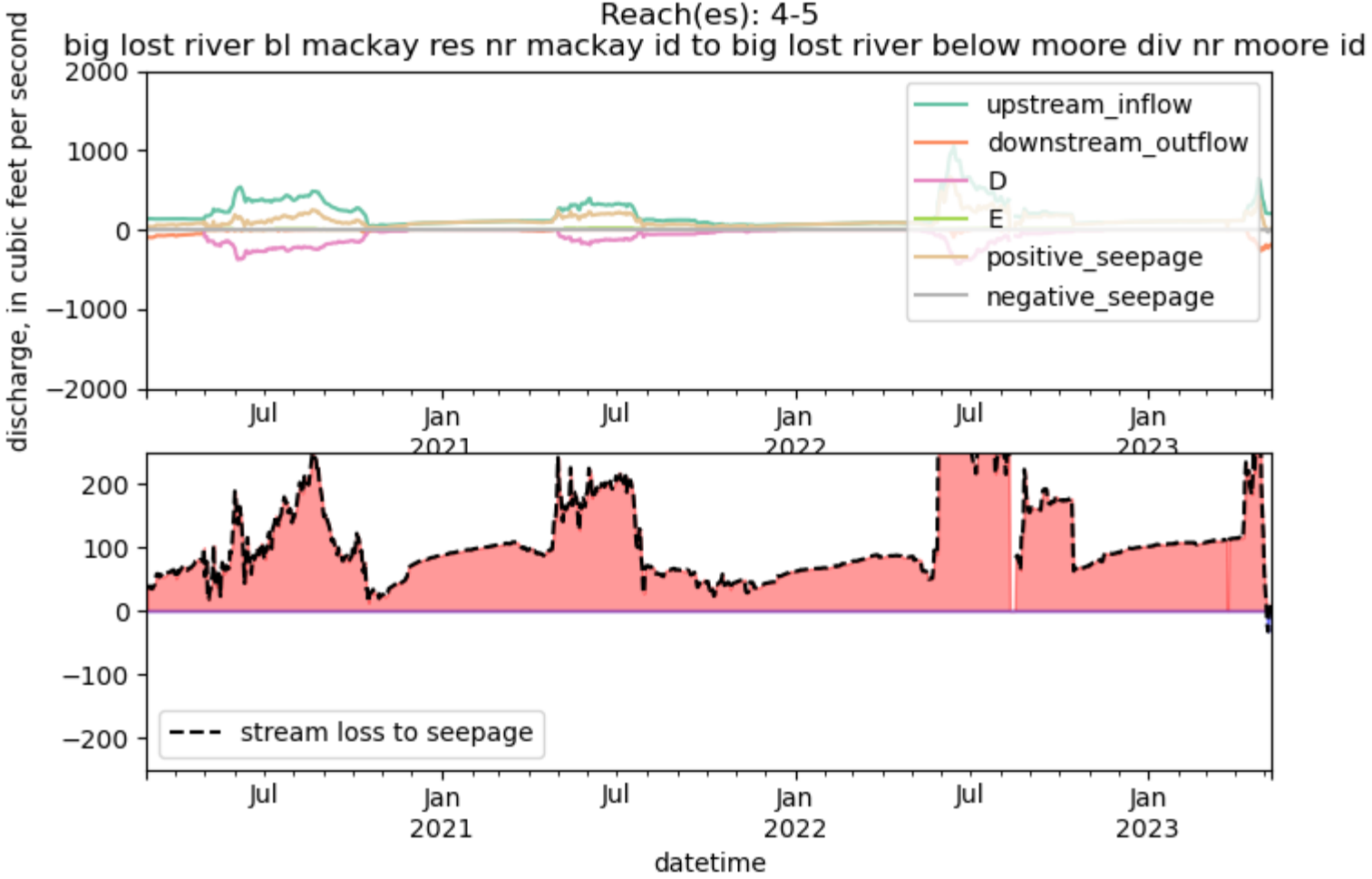

USGS
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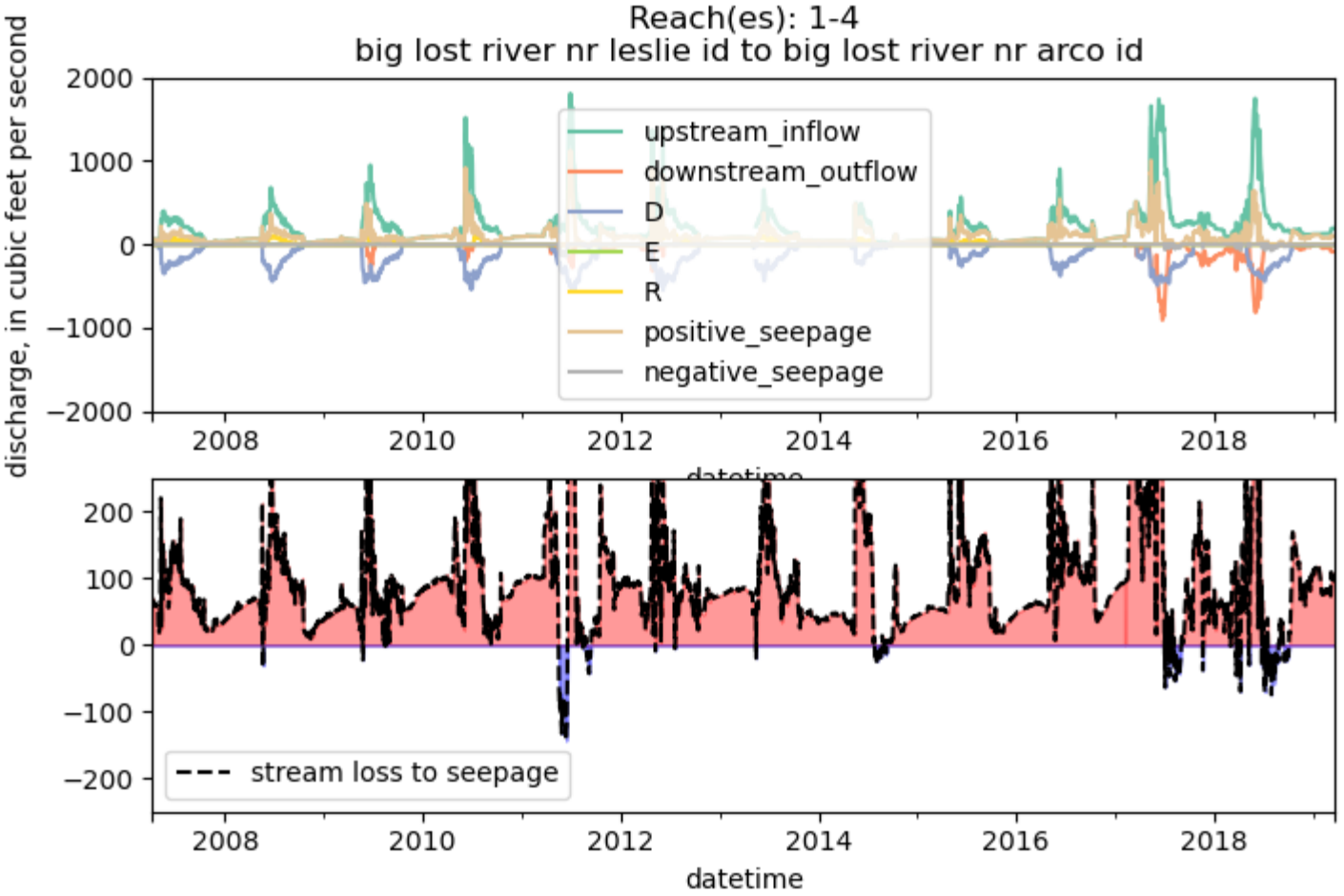

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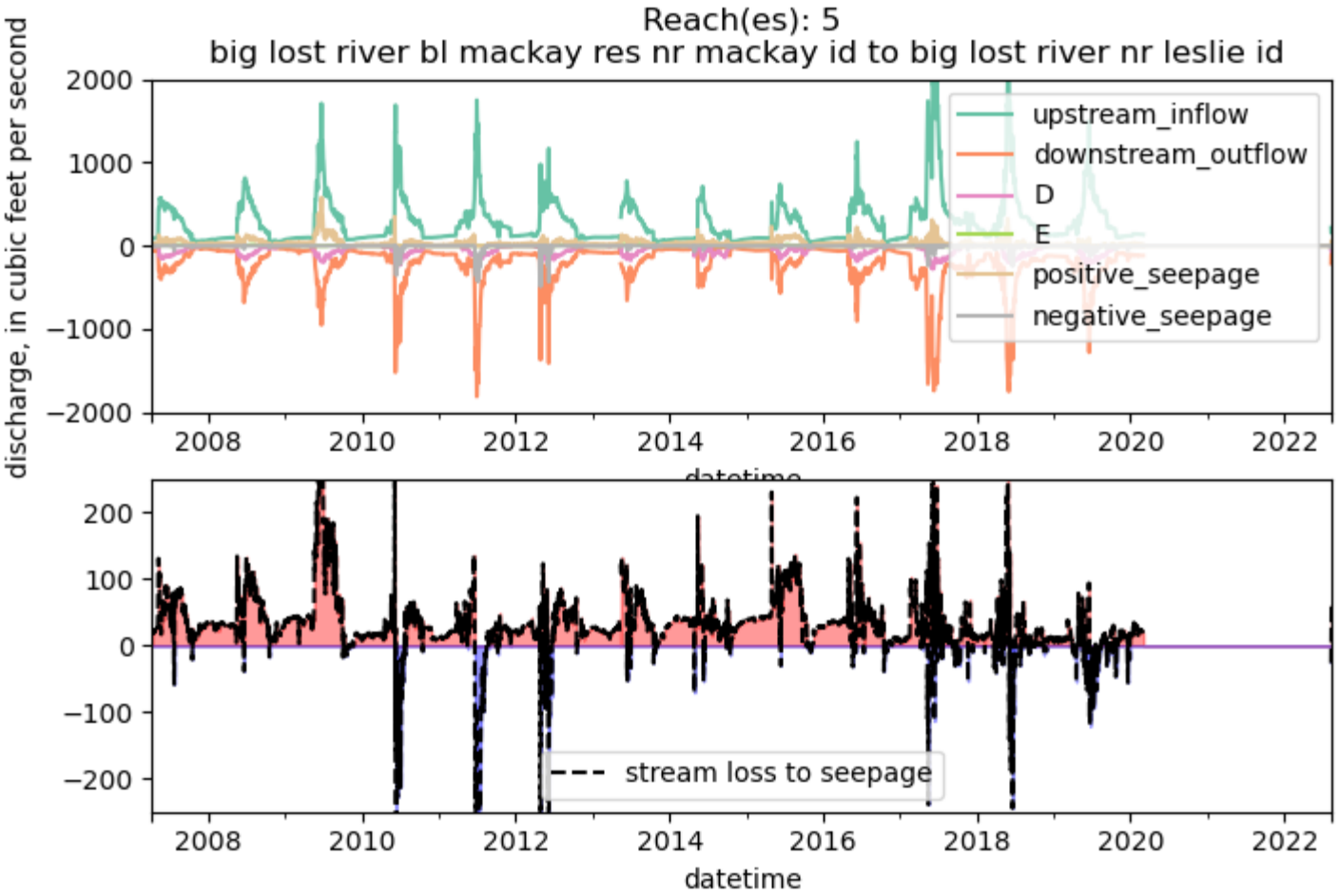
5
4
3
1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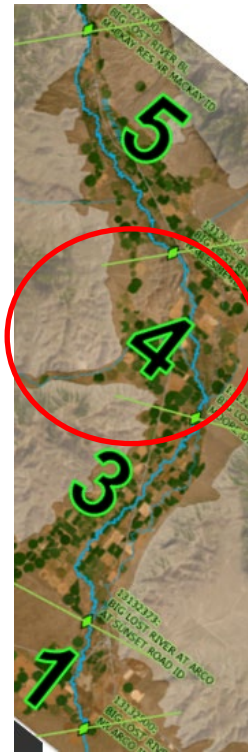
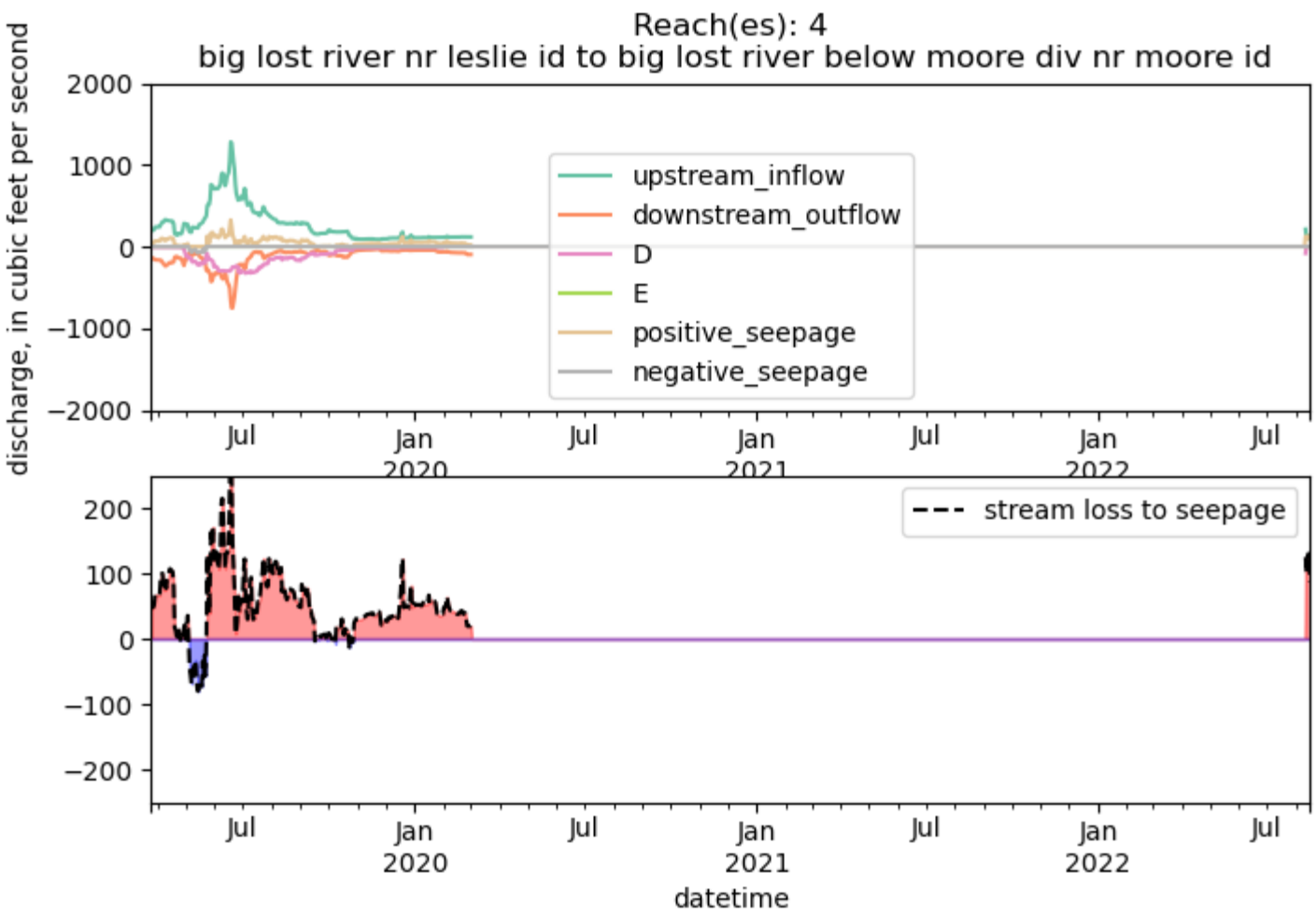
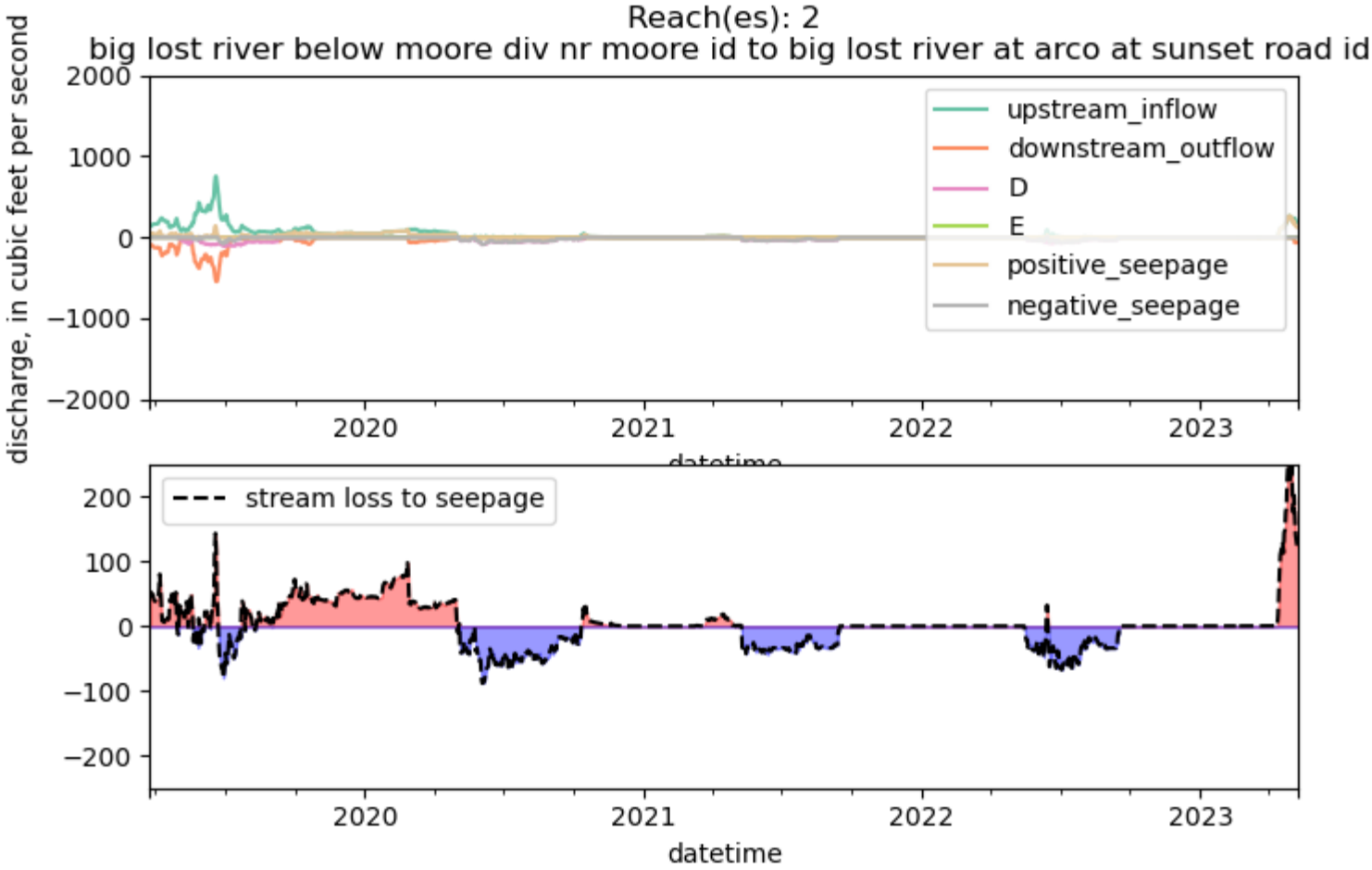
big lost river bl mackay res nr mackay id to big lost river nr leslie id
discharge, in cubic feet per second
2000
1000
0
−1000
−2000
2008
2010
2012
2014
2016
2018
2020
2022
upstream_inflow
downstream_outflow
D
E
positive_seepage
negative_seepage
200
100
0
−100
−200
stream loss to seepage
datetime


5
4
3
1


Reach(es): 4
big lost river nr leslie id to big lost river below moore div nr moore id
discharge, in cubic feet per second
2000
1000
0
−1000
−2000
upstream_inflow
downstream_outflow
D
E
positive_seepage
negative_seepage
Jul
Jan
2020
Jul
Jan
2021
Jul
Jan
2022
Jul
200
100
0
−100
−200
stream loss to seepage
datetime



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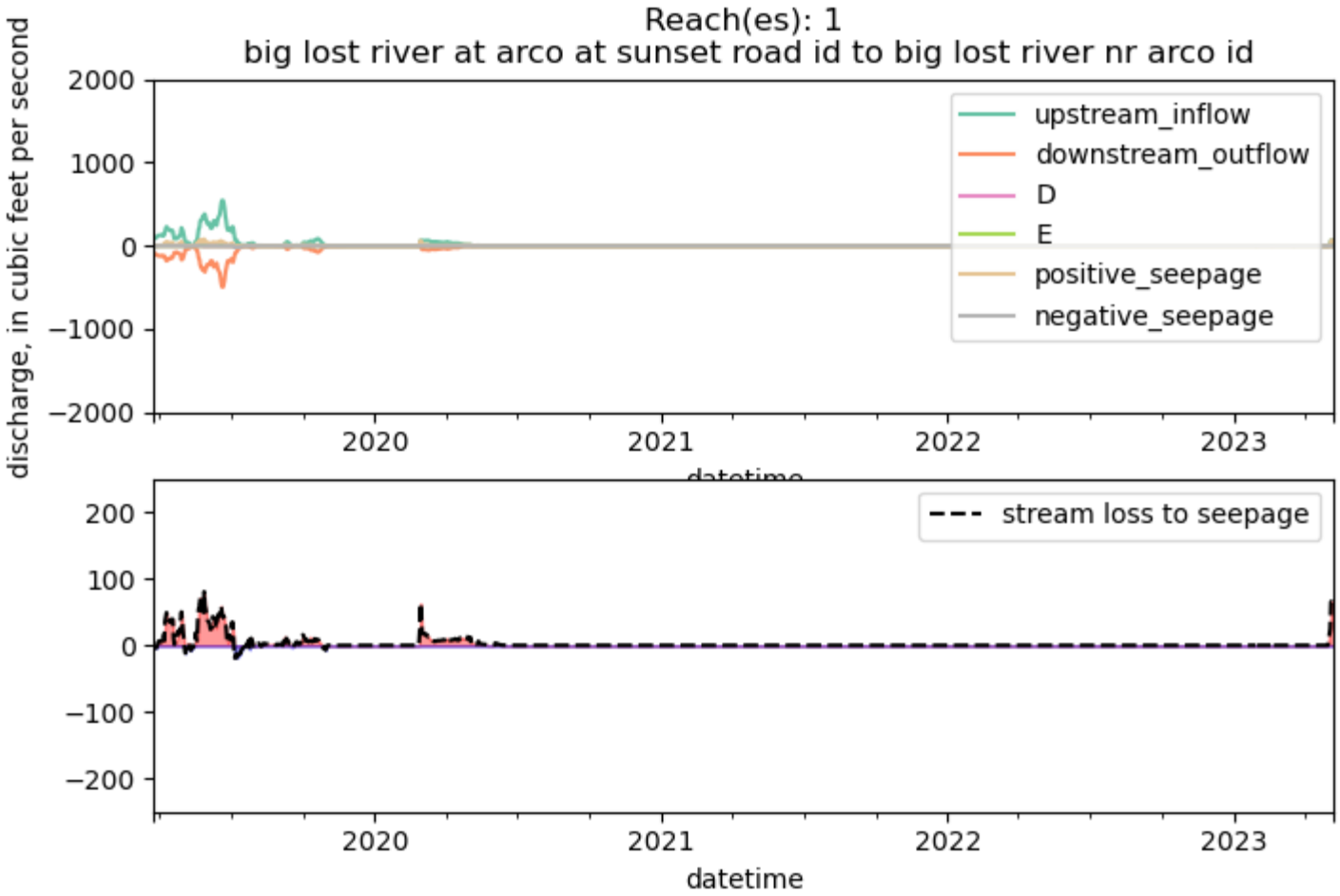

USGS
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Stream Seepage in Big Lost – Unmeasured Tributaries?

Still not sure what to do about unmeasured tributary inflow

- **Ignore**

- Only use months with likely little flow

- Estimate inflow
  - Mutliple linear regression
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2009	126,101	214,110	33,161	502	***10,047***	***–55,229***	***–65,275***
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[1]Streamflow datasets were accessed from Idaho Power (2020).

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Clark (2021)

Stream Seepage in Big Lost – Unmeasured Tributaries?

Still not sure what to do about unmeasured tributary inflow

- **Ignore**

- Only use months with likely little flow

- Estimate inflow
  - Mutliple linear regression
  - Index gage

- Only use months when we have USGS gage + diversions + Pivotrac for Antelope

Table 9.4. Estimated seepage, Leslie (Idaho Power streamgage 13130500) to Arco (USGS streamgage 13132500), in the Big Lost River below Mackay Dam, south-central Idaho, 2000–19.

[All values in ***bold italics*** are estimated. Groundwater budget includes seepage using tributary flows. All values in the table are in acre-feet per year. Negative seepage values indicate a losing reach condition and positive values indicate a gaining reach condition. **Abbreviations:** USGS, U.S. Geological Survey; IDWR, Idaho Department of Water Resources]

Year	Arco streamgage[1]	Leslie streamgage[2]	Diversions[3]	Groundwater pumpage to canals[3]	Burnett TE return flow[4]	East Side Out return flow (13132350)[5]	Antelope Creek (13131000)[1]	Seepage without Antelope Cr.	Seepage with Antelope Cr.
2000	17,580	***117,288***	75,503	0	***1,639***	***12,992***	***25,229***	[illegible]	[illegible]
2001	0	***77,737***	31,058	0	***728***	***10,074***	***18,560***	***−57,481***	***−76,041***
2002	0	***79,811***	35,204	0	***673***	***10,509***	***21,579***	***−55,789***	***−77,367***
2003	0	***88,380***	39,528	0	***1,023***	11,909	***32,372***	***−61,783***	***−94,155***
2004	0	***71,726***	31,399	0	***1,041***	9,629	***27,083***	***−50,997***	***−78,080***
2005	3,995	***142,102***	73,852	0	***1,659***	11,249	***52,823***	***−77,162***	***−129,985***
2006	36,642	***226,970***	119,005	0	***2,130***	15,061	***51,239***	***−88,515***	***−139,753***
2007	0	109,766	56,521	0	***1,397***	14,219	***20,419***	***−68,861***	***−89,280***
2008	0	101,714	60,005	0	***1,229***	12,462	***22,311***	***−55,400***	***−77,712***
2009	9,273	126,101	78,390	0	***1,628***	12,834	***47,129***	***−52,901***	***−100,029***
2010	3,830	158,010	76,857	0	***1,458***	6,115	***47,041***	***−84,897***	***−131,938***
2011	18,494	197,177	95,844	0	***1,688***	***16,139***	***40,377***	***−100,667***	***−141,043***
2012	10,049	154,033	94,910	0	***1,711***	19,746	***47,132***	***−70,531***	***−117,663***
2013	305	108,551	58,946	0	***1,044***	14,751	***14,872***	***−65,094***	***−79,966***
2014	0	66,380	26,065	6,739	***1,146***	7,329	***26,103***	***−52,699***	***−78,802***
2015	0	85,869	36,642	0	***1,066***	8,424	***25,736***	***−58,718***	***−84,453***
2016	0	124,927	55,630	0	1,217	11,620	***48,370***	***−82,134***	***−130,504***
2017	100,189	324,165	106,363	0	506	15,277	***94,831***	***−133,395***	***−228,226***
2018	82,880	230,369	89,052	0	2,458	18,376	65,860	***−79,270***	***−145,131***
2019	45,134	192,147	91,832	0	2,349	10,147	70,413	[illegible]	[illegible]
Mean	16,419	139,161	66,630	337	1,390	12,443	39,974	***−70,140***	***−110,114***

[1]Streamflow datasets were accessed from U.S. Geological Survey (2020).

[2]Streamflow datasets were accessed from Idaho Power (2020).

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[5]East Side Out return flow datasets were accessed from IDWR (2020d) during 2003–10 and 2012–19 and from PivoTrac Monitoring (http://www.pivotrac.com/, contracted to Water District 34, unpub. data, 2021; data available upon request from Water District 34 watermaster, Lucas Yockey, at 208-589-3183) for 2015–19.

Clark (2021)

Stream Seepage in Big Lost – Unmeasured Tributaries?

Still not sure what to do about unmeasured tributary inflow

- **Ignore**

- Only use months with likely little flow

- Estimate inflow
  - Mutliple linear regression
  - Index gage

- Only use months when we have USGS gage + diversions + Pivotrac for Antelope

Table 4. Summary of streamflow, associated estimates of uncertainty, and streamflow gains and losses on measured reaches and subreaches in the Big Lost River Valley, south-central Idaho, October 16–17, 2019.

[Location of sites is shown in figure 1. See table 1 for site names according to river miles. Values at streamgages represent instantaneous measurement rather than daily mean streamflows. **Site name:** ID, Idaho; N, North; Rd, Road; W, West. **Remarks:** G, gaining reach; L, losing reach; U, uncertainty of measurements in subreach are greater than measured accrual; **Abbreviations and symbols:** No., number; ft³/s, cubic feet per second; ±, plus or minus; —, no data

Site No.	Site name	Main-stem streamflow and associated measurement uncertainty (ft³/s)	Tributary (+) or diversion (–) streamflow and associated measurement uncertainty (ft³/s)	Streamflow accrual, gain (+) or loss (–) and associated measurement uncertainty (ft³/s)	Remarks
	October 16, 2019				
B01	Big Lost River below Mackay Reservoir near Mackay, ID[1]	211±2.98	—	—	
D01	Swauger Slough east of Beverland Lane in Mackay, ID	—	(–)10.9±0.41	—	
B02	Big Lost River at Smelter Avenue, Mackay, ID	215±14.2	—	(+)14.9±14.5	G
D02	Rogers Canal near Mackay, ID	—	(–)6.27±0.31	—	
D03	Burnett Ditch near Mackay, ID	—	(–)15.9±1.38	—	
B03	Big Lost River at Alder Creek Road Bridge near Mackay, ID	147±8.67	—	(–)45.8±16.7	L
B05	Big Lost River below Alder Creek near Mackay, ID	174±14.6	—	(+)27.0±17.0	G
B06	Big Lost River near Leslie, ID	165±7.10	—	(–)9.0±16.2	U
	Overall net gain (+) or loss (–) throughout the upper reach:			**(–)12.9±7.83**	**L**
T02	Spring Creek at Houston Road, Mackay, ID	—	(+)2.98±0.36	—	
D04	Beck and Evan Ditch near Leslie, ID	—	(–)2.86±0.28	—	
D05	Unnamed ditch above Leslie Recharge Pit, near Leslie, ID	—	0	—	
D06	Three-In-One Ditch near Leslie, ID	—	0	—	
D07	Blaine Canal below Diversion near Leslie, ID	—	(–)0.76±0.052	—	
B07	Big Lost River at Highway 93 crossing below Three-In-One Ditch near Mackay, ID	155±6.67	—	(–)9.36±9.75	U
B08	Big Lost River at 3800 N crossing near Darlington, ID	147±7.20	—	(–)8.00±9.81	U
B09	Big Lost River at Darlington Rd crossing near Darlington, ID	[illegible]	—	(–)31.0±8.96	L
T0[illegible]	Antelope Creek (Lower Fork) at Darlington, ID	—	0	—	
T04	Swauger-Burnett Canal (Unit B)		[2](+)20	—	
B10	Big Lost River near Moore, ID	177±6.90	-	(+)41.0±8.72	G
	Overall net gain (+) or loss (–) throughout the middle reach:			**(–)7.36± 9.91**	**L**
D08	East Side Ditch near 13132100	—	(–)12.2±0.16	—	
D09	West Side Ditch near 13132100	—	(–)19.7±1.22	—	
B11	Big Lost River below Moore Diversion near Moore, ID[3]	138±7.04	—	(–)7.10±9.93	U

Dudunake & Zinsser (2021)

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Table 9.4. Estimated seepage, Leslie (Idaho Power streamgage 13130500) to Arco (USGS streamgage 13132500), in the Big Lost River below Mackay Dam, south-central Idaho, 2000–19.

[All values in ***bold italics*** are estimated. Groundwater budget includes seepage using tributary flows. All values in the table are in acre-feet per year. Negative seepage values indicate a losing reach condition and positive values indicate a gaining reach condition. **Abbreviations:** USGS, U.S. Geological Survey; IDWR, Idaho Department of Water Resources]

Year	Arco streamgage[1]	Leslie streamgage[2]	Diversions[3]	Groundwater pumpage to canals[3]	Burnett TE return flow[4]	East Side Out return flow (13132350)[5]	Antelope Creek (13131000)[1]	Seepage without Antelope Cr.	Seepage with Antelope Cr.
2000	17,580	***117,288***	75,503	0	***1,639***	***12,992***	***25,229***	***–36,837***	***–64,985***
2001	0	***77,737***	31,058	0	***728***	***10,074***	***18,560***	***–57,481***	***–76,041***
2002	0	***79,811***	35,204	0	***673***	***10,509***	***21,579***	***–55,789***	***–77,367***
2003	0	***88,380***	39,528	0	***1,023***	11,909	***32,372***	***–61,783***	***–94,155***
2004	0	***71,726***	31,399	0	***1,041***	9,629	***27,083***	***–50,997***	***–78,080***
2005	3,995	***142,102***	73,852	0	***1,659***	11,249	***52,823***	***–77,162***	***–129,985***
2006	36,642	***226,970***	119,005	0	***2,130***	15,061	***51,239***	***–88,515***	***–139,753***
2007	0	109,766	56,521	0	***1,397***	14,219	***20,419***	***–68,861***	***–89,280***
2008	0	101,714	60,005	0	***1,229***	12,462	***22,311***	***–55,400***	***–77,712***
2009	9,273	126,101	78,390	0	***1,628***	12,834	***47,129***	***–52,901***	***–100,029***
2010	3,830	158,010	76,857	0	***1,458***	6,115	***47,041***	***–84,897***	***–131,938***
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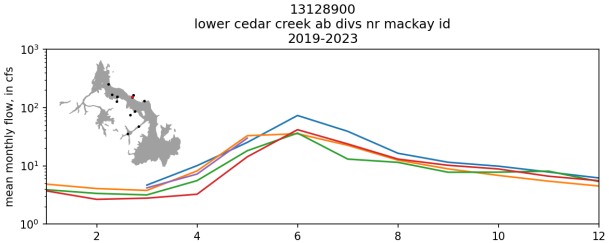
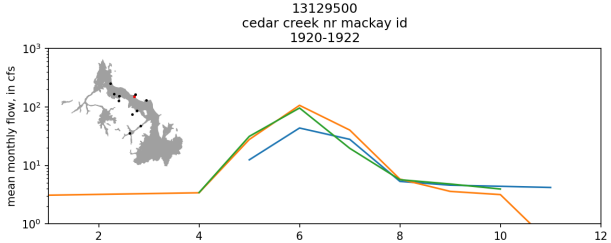
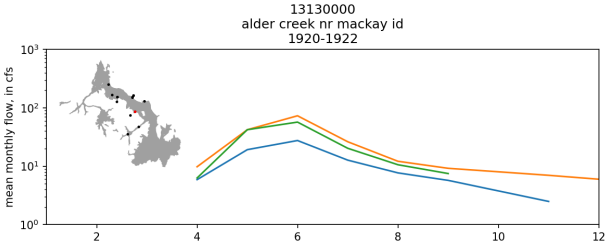
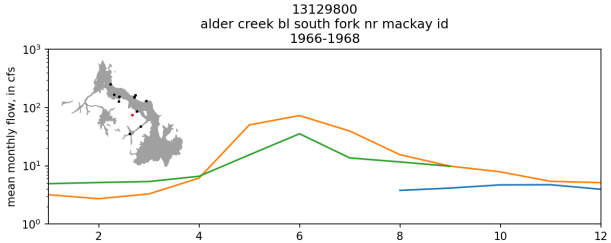
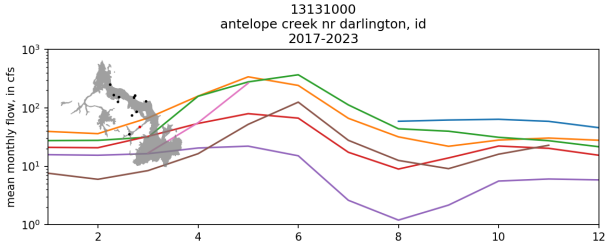
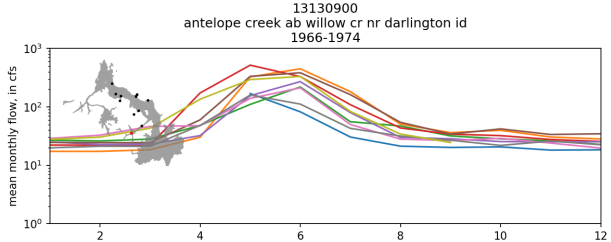




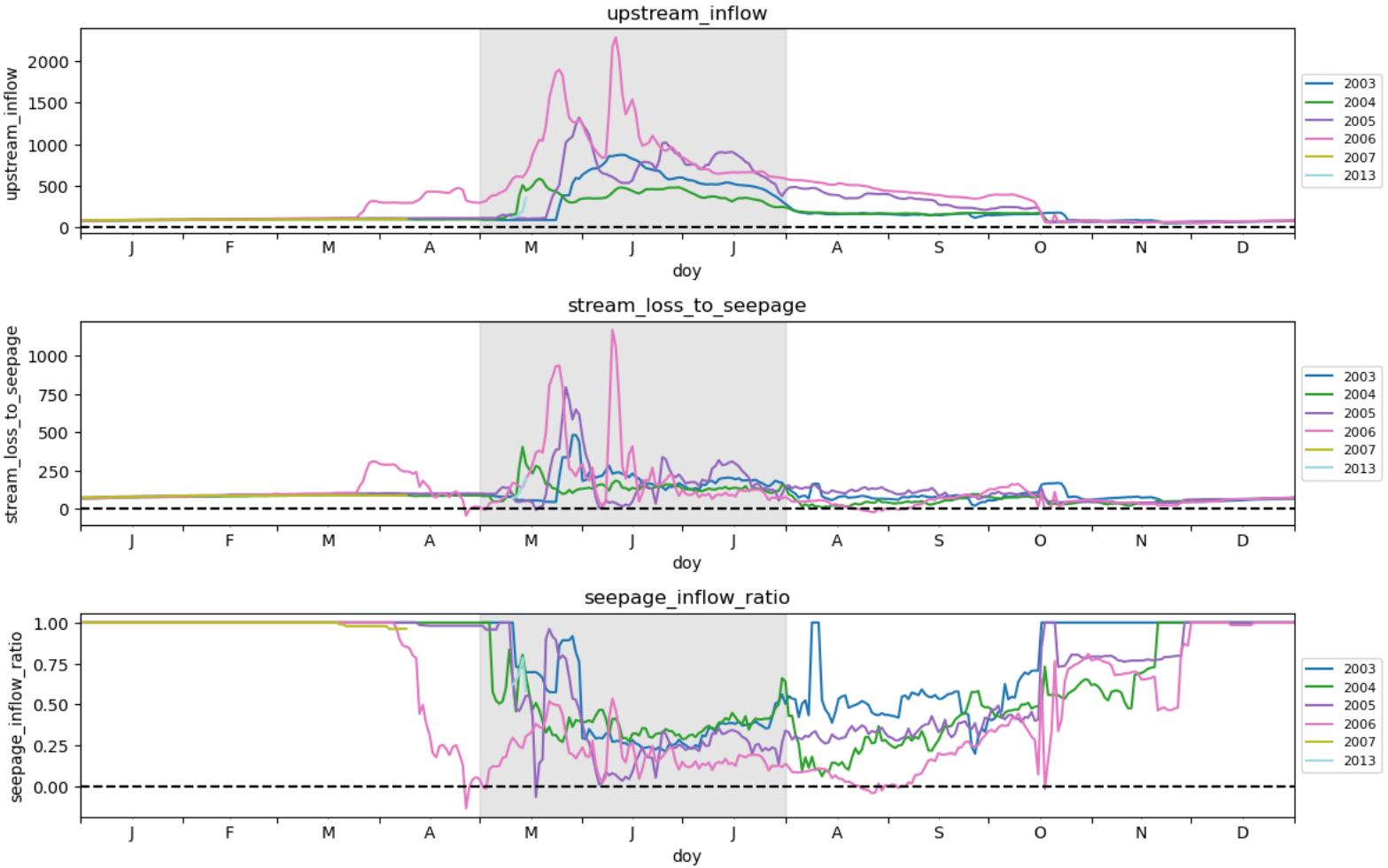








Reach(es): 1-5
big lost river bl mackay res nr mackay id to big lost river nr arco id



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Reach(es): 1-5
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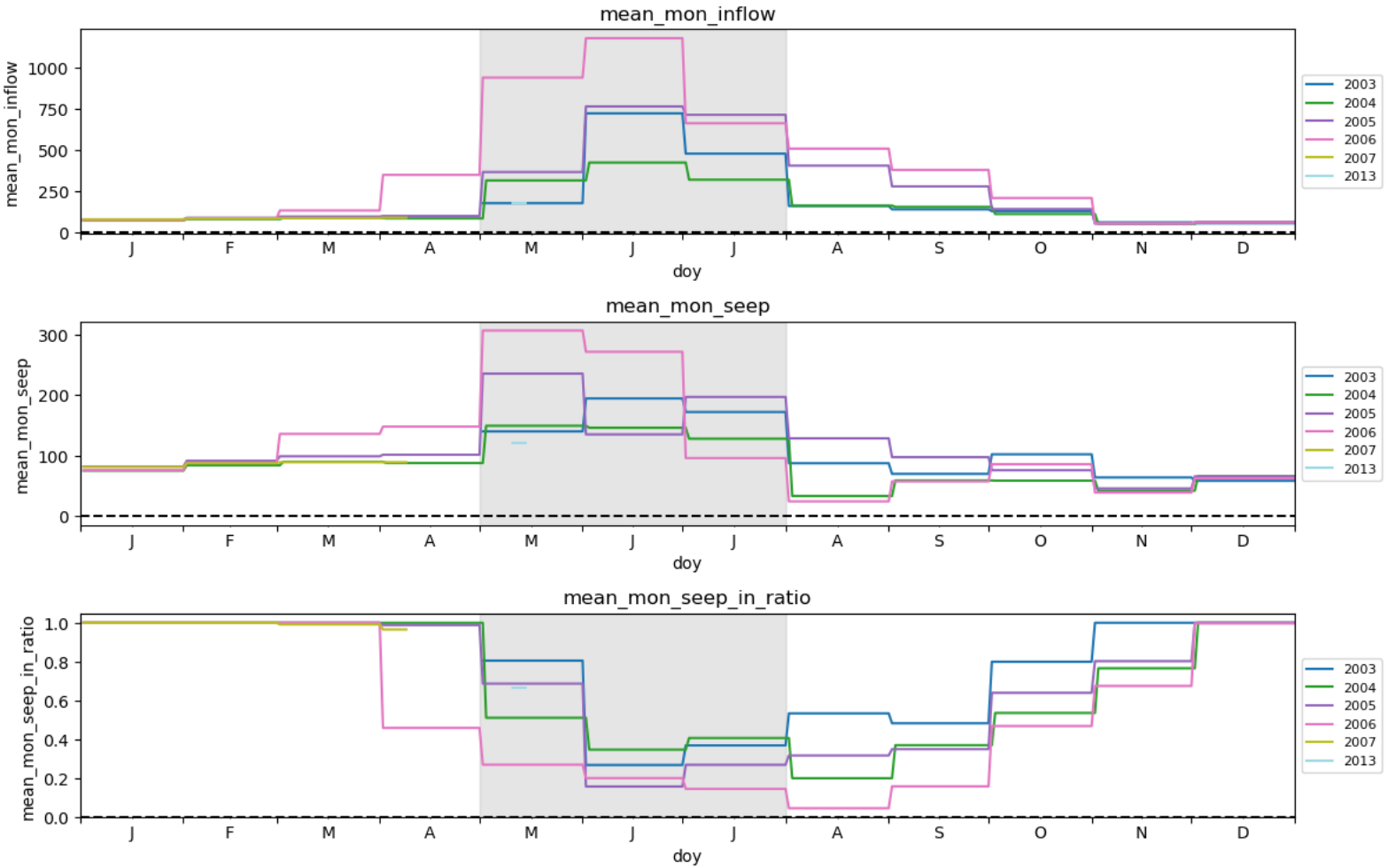

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Reach(es): 4-5
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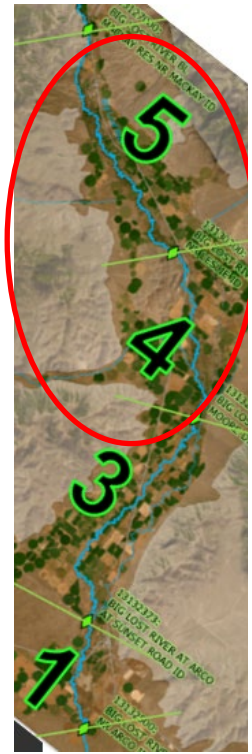

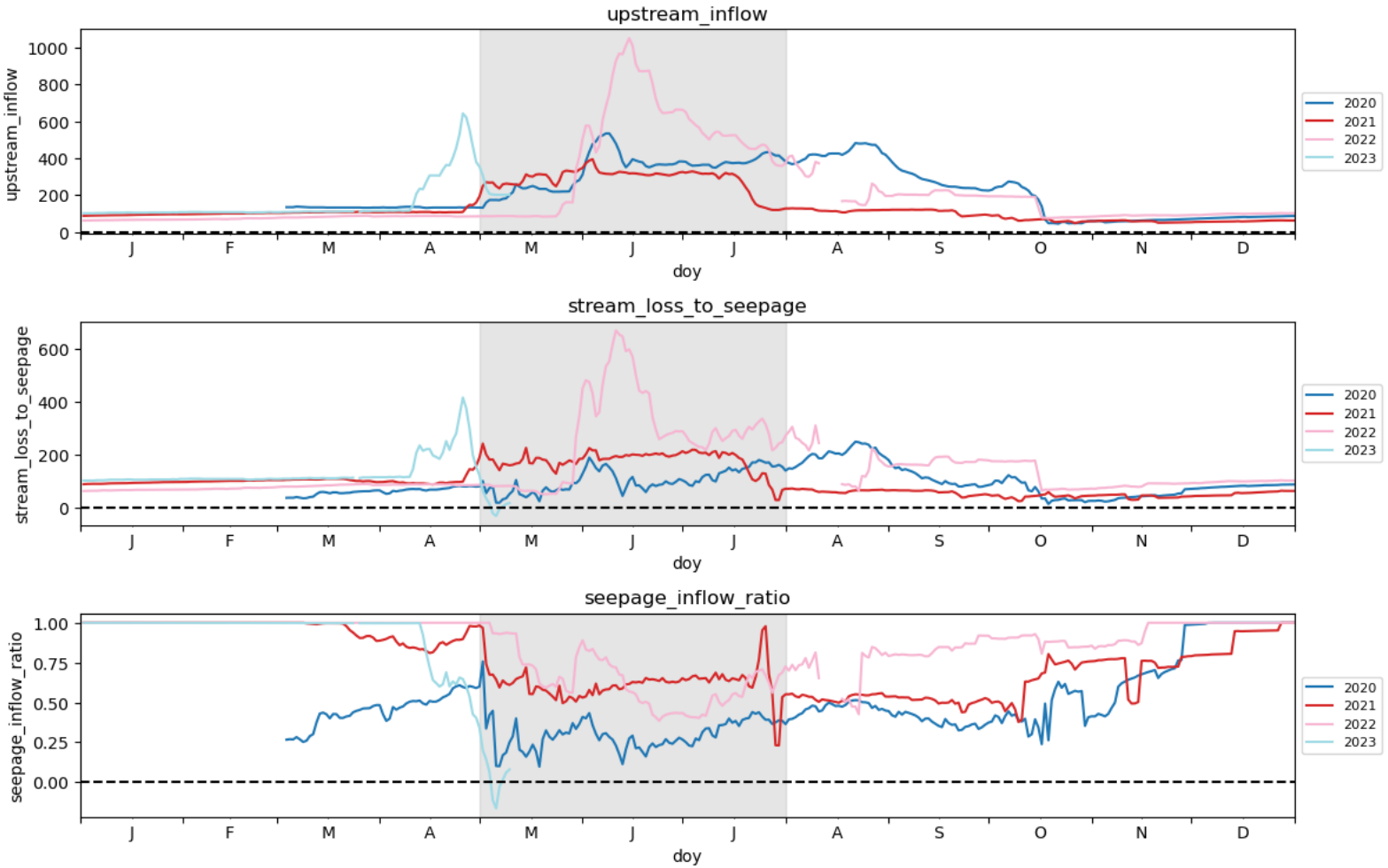

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Reach(es): 4-5
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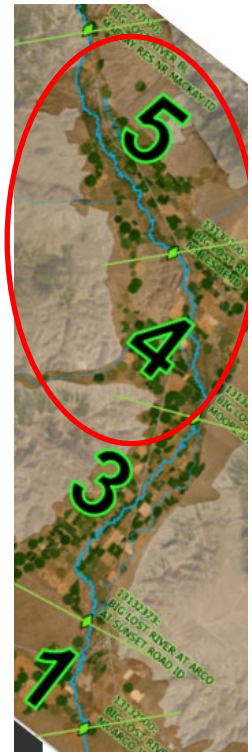

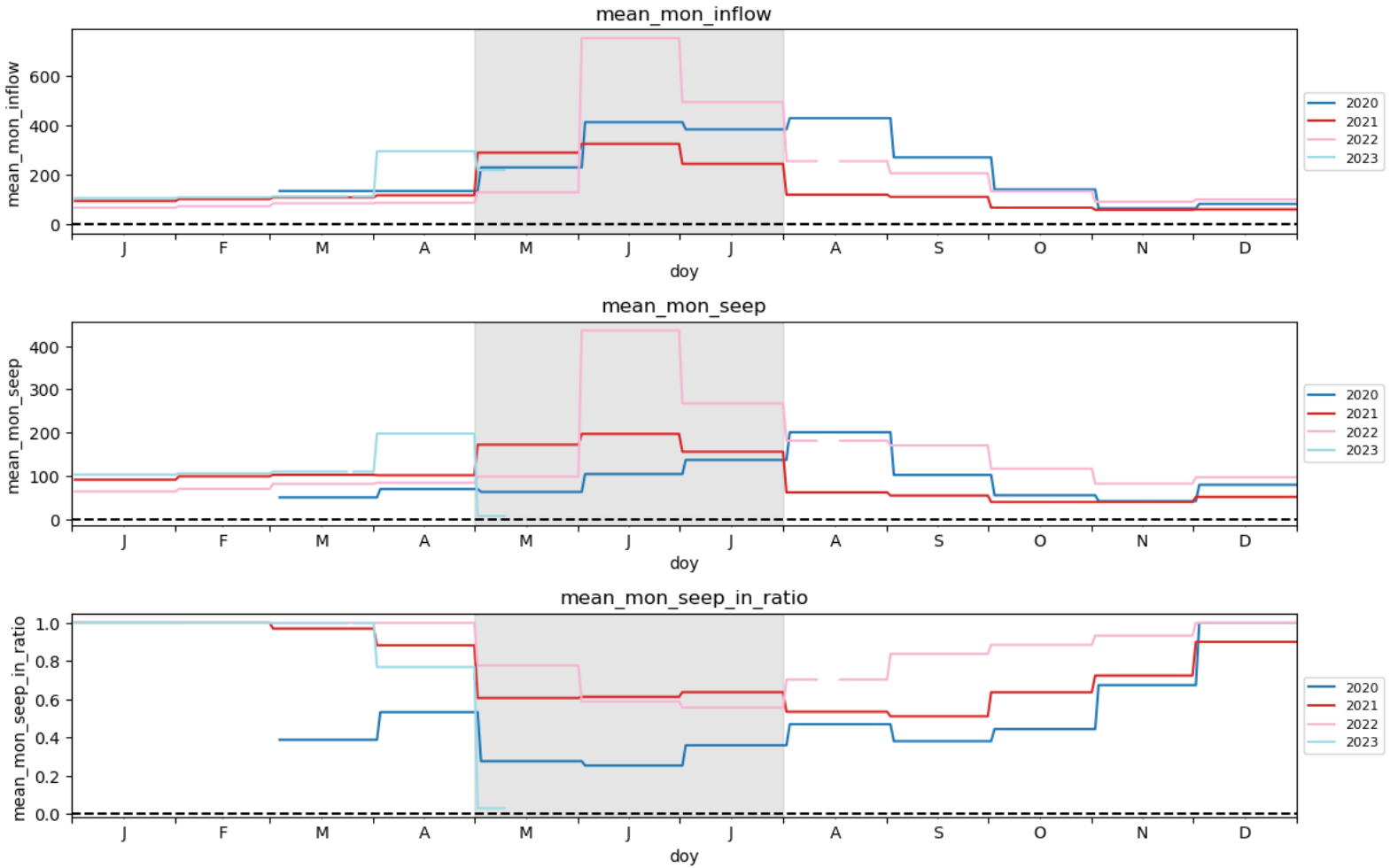

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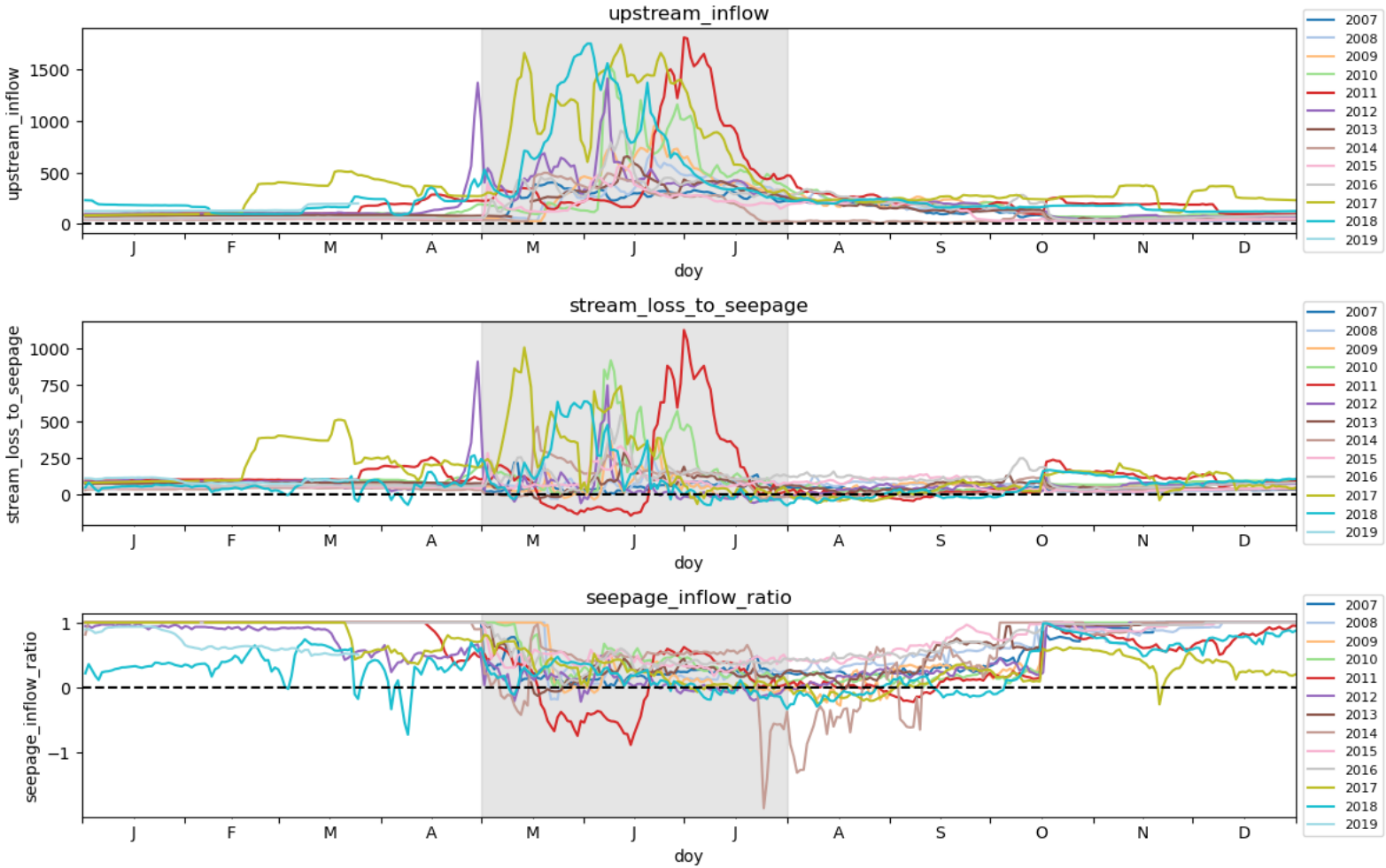
Reach(es): 1-4
big lost river nr leslie id to big lost river nr arco id



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Reach(es): 1-4
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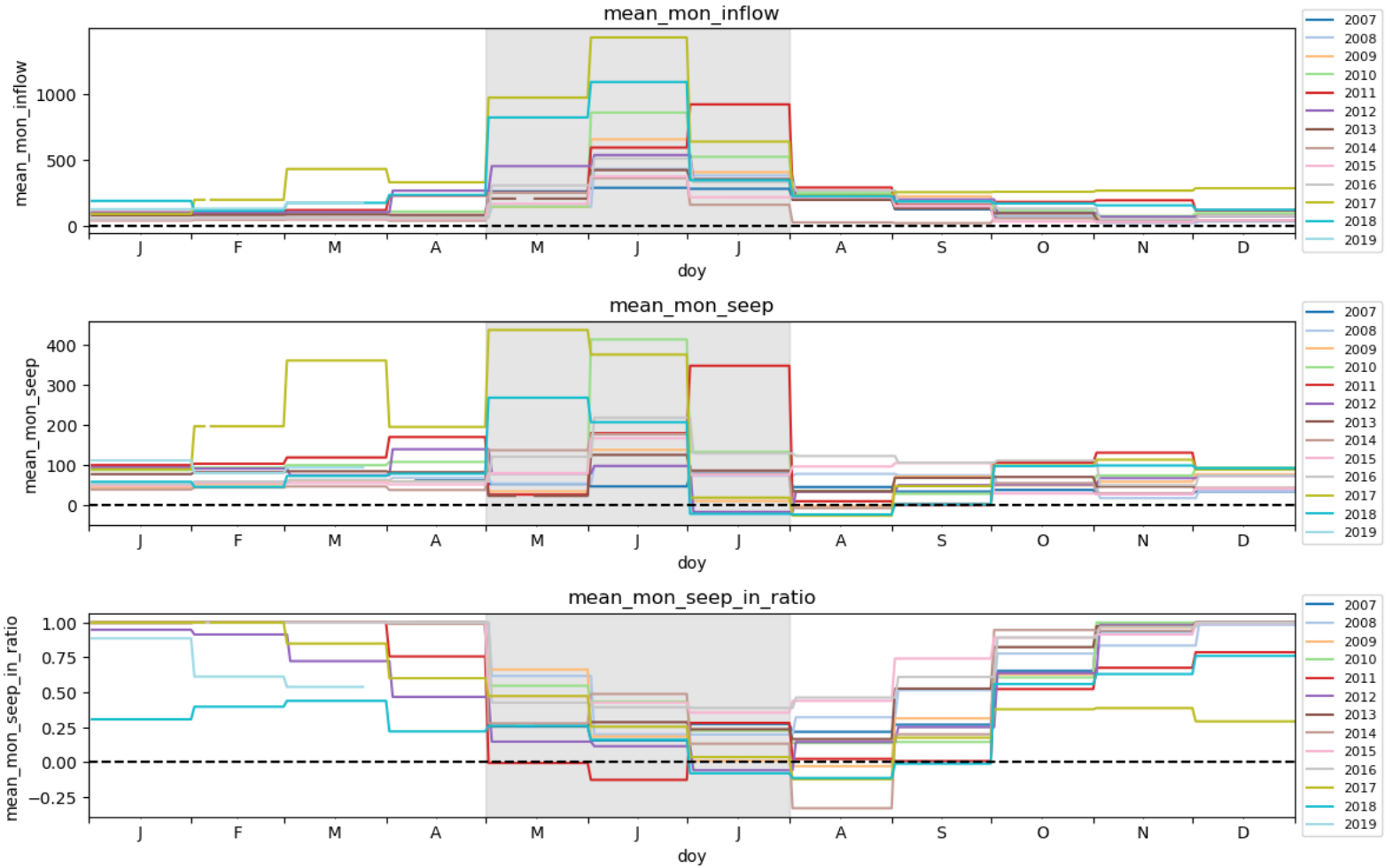

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Reach(es): 5
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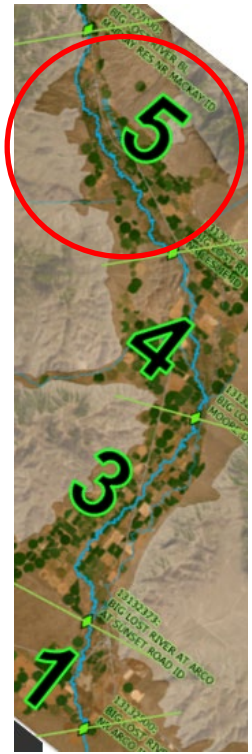

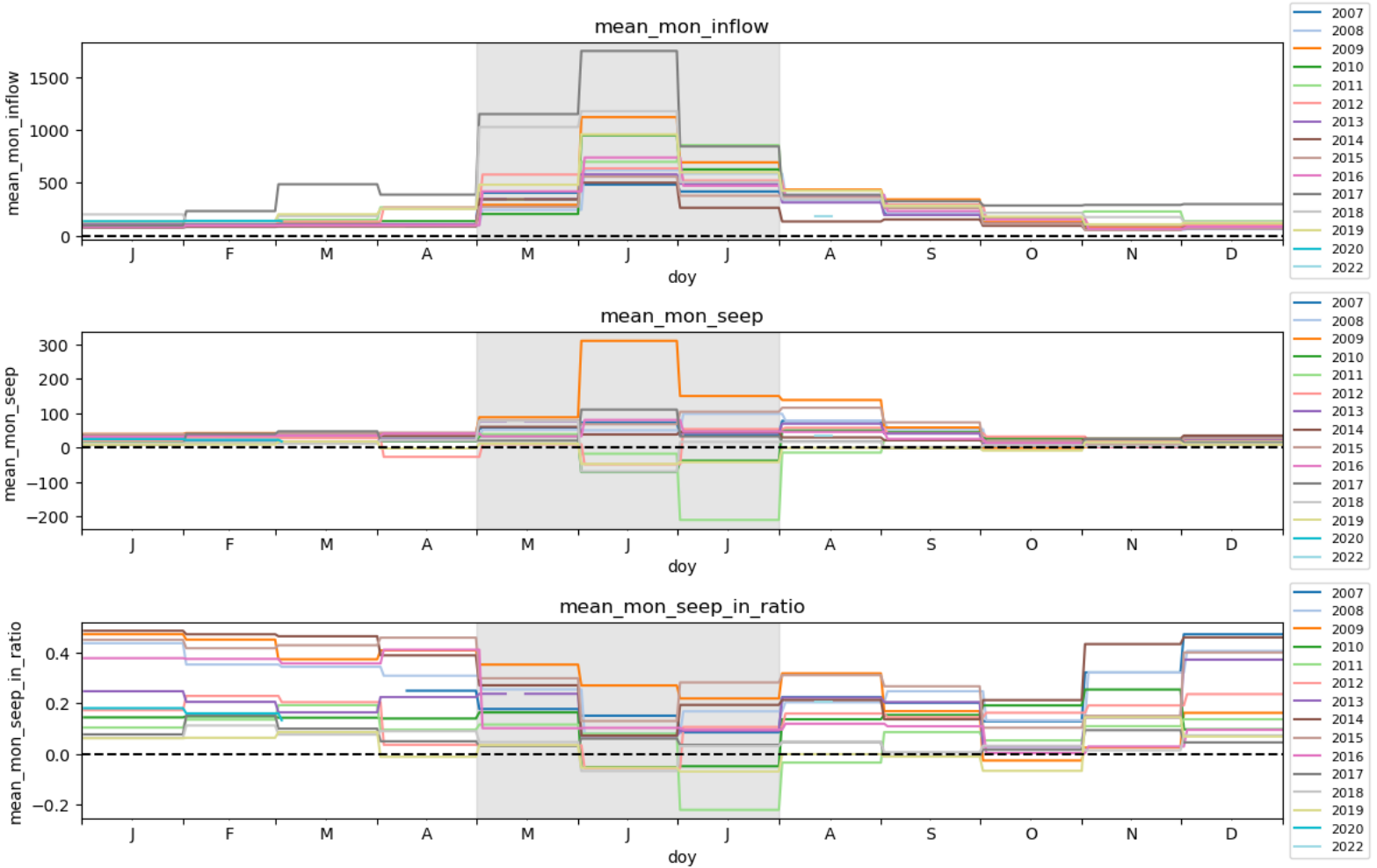

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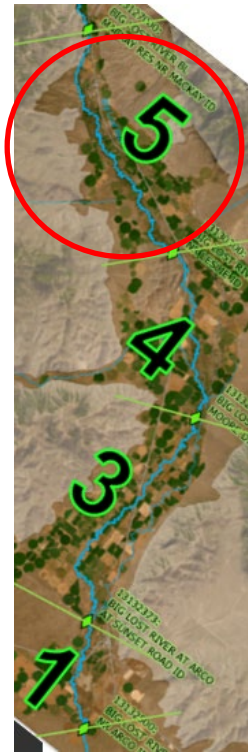
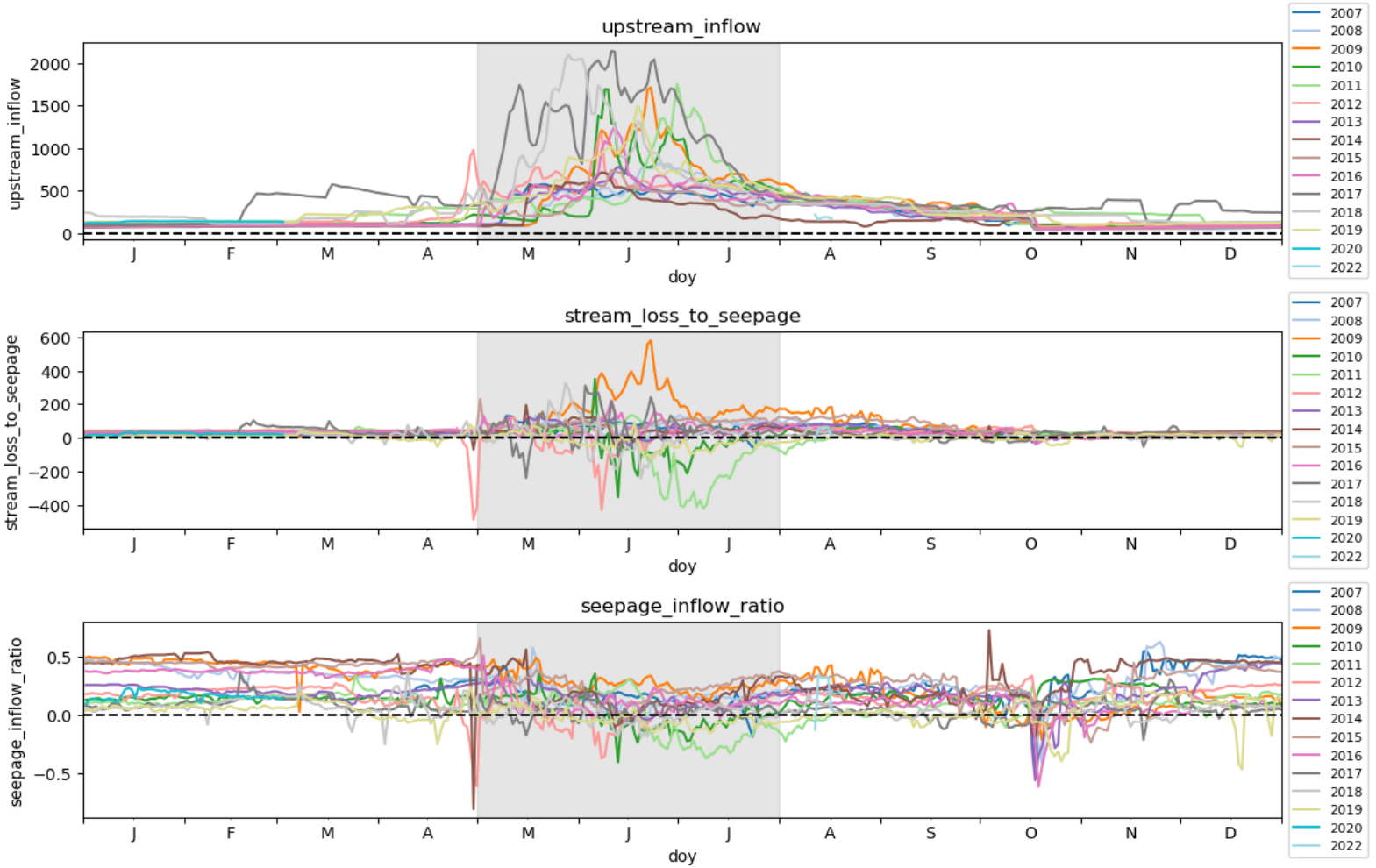


Reach(es): 5
big lost river bl mackay res nr mackay id to big lost river nr leslie id



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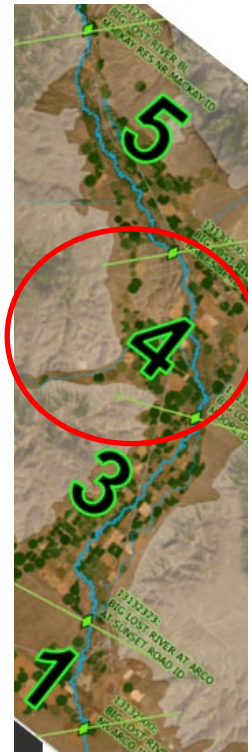
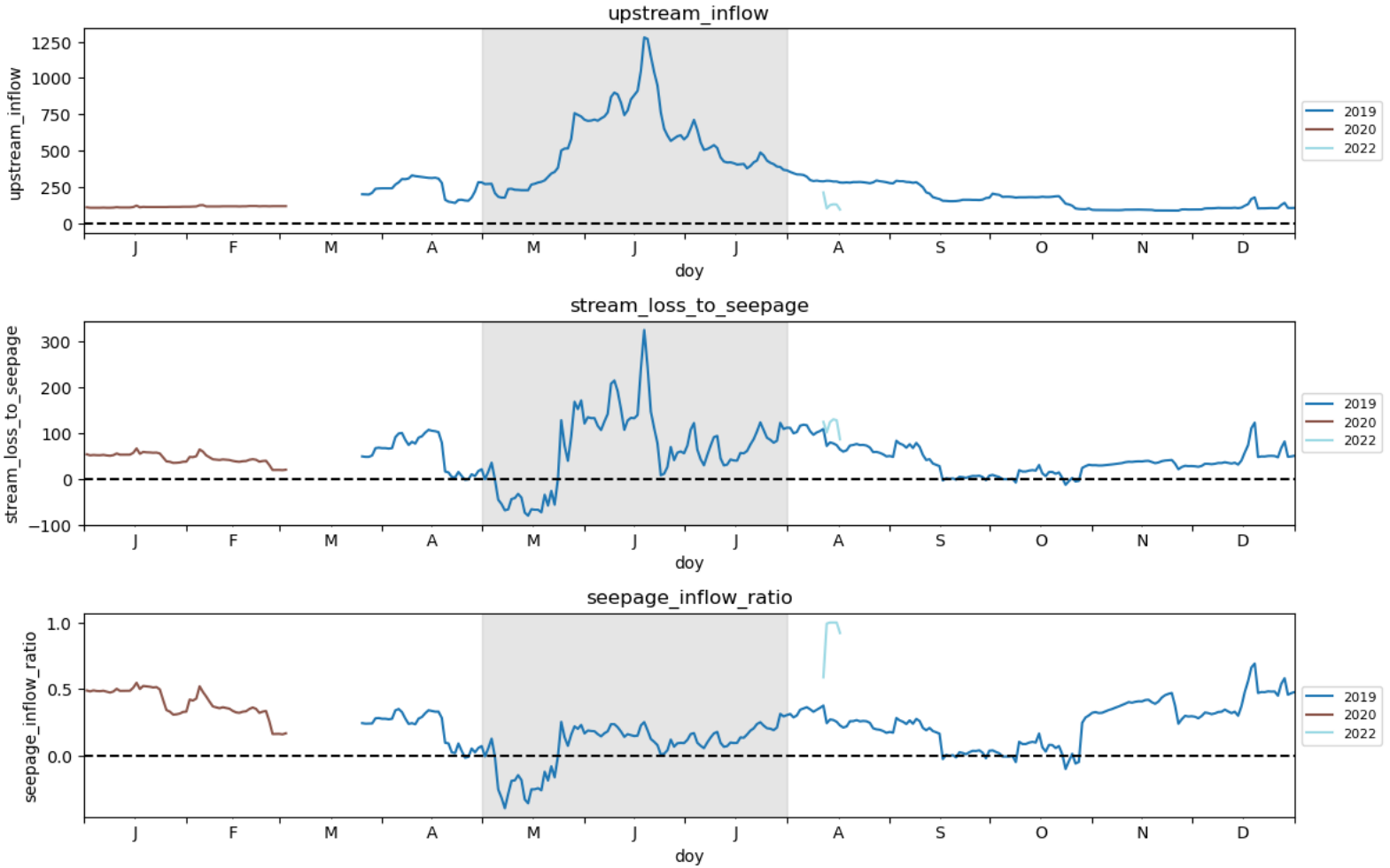


Reach(es): 4
big lost river nr leslie id to big lost river below moore div nr moore id



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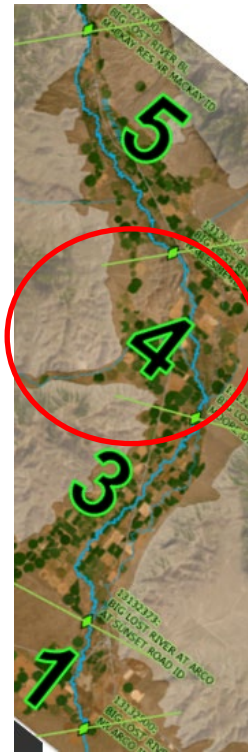
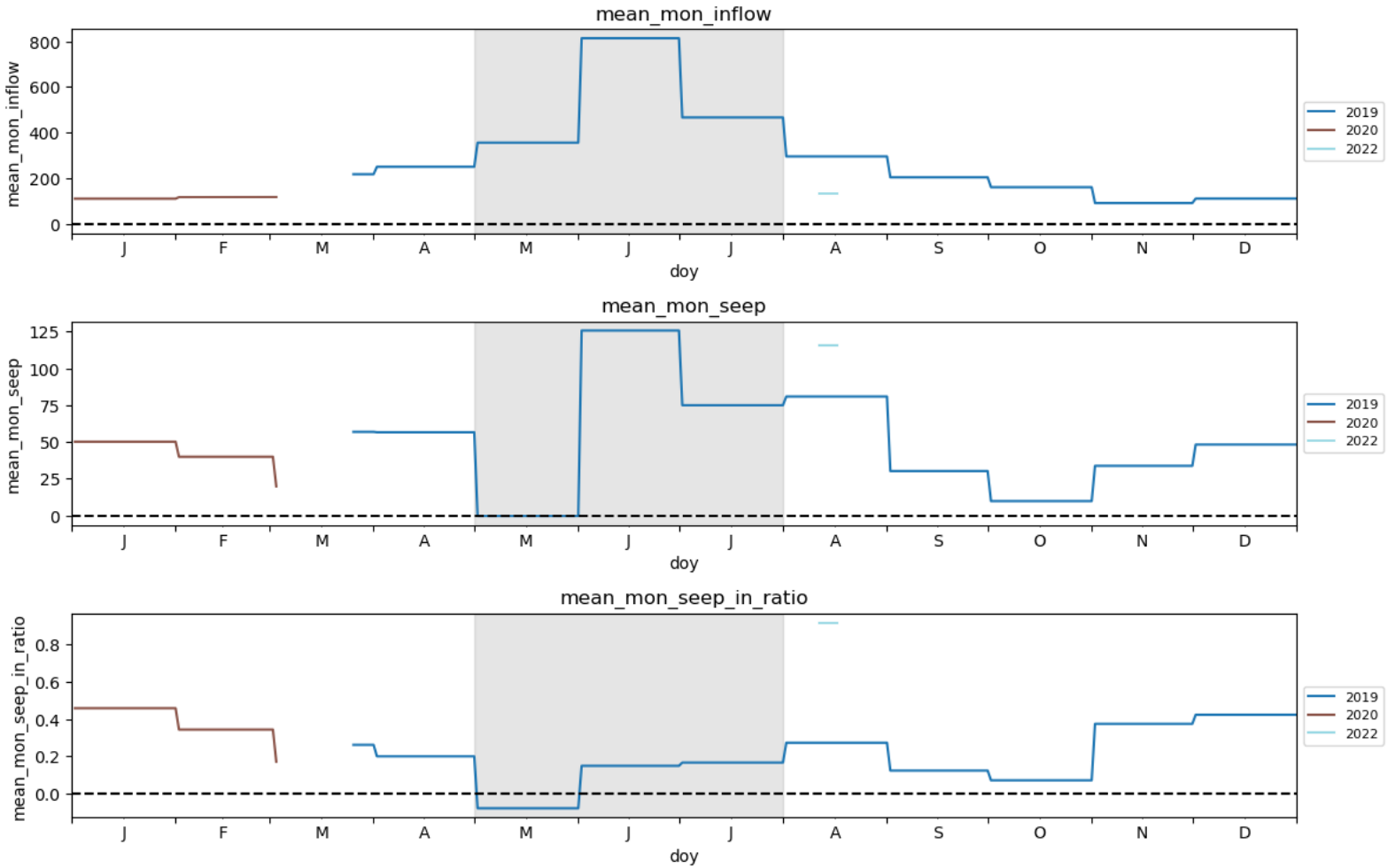
Reach(es): 4
big lost river nr leslie id to big lost river below moore div nr moore id





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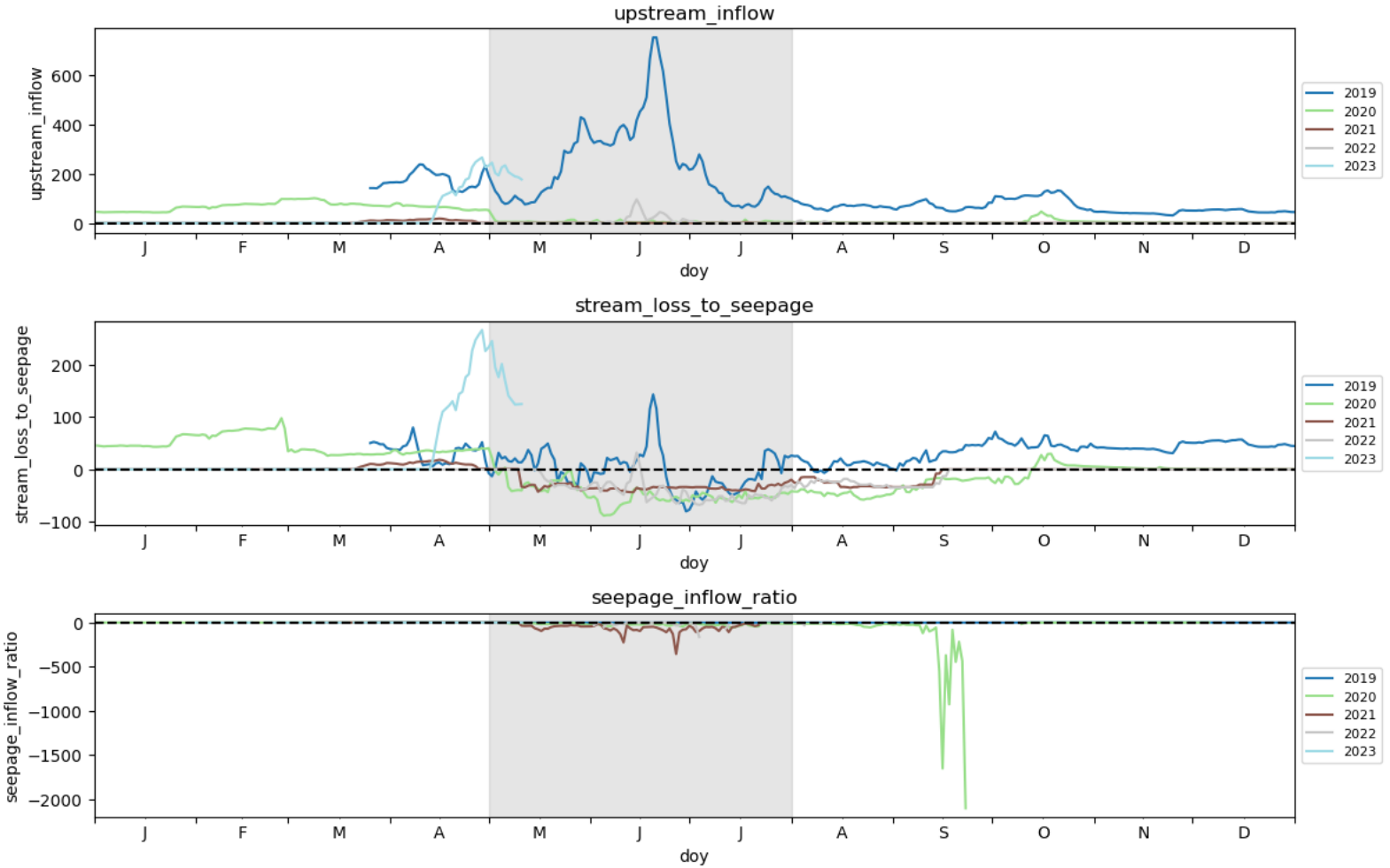
Reach(es): 2
big lost river below moore div nr moore id to big lost river at arco at sunset road id



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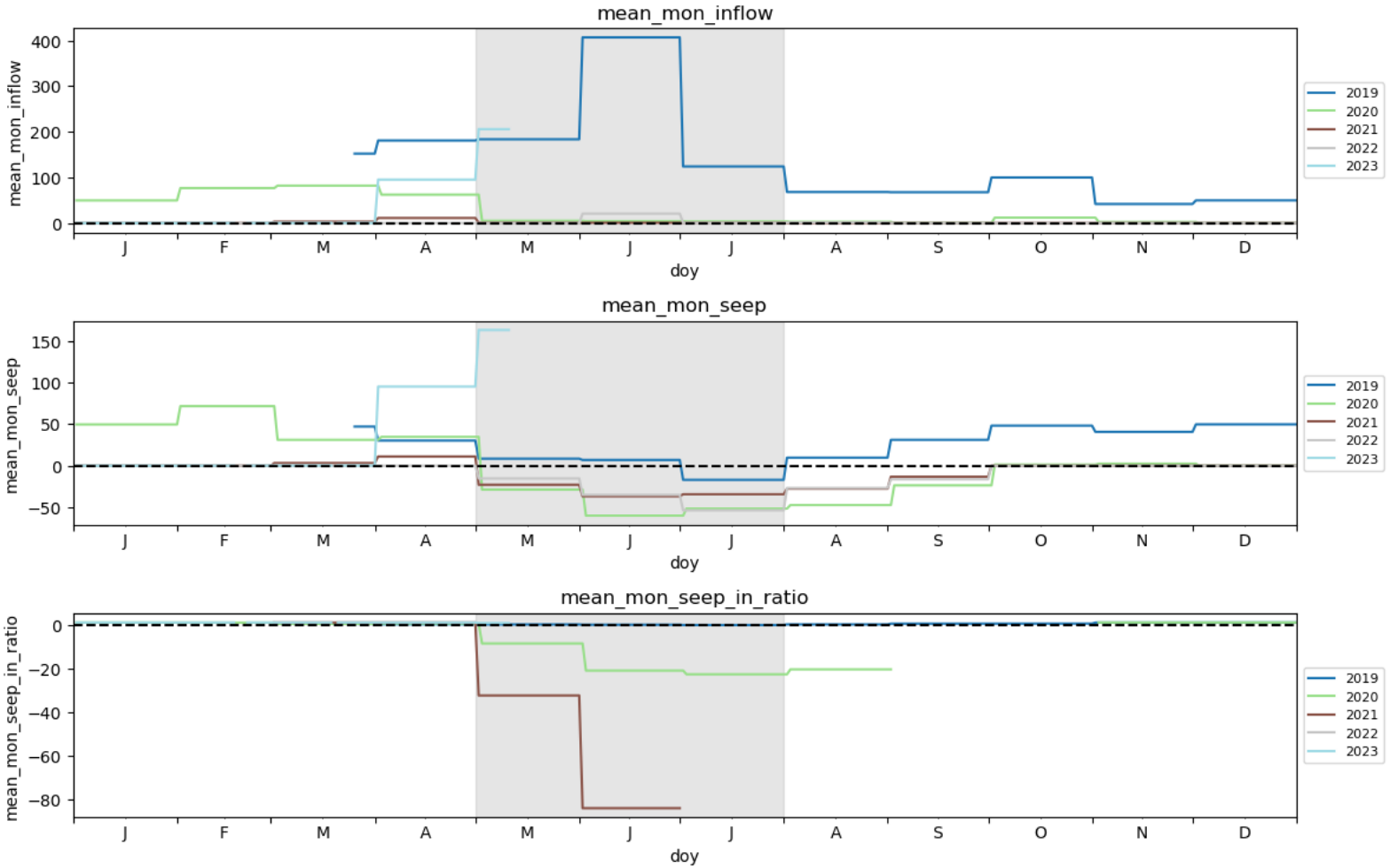

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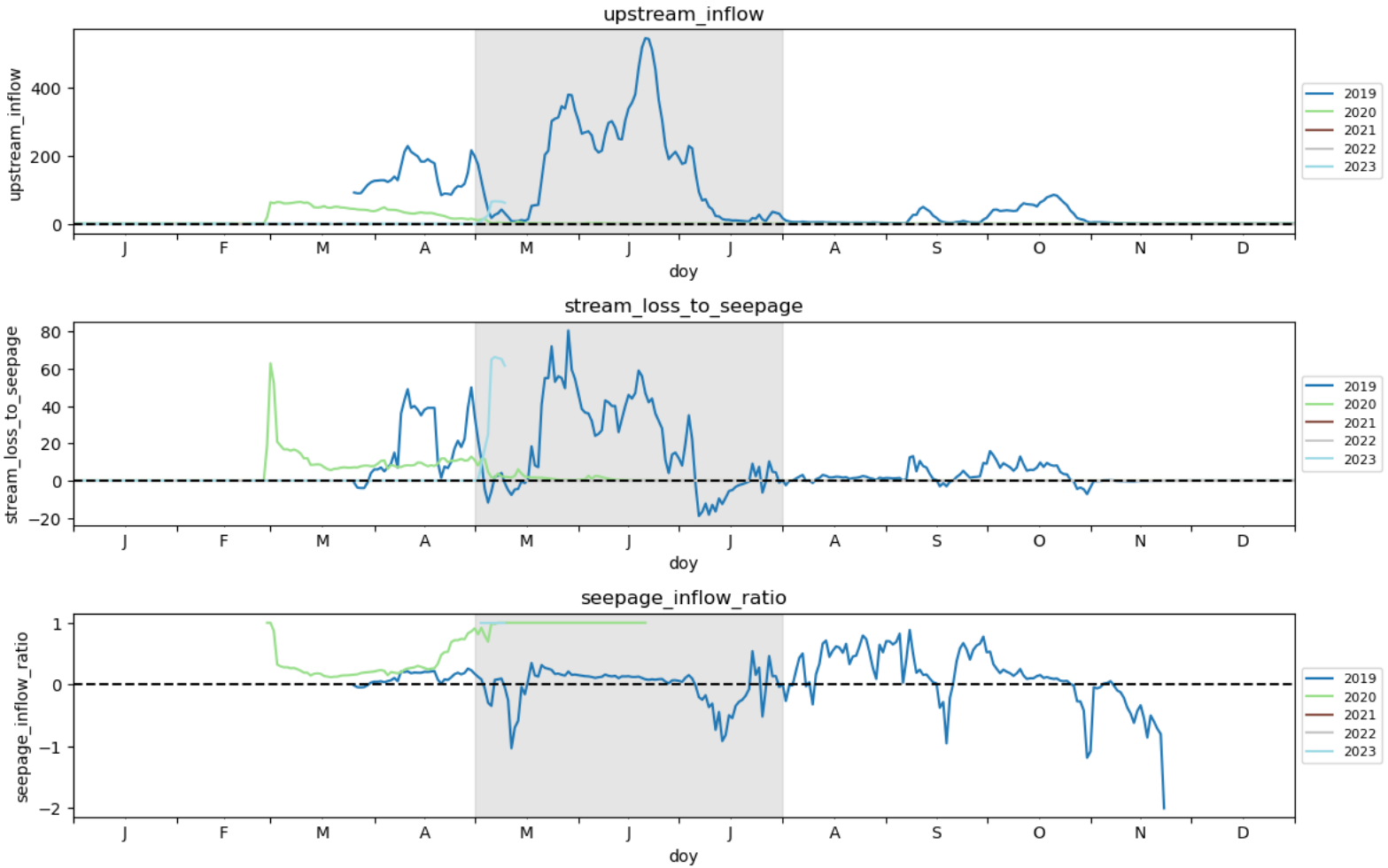
Reach(es): 1
big lost river at arco at sunset road id to big lost river nr arco id



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Reach(es): 1
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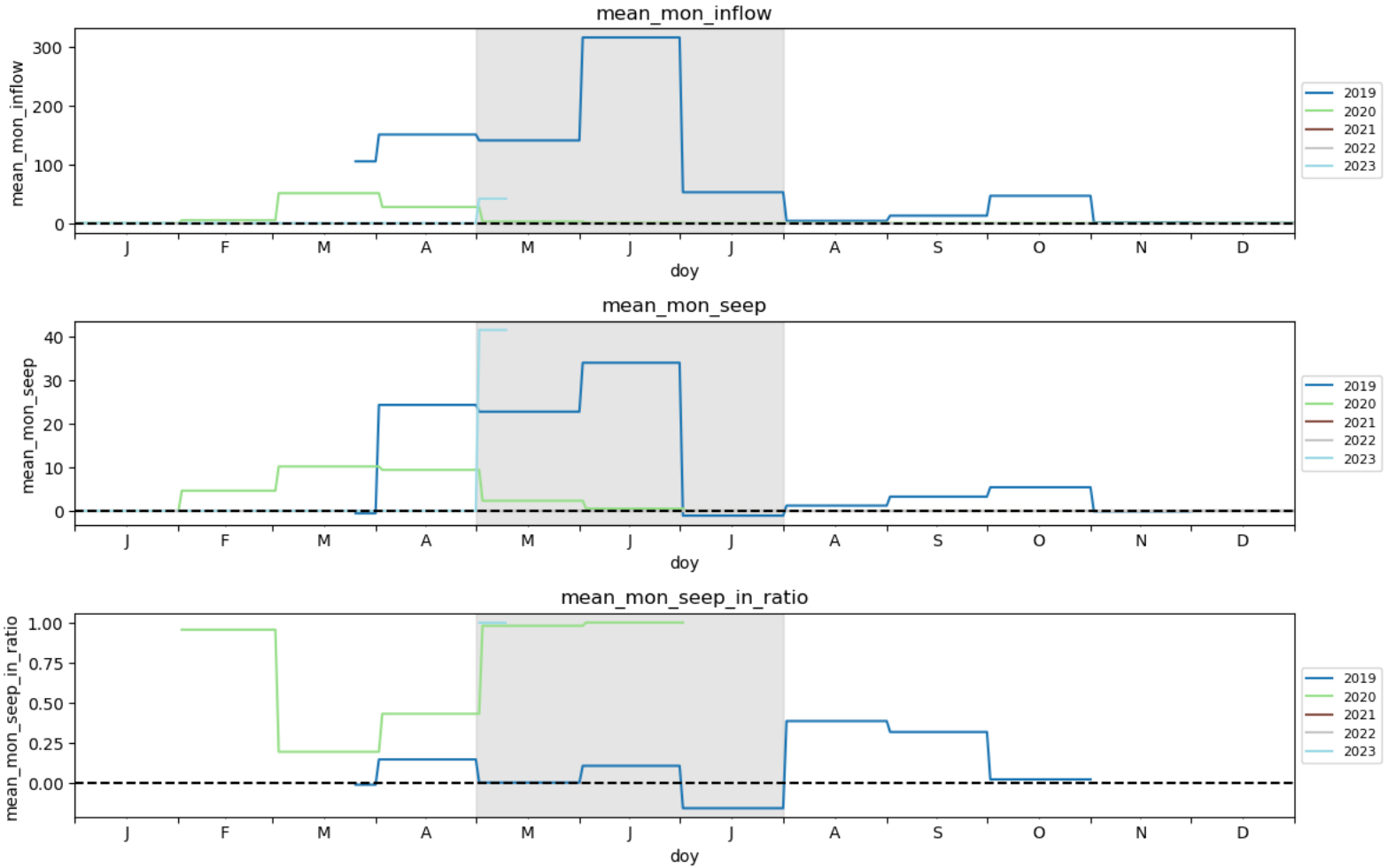

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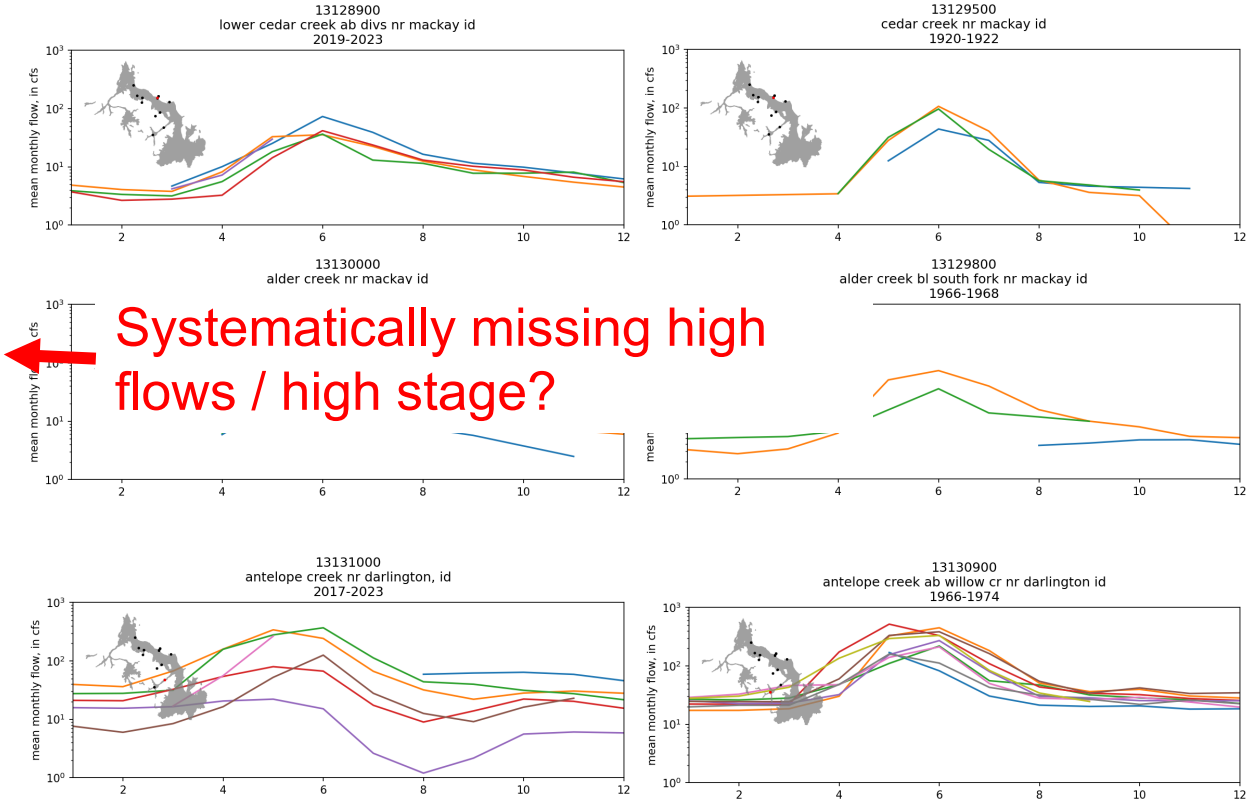

SFR stage & discharge

- In SFR (and reality) stage, discharge, and seepage are nonlinearly related
- It would be good to constrain this relationship with seepage data at a range of values for all three
- SFR assumes wide rectangular channel with Manning's for stage-discharge

Active Reaches

The SFR Package in MODFLOW 6 assumes each active reach is rectangular and uses Manning's equation to determine stream depth as a function of streamflow, unless the simple routing option is used for a reach. This differs from the SFR Package in MODFLOW-2005, which included four options for calculating stream depth. The relation between streamflow and stream depth is

$$Q_{nb} = \frac{C_u}{n_{nb}} A_{S_{nb}} R_{nb}^{2/3} S_{0_{nb}}^{1/2}, \tag{7–7}$$

where Q_{nb} is the stream discharge at the midpoint of reach nb (L^3T^{-1}); C_u is a units constant, which is 1.0 for units of m^3sec^{-1} or 1.486 for units of ft^3sec^{-1}; n_{nb} is Manning's roughness coefficient ($TL^{-1/3}$); $A_{S_{nb}}$ is the cross-sectional area of the stream (L^2); R_{nb} is hydraulic radius of the stream (L); and $S_{0_{nb}}$ is slope of the stream channel (unitless).

Assuming a wide rectangular stream channel in which the stream width is much greater than the stream depth, equation 7–7 can be simplified to

$$Q_{nb} = \frac{C_u}{n_{nb}} W_{nb} D_{nb}^{5/3} S_{0_{nb}}^{1/2}, \tag{7–8}$$

where D_{nb} is the stream depth at the midpoint of reach nb (L). Solving for depth yields

$$D_{nb} = \left[\frac{Q_{nb} n_{nb}}{C_u W_{nb} S_{0_{nb}}^{1/2}} \right]^{3/5}. \tag{7–9}$$

Because leakage through the streambed is a function of depth, a mixed bisection-Newton-Raphson method is used to reduce the difference between the streamflow at the midpoint of a reach calculated using equations 7–6 and 7–8 and computed stream depth. Depth (D) is solved by iteratively computing flow for an estimated depth until the difference between computed flow at the midpoint of the reach (Q_{nb}) and streamflow at the midpoint of the reach ($Q_{mdpt_{nb}}$) are acceptably small. The generalized form of the Newton-Raphson equation used to determine stream depth is

$$D_{nb}^k = D_{nb}^{k-1} - f(D_{nb}^{k-1}) \frac{(D_{nb}^{k-1} - (D_{nb}^{k-1} + \epsilon))}{f(D_{nb}^{k-1}) - f(D_{nb}^{k-1} + \epsilon)}, \tag{7–10}$$

where k is the iteration number and $f(D_{nb}^{k-1})$ is $Q_{nb}^{k-1} - Q_{mdpt_{nb}}^{k-1}$ for depth D_{nb}^{k-1}.

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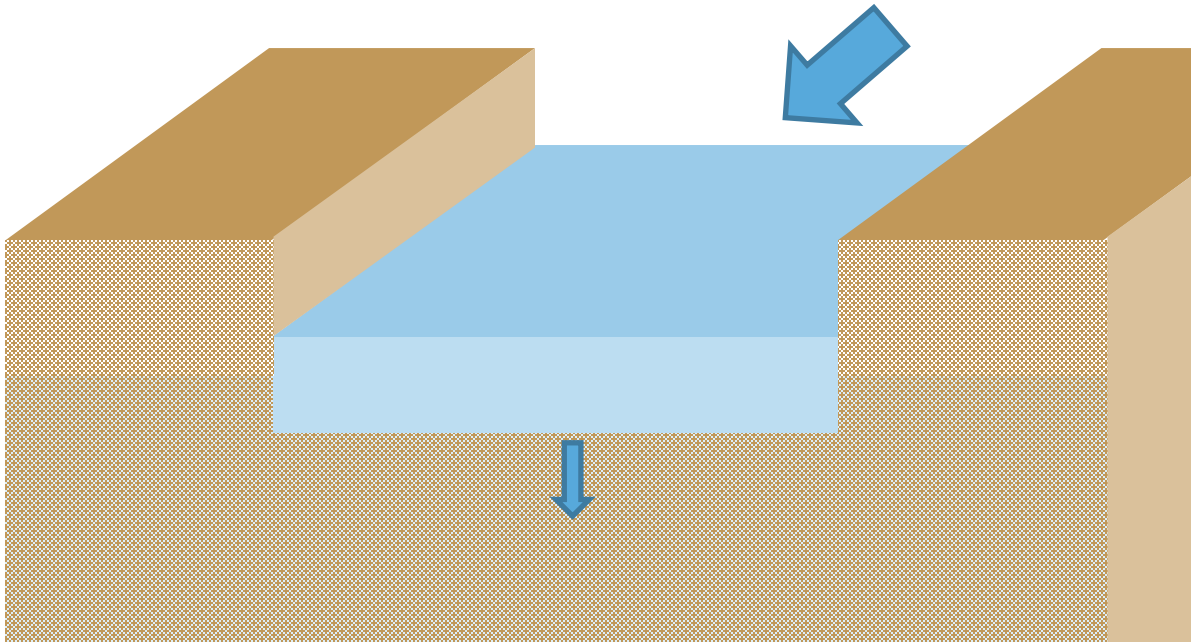
SFR stage & discharge

- In SFR (and reality) stage, discharge, and seepage are nonlinearly related
- It would be good to constrain this relationship with seepage data at a range of values for all three
- SFR assumes wide rectangular channel with Manning's for stage-discharge



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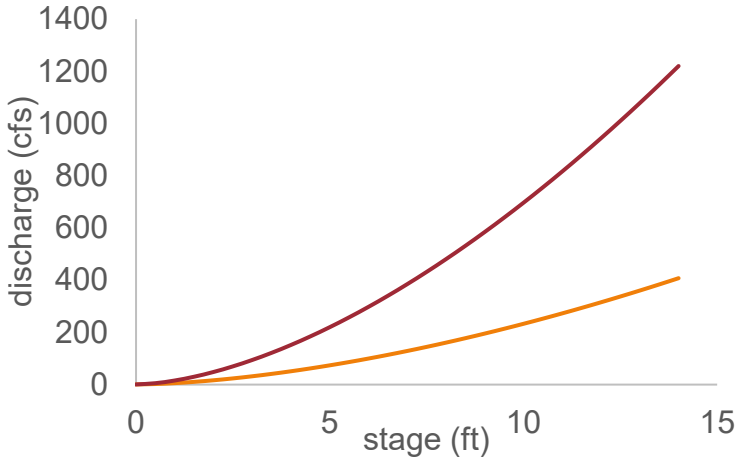

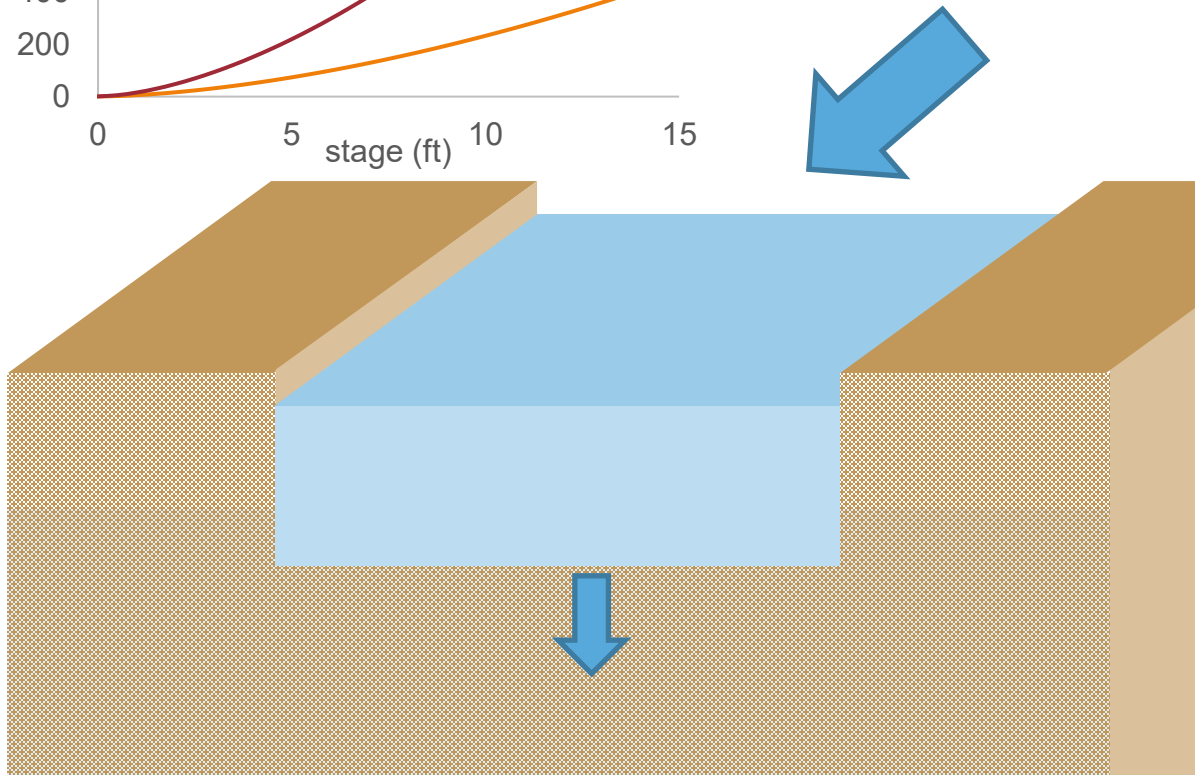

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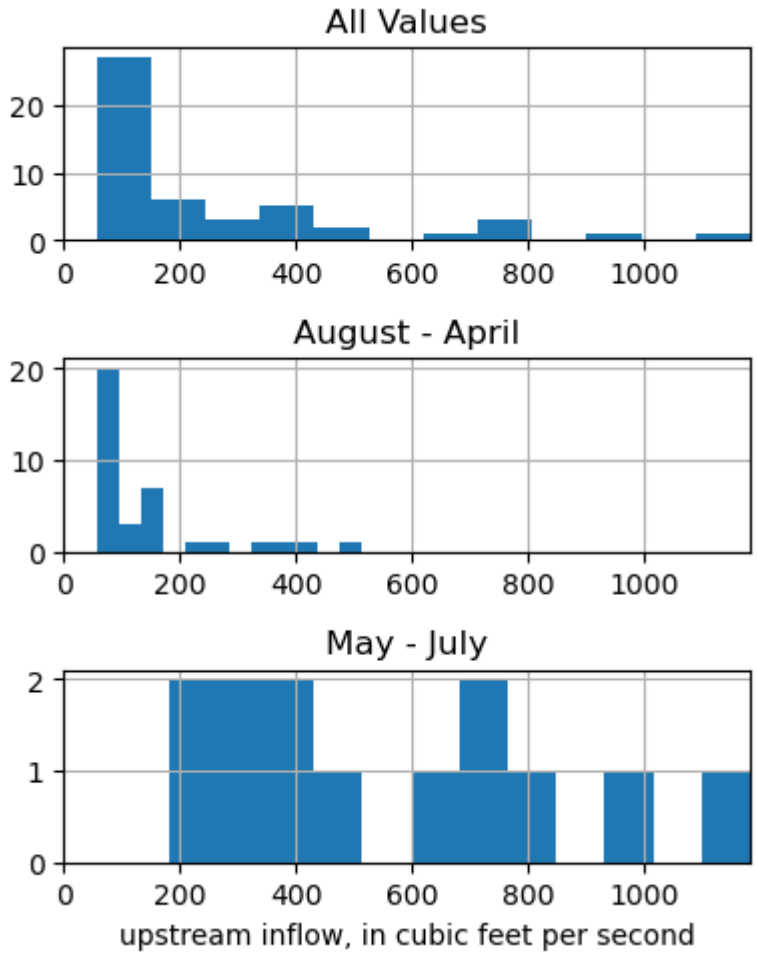

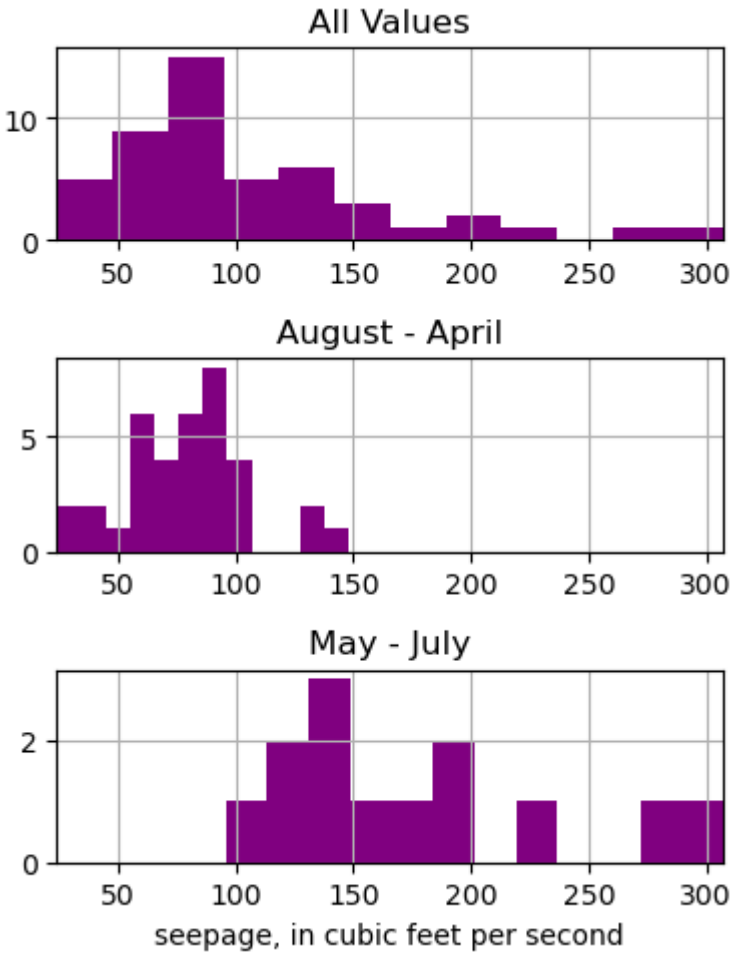

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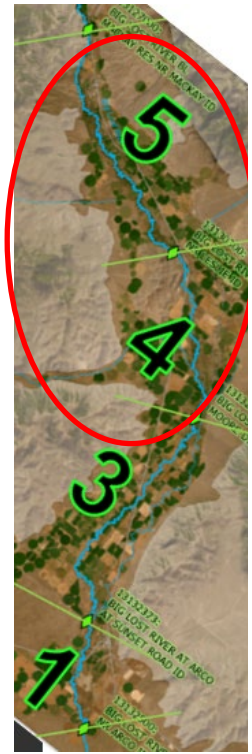

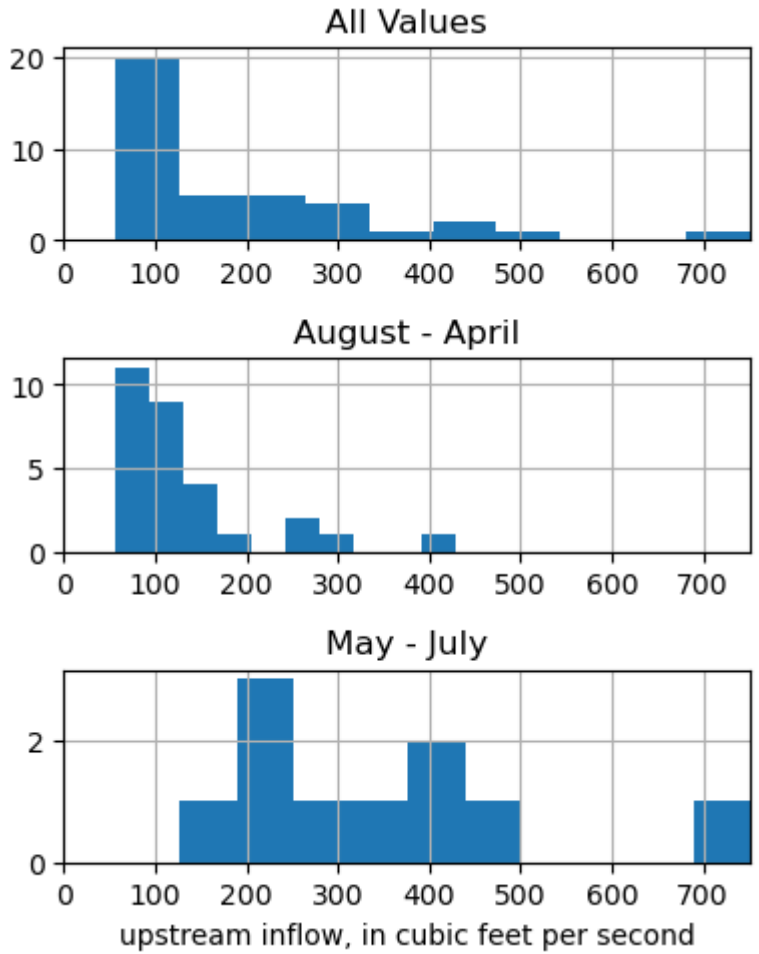

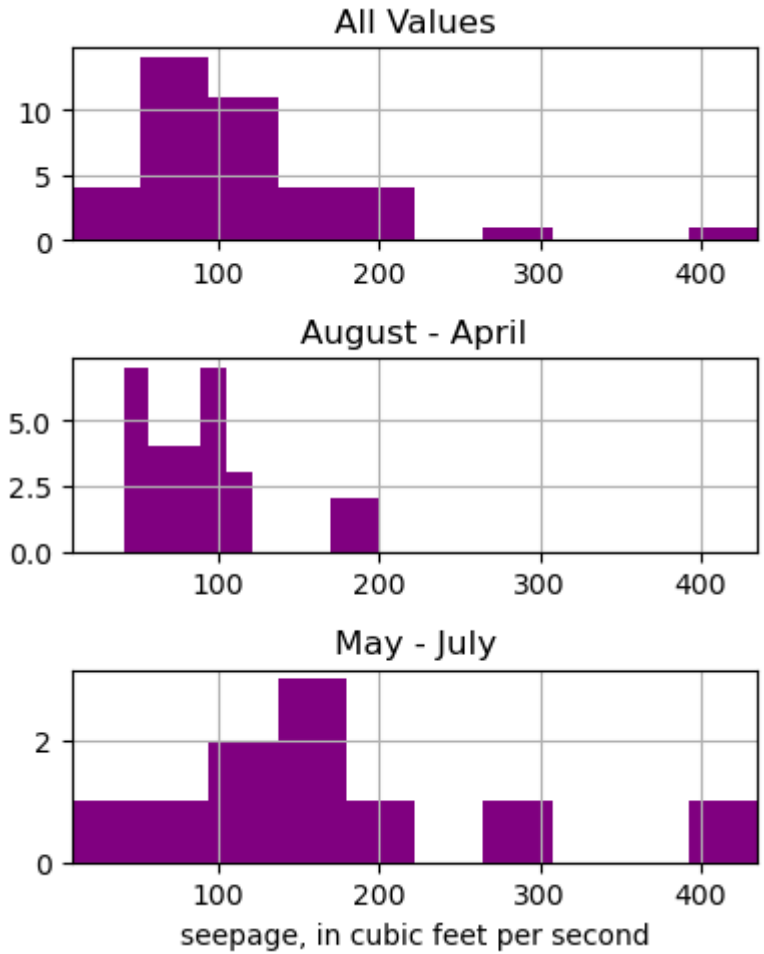

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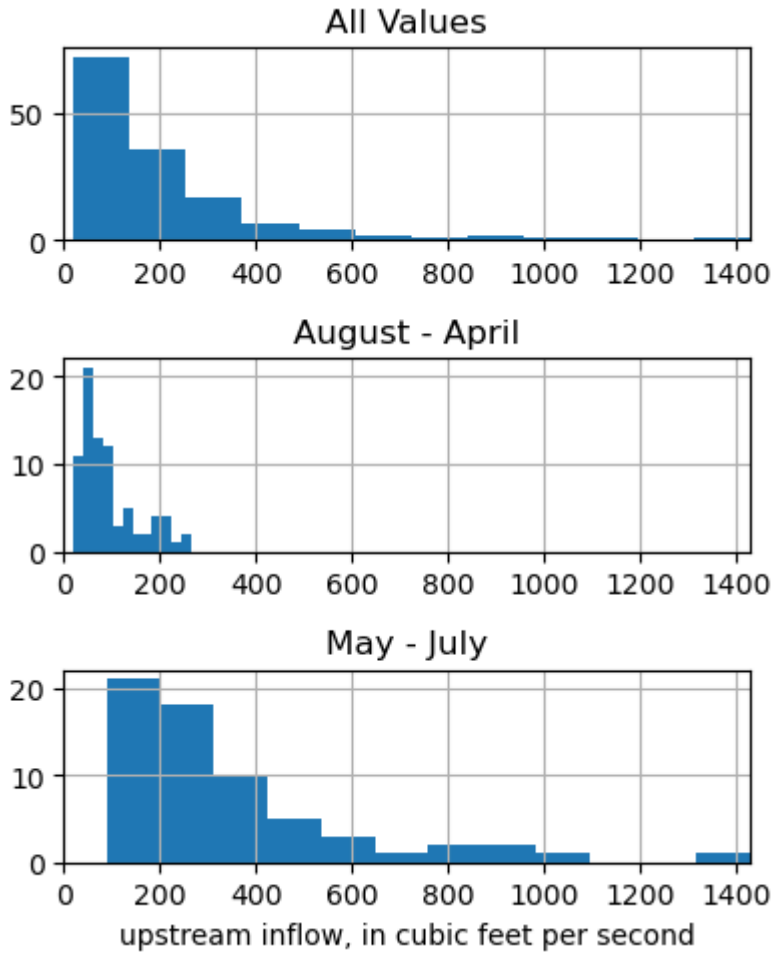

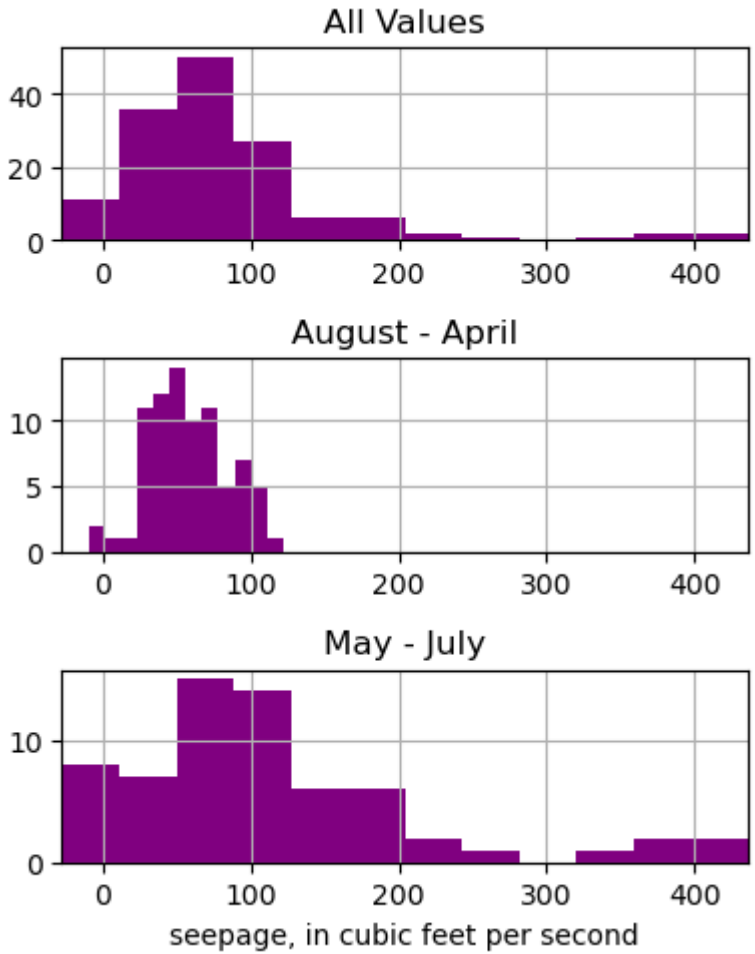

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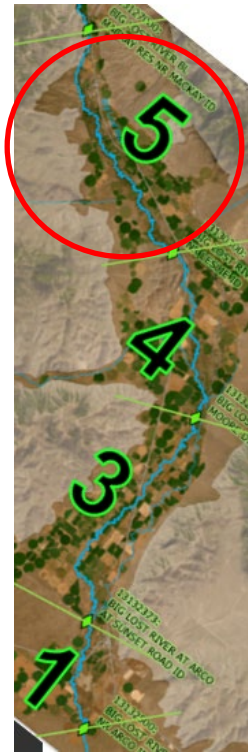

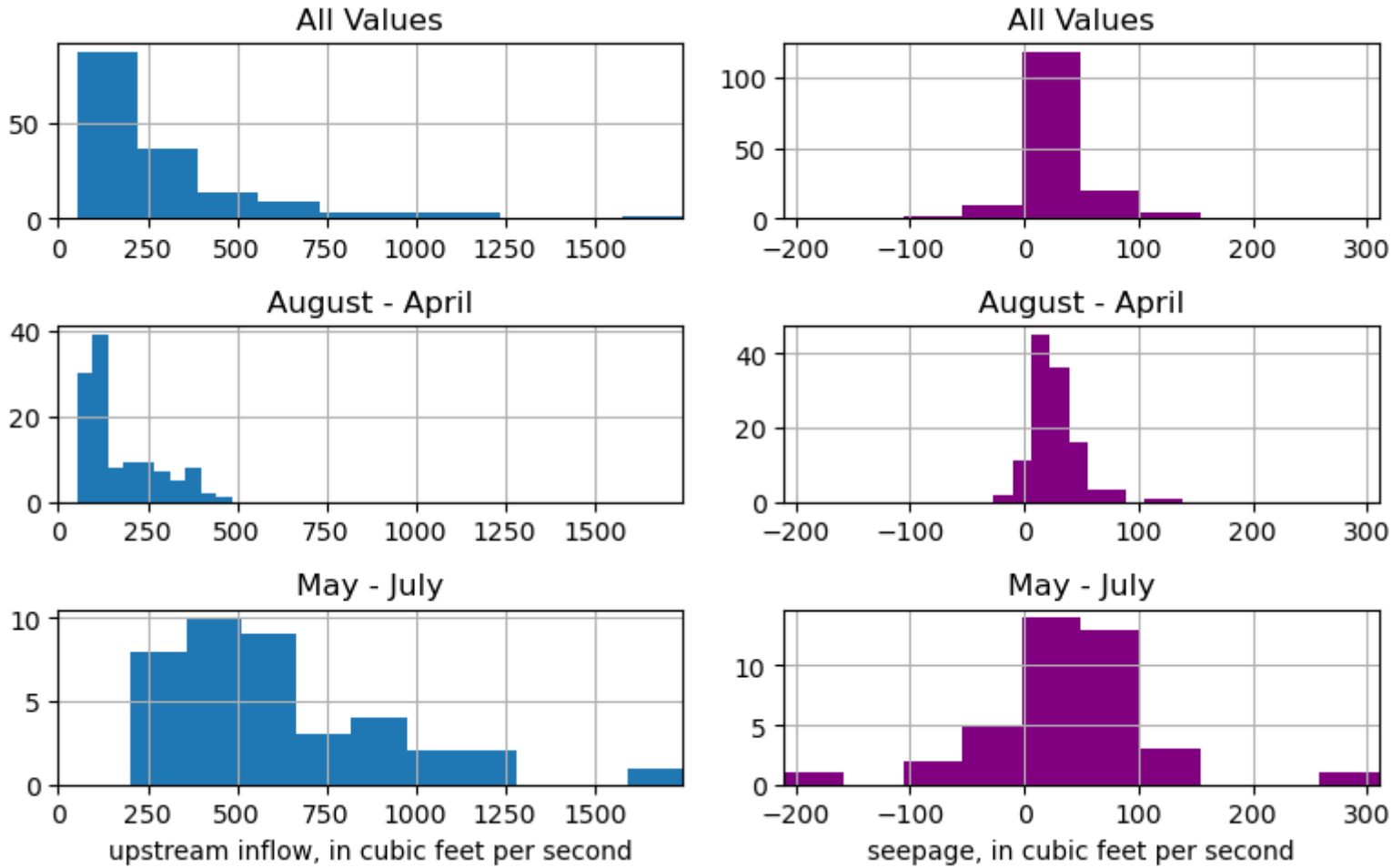

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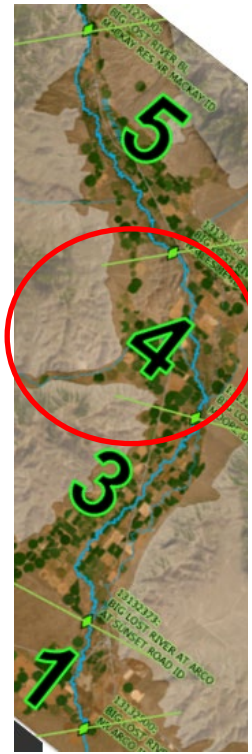

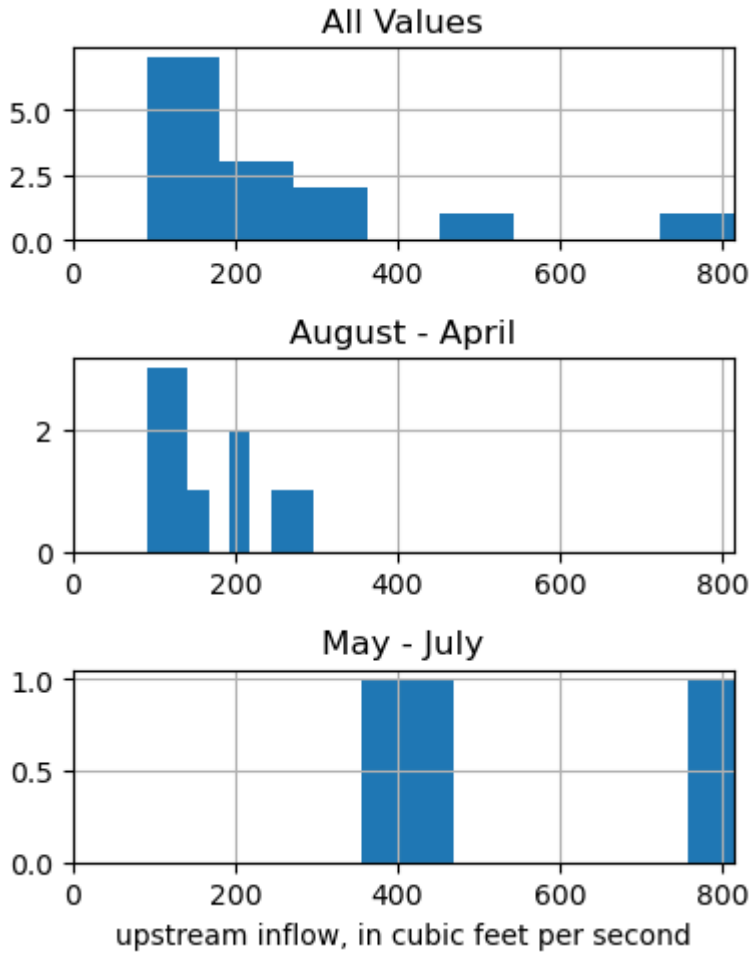

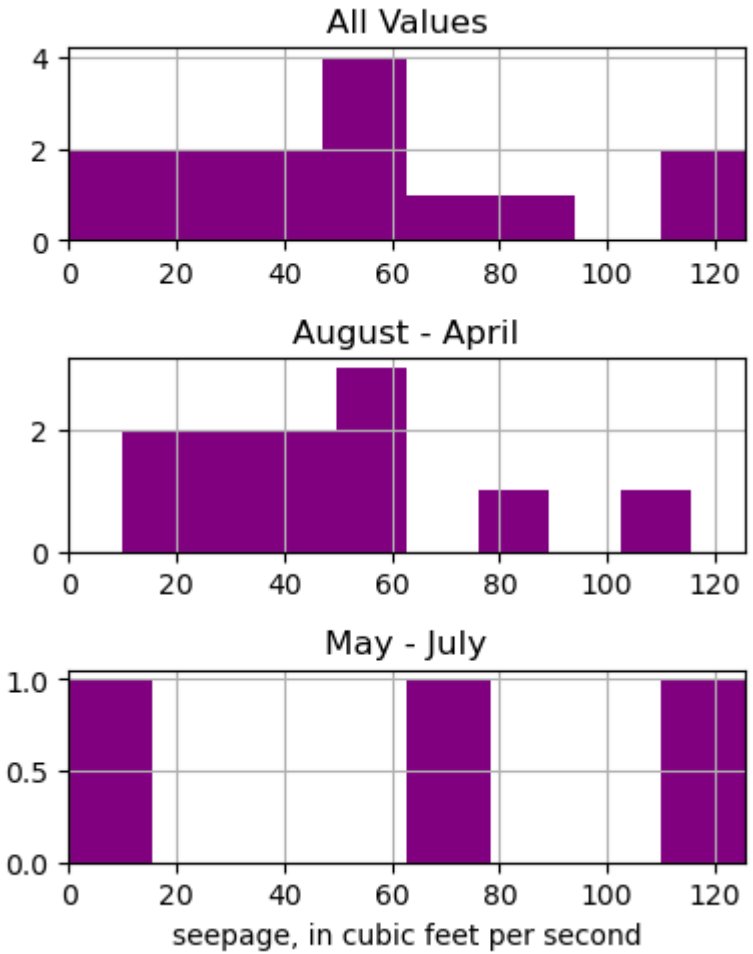

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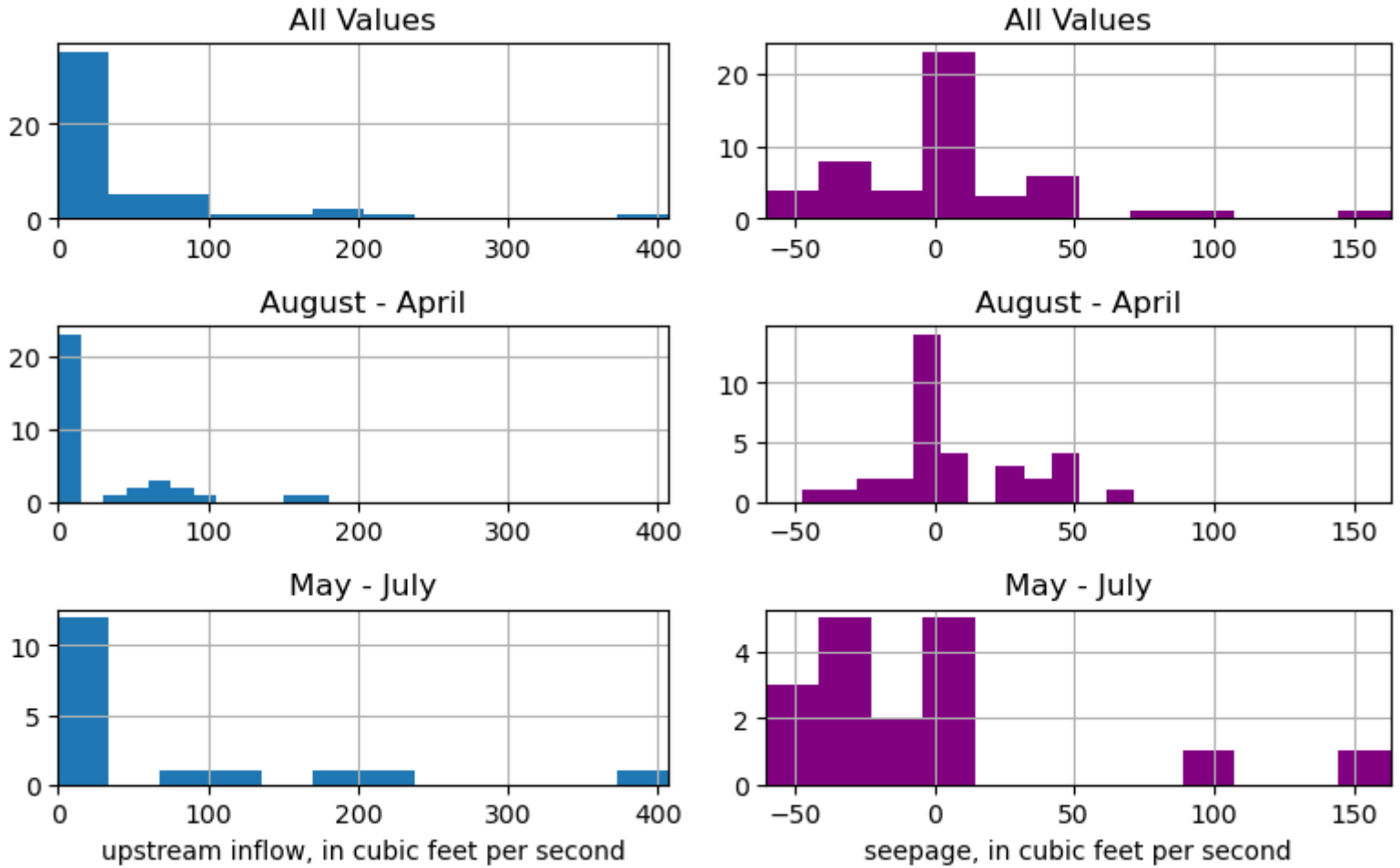

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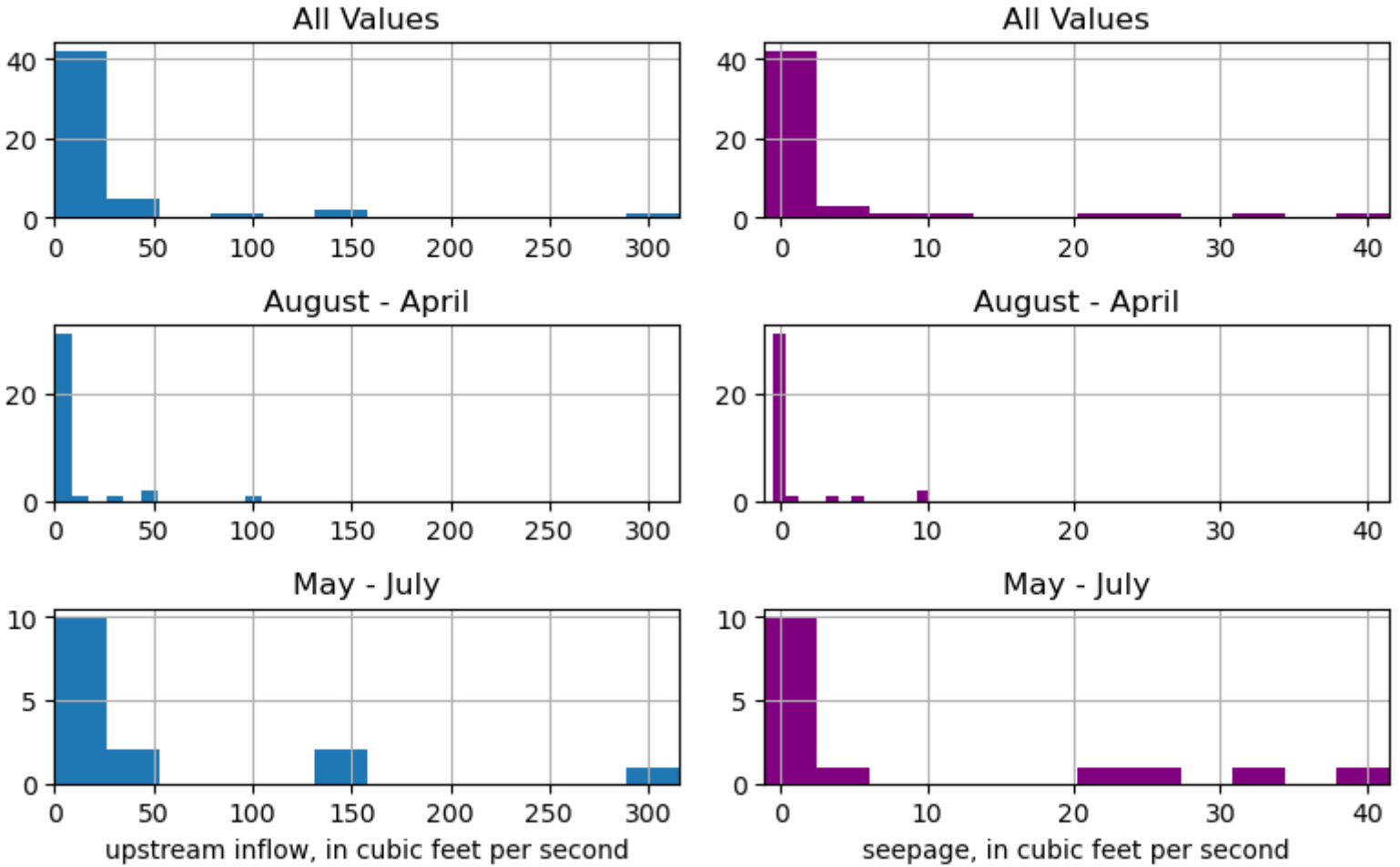

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Stream Seepage in Big Lost – Unmeasured Tributaries?

Still not sure what to do about unmeasured tributary inflow

- Ignore

- Only use months with likely little flow (not May, June, July)

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  - Mutliple linear regression
  - Index gage

- Only use months when we have USGS gage + diversions + Pivotrac for Antelope

Table 9.4. Estimated seepage, Leslie (Idaho Power streamgage 13130500) to Arco (USGS streamgage 13132500), in the Big Lost River below Mackay Dam, south-central Idaho, 2000–19.

[All values in ***bold italics*** are estimated. Groundwater budget includes seepage using tributary flows. All values in the table are in acre-feet per year. Negative seepage values indicate a losing reach condition and positive values indicate a gaining reach condition. **Abbreviations:** USGS, U.S. Geological Survey; IDWR, Idaho Department of Water Resources]

Year	Arco streamgage[1]	Leslie streamgage[2]	Diversions[3]	Groundwater pumpage to canals[3]	Burnett TE return flow[4]	East Side Out return flow (13132350)[5]	Antelope Creek (13131000)[1]	Seepage without Antelope Cr.	Seepage with Antelope Cr.
2000	17,580	***117,288***	75,503	0	***1,639***	***12,992***	***25,229***	***–36,837***	***–64,985***
2001	0	***77,737***	31,058	0	***728***	***10,074***	***18,560***	***–57,481***	***–76,041***
2002	0	***79,811***	35,204	0	***673***	***10,509***	***21,579***	***–55,789***	***–77,367***
2003	0	***88,380***	39,528	0	***1,023***	11,909	***32,372***	***–61,783***	***–94,155***
2004	0	***71,726***	31,399	0	***1,041***	9,629	***27,083***	***–50,997***	***–78,080***
2005	3,995	***142,102***	73,852	0	***1,659***	11,249	***52,823***	***–77,162***	***–129,985***
2006	36,642	***226,970***	119,005	0	***2,130***	15,061	***51,239***	***–88,515***	***–139,753***
2007	0	109,766	56,521	0	***1,397***	14,219	***20,419***	***–68,861***	***–89,280***
2008	0	101,714	60,005	0	***1,229***	12,462	***22,311***	***–55,400***	***–77,712***
2009	9,273	126,101	78,390	0	***1,628***	12,834	***47,129***	***–52,901***	***–100,029***
2010	3,830	158,010	76,857	0	***1,458***	6,115	***47,041***	***–84,897***	***–131,938***
2011	18,494	197,177	95,844	0	***1,688***	***16,139***	***40,377***	***–100,667***	***–141,043***
2012	10,049	154,033	94,910	0	***1,711***	19,746	***47,132***	***–70,531***	***–117,663***
2013	305	108,551	58,946	0	***1,044***	14,751	***14,872***	***–65,094***	***–79,966***
2014	0	66,380	26,065	6,739	***1,146***	7,329	***26,103***	***–52,699***	***–78,802***
2015	0	85,869	36,642	0	***1,066***	8,424	***25,736***	***–58,718***	***–84,453***
2016	0	124,927	55,630	0	1,217	11,620	***48,370***	***–82,134***	***–130,504***
2017	100,189	324,165	106,363	0	506	15,277	***94,831***	***–133,395***	***–228,226***
2018	82,880	230,369	89,052	0	2,458	18,376	65,860	***–79,270***	***–145,131***
2019	45,134	192,147	91,832	0	2,349	10,147	70,413	***–67,678***	***–136,900***
Mean	16,419	139,161	66,630	337	1,390	12,443	39,974	***–70,140***	***–110,114***

[1]Streamflow datasets were accessed from U.S. Geological Survey (2020).

[2]Streamflow datasets were accessed from Idaho Power (2020).

[3]Surface-water diversion and groundwater pumpage datasets were accessed from IDWR (2020d).

[4]Burnett TE return flow datasets were accessed from PivoTrac Monitoring (http://www.pivotrac.com/, contracted to Water District 34, unpub. data, 2021; data available upon request from Water District 34 watermaster, Lucas Yockey, at 208-589-3183).

[5]East Side Out return flow datasets were accessed from IDWR (2020d) during 2003–10 and 2012–19 and from PivoTrac Monitoring (http://www.pivotrac.com/, contracted to Water District 34, unpub. data, 2021; data available upon request from Water District 34 watermaster, Lucas Yockey, at 208-589-3183) for 2015–19.

Stream Seepage in Big Lost – Unmeasured Tributaries?

Still not sure what to do about unmeasured tributary inflow

- Ignore

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- **Estimate inflow**
  - Index gage
  - **Mutliple linear regression +**

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potential flows.

StreamStats (U.S. Geological Survey, 2016) flagged some results returned during tributary basin delineation as having one or more parameters outside the range of the basin characteristics for the sites used to develop the supporting regression equations, causing the results to be extrapolated. Hortness and Berenbrock (2001) prepared regression equations for the Big Lost Basin as part of an evaluation of ungaged tributary basins using three streamgages (North Fork of the Big Lost River at Wild Horse, Big Lost River at Howell Ranch, and Lower Cedar Creek), with a reported median (Q50) standard error range of –55 to +120 percent. Therefore, estimates of unmeasured streamflow within the Big Lost River Basin may include appreciable errors related to the regression equations.

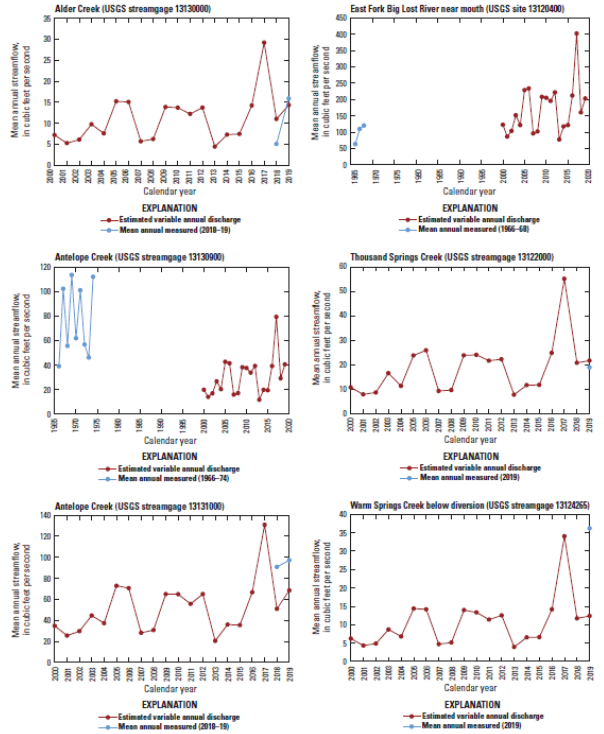

Figure 9.2. Measured and estimated tributary streamflow for the Big Lost River Basin, south-central Idaho, 2000–19. Measured values from U.S. Geological Survey, 2020. USGS, U.S. Geological Survey.

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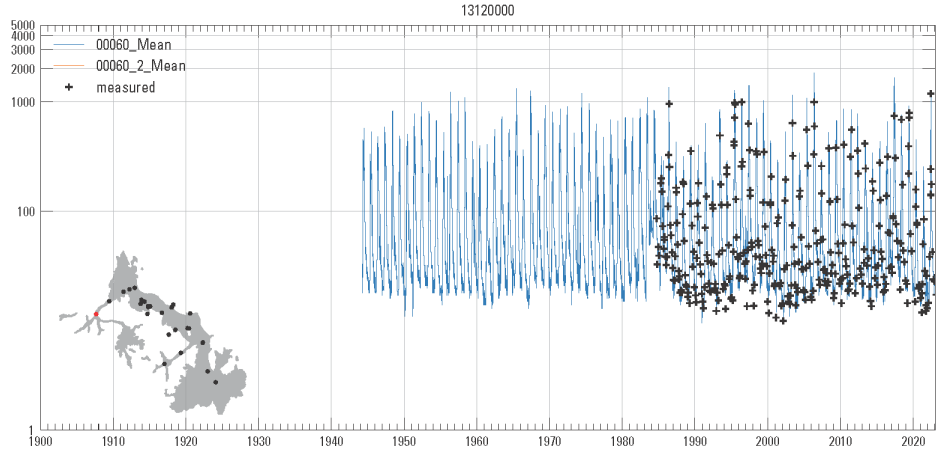

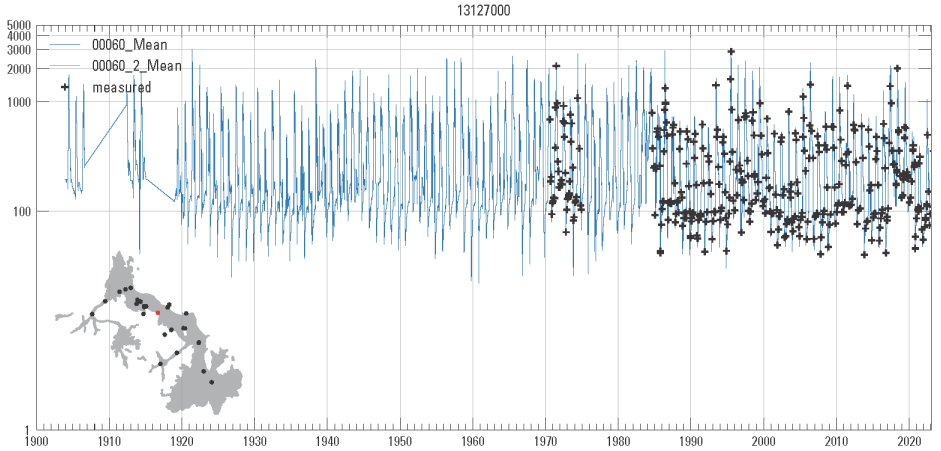

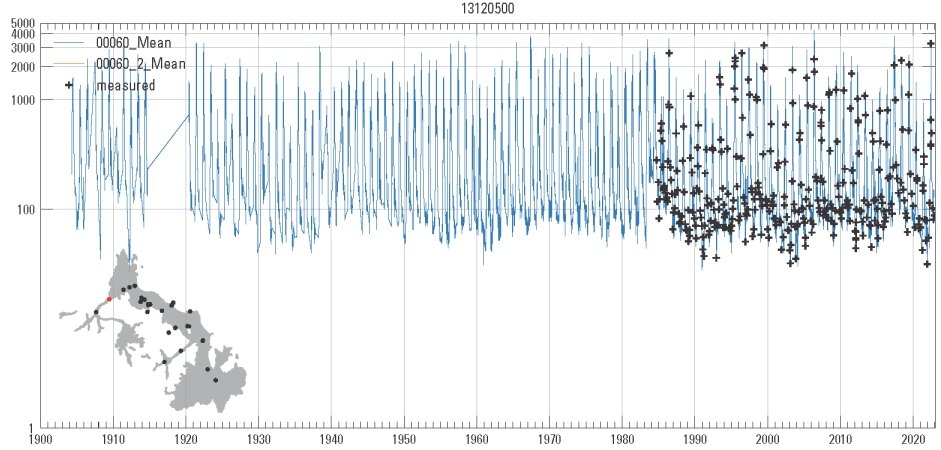

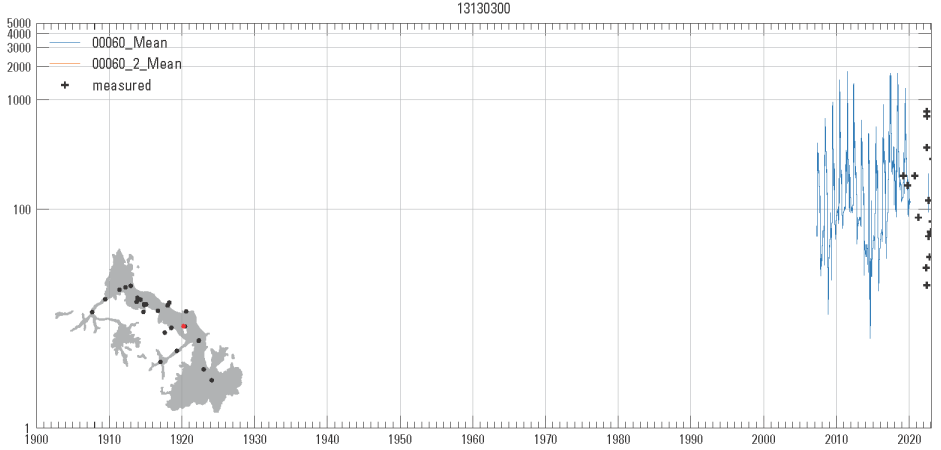

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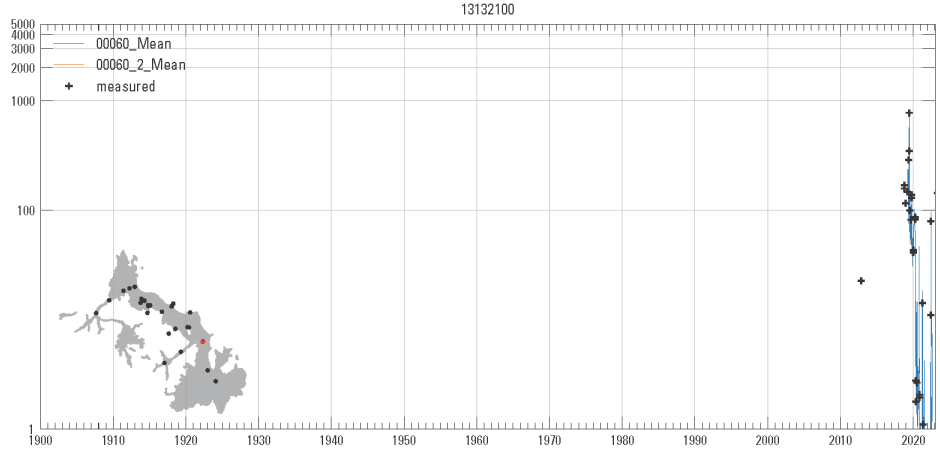

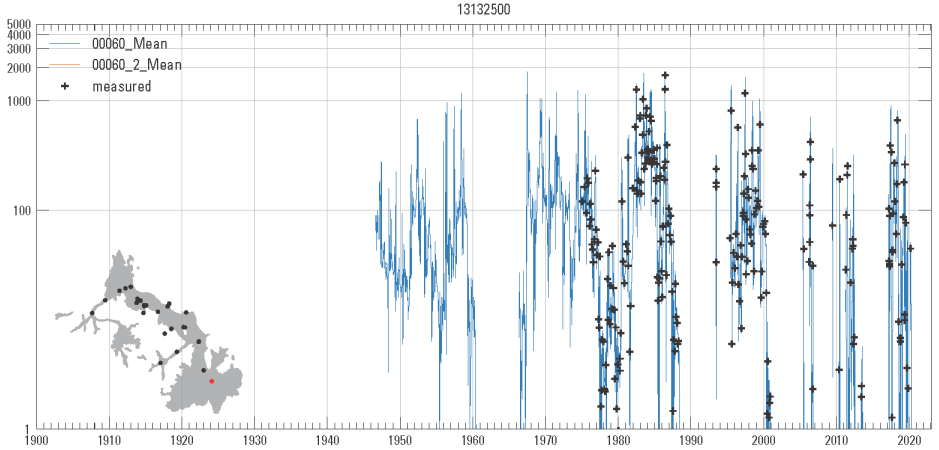

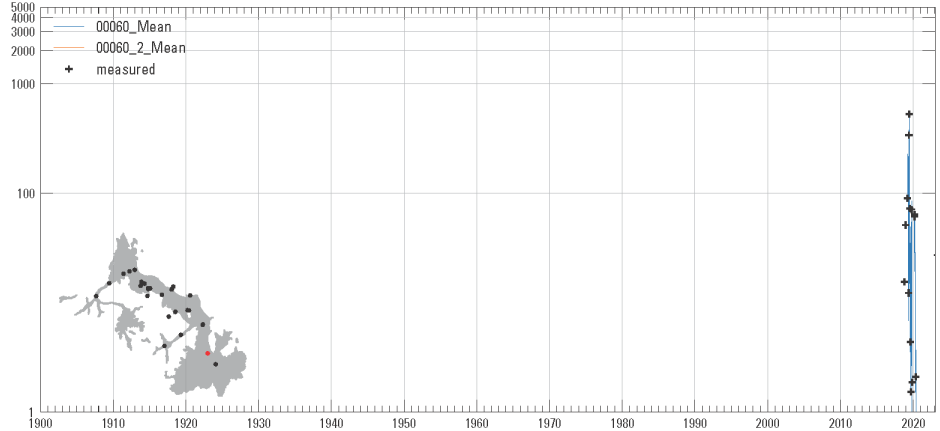

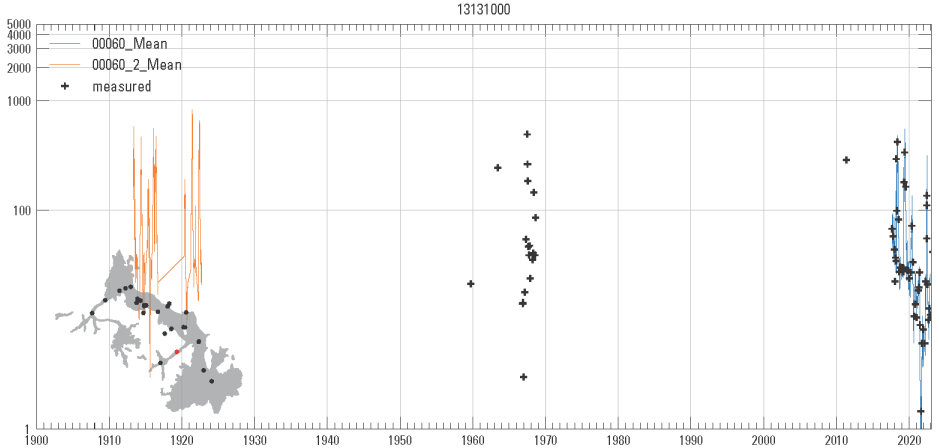

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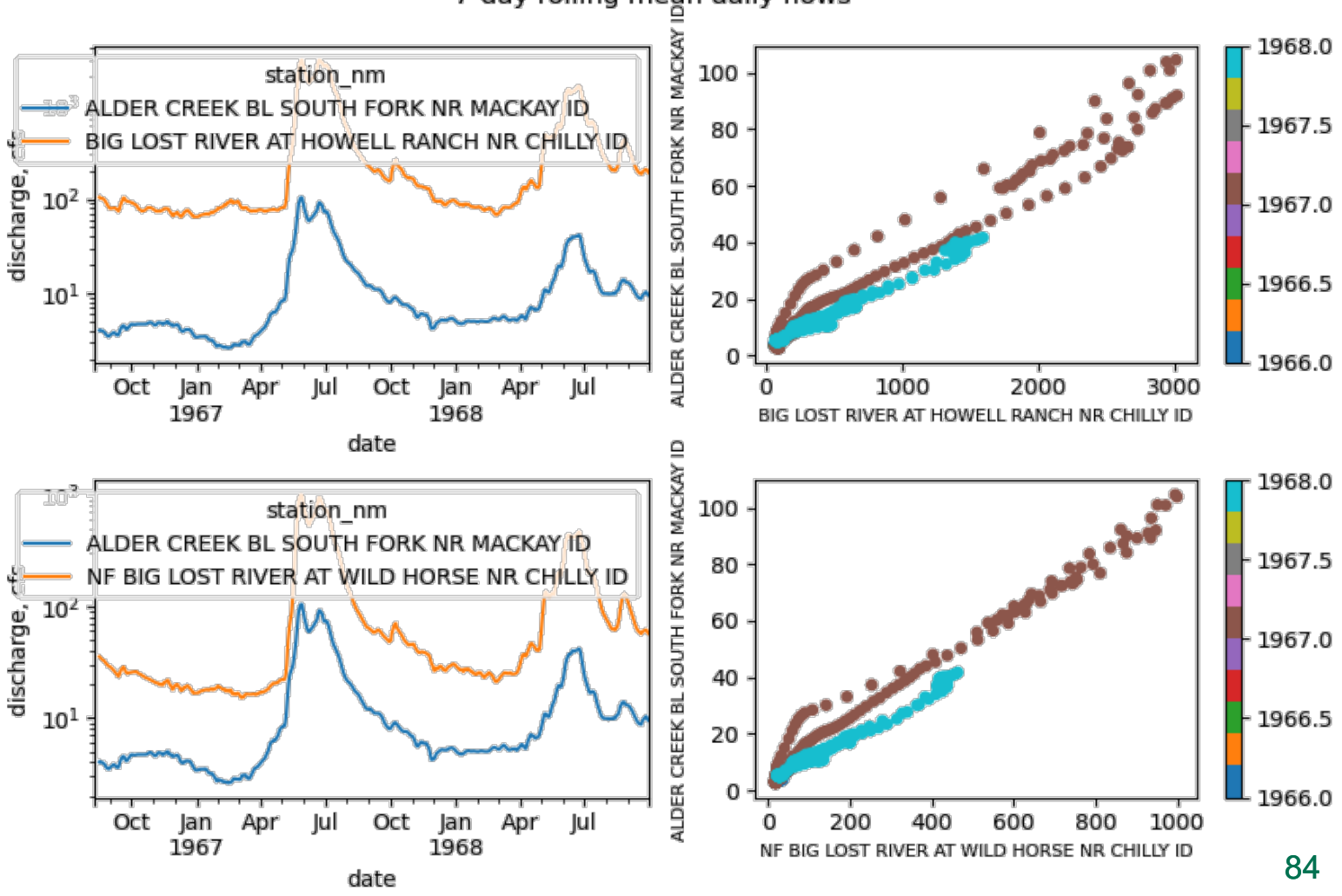

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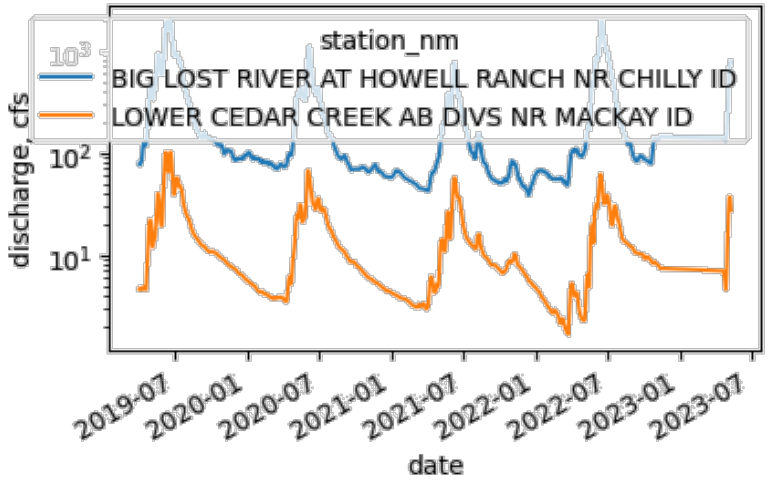
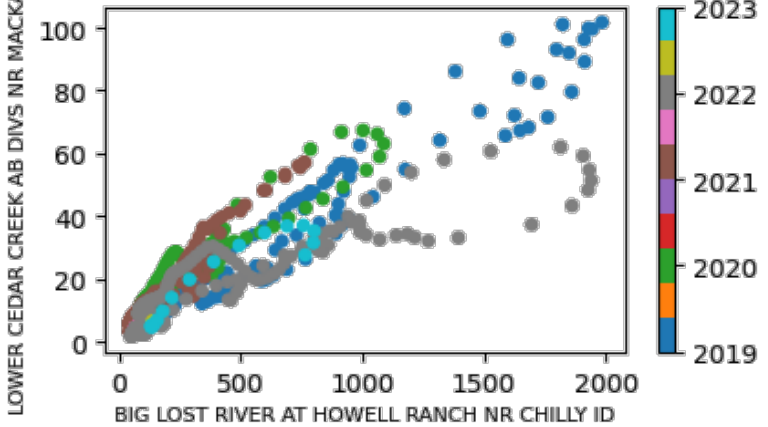
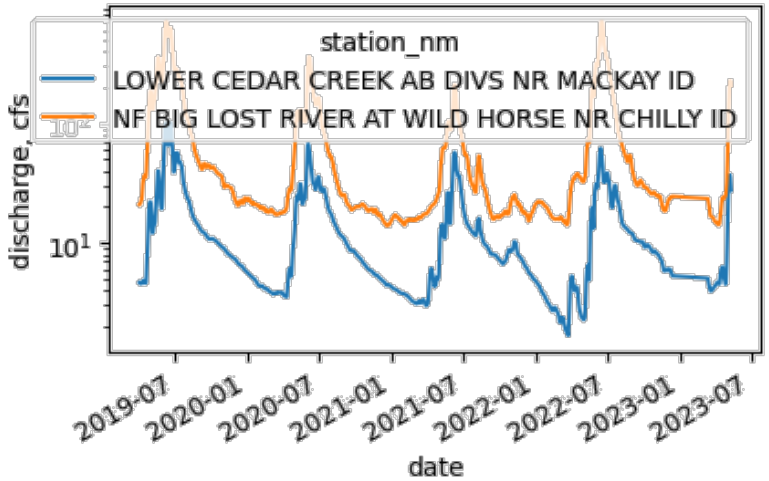
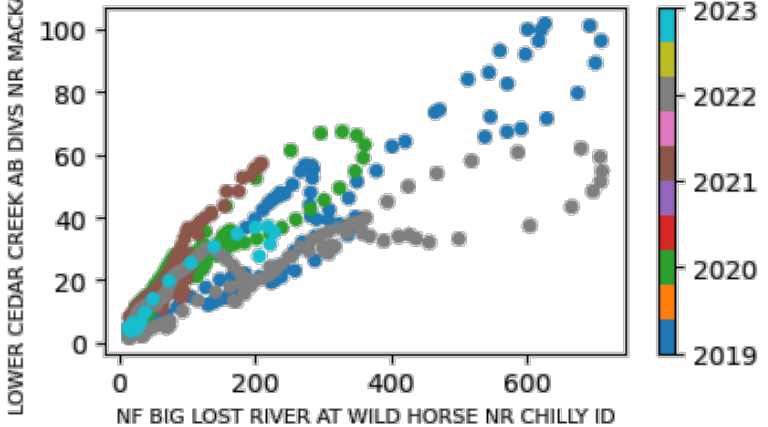
7-day rolling mean daily flows









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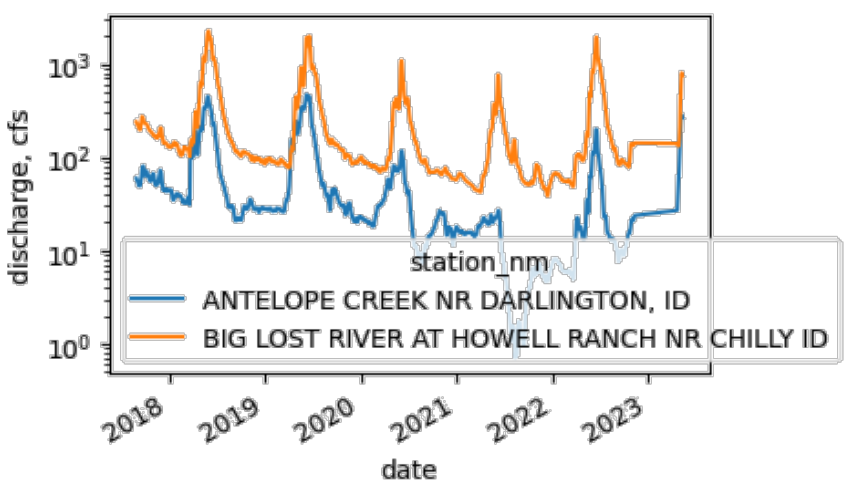

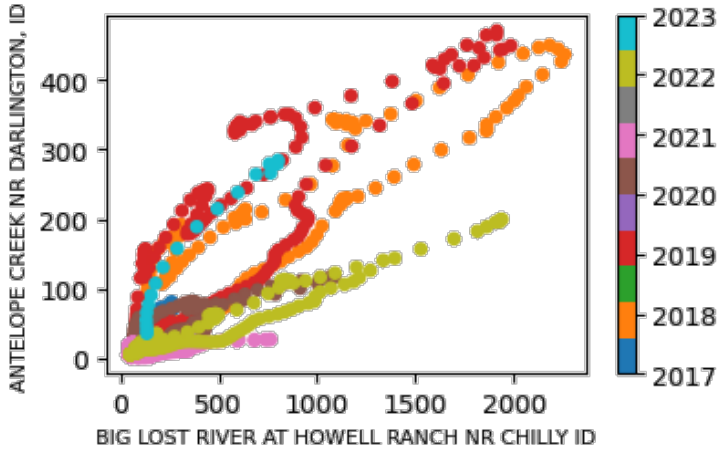

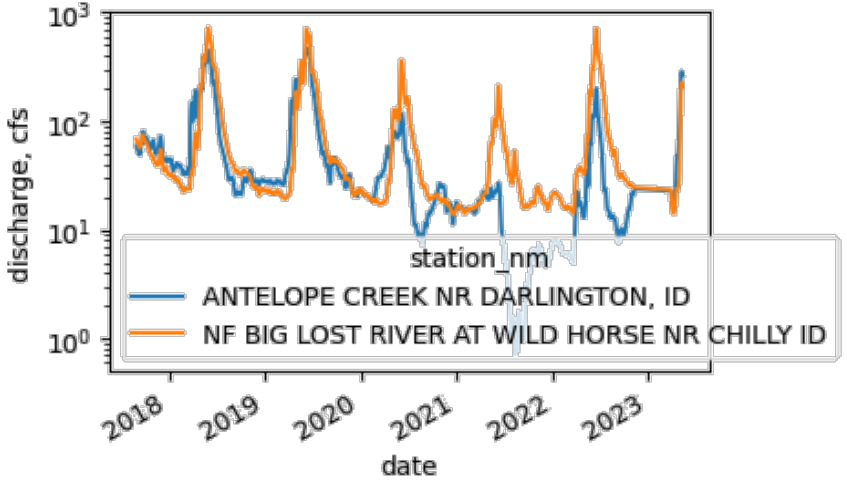

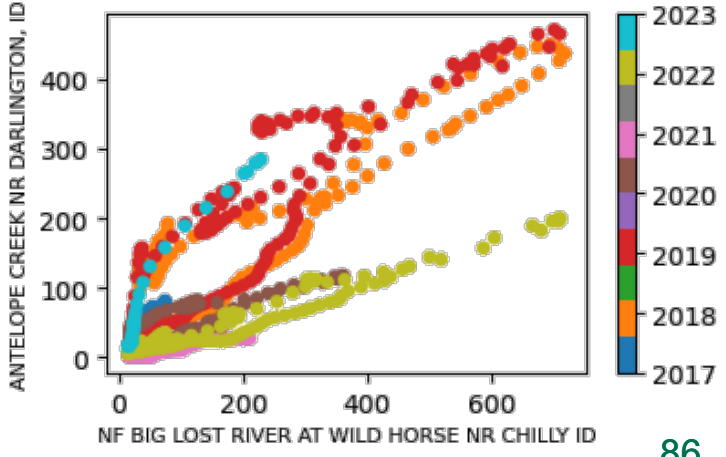

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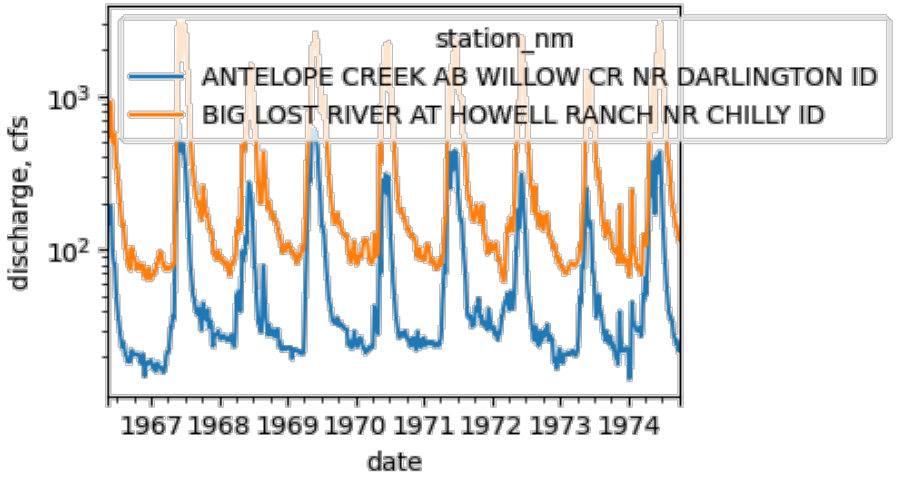

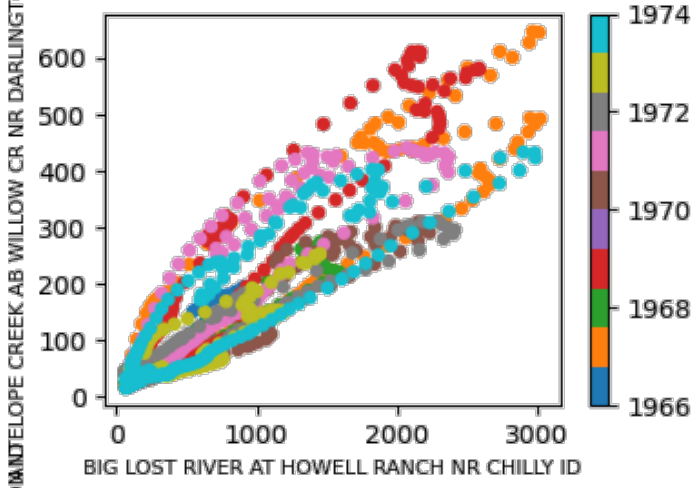

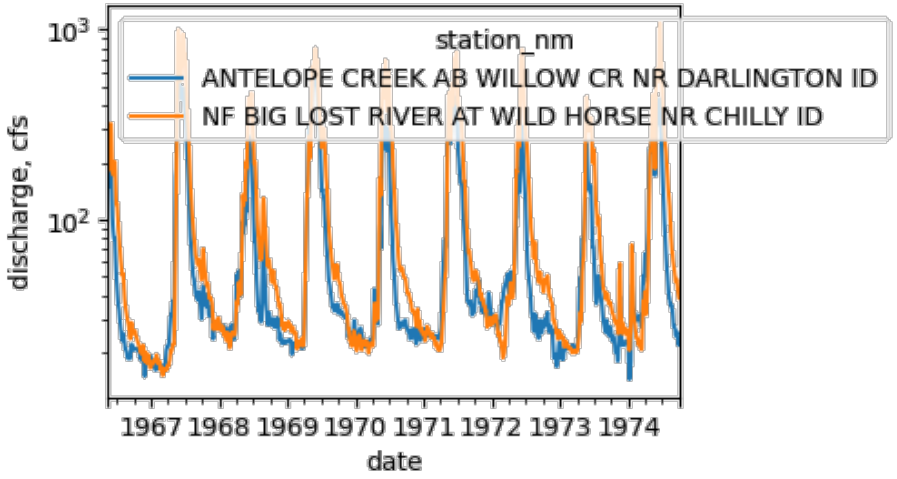

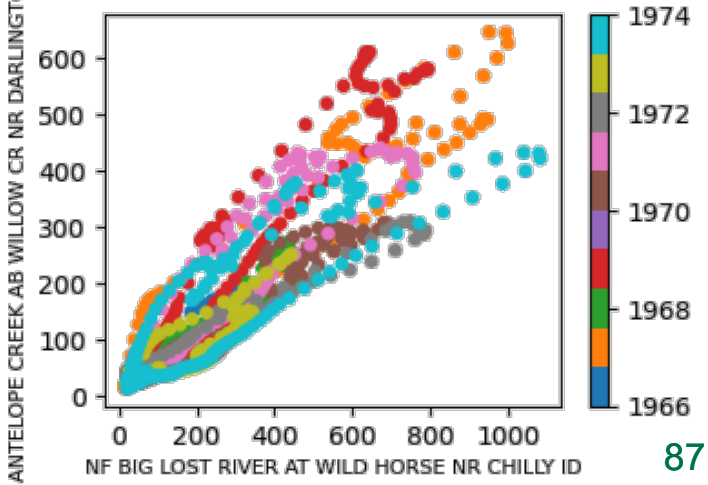

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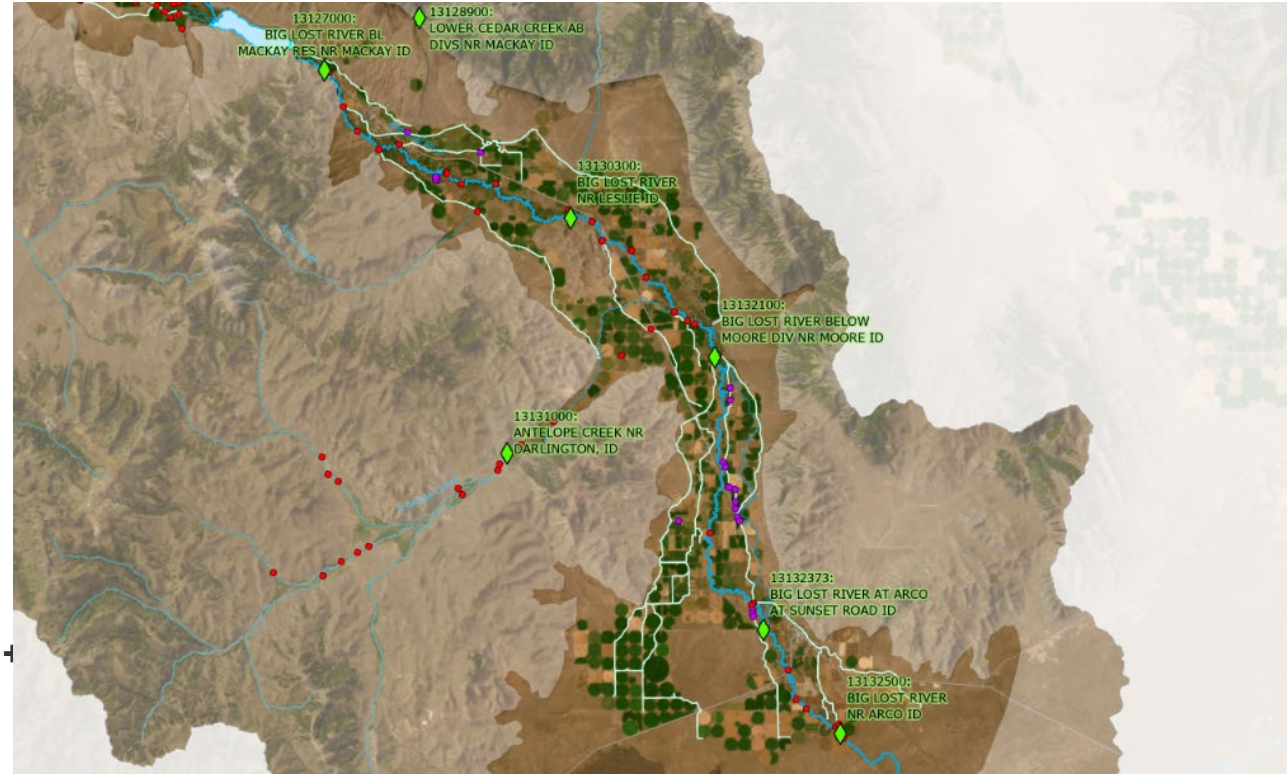

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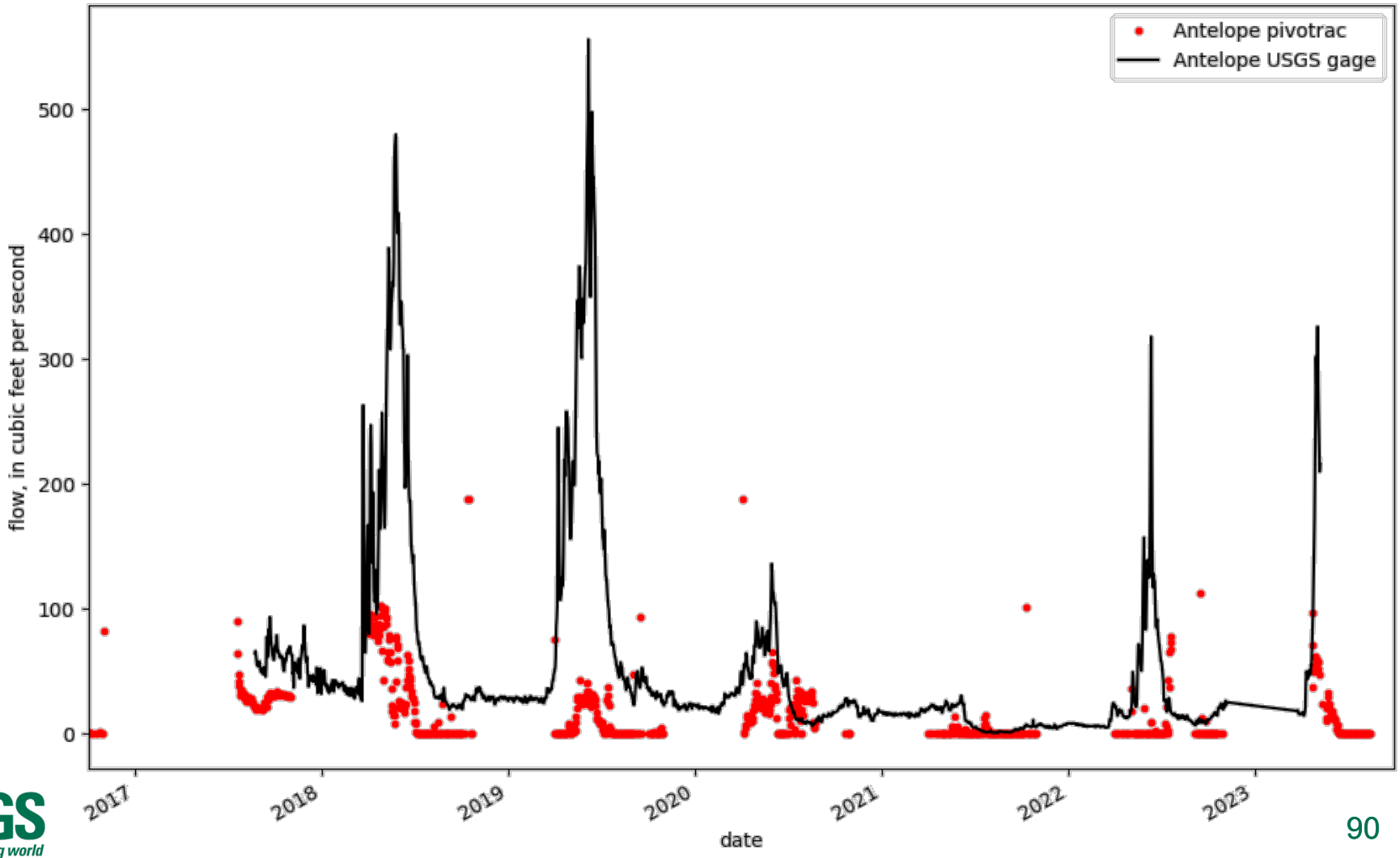
- **Only use months when we have USGS gage + diversions + Pivotrac for Antelope**



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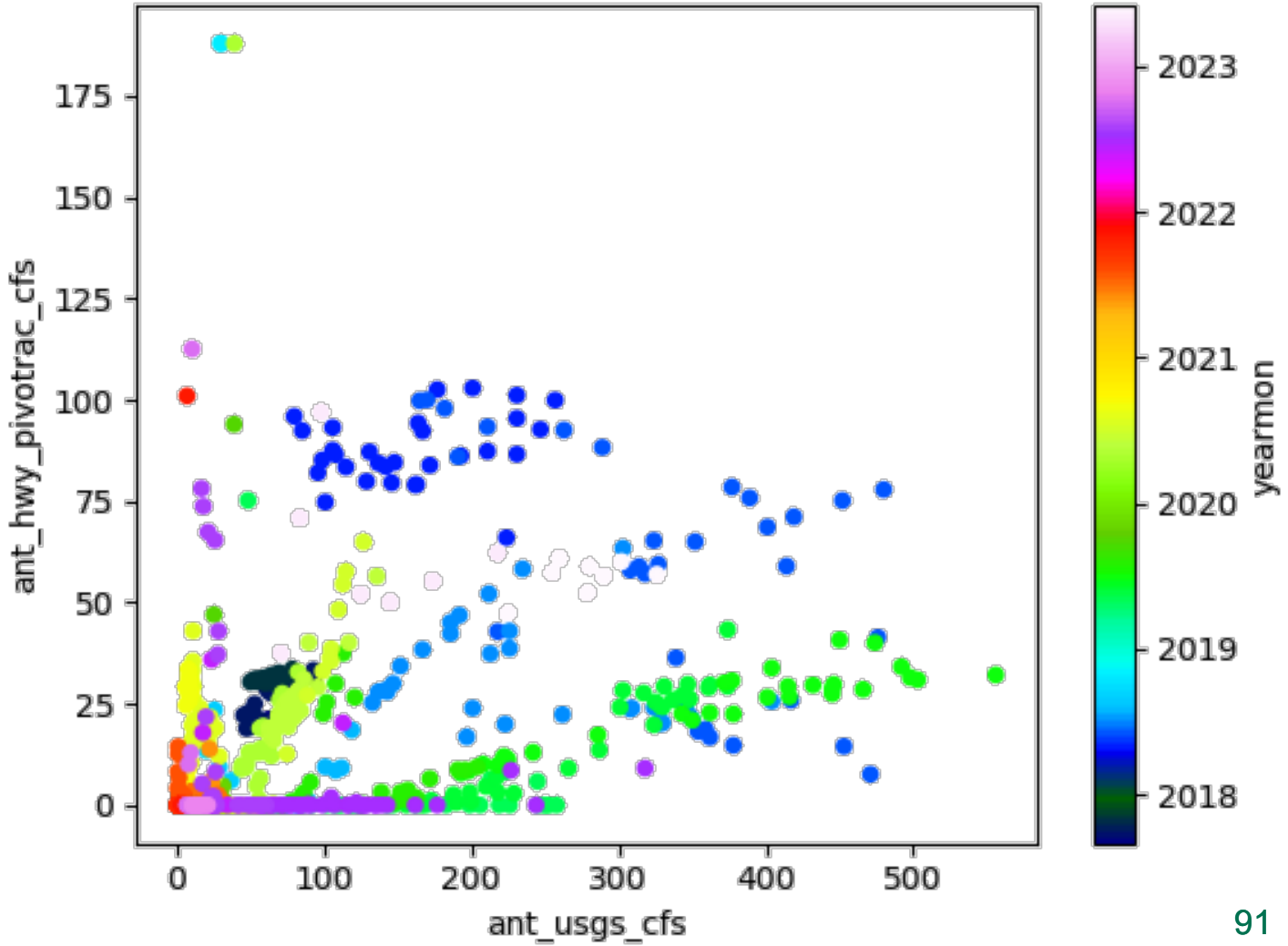

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Thanks!

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