Nevada Division of
WATER RESOURCES

STATE OF NEVADA
Department of Conservation and Natural Resources
Joe Lombardo, *Governor*
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HUMBOLDT WORKING GROUP SCOPING DOCUMENT

TIMELINE AND PROCESS FOR DEVELOPING CONJUNCTIVE MANAGEMENT STRATEGY

In 2023, the Nevada Division of Water Resources (NDWR) launched a series of workshops and listening sessions designed to explore practical strategies for implementing conjunctive management and addressing conflicts between groundwater pumping and surface water rights in the Humboldt River region. As part of this effort, the NDWR sought to ensure the inclusion of new and diverse ideas from stakeholders, ensuring that various voices were heard. This process involved issuing a call for abstracts on Humboldt River Basin conjunctive management, inviting stakeholders to submit proposals and present their ideas to the State Engineer and other interested parties. All of the information that was presented by NDWR and stakeholders in 2023 and March 2024 is available on the NDWR website.

Findings from these meetings, presentations, and comments were gathered, and the ideas presented were refined, summarized, and narrowed down to 19 concepts based on key criteria of authority, implementation, and impacts/benefits.

To further evaluate these ideas and advance the development of conjunctive management strategies that prevent future conflicts, mitigate the impacts of existing ones and avoid the curtailment of established rights - a stakeholder working group was convened. Stakeholders had the opportunity to nominate representatives to act on their behalf. This process resulted in diverse representation from various sectors and regions, enabling collaborative analysis and further refinement of ideas for water management in the region. The group held its inaugural quarterly meeting in June 2024 and met for a second time in October 2024.

STAKEHOLDER WORKING GROUP PURPOSE STATEMENT

The Humboldt Working Group represents a diverse range of water users in the region. Its primary purpose is **to evaluate and propose strategies for reducing water right conflicts in the Humboldt River region, including solutions beyond the authority of the NDWR**. Specifically, the Working Group will conduct in-depth reviews of ideas, engage in technical analyses, and introduce solutions that support the long-term well-being of the region.

Additionally, the group may advocate for policies, legislative actions, and other initiatives outside the NDWR's jurisdiction that are feasible, reasonable, and effective in mitigating conflict. Should the curtailment of water rights become necessary, the group will be informed about the rationale behind it, as well as the process and timeline involved.

STAKEHOLDER WORKING GROUP OBJECTIVES

1. **Collaborative and Inclusive Discussion**

To facilitate inclusive and constructive discussions, ensuring that all perspectives are considered and that the solutions reflect the interests and concerns of the entire Humboldt River community.

2. **In-depth Analysis and Solution Development**

To conduct in-depth discussion on technical analyses and develop actionable, evidence-based solutions that reduce water right conflict in order to address the long-term health, economic, and environmental needs of the Humboldt River region.

3. **Consensus-driven Actionable Recommendations**

To deliver clear, consensus-driven recommendations to the State Engineer and other relevant parties to foster sustainable water management practices, provide certainty to both surface water and groundwater users, and to enhance the overall welfare of the Humboldt River region.

NDWR APPROACH FOR CONJUNCTIVE MANAGEMENT IN THE HUMBOLDT RIVER REGION

The following approach and principles will guide the Humboldt Working Group's efforts in developing effective water management strategies for the region:

1) *Core tenets of conjunctive management strategy:*
   - Optimize beneficial use of water resources, both underground and surface water.
   - Adhere to the Prior Appropriation Doctrine.
   - Prevent increase in conflict from underground water rights moving into the future.
   - Reduce conflict from existing UG water rights.
   - Minimize harm to local and regional economies.
   - Use data- and science-based, building block approach.
   - Through engagement with stakeholders.
2) *Conjunctive management must work within the confines of Nevada water law and the Humboldt Decree.*

DISCUSSION PRIORITIES FOR THE WORKING GROUP

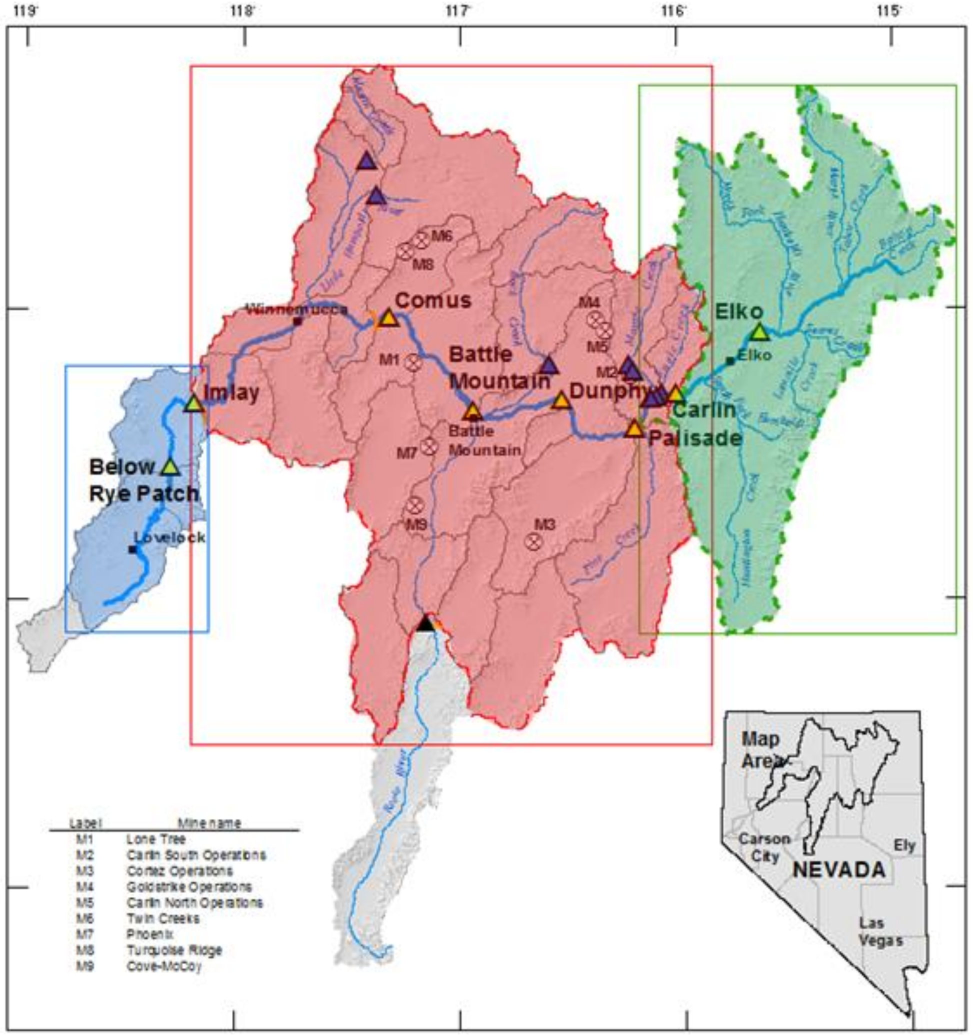
Since its inception, the stakeholder working group has held two meetings, during which various important topics and proposals were discussed:

- Updates on the Middle Humboldt Model and Report ETA
- Goals of conjunctive Management
- Capture management goals and tools
- Process and timeline for implementing conjunctive management in the Humboldt
- Consideration of forming Conservancy District(s)
- Offset requirements
- Possible curtailment timeline
- Historical and legacy capture

In upcoming meetings scheduled for 2025, the remaining ideas and concepts proposed by stakeholders (see list below) will be further explored through focused discussions. Of particular interest for the first meeting in 2025 is the topic of offsets (items 7, 11, 12 in the list of ideas below) which the group has expressed a strong desire to learn more about due to its centrality to any future solutions for the Humboldt River conjunctive management issue.

LIST OF CONJUNCTIVE MANAGEMENT IDEAS FOR THE HUMBOLDT RIVER REGION

1) Curtailment of UG by priority
2) Focused curtailment of UG by impact
3) Establish Capture Management Zone
4) Establish conservancy district
5) Special considerations for public water supply
6) Consider methods from other Western States
7) Use of Decree to offset capture
8) Use of pumping reductions or UG relinquishments
9) Limit irrigation seasons and duties to that of Decree
10) Improved management of Decree
11) Managed recharge as offset
12) Augmentation as offset
13) Conservation as offset
14) Water right buy back
15) Use of private agreements
16) Market-based approach
17) Nature-based solutions
18) Exemptions
19) No Action



NEVADA DIVISION OF WATER RESOURCES

Nevada Department of CONSERVATION & NATURAL RESOURCES

PRESENTATION OF CONJUNCTIVE MANAGEMENT IDEAS AND CONCEPTS

NDWR

January 08, 2025

Summary of Conjunctive Management Ideas and Concepts for the Humboldt River Region

This series of slides summarizes concepts presented by a range of stakeholders in three meetings held at the NDWR office in Carson City in August and September of 2023. The summary was prepared by State Engineer staff for a public meeting on March 19, 2024, for initial evaluation of the feasibility and implications of each concept. The information here is abbreviated and preliminary for discussion purposes, and not a full representation of the original concept presented by stakeholders. Those full presentations can be viewed at: https://water.nv.gov/index.php/bulletinboard/humboldt-river-communications/

Management ideas

- No Action
- Curtailment of UG by priority
- Focused curtailment of UG by impact
- Establish Capture Management Zone
- Establish conservancy district
- Special considerations for public water supply
- Consider methods from other Western States
- Use of Decree to offset capture
- Use of pumping reductions or UG relinquishments
- Limit irrigation seasons and duties to that of Decree
- Improved management of Decree
- Managed recharge as offset
- Augmentation plans
- Conservation as offset
- Water right buy back
- Use of private agreements
- Market-based approach
- Nature-based solutions
- Exemptions

Presentation of Conjunctive Management Ideas and Concepts

Summary - Bulleted summary of idea or concept.

Authority – Does **State Engineer** currently have authority, or does it require action by others e.g., **Legislative**, **County**, or **Court**.

Implementation – How long might it take to implement? **Near term** (1 – 5 yrs); **mid term** (3 – 7 yrs); **long term** (5 – 10+ years); **Ongoing** (already implemented or is a current practice). Does not imply that specific action will be undertaken.

Impacts/Benefits – What impacts to UG use, SW use, and to communities can be expected from implementation of specific idea or concept.

Testing - Can actions be tested with models to estimate effect of action.

No Action

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Suggested by many. • Manage UG as separate source - Manage UG only by basin perennial yields.	State Engineer	Current status	Ongoing economic harm to SW users. Ongoing economic benefit to UG users. Resumption of legal action-Court will decide	~25K AFY current conflict. ~50K AFY in 100 yrs under order 1329 >50K AFY under No Action

Curtailment of UG rights by Priority

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Strict curtailment of UG rights by priority, by basin. • Suggested by many as best or only legal approach. • Strictest application of Prior Appropriation Doctrine. • Ignores reality of impacts by location.	State Engineer or Courts	At Any Time: Possible outcome of legal action	Widespread/ catastrophic economic damage. Eliminates most UG. SW would incrementally increase.	Yes

Focused Curtailment of UG Water Rights by Impact

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Curtail UG rights based on impact/conflict. • Requires determination of minimum threshold criteria for curtailment (e.g., 10% capture after 50 years). • Would most affect UG water rights near connected rivers and streams.	State Engineer	Mid – Long term	Potential for variable economic impact. Eliminates much UG near connected Rivers and Streams. SW would increase.	Yes

Establish Capture Management Zone (CMZ)

Summary	Authority	Implementation	Impact/ Benefit	Testing
• CMZ defined by a minimum level of conflict (e.g., 5% capture in 50 yrs). • Areas within CMZ subject to capture management. - Areas outside would be exempt. • Gradual implementation more manageable with less immediate impact. - But would take longer for conflict reduction. • Managed locally (e.g., Conservancy District). - Manage capture through $ assessments on conflict (capture).	State Engineer or Legislative Action	Short - Long term	Dependent on CMZ boundaries. UG could reduce. SW would increase.	Yes

Establish Humboldt River Conservancy District (HRCD) (NRS 541)

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Locally managed District to administer conjunctive management strategy. • Governed by locally elected board members. • Boundaries defined by CMZ. • Base assessments on UG and SW users within CMZ to fund staff and facilities. • Capture assessments for UG rights within CMZ based on magnitude of conflict. - Used to purchase UG and SW rights.	Legislative Action or Collective County Action NRS 541	Mid - Long term	Dependent on program.	No

Special Considerations for Public Supply

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Special allowances and considerations for 'regulated utilities' (public water supplies). • Exemption to capture management when outside of direct connection with main stem of Humboldt River. • Exemption for utilities with integrated/intertied systems. • "Back-end" conflict analysis. Conflicts to be managed with pumping strategies rather than a determining factor for granting of permits. • Use of treated wastewater for return flow credit – either direct discharge or through RIBS. • Use of local test data to refine analysis.	State Engineer and/or Legislature	Short - Long term	Unknown	Unknown

Consider methods from other Western States

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Establish specific area and rules for special groundwater management. • Consider conjunctive management strategies that have been successfully implemented in other western states.	Legislative	Mid - Long term	Would depend on specifics.	Unknown.

Use of Decree water to Offset capture

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Allow for use of Humboldt Decree water to offset conflict from UG use.	State Engineer	Ongoing	No change in UG. SW would increase.	Yes

Use of pumping reductions or UG relinquishment/retirement/withdrawal to offset capture

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Allow for use of pumping reductions or relinquishments of UG rights to offset capture.	State Engineer	Ongoing	UG would decrease. SW could increase.	Yes

Limit UG irrigation seasons and duties to Humboldt Decree

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Limit UG irrigation to same season and duties as established in Humboldt Decree.	Legislative	Short - Mid term	Possible substantial community impact UG would decrease. SW would increase.	Yes

Improved Management of Humboldt Decree

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Serve equal priority in Upper and Lower basins. • More closely manage diversions. • Improve transparency. - Record and report all demands and deliveries. - Website showing priority being served. • Set priorities based on snowpack and forecast rather than daily streamflow. • Increase assessments and hire more field staff.	State Engineer Decree Court? Legislative	Short - Mid term	UG would not change. SW could increase or decrease.	No

Managed Recharge as Offset

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Allow for offset of impacts through managed recharge. • Can be through RIBS, injections wells, or ASR.	State Engineer	Short term	UG could reduce or stay same. SW would increase.	Yes. But requires specifics of a MAR program.

Augmentation as Offset (similar to Colorado)

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Augmentation plans required for UG use – similar to Colorado. • Augmentation plans approved by Decree court. • Augmentation using surface water or new storage. • Allow for ASR, RIBS, and recharge wells to also be used for augmentation (see previous slide). • Pipe UG water from areas of no/low impact to discharge directly into river or stream. (augmentation wells)	State Engineer or Legislature	Short - Mid term	UG could reduce or stay same. SW would increase.	Yes, but depends on scenario.

Conservation as Offset

Summary	Authority	Implementatio n	Impact/ Benefit	Testing
• Promote conservation through various means. • Conservation credits. Buy or Sell on a market. • Tax breaks for conservation efforts. • Credits used to offset capture impacts?	Legislature	Mid - Long term	Unknown	Unknown

Water right buy back

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Voluntary sale of UG water rights as part of water right buy back program.	Legislature	Current, but future program depends on funding	Depends on rights purchased UG could reduce SW could increase.	Yes. For specific purchase options.

Use of private agreements

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Use of agreements between private parties or entities to resolve conflict.	State Engineer	On going	No effect.	No.

Market-based approach to manage capture

Summary	Authority	Implementatio n	Impact/ Benefit	Testing
• Create water markets that can be used for efficient trading/transfer/sale of water rights. • Consider Decentralized markets to coordinate sale of water rights. Lacks transparency and has high transaction costs. • Consider Centralized markets to coordinate sale of water rights based on 'willingness' of participants.	Legislature	Mid – Long Term	Market dependent.	No.

Nature-based Solutions

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Sustainable management and use of natural features and processes to help address conjunctive management. • Use of MAR (discussed earlier) in places that provide benefit to wetlands and springs and increase the surface water available through increased groundwater levels • Restoration projects – wetlands, river channels, floodplains, etc.	State Engineer	Near – Long term	UG no change Potential shift in SW hydrographs Water quality Wildlife	Depends on scenarios

Exemptions

Summary	Authority	Implementation	Impact/ Benefit	Testing
• Minimal impact (e.g., < 5 acre-ft/yr capture). • Domestic Wells • Public Water Supply (see earlier)	State Engineer Legislative	Short - Mid term	Variable depending on exemption.	Depends on exemption

Nevada Division of Water Resources | Nevada Department of Conservation & Natural Resources

Offsets in Conjunctive Management: What are they and how do they work?

Humboldt River Stakeholder Working Group

January 8, 2025, Battle Mountain, Nevada

NDWR

Offset - Definition

A quantity of water or other form of credit that can be used to ’mitigate’ the portion of a groundwater right that conflicts with senior surface water rights.

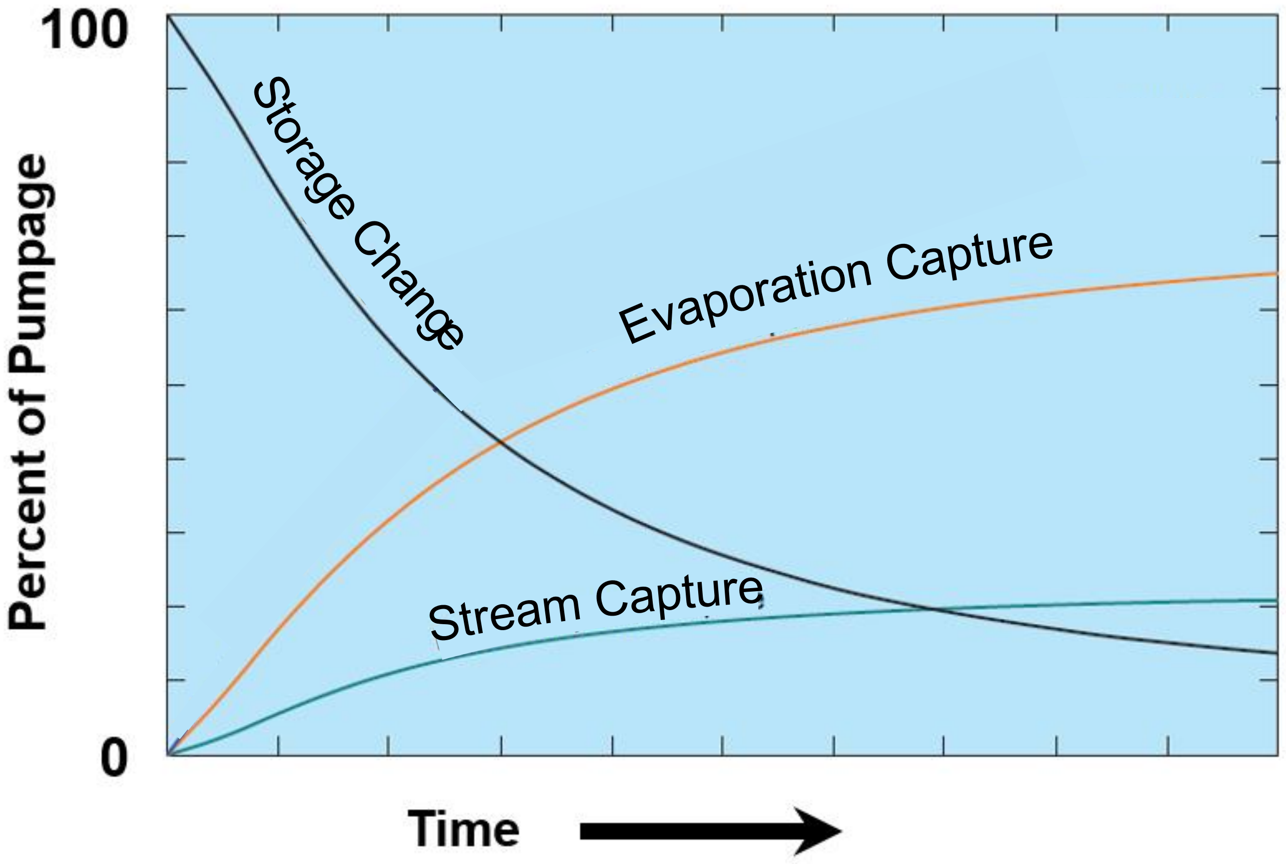
Offset types for Todays Discussion

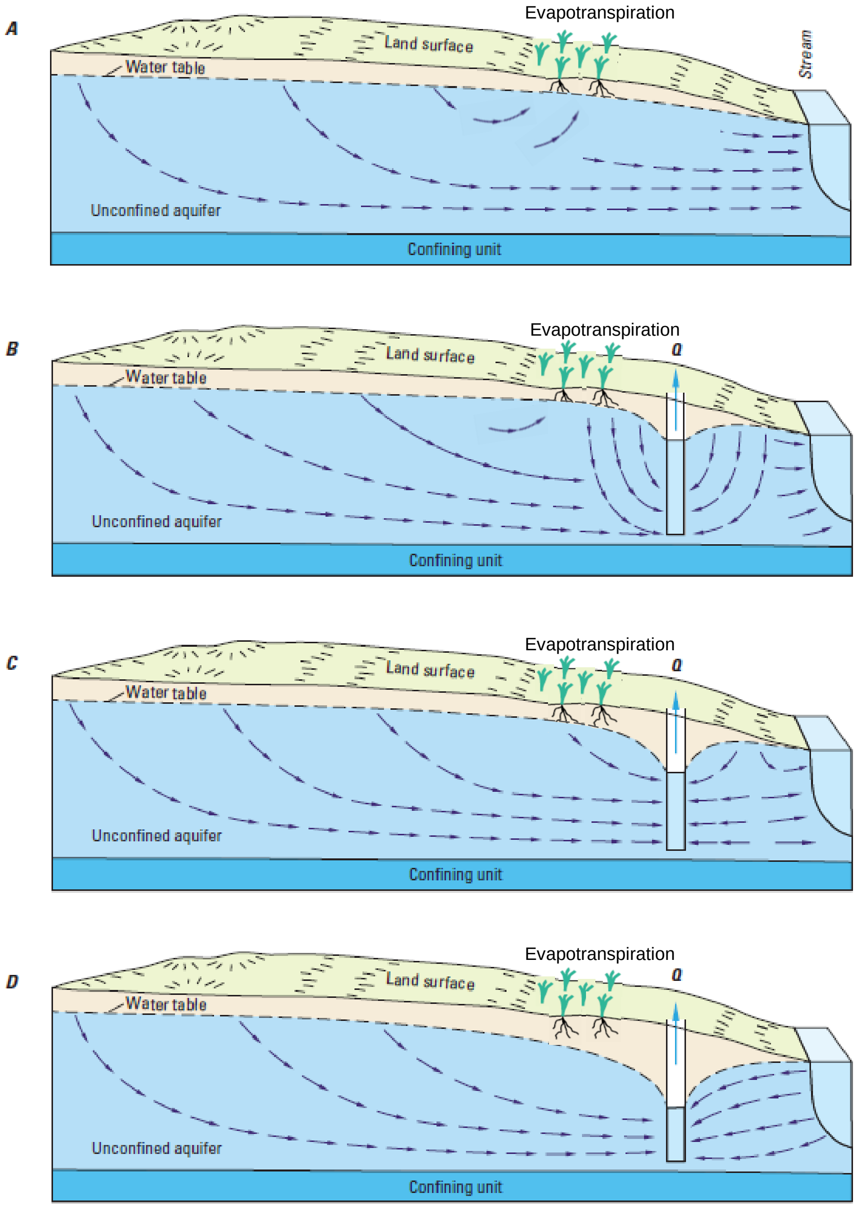
Augmentation of streamflow

In-stream replacement using Humboldt Decree water

Managed Aquifer Recharge (MAR)

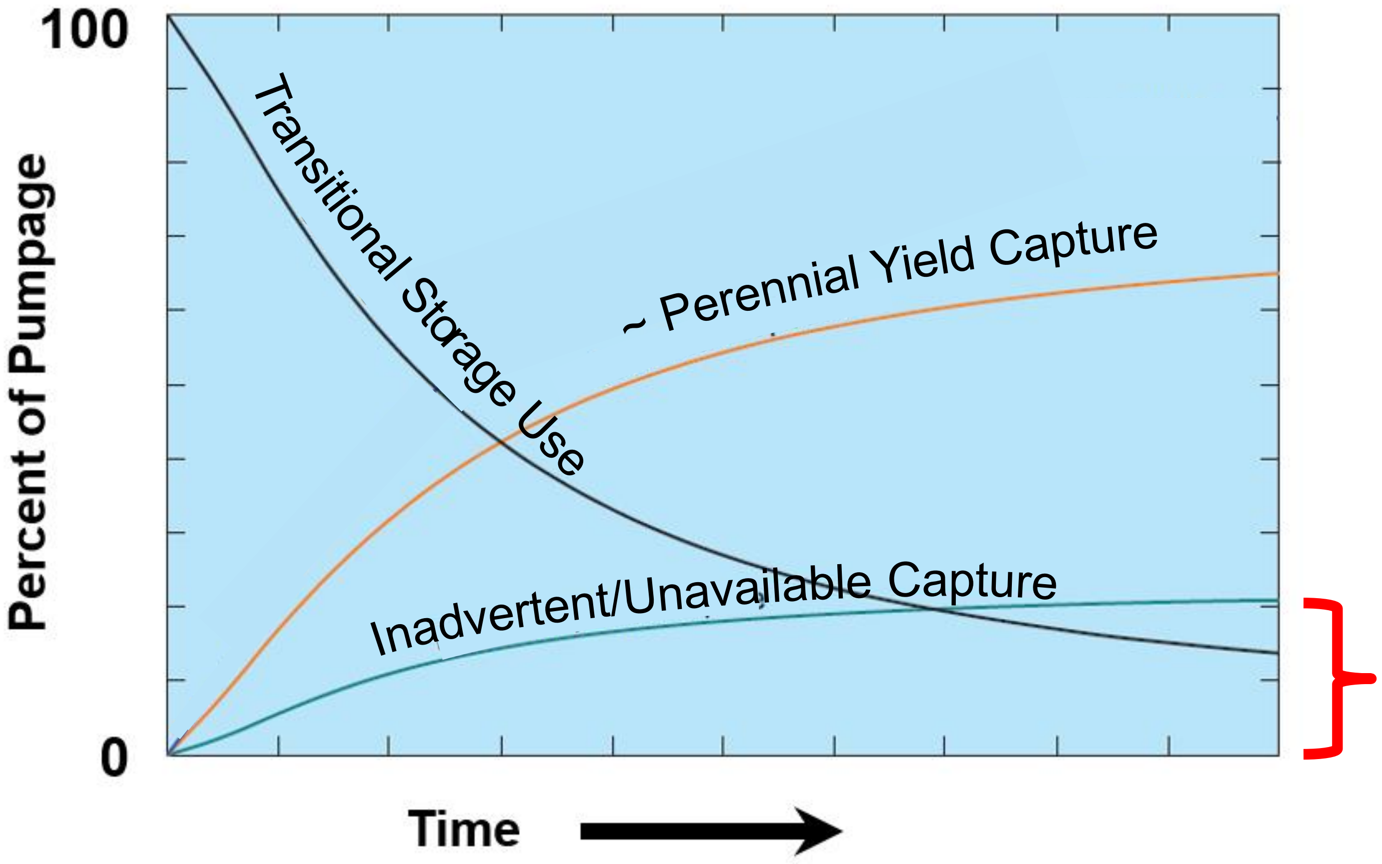
WHAT IS STREAM CAPTURE?





Stream Capture = Streamflow Depletion

Water Management Perspective

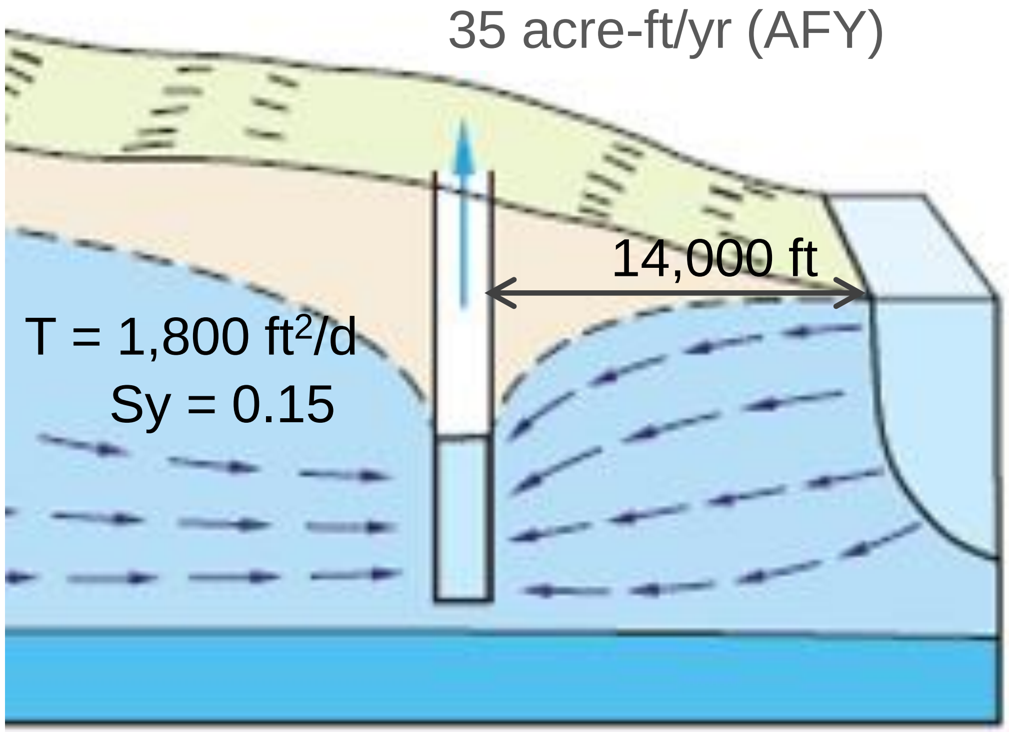


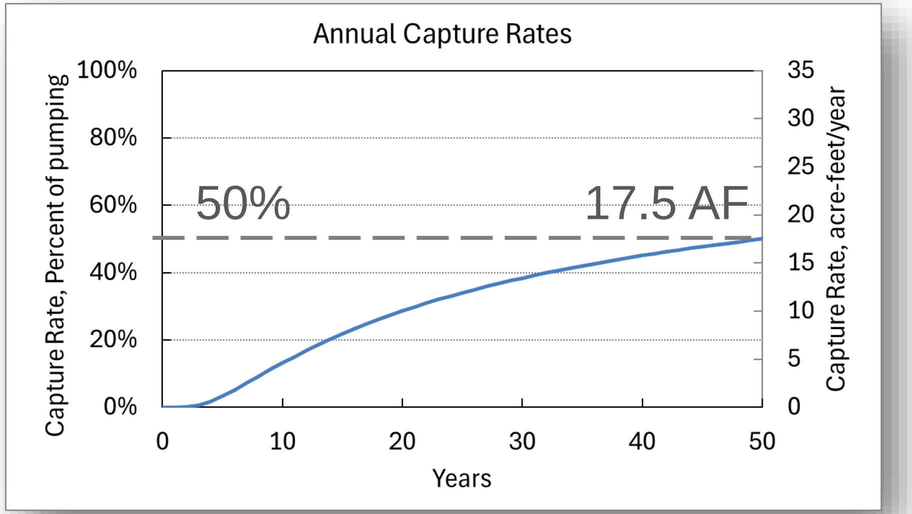
Capture curves conceptualized through water management perspective.

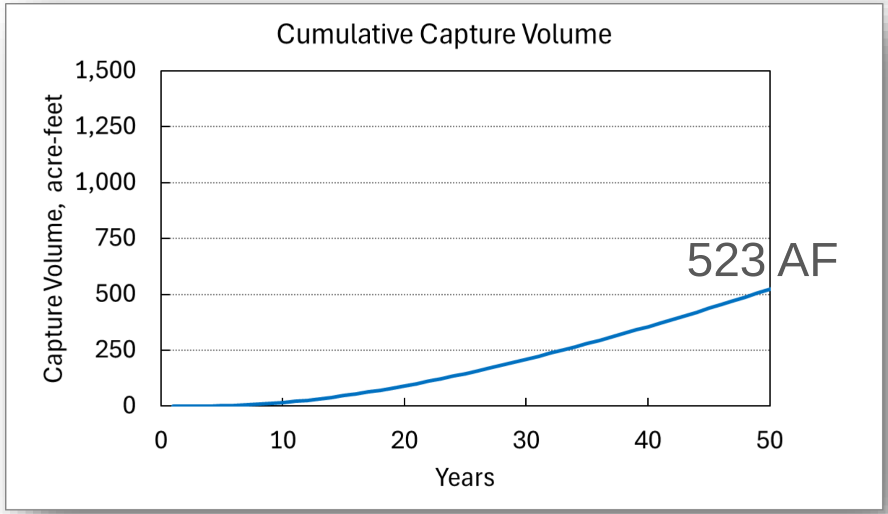
Conflict when coming from fully appropriated SW source.

Hypothetical Capture used in this Demonstration

Hypothetical well that pumps for 50 years



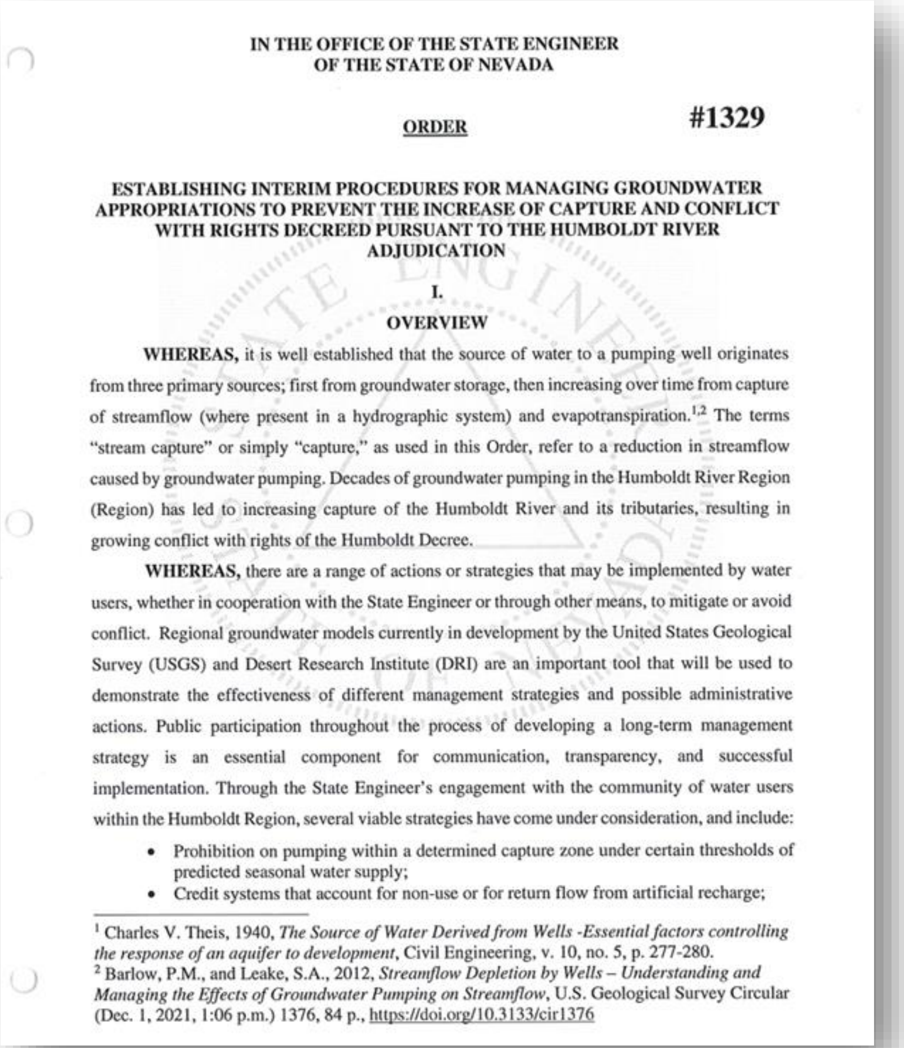




Capture Conflict Criteria –
Capture evaluated over 50-year period

- Exemption status:
  - <5 AFY after 50 yrs of pumping – exempt.
  - <10% capture after 50 yrs of pumping – exempt.
  - otherwise, Offset is required.

- Successful Offset Criteria:
  - equal or exceed cumulative volume of capture within 50 years.
  - equal or exceed annual capture in 40 out of 50 years (80 percent rule).



IN THE OFFICE OF THE STATE ENGINEER
OF THE STATE OF NEVADA

ORDER #1329

ESTABLISHING INTERIM PROCEDURES FOR MANAGING GROUNDWATER APPROPRIATIONS TO PREVENT THE INCREASE OF CAPTURE AND CONFLICT WITH RIGHTS DECREED PURSUANT TO THE HUMBOLDT RIVER ADJUDICATION

I.

OVERVIEW

WHEREAS, it is well established that the source of water to a pumping well originates from three primary sources; first from groundwater storage, then increasing over time from capture of streamflow (where present in a hydrographic system) and evapotranspiration.[1,2] The terms "stream capture" or simply "capture," as used in this Order, refer to a reduction in streamflow caused by groundwater pumping. Decades of groundwater pumping in the Humboldt River Region (Region) has led to increasing capture of the Humboldt River and its tributaries, resulting in growing conflict with rights of the Humboldt Decree.

WHEREAS, there are a range of actions or strategies that may be implemented by water users, whether in cooperation with the State Engineer or through other means, to mitigate or avoid conflict. Regional groundwater models currently in development by the United States Geological Survey (USGS) and Desert Research Institute (DRI) are an important tool that will be used to demonstrate the effectiveness of different management strategies and possible administrative actions. Public participation throughout the process of developing a long-term management strategy is an essential component for communication, transparency, and successful implementation. Through the State Engineer's engagement with the community of water users within the Humboldt Region, several viable strategies have come under consideration, and include:

- Prohibition on pumping within a determined capture zone under certain thresholds of predicted seasonal water supply;
- Credit systems that account for non-use or for return flow from artificial recharge;

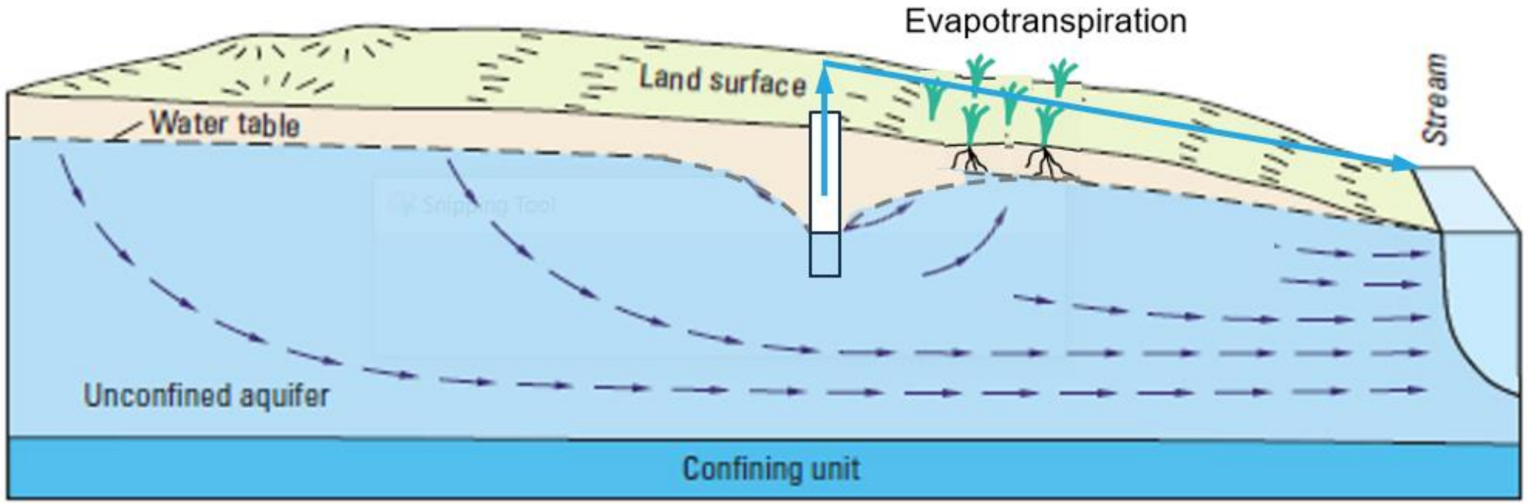
[1] Charles V. Theis, 1940, *The Source of Water Derived from Wells -Essential factors controlling the response of an aquifer to development*, Civil Engineering, v. 10, no. 5, p. 277-280.
[2] Barlow, P.M., and Leake, S.A., 2012, *Streamflow Depletion by Wells – Understanding and Managing the Effects of Groundwater Pumping on Streamflow*, U.S. Geological Survey Circular (Dec. 1, 2021, 1:06 p.m.) 1376, 84 p., https://doi.org/10.3133/cir1376

AUGMENTATION OF STREAMFLOW

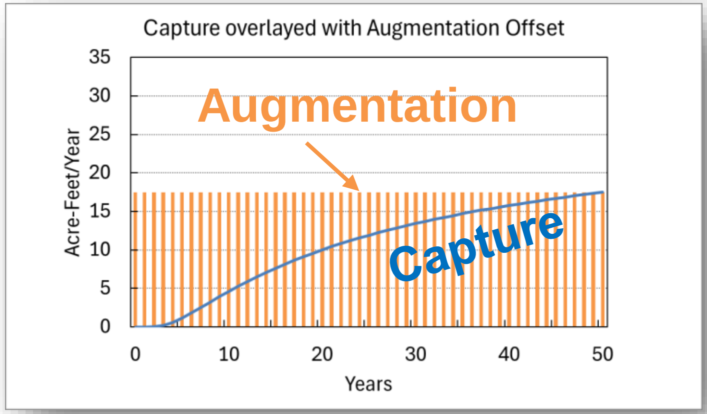
Augmentation of streamflow

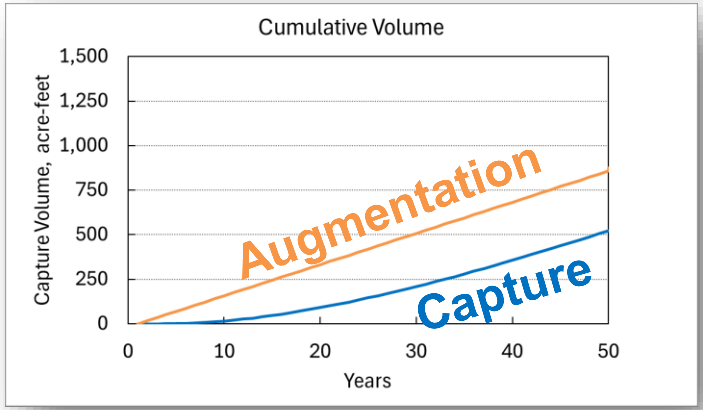
Increasing streamflow through direct addition of water

- Direct discharge to stream or tributary.
- Source:
  - Groundwater with low to no stream capture.
  - Reservoirs.
  - Imported from other surface water/streams.
  - Wastewater discharge.



What augmentation offsets could look like





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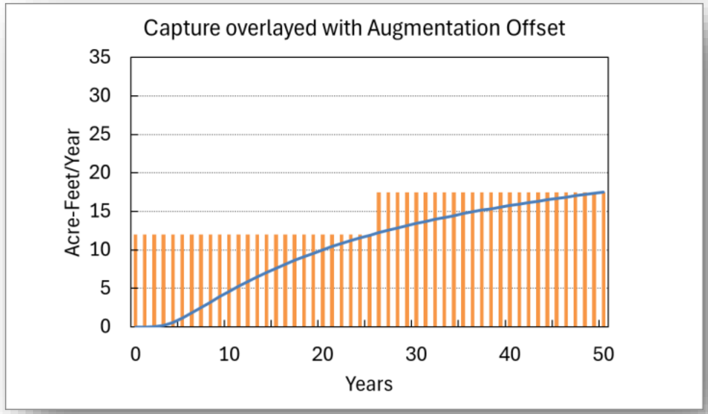

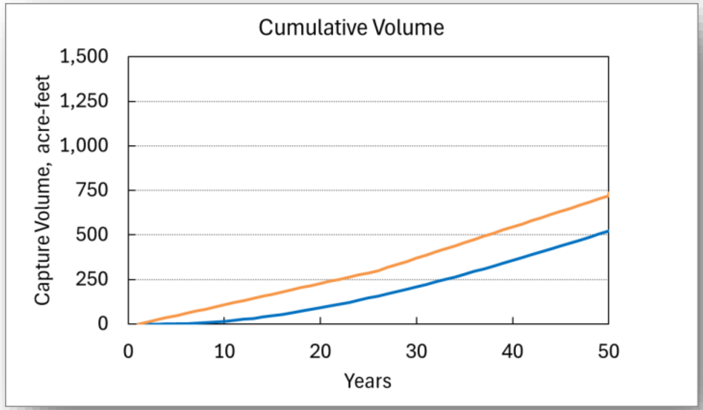

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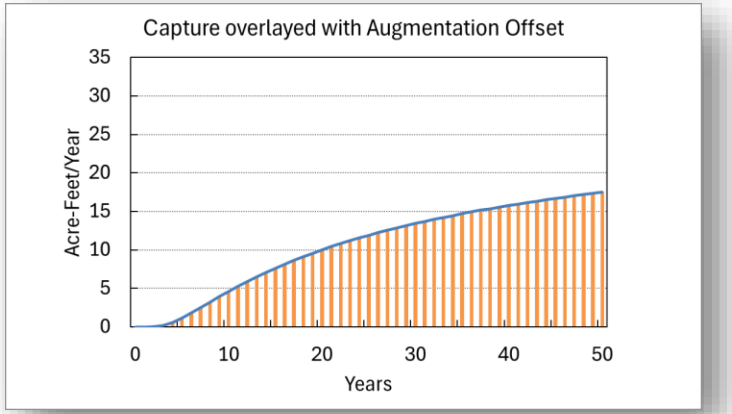
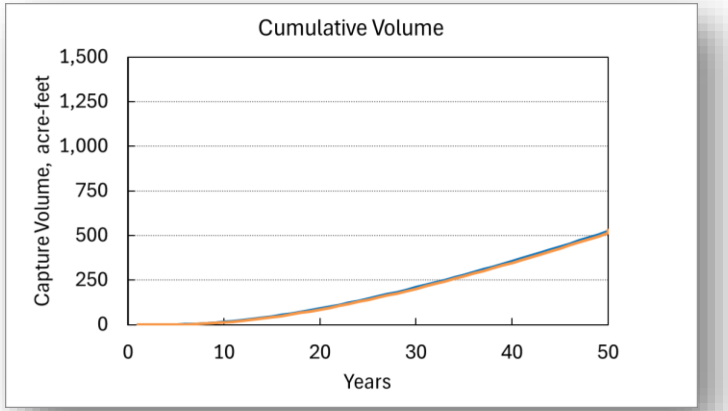




AUGMENTATION – EXAMPLES OF EXISTING AUGMENTATIONS

Mine Discharge

Treated Wastewater Effluent

In-stream offset using Humboldt Decree water

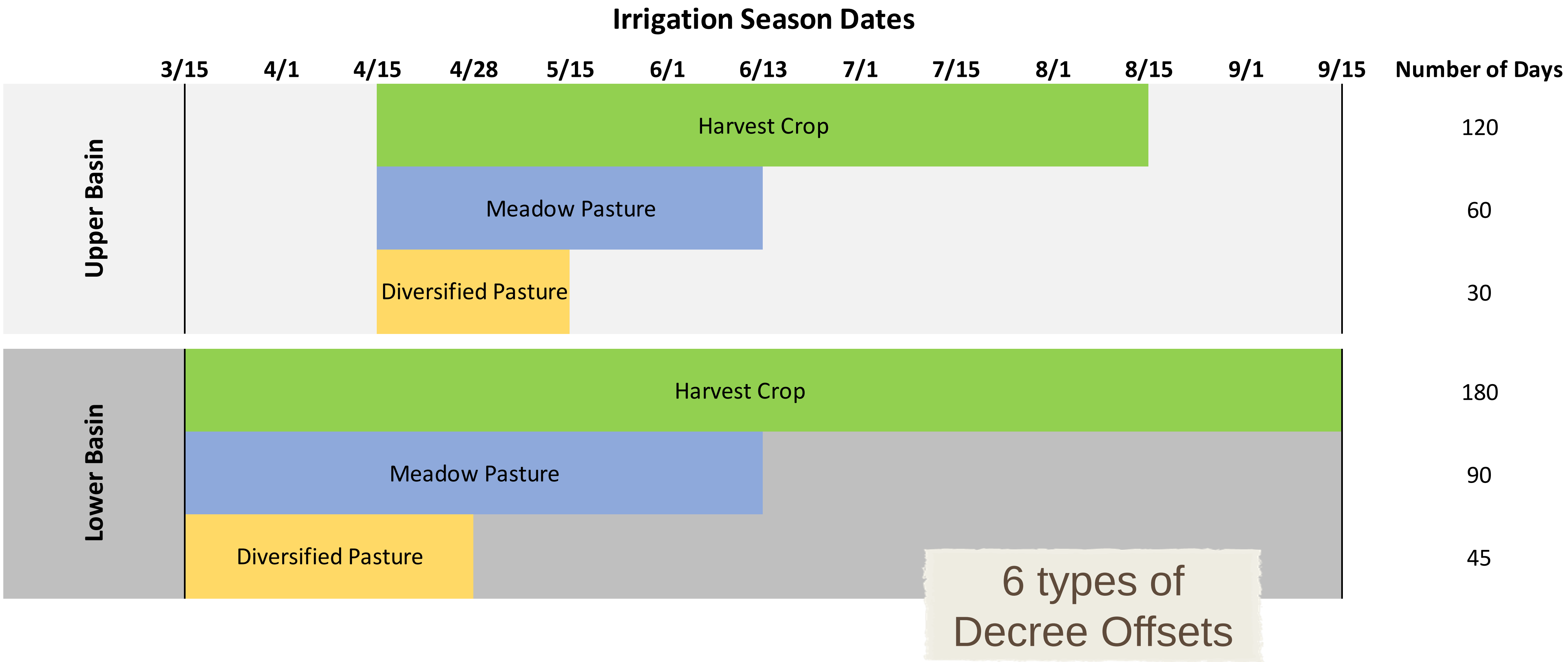
In-stream offset using Humboldt Decree water

Primary Considerations:

Priority, Duty, Location, Culture Class

- Complex conversion calculation.
- Subject to year-to-year water availability (wetness factor).
- Can move from downstream to upstream relatively easily.
- Very difficult to move from upstream to downstream due to inherent losses in the system.
- Can use tributary stream decree to offset main stem impacts.
- Cannot use mainstream decree to offset tributary impacts.
- Available in the Humboldt.

Decree water Offset – Wetness factor computation – Different seasons for Upper vs Lower Basin and Culture Class



Decree water Offset – Wetness factor computation – Priority is determined based on Palisade Flow

HUMBOLDT RIVER PRIORITY

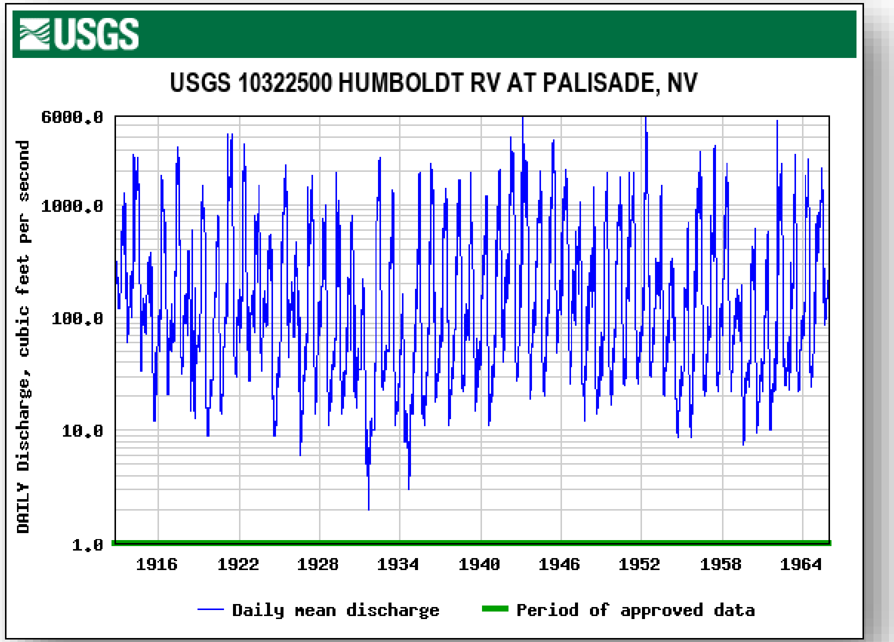
CHART AT PALISADE

Priority	3/15 - 4/28 (Palisade)	(Rye Patch)	4/28 - 6/13		6/13 - 9/15	
1861	7.951	6.361	2.840	2.272	2.154	1.723
1862	9.071	7.257	3.960	3.168	3.221	2.619
1863	23.129	10.676	10.295	4.232	7.681	3.683
1864	56.679	20.747	29.119	11.126	17.341	3.968
1865	60.733	20.747	31.501	11.126	19.008	3.968
1866	68.325	26.821	35.211	14.030	22.638	6.872
1867	77.664	34.292	43.305	20.505	27.269	10.577
1868	80.433	35.440	45.251	21.653	28.308	11.226
1869	82.946	35.440	47.411	21.653	30.415	11.226
1870	91.188	35.440	54.354	21.653	35.784	11.226
1871	148.116	50.008	95.058	29.948	68.531	17.062
1872	156.793	50.839	102.879	30.779	75.334	17.078
1873	257.246	102.180	167.818	65.074	134.100	49.124
1874	353.259	124.074	235.221	83.353	173.805	63.927
1875	365.413	125.554	245.044	84.770	177.759	65.344
1876	415.715	157.665	286.178	112.628	210.686	87.838
1877	500.940	215.013	319.905	131.927	230.969	98.209
1878	545.165	240.685	340.270	144.757	249.184	109.893
1879	590.779	241.935	374.808	146.007	267.876	110.328
1880	666.304	272.389	412.449	160.657	294.566	121.185
1881	675.331	277.492	417.946	164.149	299.500	124.377
1882	679.268	278.461	419.929	164.874	300.862	125.102
1883	724.471	299.637	448.949	177.530	327.976	137.374
1884	729.158	303.061	453.499	180.891	332.110	140.681
1885	739.206	309.977	464.444	188.948	342.378	148.738
1886	768.491	315.035	478.838	192.169	349.826	151.959
1887	910.371	372.680	547.144	208.837	391.295	167.533
1888	1003.075	421.974	621.443	254.625	455.934	213.222
1889	1004.639	422.899	623.006	255.550	457.498	214.447
1890	1040.971	442.427	645.296	269.773	475.168	227.337

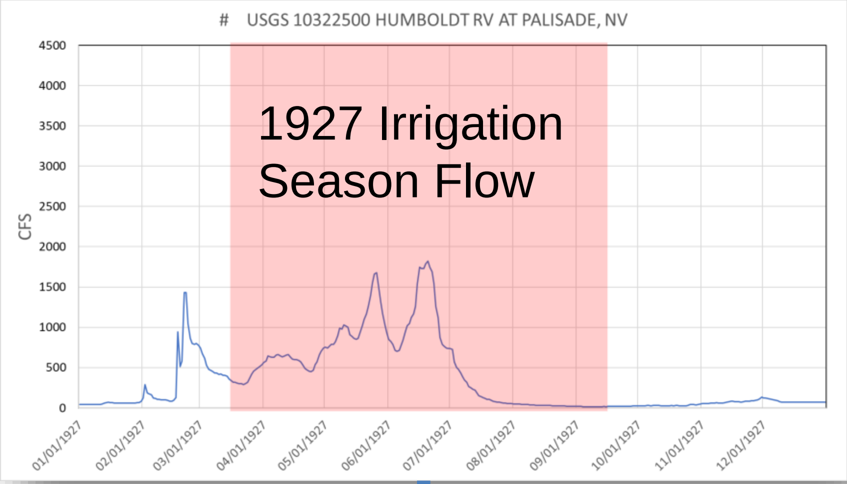
1890	1040.971	442.427	645.296	269.773	475.168	227.337
1891	1055.163	451.280	656.118	277.249	483.594	234.078
1892	1058.198	453.708	657.486	278.344	484.963	235.173
1893	1080.443	471.504	670.229	288.538	486.780	236.627
1894	1083.893	474.264	673.679	291.298	488.363	237.843
1895	1084.655	474.874	674.441	291.908	489.125	238.503
1896	1084.903	475.072	674.689	292.106	489.373	238.701
1897	1106.708	475.852	679.210	292.838	493.894	239.433
1898	1115.814	477.579	681.776	294.565	496.055	241.160
1899	1117.650	479.048	683.613	296.034	497.889	242.629
1900	1160.320	513.184	724.573	328.802	538.849	275.397
1901	1163.516	515.661	726.528	330.293	540.754	276.873
1902	1170.090	516.419	730.794	331.051	541.701	277.631
1903	1171.430	517.491	732.134	332.123	543.041	278.703
1904	1186.650	518.293	740.683	332.890	544.305	279.470
1905	1186.751	518.374	740.784	332.971	544.406	279.551
1906	1190.080	521.037	744.113	335.634	547.735	282.214
1907	1190.233	521.159	744.265	335.756	547.888	282.336
1908	1191.724	522.352	745.756	336.949	549.379	283.529
1909	1194.434	524.519	748.129	338.847	551.751	285.427
1910	1196.804	526.416	750.500	340.744	554.123	287.324
1911	1197.565	527.025	751.206	341.309	554.829	287.889
1912	1216.288	530.300	761.984	344.584	565.546	291.164
1913	1220.275	533.490	765.971	347.774	569.534	294.354
1914	1230.073	536.559	772.494	350.232	576.021	296.812
1915	1231.365	537.593	773.786	351.266	577.314	297.846
1916	1234.256	539.906	776.677	353.579	580.205	300.159
1917	1236.999	542.100	779.420	355.773	582.948	302.353
1918	1241.748	545.184	784.169	358.857	587.696	305.437
1919	1242.991	546.179	785.413	359.852	588.940	306.432
1920	1244.851	547.667	787.273	361.340	590.800	307.920
1921	1244.900	547.706	787.321	361.379	590.849	307.959

Decree water Offset– Wetness factor computation –
Priority served based on historic irrigation season flow record

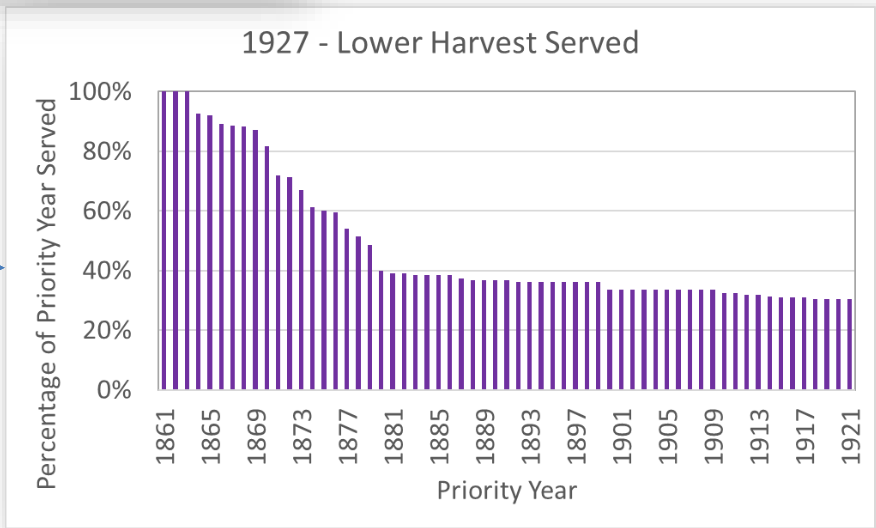
How much of each priority was historically served?



Period used: 1912 - 1965



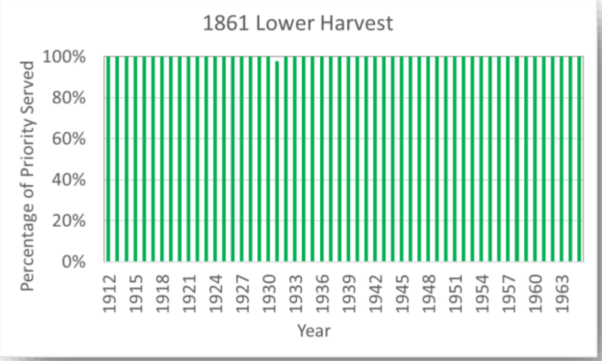
1927 example: a normal year

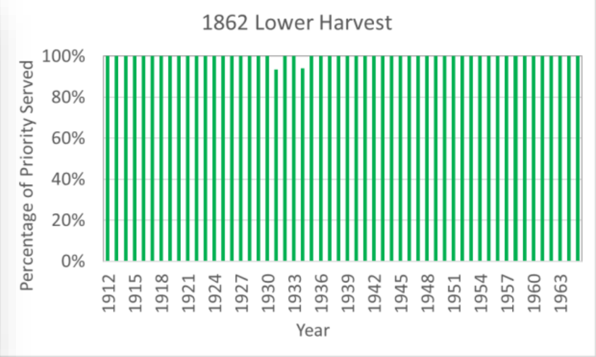


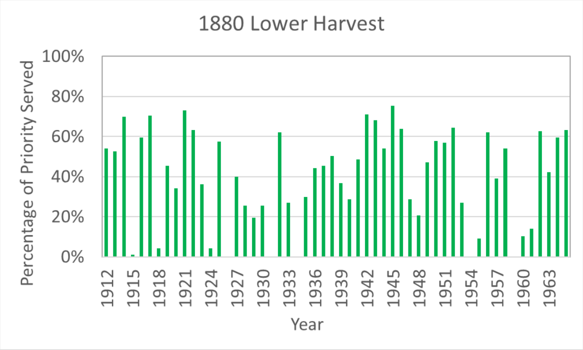
DECREE WATER OFFSET – WETNESS FACTOR COMPUTATION – PRIORITY SERVED BASED ON HISTORIC IRRIGATION SEASON FLOW RECORD

Most Senior

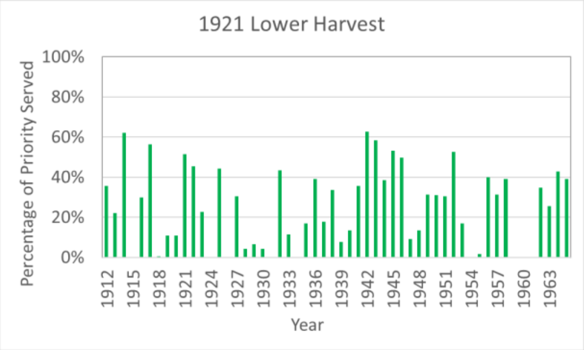
Junior





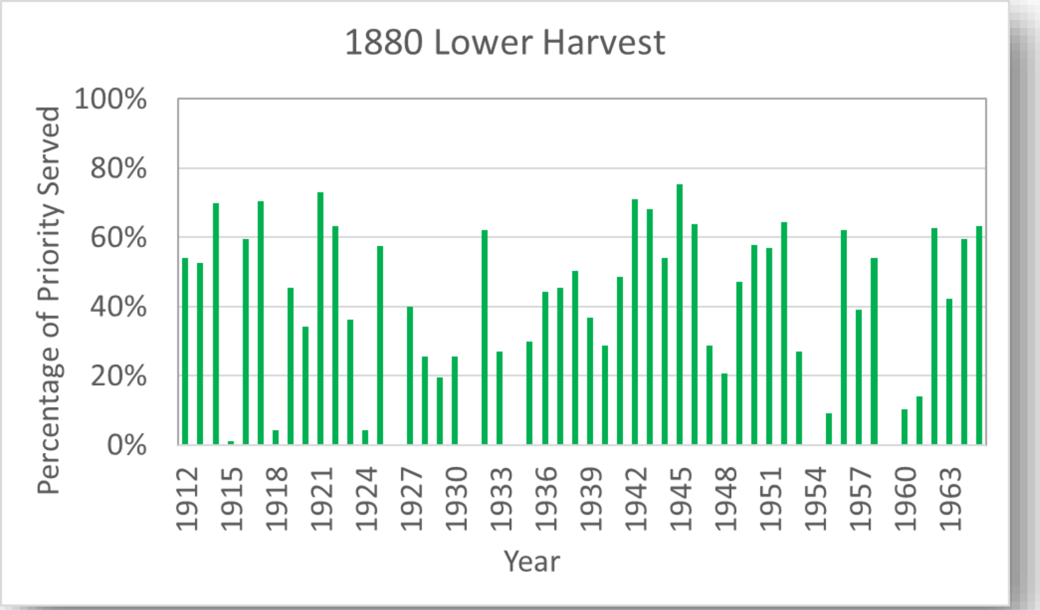


Most Junior

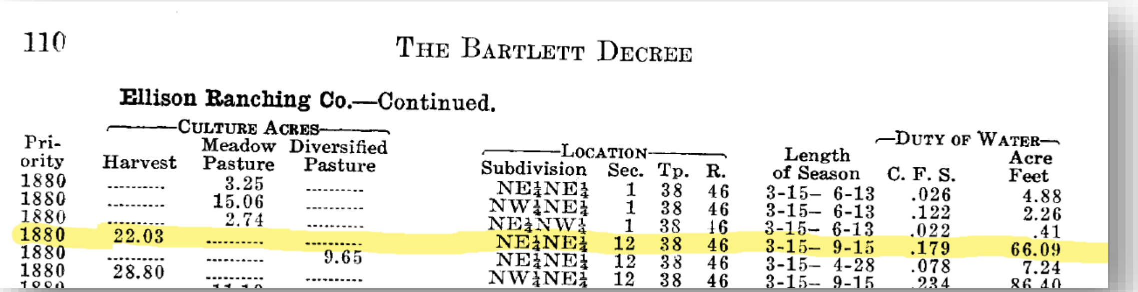


Senior decree was served more than junior decree

Decree water Offset – Wetness factor computation – Conversion of Decree Right to Annual Duty served



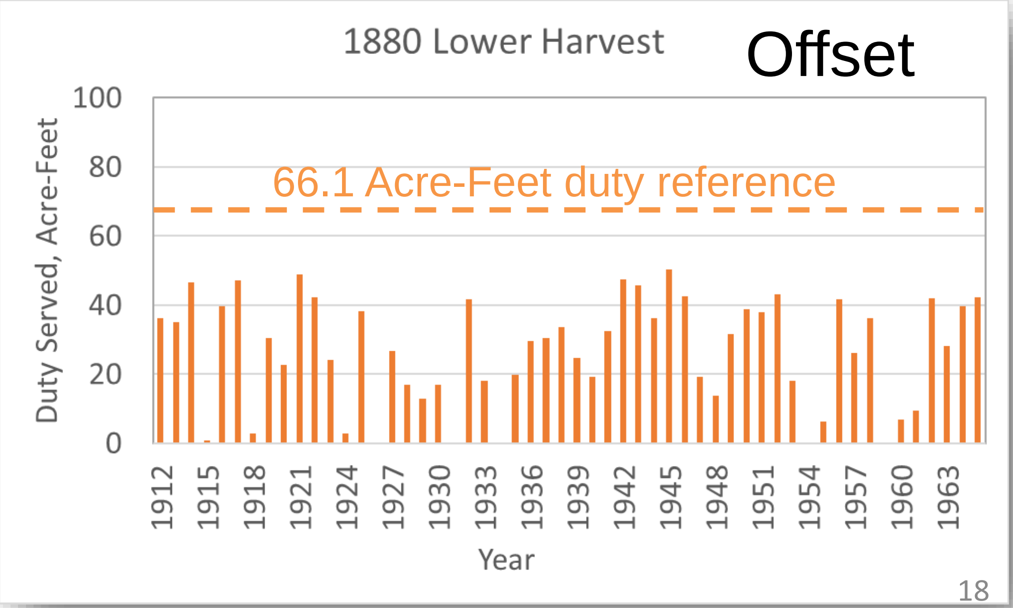
Duty of this 1880 Lower Harvest Decree Right = 66.1 AF



110 THE BARTLETT DECREE

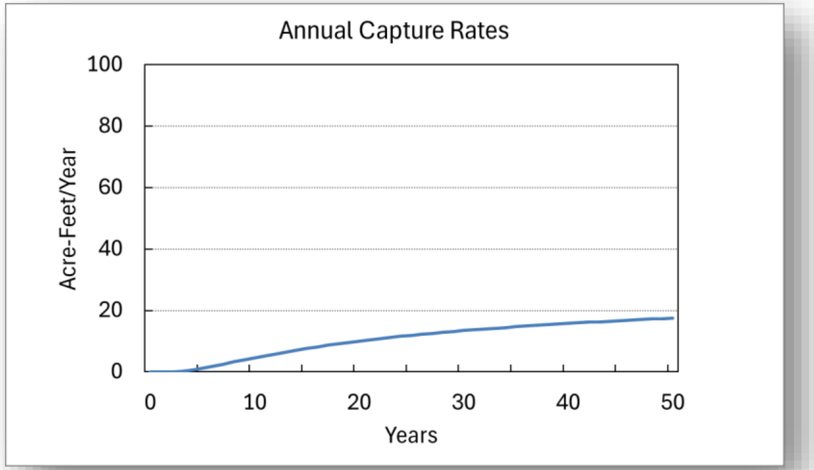
Ellison Ranching Co.—Continued.

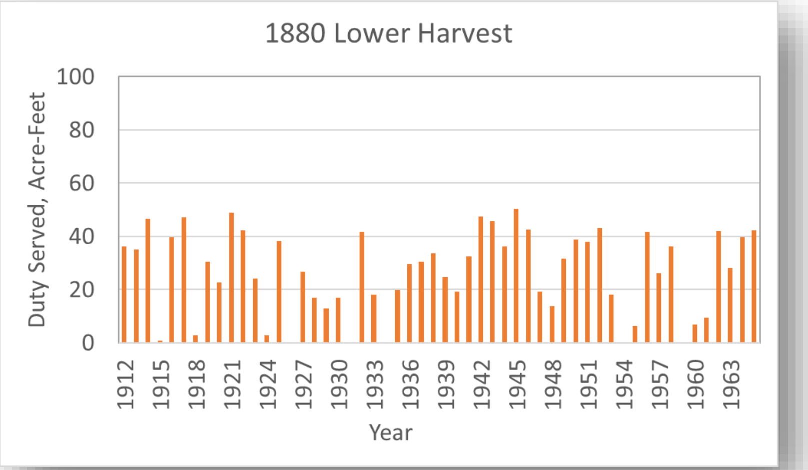
Priority	Culture Acres: Harvest	Culture Acres: Meadow Pasture	Culture Acres: Diversified Pasture	Location: Subdivision	Sec.	Tp.	R.	Length of Season	Duty of Water: C. F. S.	Duty of Water: Acre Feet
1880	....	3.25	....	NE¼NE¼	1	38	46	3-15– 6-13	.026	4.88
1880	....	15.06	....	NW¼NE¼	1	38	46	3-15– 6-13	.122	2.26
1880	....	2.74	....	NE¼NW¼	1	38	46	3-15– 6-13	.022	.41
1880	22.03	....	....	NE¼NE¼	12	38	46	3-15– 9-15	.179	66.09
1880	....	....	9.65	NE¼NE¼	12	38	46	3-15– 4-28	.078	7.24
1880	28.80	....	....	NW¼NE¼	12	38	46	3-15– 9-15	.234	86.40

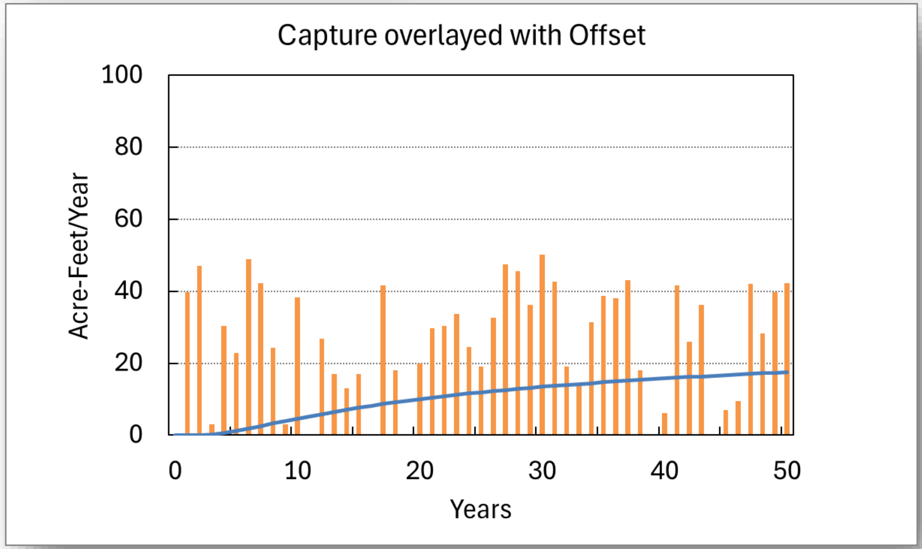


For most priority dates, actual duty served is less than duty of water right.

Decree water Offset – Wetness factor computation – Determined against capture liability curve



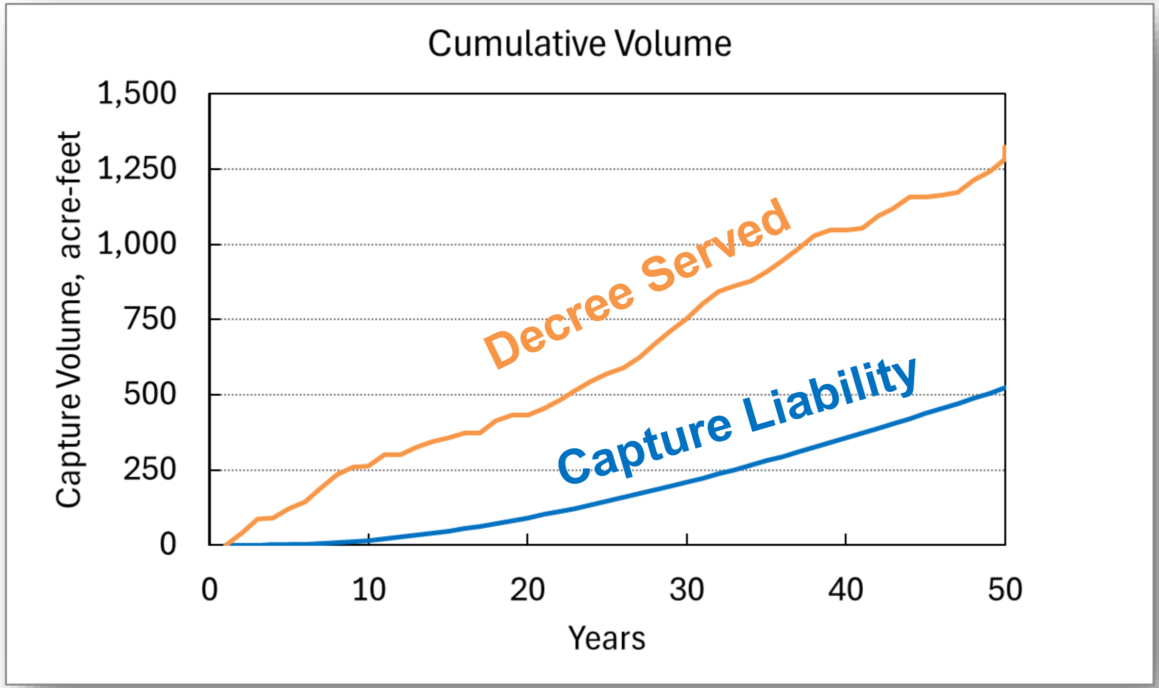




Offset is compared with capture curve and criteria evaluated.

Decree water Offset – Wetness factor computation – Criteria Evaluation

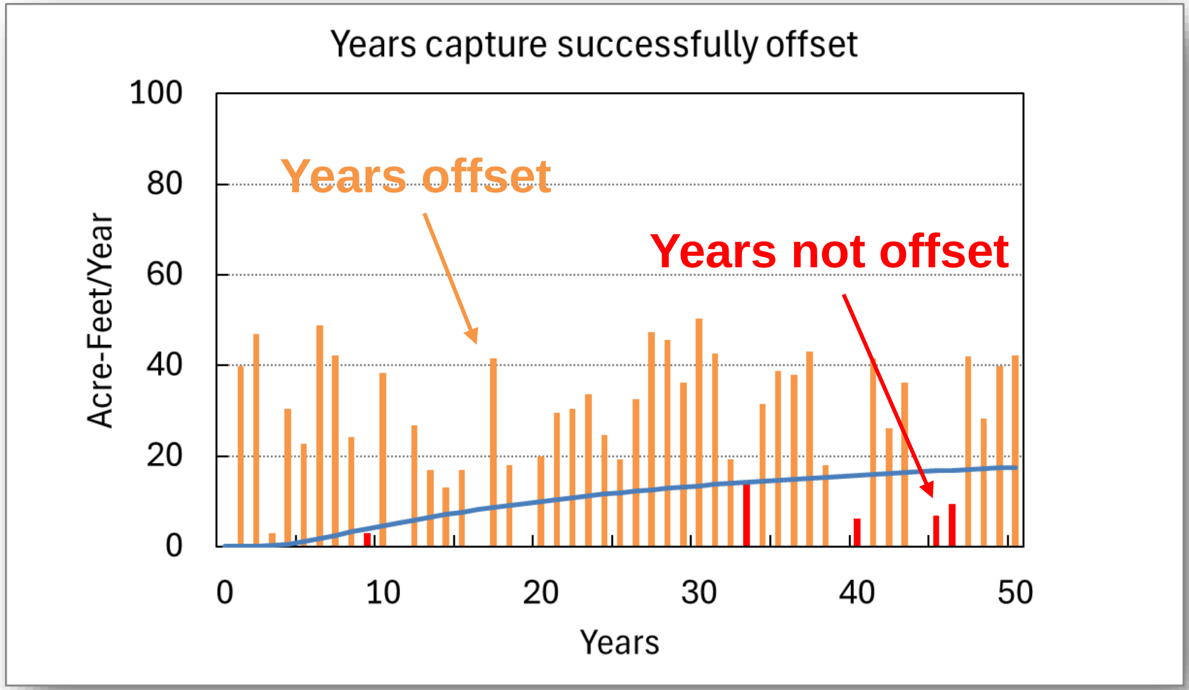
Cumulative Volume Criteria



Cumulative Offset volume > Capture Liability

☑

Percentage of years capture successfully offset criteria (80 percent rule)

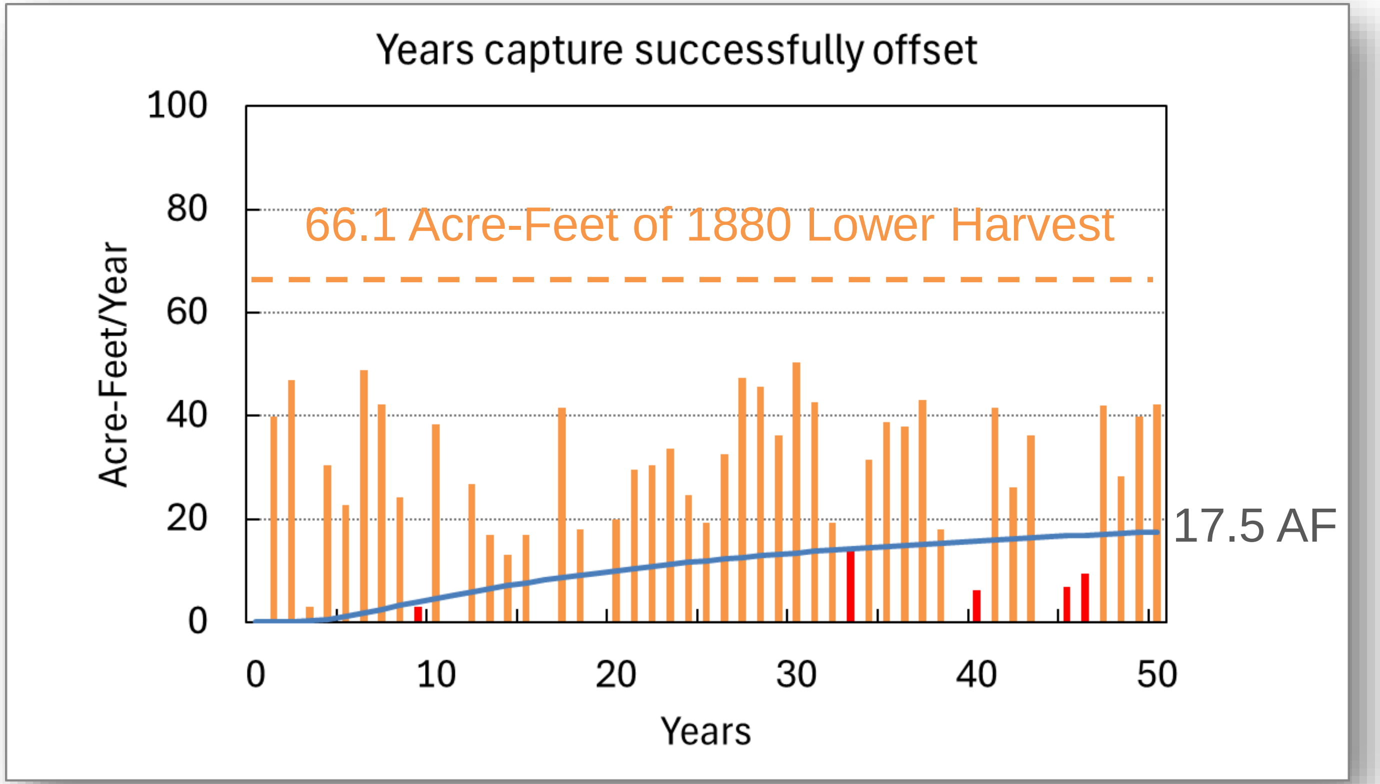


40 of 50 years successfully offset.

☑

DECREE WATER OFFSET – WETNESS FACTOR COMPUTATION

$$Wetness\ Factor_{Priority,Basin,Culture} = \frac{50\ yr\ capture\ liability}{Duty\ of\ offset}$$

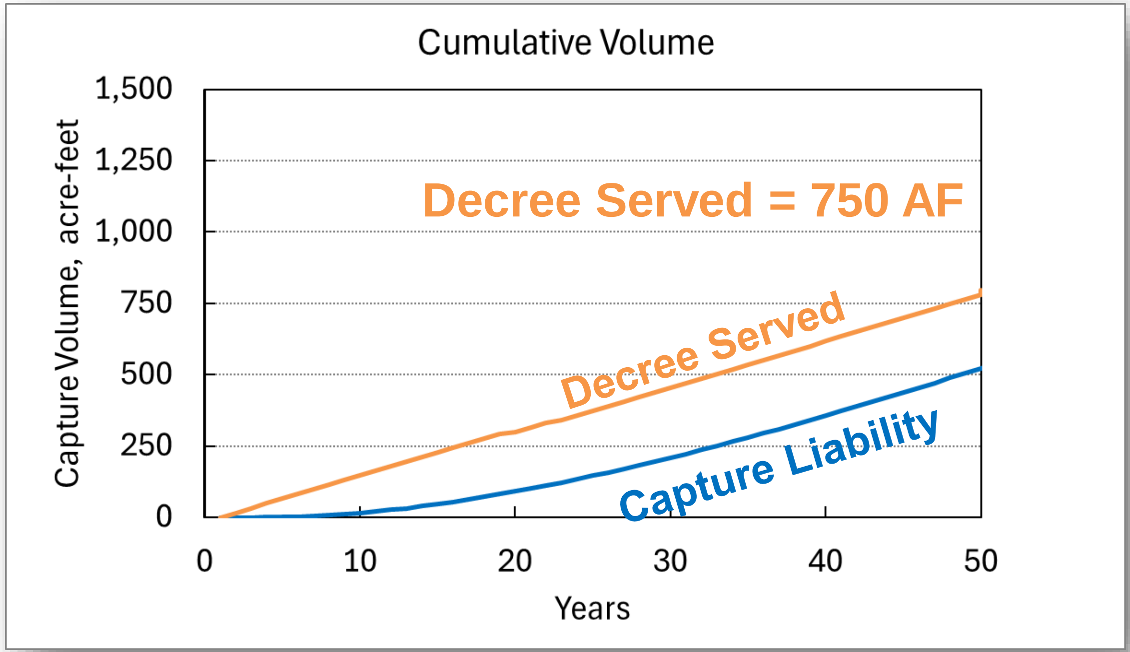


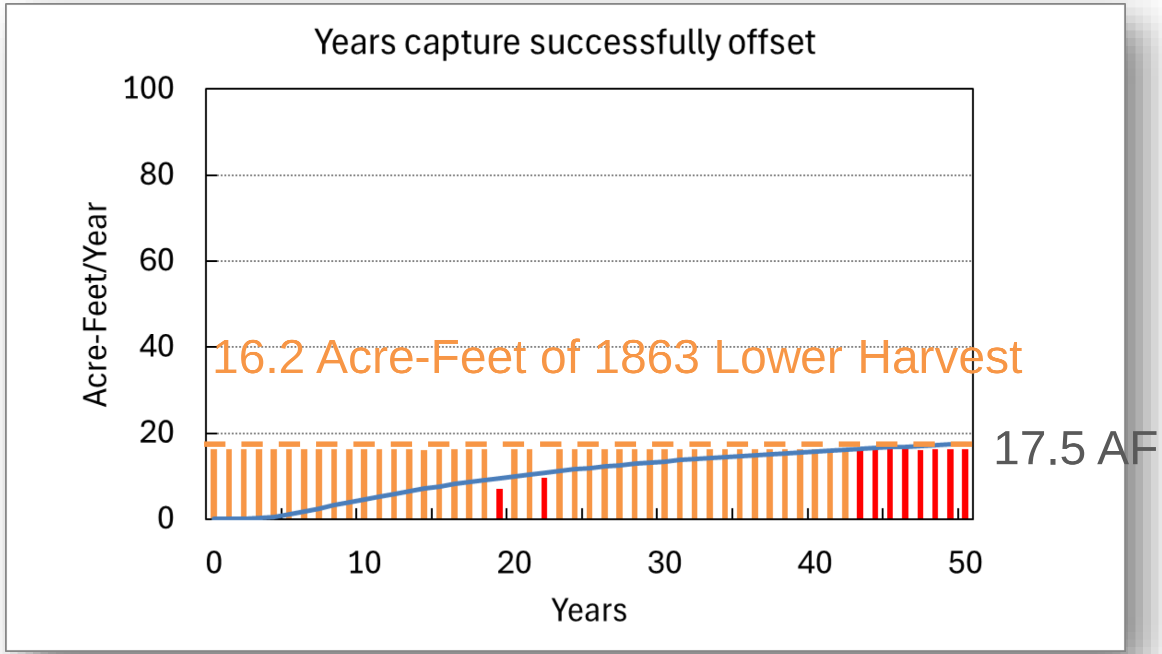
$$WF_{1880LH} = \frac{17.5\ AF}{66.1\ AF} = 26.5\%$$

Decree water Offset – Wetness factor for a very Senior decree

For an 1863 Lower Harvest. A duty of only 16.2 AF is needed:

$$WF_{1863LH} = \frac{17.5\ AF}{16.2\ AF} = 108\%$$





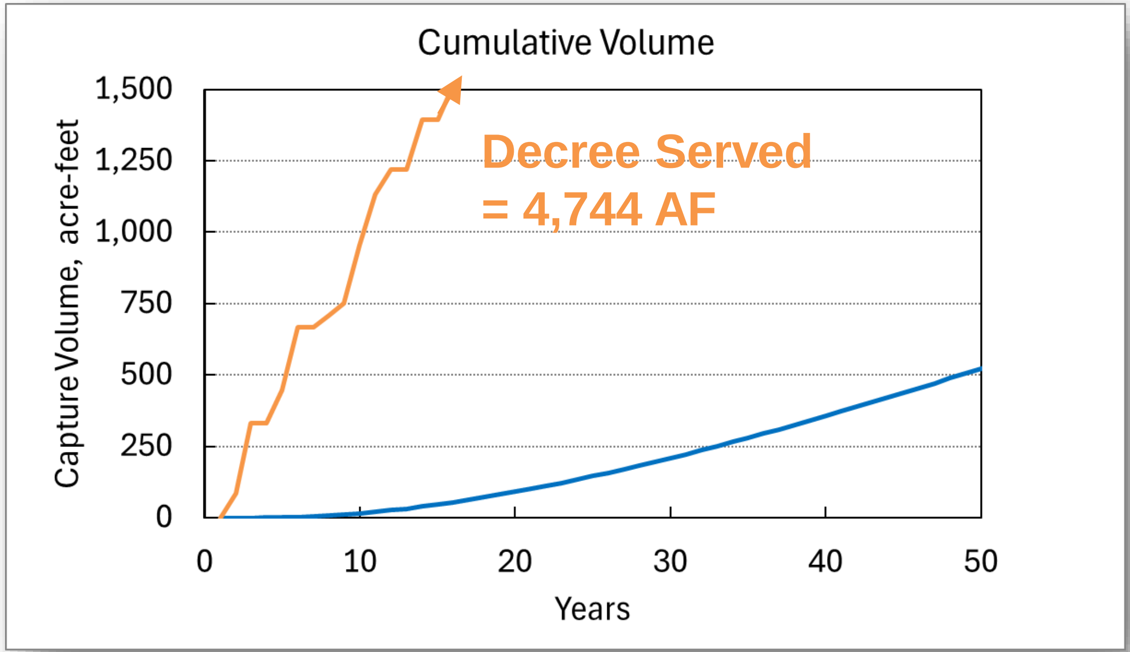
Cumulative Offset volume > Capture Liability ☑

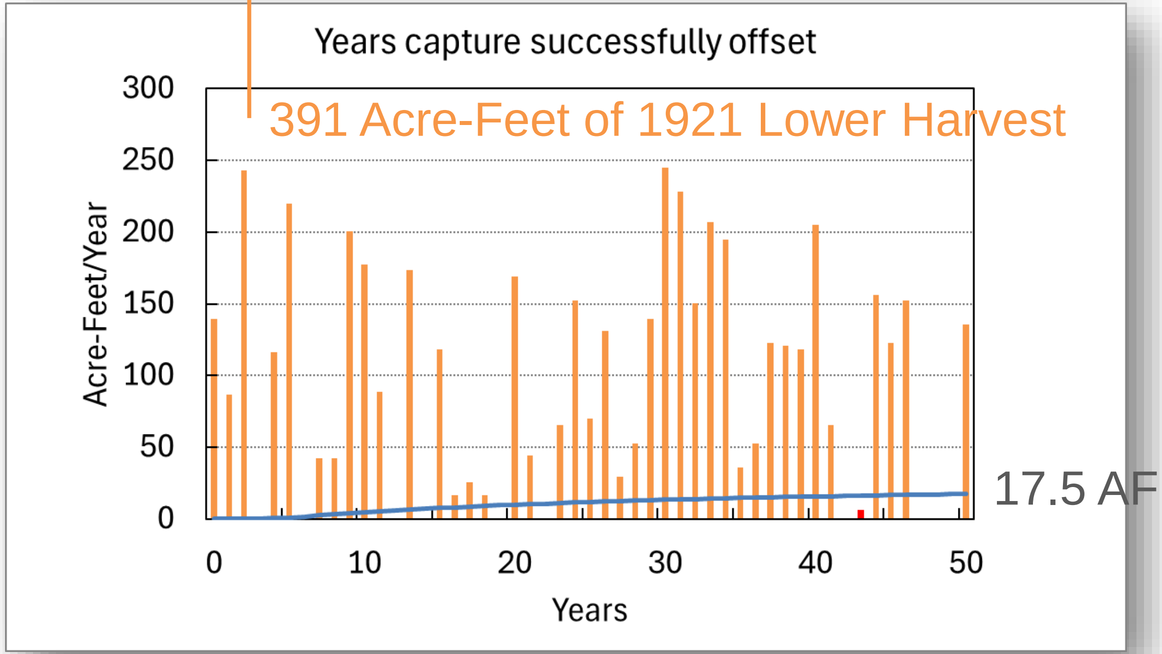
40 of 50 years successfully offset. ☑

Decree water Offset – Wetness factor for a very Junior decree

For a 1921 Lower Harvest. A duty of 391 AF is needed:

$$WF_{1863LH} = \frac{17.5\ AF}{391\ AF} = 4.4\%$$





Cumulative Offset volume >> Capture Liability ☑

40 of 50 years successfully offset. ☑

DECREE WATER AS OFFSET – TWO EXAMPLE PERMITS – 92433 (SHOWN HERE) & 90379

Application No. 92433

APPLICATION FOR PERMISSION TO CHANGE POINT OF DIVERSION, MANNER OF USE AND PLACE OF USE OF THE PUBLIC WATERS OF THE STATE OF NEVADA HERETOFORE APPROPRIATED

THIS SPACE FOR OFFICE USE ONLY

Date of filing in State Engineer's Office FEB 16 2023

Returned to applicant for correction

Corrected application filed Map filed FEB 16 2023

hereby make(s) application for permission to change the

☐ Point of diversion ☑ Place of use ☑ Manner of use ☑ of a portion

of water heretofore appropriated under (Identify existing right by Permit, Certificate, Proof or Claim Nos. If Decreed, give title of Decree and identify right in Decree)

Humboldt River Decree Proof 00446.

1. The source of water is Rabbit Creek
Name of stream, lake, underground, spring or other sources.

2. The amount of water to be changed 0.149 cfs 36.5 afs with a priority date of 1872
Give diversion rate in cubic feet per second (CFS) AND duty in acre-feet annually (AFA)

3. The water to be used for Instream flow to replace captured water by the well under the application for being filed concurrently herewith. 92432
Irrigation, power, mining, commercial, etc. If for stock state number and kind of animals. Must limit to one major use.

4. The water heretofore used for As Decreed
If for stock state number and kind of animals.

5. The water is to be diverted at the following point (Describe as being within a 40-acre subdivision of public survey and by course and distance to a found section corner. If on unsurveyed land, it should be so stated.)
Water to be administered for non-diversion in Rabbit Creek, as Decreed under Humboldt River Decree Proof 00446

☐ Point of diversion ☑ Place of use ☑ Manner of use ☑ of a portion

of water heretofore appropriated under (Identify existing right by Permit, Certificate, Proof or Claim Nos. If Decreed, give title of Decree and identify right in Decree)

Humboldt River Decree Proof 00446.

1. The source of water is Rabbit Creek
Name of stream, lake, underground, spring or other sources.

2. The amount of water to be changed 0.149 cfs 36.5 afs with a priority date of 1872
Give diversion rate in cubic feet per second (CFS) AND duty in acre-feet annually (AFA)

3. The water to be used for Instream flow to replace captured water by the well under the application for being filed concurrently herewith. 92432
Irrigation, power, mining, commercial, etc. If for stock state number and kind of animals. Must limit to one major use.

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5. The water is to be diverted at the following point (Describe as being within a 40-acre subdivision of public survey and by course and distance to a found section corner. If on unsurveyed land, it should be so stated.)
Water to be administered for non-diversion in Rabbit Creek, as Decreed under Humboldt River Decree Proof 00446

MANAGED AQUIFER RECHARGE

Managed Aquifer Recharge (MAR) – What is it?

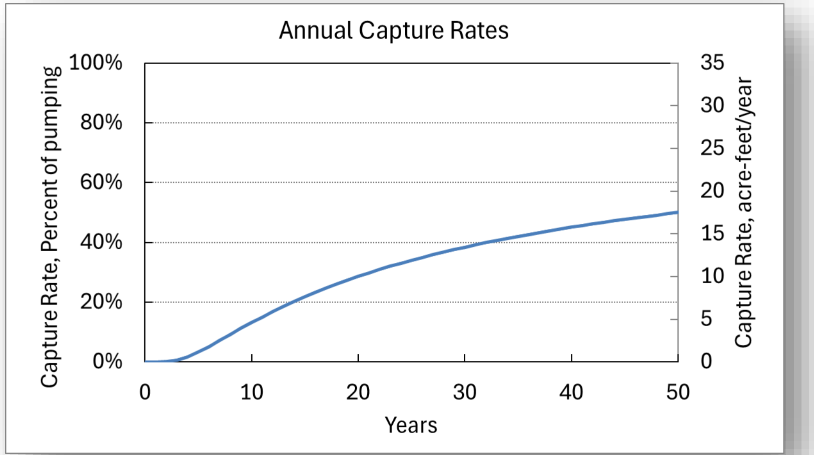
The intentional recharging of aquifers.

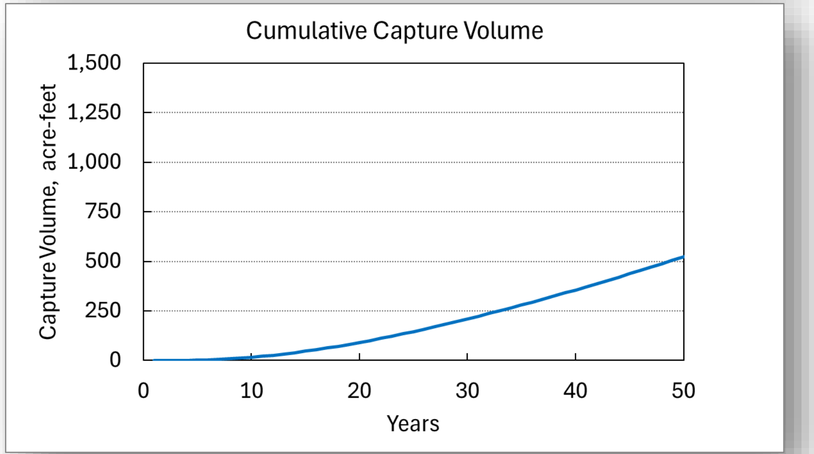
Rapid Infiltration Basins (RIBS)

Direct Injection using Wells

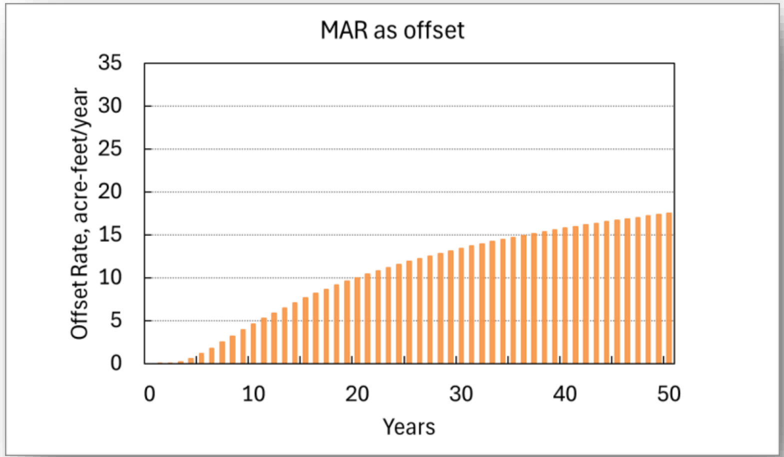
MAR as offset – Works same as capture from a well, but Opposite effect

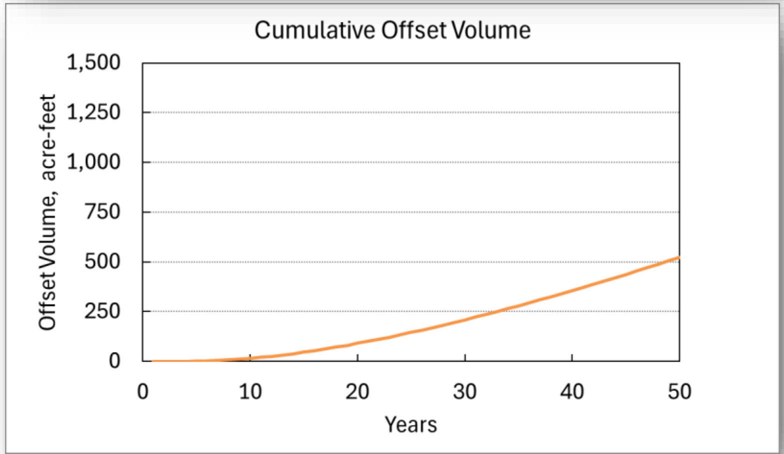
Hypothetical Well from earlier





MAR at same location with same annual duty





A hypothetical RIB with infiltration of 35 AFY.

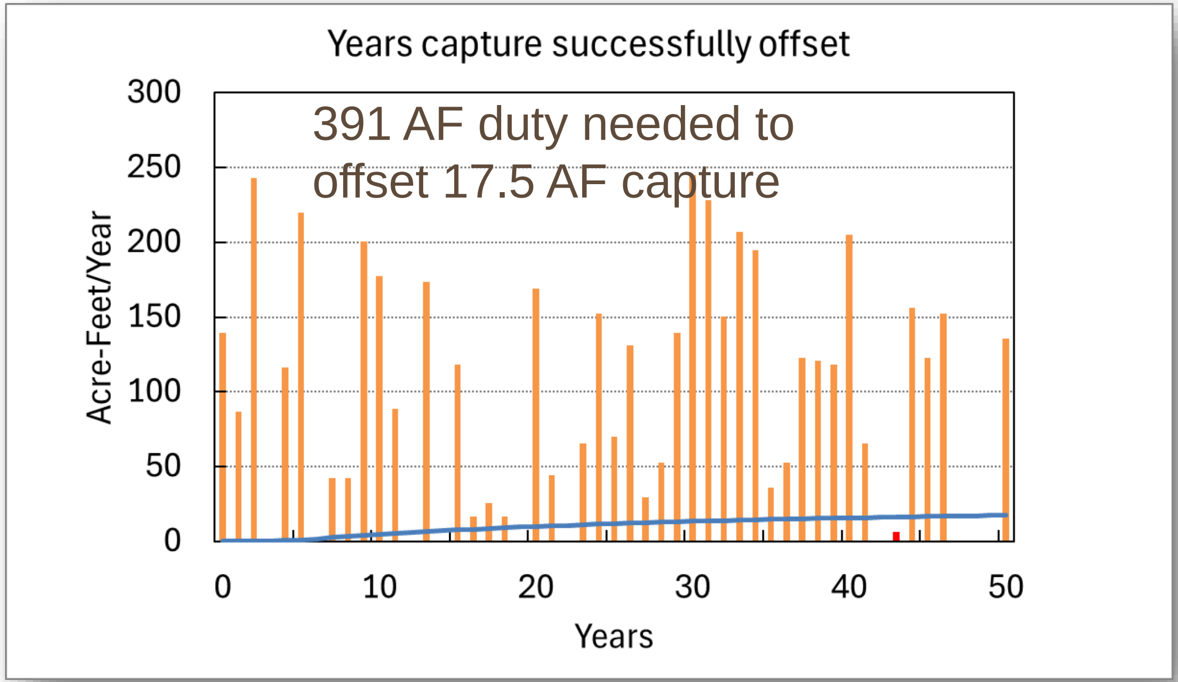
14,000 ft from the river.

T = 1,800 ft^2/d.

Sy of 0.15

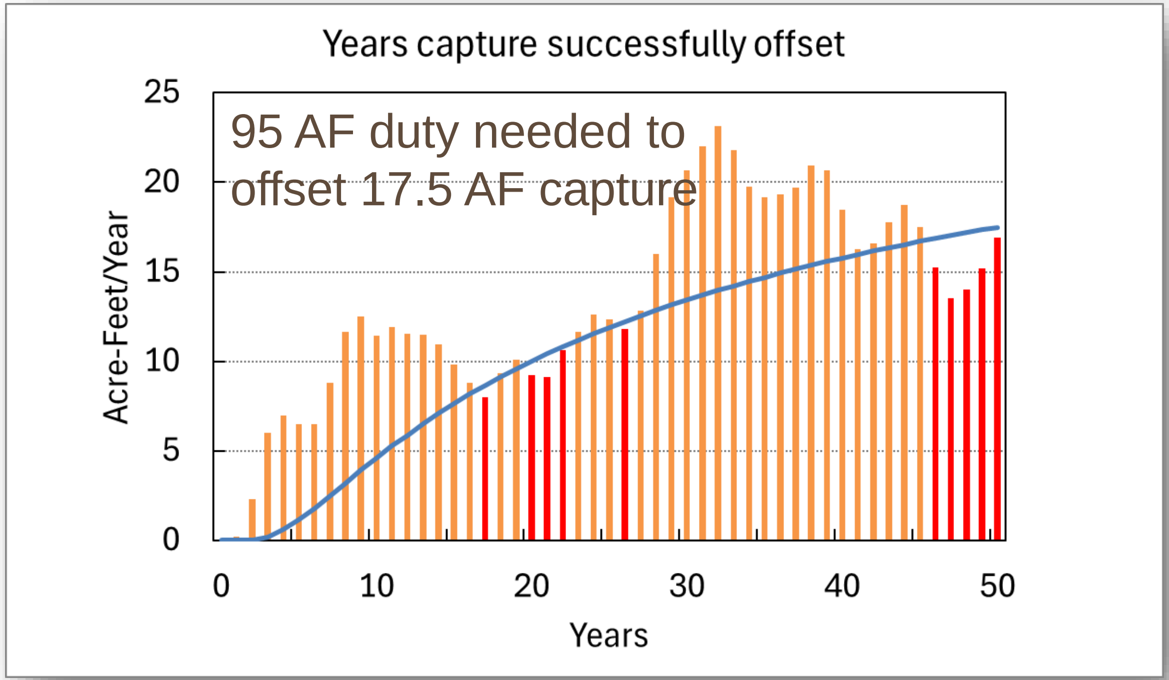
MAR as offset – Use of Junior Decree in MAR – 80% Rule

Recall the 1921 Lower Harvest Decree in-stream offset



Wetness Factor = 4.1%

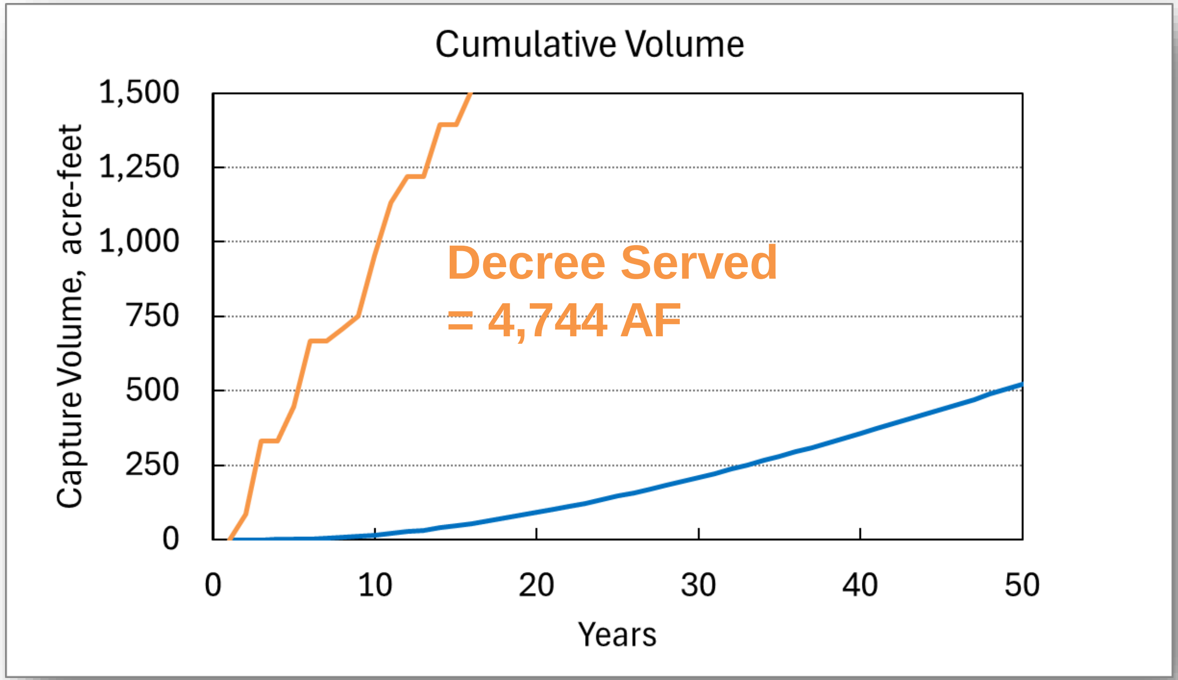
The 1921 Lower Harvest Decree placed into a RIB ~1 mile from the river.



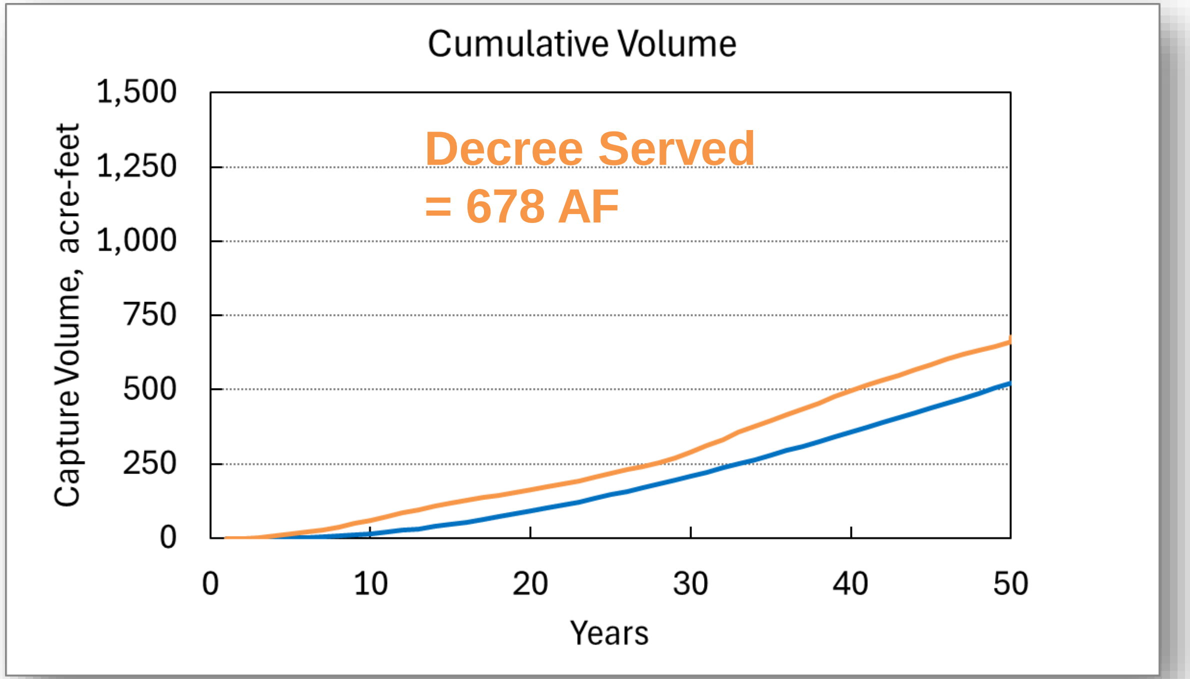
Wetness Factor = 18%

MAR as offset – Use of Junior Decree in MAR – Cumulative

Recall the 1921 Lower Harvest Decree in-stream offset



The 1921 Lower Harvest Decree placed into a RIB ~1 mile from the river.

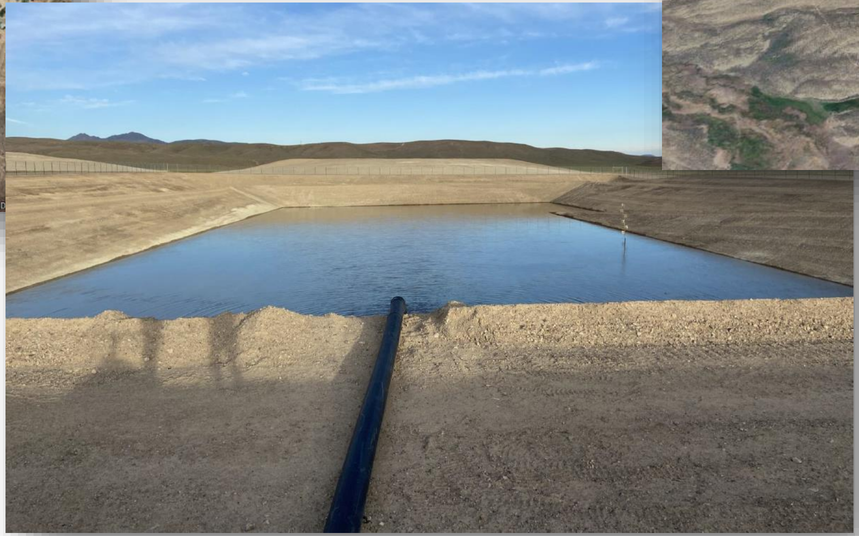


Example is for a RIB at ~1 mile from river; T=1,800 ft^2/d; Sy=0.15

Managed Aquifer Recharge - Examples

Elko wastewater RIBS

Spring Creek Domestic Septic Systems



Mine RIBS

Discussion

Discussion

Are these concepts feasible?

Practical implementation of these concepts?

Potential concerns (financial burden, technical capacity)?

What additional tools and information might be needed?

How would offsets be registered, permitted, tracked?

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Advantages of a Market-based Approach to Conjunctive Management in the Humboldt River Basin, Nevada, USA

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ABSTRACT

In basins with a hydrologic connection between groundwater pumping and stream flow, it can be valuable to jointly, or conjunctively, manage groundwater and surface water. Nevada, like many other states, is currently revising its water management approaches and policies to support the implementation of conjunctive management. Nevada's efforts are focused on the Humboldt River, where groundwater-pumping-induced losses in surface flows have resulted in legal action and where the State is currently leading a stakeholder-involved process to develop a strategy for conjunctive management. This article advocates for a market-based approach to conjunctive management in the Humboldt River Basin. The proposed market-based approach would require groundwater extractors to obtain "offsets" that introduce a volume of water into the river during the irrigation season equivalent to the amount their pumping is estimated to capture. Groundwater pumpers holding offsets could pump their full duty each year without imposing an external cost on downstream surface water right holders through reduced streamflow. We argue that this approach (i) aligns with Nevada water law, including prior appropriations and the Humboldt Decree, (ii) protects the rights of senior surface water users, and (iii) minimizes the negative economic consequences of restricting groundwater extraction in the basin. This article is a commentary paper focused on the potential advantages of a market-based approach and issues related to its implementation in the Humboldt River Basin; further quantitative analysis is necessary to determine the merits of this approach relative to other viable alternatives.

Keywords: groundwater, surface water, conjunctive management, water rights, water markets, offsets

Abbreviations: Capture management zone (CMZ), Nevada Division of Water Resources (NDWR), managed aquifer recharge (MAR), Humboldt River Basin in Nevada (HRB), Desert Research Institute (DRI), U.S. Geological Survey (USGS)

Ayres, Andrew B. and Taylor, Michael H., 2024, Advantages of a Market-based Approach to Conjunctive Management in the Humboldt River Basin, Nevada, USA. Journal of the Nevada Water Resources Association, Winter 2024, p. 4-17. DOI: 10.22542/jnwra/2024/1/1.

INTRODUCTION

In basins with a hydrologic connection between groundwater pumping and stream flow, it can be valuable to jointly manage groundwater and surface water (hereafter *conjunctive management*). The hydrologic connection between groundwater and surface flow arises because when groundwater pumping causes water table elevations to decline it can (i) intercept groundwater that would otherwise be discharged into hydrologically connected streams, lakes, and wetlands and/or (ii) induce water from these surface water features to move downwards thereby replenishing, or recharging, the aquifer. These pumping-induced surface water losses are referred to as “capture” or “stream depletion” (Barlow and Leake, 2012). Despite the rationale for conjunctive management, many states in the United States, including Nevada, are only now revising their water laws and policies to facilitate its implementation (Sullivan et al., 2023). In this article, we argue for the advantages of a market-based approach to conjunctive management in the Humboldt River Basin in Nevada (hereafter HRB), as well as explore the likely challenges involved in implementing such an approach in the HRB. Market-based approaches focus on creating economic incentives to meet water management objectives at the lowest societal cost and have been implemented successfully elsewhere in the United States to address conjunctive management (Ayres, 2021). These advantages of market-based approaches to conjunctive management in the HRB are likely shared by other hydrographic basins with fully appropriated streams and rivers seeking to revise their regulatory frameworks to address conflict introduced by groundwater pumping.

Nevada water law, based on the doctrine of prior appropriations, was established before the hydrological connection between groundwater pumping and streamflow in many basins in the state was recognized. The prior appropriations doctrine grants rights over surface water and groundwater in periods of scarcity in order of priority, where priority order is determined by the date use began (i.e., the principle of “first in time, first in right”). Because surface water was generally utilized first, surface water diverters typically hold senior water rights in Nevada’s basins. This means that the application of prior appropriations to address conjunctive management would, in most instances, involve restricting the groundwater extraction by junior users whose pumping results in streamflow capture to avoid conflict with downstream surface water diverters' senior rights. The downside of this approach, and why we advocate for an alternative, is that the economic costs of curtailing groundwater pumping to limit capture are perceived to be considerably higher than the benefits of eliminating conflict in most basins.

The market-based approach to conjunctive management would require groundwater extractors to obtain “offsets” that introduce a volume of water into the river through the irrigation season equivalent to the volume of water that their pumping is estimated to capture, on average, each year. These offsets could be generated by re-allocating existing surface water rights – known as “decree” rights in the HRB as they were adjudicated in the *Humboldt Decree* (Nevada Division of Water Resources, 2018) – or through various other approaches to streamflow augmentation, as detailed below. Groundwater pumpers that hold offsets would be able to pump their full duty each year without imposing an external cost on downstream surface water right holders from their streamflow capture. We argue that this approach (i) aligns with Nevada water law, including prior appropriations and the *Humboldt Decree*, (ii) safeguards the rights of senior surface water users, and (iii) minimizes the negative economic consequences associated with restricting groundwater extraction in the basin.

We believe this article is timely for two reasons. First, the State of Nevada has recently sought to strengthen its legal authority to manage the impacts of groundwater pumping on surface water rights holders. In January 2024, the Nevada Supreme Court ruled that the State has the authority to conjunctively manage surface waters and groundwater as a connected source (Rothberg, 2024). Second, concurrent with these legal developments, the DWR held a series of workshops starting in 2023 to solicit stakeholder input to develop a strategy to address groundwater capture in the HRB. Building on these workshops, DWR formed a stakeholder working group focused on conjunctive management in the HRB that started meeting quarterly in June 2024.

The remainder of this article is organized as follows. The next section provides background on conjunctive management in the HRB. Thereafter, we describe the advantages of the offset-based approach. How the offset-based approach conforms with the core tenets of the Nevada Division of Water Resources' (NDWR) approach to conjunctive management in the HRB is then explained in the following section. We then turn our focus to several practical considerations for implementing an offset-based scheme in the HRB before describing the successful implementation of a similar market-based offset system in California's Mojave Desert. Finally, we conclude with a discussion of several additional hurdles the offset-based approach in the HRB would contend with and offer some potential fixes for these issues.

CONJUNCTIVE MANAGEMENT IN THE HUMBOLDT RIVER BASIN

In August 2015, the Pershing County Water Conservation District (PCWCD) filed a petition in District Court asserting that groundwater pumping was depleting surface flows in the Humboldt River and conflicting with their senior decree water rights. The petition asserted that senior surface water rights holders in the PCWCD had received less than 50% of their full allotment in 10 of the preceding 20 years while during the same period junior groundwater pumpers in the basin received their full allotment (PCWCD, 2016). The PCWCD petitioned the court to require that NDWR use its statutory authority to eliminate all cones of depression, i.e., areas around wells where the water table has been lowered due to groundwater pumping, that cause interference with Humboldt River surface flows. In October 2020, PCWCD and NDWR reached a settlement agreement. Under the settlement agreement, NDWR agreed to develop a Draft Order that is intended to provide clear procedures and standards for review of new groundwater applications within the Humboldt River region. As of October 2021, the draft order has been issued and made available to the public but a final order has yet to be issued.

If PCWCD's petition had been successful, it would have curtailed groundwater pumping across the Humboldt region where pumping conflicts with Humboldt Decree right holders' access, impacting agricultural irrigators, municipal water providers, and mining operations. Concerned about the economic impact of extensive groundwater curtailment, NDWR proposed an alternative approach where junior groundwater users provide mitigation to senior surface rights holders for reduced surface water availability due to groundwater capture. NDWR's approach, as proposed in 2018 as preliminary draft regulations, set forth a framework for groundwater users to pay financial compensation, based on their streamflow capture, to surface water users for the volume of water they do not receive due to conflict (Nevada Division of Water Resources, 2018). While NDWR is no longer pursuing this approach to mitigation after it failed to gain traction in the 2021 legislative session, limiting disruption to the regional economy and optimizing the beneficial use of limited water resources remains a critical part of NDWR's approach to conjunctive management in the HRB.

To help evaluate the merits of different conjunctive management concepts, NDWR has supported recent published work by the Desert Research Institute (DRI) and the U.S. Geological Survey (USGS) that quantifies streamflow capture in the upper HRB (Carroll et al., 2023) and lower HRB (Nadler et al., 2023).[1] Preliminary results have been circulated for the middle HRB (Sullivan et al., 2023), with final results expected to be published before the end of 2024. These studies find that, region-wide, approximately 400,000 acre-feet of groundwater pumping resulted in 24,600 acre-feet of streamflow capture in 2015 (6% capture rate). The upper Humboldt has the highest capture rate, with 23,600 acre-feet of groundwater pumping resulting in 11,000 acre-feet of capture (47% capture).[2] The middle Humboldt has the largest estimated total capture, at 13,500 acre-feet; however, this capture represents only 4% of the 378,500 acre-feet pumped in the region. Total estimated pumping (1,700 acre-feet) and capture (250 acre-feet) in the lower HRB are comparatively small. These studies forecast that in 100 years, total capture will increase by 1,000 acre-feet in the upper HRB, by 10,000 acre-feet in the middle HRB, and remain roughly constant in the lower HRB.

DRI and USGS's work has two immediate implications for the offset-based approach to conjunctive management in the HRB. First, the estimated 24,600 acre-feet of current streamflow capture, or even 35,600 acre-feet in the 100-year forecast, is less than 10% of total groundwater pumping in the HRB. The low overall capture rate agrees with the proposition that the total cost to the regional economy of addressing hydrologic conflicts is likely to be smaller with an offset-based approach than a curtailment approach. Offsets could allow highly profitable and/or low-conflict wells to remain in operation, while curtailment through priority may see all junior wells in the conflict regions face the possibility of curtailment. Second, given that capture is concentrated in the upper HRB, the reduction in groundwater pumping in an offset-based scheme, which, as is described below, will lead to the greatest increases in the cost of pumping in high-capture wells, is likely to be concentrated in the upper HRB. As such, any economic development policy to mitigate the economic fallout from the reduction in groundwater pumping might productively focus on the upper HRB.

More recently, NDWR has proposed the creation of a Capture Management Zone (CMZ) in which groundwater right holders would be subject to capture management regulations and procedures. The CMZ would be determined by the forecasted impact of conflict for a well over a set period of time which would be based on models developed by DRI and USGS. According to the current plans, within the CMZ, groundwater right holders would be required to mitigate capture

[1] In these studies, the upper HRB is defined between the headwaters and the Carlin Gage, the middle HRB between the Carlin Gage and the Imlay Gage, and the lower HRB between the Imlay Gage and the Humboldt Sink (Carroll et al., 2023).

[2] Carroll et al. (2023) state that uncertainty about their capture estimate for the upper HRB is less than 10% of the total capture volume.

impacts either by providing for an offset, paying an assessment, or facing curtailment. Any offset-based approach would require the delineation of a CMZ that captures important groundwater-surface water interactions.

ADVANTAGES OF A MARKET-BASED APPROACH

There are several advantages to an offset-based approach to conjunctive management. First, groundwater pumpers who are using the water most profitably could opt to obtain offsets and remain in operation. In contrast, owners of less profitable groundwater wells might decide to cease pumping instead of incurring the cost of purchasing offsets. The offset-based approach would thus minimize the economic loss from restricting groundwater pumping in the CMZ. Additionally, the number of offsets required for a well to continue pumping is based on its estimated streamflow capture. Consequently, wells with higher streamflow capture would face higher operational costs compared to those with lower capture in an offset-based system. This higher cost of compliance incentivizes shifting pumping from higher capture wells to lower capture wells, as well as drilling new wells in lower capture locations.

Second, an offset-based approach would enhance the value of surface water rights in two ways. First, it would reduce the number of shortage days during the irrigation season for any given surface water right by preventing losses in water deliveries caused by capture from upstream groundwater pumping. Second, the offset-based approach would boost the demand—and consequently the price—for decree rights used as offsets. The increased price would likely encourage some decree rights holders to sell, which, since these trades would be voluntary, would benefit both the buyers and the sellers.

Third, the offset-based approach would not violate existing Nevada water law. Participation in the offset program would be voluntary for groundwater pumpers in the CMZ. Junior groundwater pumpers who opt not to participate might face curtailment of their pumping rights by NDWR under the prior appropriations doctrine. The only potential revision to Nevada water law that may be required is to make offsetting groundwater capture a legitimate use of surface water rights under existing Decrees.

Fourth, a key advantage of an offset-based approach is that it would create a dynamic economic incentive for individuals and firms to discover cost-effective methods to increase streamflow in the Humboldt, generating marketable offsets. These dynamic incentives would reduce the overall cost of implementing conjunctive management. Additionally, the offset price would provide valuable insights into the profitability of specific streamflow augmentation projects, indicating whether the revenue from offset sales is likely to exceed the costs of development, operation, and maintenance.

Finally, another advantage of the offset-based approach is that the prices for offsets would be determined by voluntary trade in the market. As such, this approach would not require that participants agree on the price of an acre-foot of water. In contrast, NDWR's 2018 proposed approach to conjunctive management based on financial compensation (discussed earlier) would require that groundwater pumpers pay into a compensation fund (likely in proportion to their capture) and surface water diverters would receive compensation for losses in water deliveries due to conflict from groundwater pumping. Such a system would require agreement on a single value for an acre-foot of water based on the economic value of water lost due to conflict to senior surface rights holders.[3]

TENETS FOR CONJUNCTIVE MANAGEMENT IN THE HUMBOLDT RIVER BASIN

In 2023, NDWR hosted a series of events entitled "NDWR Stakeholder Workshops on Conjunctive Management Concepts and Ideas for the Humboldt River Region." At the August 1st, 2023, event, Kip Allander, senior Hydrogeologist for NDWR, outlined the core tenets of NDWR's approach to conjunctive management. This section describes how an offset-based approach, given its advantages outlined in the previous section, would satisfy each of these core tenets.

Tenet 1: "Continue to maximize beneficial use of water resources, both underground and surface water." As explained above, an offset-based approach creates incentives to promote the profitable use of the water in the basin subject to the constraint that all surface water captured by groundwater pumping is offset to restore streamflow.

Tenet 2: "Adhere to the Prior Appropriation Doctrine." As explained above, implementing an offset-based approach would respect the prior appropriations doctrine in that senior surface water rights holders would not have their water deliveries interfered with by junior groundwater users. The only potential change required to Nevada water law is that offsetting groundwater capture would have to be included as a valid use for surface water rights.

Tenet 3: "Prevent increase in conflict from underground water rights moving into the future." All new groundwater wells in the CMZ would be required to purchase offsets equal to their estimated capture. In this way, new wells would not harm senior surface water diverters downstream.

Tenet 4: "Reduce existing conflict from underground water rights." Once all groundwater capture in the CMZ is offset, no senior surface water diverter should have their water rights impacted by groundwater capture.

Tenet 5: "While minimizing harm to the regional economy." An offset-based approach maximizes the profitable use of water in the basin while addressing harm to senior surface water diverters. As such, this approach would minimize the harm to the regional economy from reducing groundwater pumping.

Tenet 6: "Through engagement with stakeholders." For the offset-based approach to be implemented, significant stakeholder engagement would be required to identify and overcome legal, institutional, and social feasibility challenges to implementing an offset-based approach in the Humboldt.

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[3] An alternative approach to mitigation has also been suggested where groundwater users pay into a mitigation fund used to finance on-the-ground projects designed to prevent or offset capture. This approach to mitigation would not require that participants agree on a price per acre-foot of water. Rather, groundwater pumpers would pay into the fund in proportion to their estimated capture, with the level of contributions determined by the costs of mitigation projects.

PRACTICAL CONSIDERATIONS FOR THE IMPLEMENTATION OF A MARKET-BASED OFFSET PROGRAM IN THE HUMBOLDT RIVER BASIN

There are several practical considerations that would need to be addressed before an offset-based approach could be implemented. First, the regulator would have to quantify the capture from each groundwater well in the CMZ in order to implement the offset-based approach. In the HRB, DRI and USGS have developed a capture map illustrating how groundwater pumping impacts on streamflow depend on location and are currently finalizing the "Humboldt Capture Query Tool", which will provide well-specific information on groundwater capture (Sullivan et al., 2023). For this reason, we do not believe that quantifying capture in a scientific and transparent way is likely to be a barrier to implementing the offset-based approach in the HRB. Further, the regulator would have to develop a process through which groundwater pumpers could contest their capture determination proposed by NDWR based on the capture maps developed by DRI and USGS. It is important to note that defining the CMZ and estimated well capture would be an element of almost any approach to addressing conjunctive management in the HRB.

Second, NDWR would have to develop protocols for the creation of offsets. There are several potential methods to generate offsets. These include:

1. Surface water rights – A groundwater pumper could offset their well capture by purchasing surface water rights, or decree rights, to offset the capture from their well. Sullivan et al. (2023) state that using decree rights to generate offsets would require calculating a "wet water factor" associated with each water right, which is the portion of total duty that is available for delivery, on average, for a decree right. The more senior the water right, the higher the wet water factor. The idea is that the duty times the wet water factor (minus anticipated return flows) would determine how much groundwater capture a given decree right could offset.[4] For surface water right-generated offsets to benefit the remaining surface water diverters, NDWR would have to periodically update how it determines which water rights are "in priority" on a given day based on streamflow to account for the reduction in the total number of surface rights in the HRB. This is consistent with the existing method for establishing daily priority between surface water diverters.
2. Managed aquifer recharge – Water banking through managed aquifer recharge (MAR) could be used to offset stream capture from groundwater pumping by supporting longer-duration return flows to the river.[5] One possible source of water for MAR is water from junior decree rights or springtime-only rights (both of which could not be used directly as offsets). Any MAR-based strategy for generating offsets would require detailed hydrologic analysis to ensure that the additional groundwater recharge accomplished through MAR would increase streamflow in the Humboldt by enough and at the right time to compensate for capture due to pumping in the CMZ.

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[4] Only the consumptive use portion of a decreed right should be used to offset groundwater capture. The portion of a decreed right that represents return flows would be available to other surface water diverters in the system if they water right remained in use and, as such, would not represent additional water in the stream to offset capture.

[5] MAR is also referred to as artificial storage and recharge (ASR).

3. Streamflow augmentation – Streamflow augmentation could take place through an out-of-basin surface water transfer, which is likely not feasible in the Humboldt given its geography and, hence, prohibitive conveyance costs, or through pumping groundwater outside the CMZ and then conveying the pumped water so that it augments streamflow. Streamflow augmentation via groundwater pumping from outside the CMZ is currently under consideration in the HRB (Smith and Dixon, 2023).

These approaches to generating offsets have all been discussed by NDWR as potential "conjunctive management concepts" to be evaluated (Sullivan et al., 2023).[6]

Third, the regulator would have to develop institutional structures to administer the offset program, including leveling fees for non-compliance or issuing curtailment orders. All of these activities would increase the regulator's administrative burden and cost of operation. It is left to be determined how these administrative costs compare to alternative approaches to resolving conflict between groundwater pumpers and surface water diverters in the HRB.

Fourth, there's the question of whether employing an offset approach can effectively utilize existing market institutions to manage the purchase of decree rights for offsets. Decentralized water markets in Nevada and other states sometimes rely on water brokers to facilitate sales between willing buyers and sellers. However, these decentralized markets might pose challenges for offset markets because (i) the lack of price transparency could obscure the potential profitability of developing new offsets, reducing the dynamic economic incentives discussed above to lower offset generation costs (see previous section), and (ii) the high transaction costs associated with this method could deter trading, potentially undermining the efficiency advantages of the offset-based approach.

An alternative to the current decentralized market setup would involve the regulator (NDWR), or other third-party entity, establishing a centralized market for offsets. This centralized market would operate annually (or possibly more frequently) and could be structured as a double auction. In this arrangement, sellers would indicate their minimum willingness-to-accept for the offsets they're willing to sell (whether generated from decree rights or another source) while buyers would specify their maximum willingness-to-pay for the volume of offsets they need. Transactions would occur for all offsets where the willingness-to-pay exceeds the willingness-to-accept (plus the transaction costs charged by the market host) at an equilibrium price per acre-foot. This system ensures that all sellers receive a price higher than their willingness-to-accept, and all buyers pay less than their willingness-to-pay, thereby guaranteeing that all participating buyers and sellers benefit from engaging in the offset program. A recently developed market for groundwater in

[6] In addition to the "conjunctive management concepts" of using MAR or decree rights to offset streamflow capture, Sullivan et al. (2023) also state that NDWR is planning on evaluating policies where curtailment is based on a capture threshold for each well, with high capture wells facing curtailment retired, or curtailment based on a distance to stream thresholds (Sullivan et al., 2023). Capture maps developed by DRI and USGS find that groundwater pumping directly adjacent to the river results in the highest rate of streamflow capture. NDWR is also evaluating an approach where pumpers can offset capture by moving or relinquishing other groundwater rights. We are not proposing including these approaches in an offset scheme because they would allow ongoing capture in some wells. As these approaches would not address all capture in the HRB, they would contravene prior appropriations and would require revision to Nevada water law in order to be implemented.

California’s Fox Canyon has developed a similar centralized system to facilitate transactions (Schumacher, 2020).

Fifth, offsets should be designed to reduce the need for NDWR to rigorously scrutinize most transfers of offsets between groundwater pumpers. One approach to accomplish this would be for NDWR to define, for each offset, the reach of the Humboldt where the offset is certain to be replacing captured streamflow. The location would correspond to the point where the mitigation project, whether managed aquifer recharge or streamflow augmentation (see above), is estimated to be capable of replacing captured streamflow. Given that approximately 95% of the river flow is generated in the seasonally snow-dominated mountain ranges surrounding the upper HRB (Plume and Smith, 2013), location is less likely to be relevant for offsets generated by converting decree rights. A given offset could then only be traded to locations in the watershed at or below the approved location. Defining offsets in this way would minimize transaction costs and facilitate trade.

Low transaction costs are an important advantage of an offset-based approach relative to some conjunctive management approaches adopted in other jurisdictions. For example, Colorado's regulatory framework assumes that all extraction of groundwater results in streamflow capture unless proved otherwise (Dixon and Mahannah, 2023). Groundwater pumpers in the state are required to undertake “augmentation,” wherein they replace, primarily through managed aquifer recharge (MAR), the projected streamflow capture associated with their groundwater pumping. Unlike Colorado, Nevada's historical assumption has been that groundwater pumping sources from perennial yield while ignoring potential impacts to streamflow. We do not believe an augmentation-based approach is appropriate for Nevada. Implementing augmentation would require that DWR approve an augmentation plan for every existing groundwater pumper in the CMZ and for every new well, which would be a time-intensive process. The advantage of an offset-based approach would be that once the offset requirements for a well are determined, a groundwater pumper could simply obtain the required volume of offsets from approved sources on the market to continue pumping rather than having to develop and submit an augmentation plan for approval.

Sixth, our approach assumes that offset obligations for each well be set based on average capture over multiple years rather than adjusted each year based on hydrologic conditions. We do not believe an annual offset scheme where the number of offsets required for every groundwater pumper changes every year is possible. Because failure of an offset approach would almost certainly result in material impacts (e.g., loss of water access for a marginal user), an annual offset scheme would require estimates of streamflow capture for each well in the CMZ each year **prior** to the irrigation season. This would require developing a methodology to estimate annual capture at the well level that is seen as credible by both groundwater pumpers required to purchase offsets and surface water diverters who are experiencing conflict, which we believe would be technically challenging. Alternatively, we could have a scheme where mitigation project developers, whether managed aquifer recharge, streamflow augmentation, or another approach (see above), sell annual offsets that are purchased by groundwater pumpers based on estimates of their average annual capture (rather than a projected, year-specific capture estimate). Annual offset sales could be appropriate if certain projects cannot be guaranteed to offset capture in perpetuity (e.g., MAR or streamflow augmentation through groundwater pumping outside of the CMZ both require ongoing funding to generate offsets). Annual offset sales could also provide flexibility to groundwater pumpers in the CMZ who do not wish to pump the same volume of water each year (e.g., due to interannual variation in crop prices, input prices, etc.).

Finally, as discussed above, the studies from DRI and USGS that quantify streamflow capture in the HRB (Carroll et al., 2023; Nadler et al., 2023; Sullivan et al. 2023) find capture is expected to increase in both the upper and middle HRB over the next 100 years. Given this predicted increase in capture, an offset scheme may want to consider either (i) declaring at the outset of the program that offset requirements are likely to be revised upwards in the future as estimated streamflow capture increases or (ii) that offset requirements be based on forecasted capture at each well to avoid having to change the offset requirements over time.

EXAMPLE OF SUCCESSFUL APPLICATION OF MARKET-BASED APPROACHES

An offset program developed in one of the West's driest regions, California's Mojave Desert, illustrates how a similar system for the HRB could deliver benefits. Located just north of the San Bernardino Mountains in southern California, this desert is home to one of the most active groundwater markets in the West. Its development was prompted by open-access conditions that resulted in persistent groundwater overdraft beginning in the first half of the 20th century. This overdraft threatened the long-term viability of cities like Victorville and Barstow, the agricultural livelihoods of rural residents, and other industrial applications, including mining. To address this overdraft, local residents considered various options including pumping taxes and other physical solutions, eventually settling on adoption of a new court-adjudicated system of volumetric property rights to groundwater.

A market for these rights emerged, overseen by the Mojave basin watermaster—a third party responsible for enforcing the adjudication agreement. Pumpers can lease or permanently trade any volume of water at low cost, as physical transfer of the transacted water simply requires pumping from a new well location. Trade of these rights began in the 1994-95 water year, and the resulting market has provided nearly $500 million in aggregate economic gains (Ayres et al., 2021).

While surface water use is not prevalent in the basin, conjunctive management issues have arisen due to the aquifer's relation to the Mojave River and the unique structure of its subsurface hydrogeology. The area with adjudicated groundwater rights in the Mojave spans over 3,400 square miles, but management is split into five separate subareas because some areas are more hydraulically connected than others; one consequence of this is that users are prohibited from trading pumping rights across subarea boundaries to avoid upsetting local aquifer conditions. These subareas, however, still exchange flow with one another, especially in areas following the course of the Mojave River. The adjudication process defined several subsurface (and one surface) flow obligations between subareas. In particular, the flow obligations from the upstream Alto subarea to the downstream Centro subarea are regularly not achieved due to hydrologic and pumping conditions, and an offset system was developed that would require Alto pumpers to make up these impacts in aggregate. The system of adjudicated pumping rights developed in the early 1990s serves as a basis for this offset scheme.

Each year, the Mojave basin watermaster estimates surface and subsurface flows between the subareas and determines whether a collective make-up obligation exists for pumpers in Alto. Alto pumpers have two options to offset reduced flows to Centro: (a) by leasing pumping rights in Centro and retiring them or (b) by paying for expensive imported water from California's State Water Project (SWP), which is connected to the Mojave basin. An individual pumper's make-up obligation is derived from the subarea's aggregate obligation according to their share of total pumping in the subarea that year.

Make-up obligations for Alto pumpers were incurred in 18 years between 1994 and 2018. In other years, flow to Centro was sufficient to avoid any make-up obligation. Purchasing water from Centro pumpers is typically cost-effective; for example, the cost of imported SWP water has exceeded $400 per acre-foot since about 2000, but the cost of an acre-foot of water rarely exceeds $150 in Centro (2019 USD). Very few Alto users opt to purchase imported water. Between 1994 and 2018, the option to lease and retire rights from Centro pumpers saved Alto pumpers approximately $15 million in offset costs (Ayres, 2021). Furthermore, this offset scheme provided an alternative way for Centro pumpers to monetize their rights: in 15 of the 18 years with make-up obligations during this period, Alto pumpers accounted for over 80% of transactions in the Centro lease market.

DISCUSSION OF FUTURE CHALLENGES

Developing policy for conjunctive management in over-appropriated or fully appropriated basins where surface and groundwater have historically been managed independently is not a problem that is unique to the HRB. The case study in Mojave discussed in the previous section demonstrates some desirable properties of market-based solutions to this issue.

This article is focused on the HRB because NDWR, the regulatory body responsible for water management in the state, is currently undertaking a comprehensive, stakeholder-engaged process to develop conjunctive management in the HRB. We hope that this article will contribute to this process. Because the Humboldt River is contained completely within the state of Nevada, NDWR has greater freedom in addressing conjunctive management in the HRB than in other river systems in Nevada where interstate compacts require the involvement of other states and the federal water master to implement policy changes.

There are three additional hurdles that we have not discussed previously that are important considerations for implementing a market-based approach based on offsets in the HRB. First, additional research is needed to establish whether the potential benefits of an offset-based approach relative to other approaches to conjunctive management, such as curtailing groundwater pumping of conflict wells in the CMZ according to prior appropriations, are sufficient to justify the cost of implementation. This analysis would need to predict which groundwater wells would be retired under each alternative approach. The analysis would also predict which surface water rights are likely to be converted to offsets. The economic consequences of these alternative scenarios for water rights retirement and conversion of surface rights to offsets for the Humboldt River region would then be evaluated. This analysis is crucial to determining the desirability of the market-based approach to conjunctive management advocated here. An important advantage of implementing an offset-based approach to conjunctive management in the HRB is that NDWR has already begun investing in modeling tools to evaluate different approaches to conjunctive management (Sullivan et al., 2023).

Second, another issue for any policy to address conjunctive management is how to address ongoing capture due to the legacy impacts of aquifer depletion throughout HRB. Recent research has shown that even with substantial reductions of pumping in the CMZ, it would take decades for the aquifers to recover and for surface flows in the Humboldt River to approach historical pre-pumping conditions (Allander, 2021). If the offset-based approach is set up using current aquifer levels as the baseline, then it would only address future streamflow capture by groundwater pumping and not these legacy impacts. We are not aware of a feasible way to address the legacy impacts of historical pumping through an offset-based program in order to restore pre-pumping streamflow conditions in the HRB. In particular, we struggle to develop an approach to assigning responsibility for offsetting legacy capture to current groundwater pumpers that is both workable and equitable. We contend it is the case, however, that the alternative solutions to conjunctive management would also have difficulty addressing residual conflict due to the legacy impacts of capture due to historic groundwater pumping.

Concerning legacy impacts, a similar problem arose in the Mojave example described in the previous section. In particular, the court was asked to adjudicate and quantify the junior pumping rights of parties in the Mojave, who, under California groundwater law, had no right to surplus water beyond safe yield and yet had pumped consistently during periods of overdraft prior to adjudication. It was conceivable that their claims could have been extinguished by the persistent state of overdraft. However, the court accepted a stipulated agreement that these pumpers with lesser claims nonetheless be allocated pumping shares in order to achieve an "equitable apportionment" of water—and to avoid further potential litigation over whether these juniors had established a "prescriptive" right to pump by doing so openly and notoriously for a substantial period of time without protest from the other pumpers in the basin with priority claims. In other words, the stipulated agreement established that legacy impacts on resource conditions were not deemed to require compensatory action; moreover, the prior pumping of these juniors was used as a basis to calculate their claims under the adjudication, similar to other pumpers.

Finally, an important consideration is that while the offset-based approach should help to ensure that scarce water in the HRB is put to its highest-valued use, it does not directly address what are known as "pecuniary" externalities that might affect communities in the HRB that are dependent on irrigation. These externalities arise because when farmers decide to sell their water rights in these communities, intermediate input suppliers (e.g., suppliers of farming equipment, fertilizer and feed, etc.) could leave the region and the local labor market could shrink, making it more difficult for farmers to manage their workforce. Further, reductions in agricultural production could impact local business through reductions in population and income, and the reduction in the tax base could erode the quality of local schools and other public goods (libraries, parks, etc.). While the offset-based plan does not consider these pecuniary externalities, it is worth noting that any plan to address conjunctive management, including curtailment by prior appropriations, will reduce irrigated agriculture in the HRB and result in pecuniary externalities. Additionally, previous empirical work has shown that these pecuniary externalities are generally small for reductions in water up to a quarter of a region's water supply (Howitt 1994). Further, it may be possible for economic development policy to mitigate the negative economic impacts of reduced groundwater pumping which, as noted above, are most likely to be concentrated in the upper Humboldt. Some water trades in Arizona are subject to a tax dedicated to supporting negatively impacted communities (Chong and Sunding, 2006), and large, long-distance transfers in California have sometimes also included community-support payments (Ayres & Bigelow, 2022; Libecap, 2022).

REFERENCES CITED

Allander, Kip. (2021). Preliminary results of the Humboldt River Capture Study. Nevada Water Resources Association Annual Meeting. (January 25, 2021)

Ayres, A. (2021). Improving California's Water Market: Technical Appendix C: Mojave Groundwater Market Assessment. Public Policy Institute of California. https://www.ppic.org/wp-content/uploads/0921aar-appendix-c.pdf

Ayres, A., & Bigelow, D. P. (2022). Engaging Irrigation Districts in Water Markets. In E. Edwards & S. Regan (Eds.), The Future of Water Markets. Property and Environment Research Center. https://www.perc.org/wp-content/uploads/2022/09/PPR-Water-Markets-220916-WEB.pdf#page=55

Ayres, A., Meng, K. C., & Plantinga, A. J. (2021). Do Environmental Markets Improve on Open Access? Evidence from California Groundwater Rights. Journal of Political Economy, 129(10), 2817–2860. https://doi.org/10.1086/715075

Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion by wells—Understanding and managing the effects of groundwater pumping on streamflow: U.S. Geological Survey Circular 1376, 84 p. (Also available at https://pubs.usgs.gov/circ/1376/.)

Carroll, R.W.H., Pohll, G., and Pham, H., 2023, Evaluation of Stream Capture Related to Groundwater Pumping, Upper Humboldt River Basin, Nevada: Desert Research Institute Publication No. 41299, and Nevada Division of Water Resources Bulletin 49, 89 p. and 3 appendices.

Chong, H., & Sunding, D. (2006). Water Markets and Trading. Annual Review of Environment and Resources, 31(1), 239–64.

Division of Water Resources (2018). Proposed Regulation of the Division of Water Resources LCB File No. R027-18I. Initial draft regulation proposed to the Legislative Counsel Bureau on 5 February 2018. Link: https://www.leg.state.nv.us/Register/2018Register/R027-18I.pdf (Accessed 15 May 2024)

Dixon, J, and Mahannah, C. Colorado Style Augmentation & Implications of Perennial Yield Based Curtailments in Nevada. Presented at the NDWR Stakeholder Workshops on Conjunctive Management Concepts and Ideas for the Humboldt River Region. September 6, 2023. Carson City, Nevada and Virtual.

Howitt, Richard E. "Empirical analysis of water market institutions: The 1991 California water market." Resource and energy economics 16.4 (1994): 357-371.

Libecap, G. (2022). High and Dry. In E. Edwards & S. Regan (Eds.), The Future of Water Markets. Property and Environment Research Center. https://perc.org/2022/09/29/high-and-dry/

Nadler, C.A., Rybarski, S.C., and Pham, H., 2023, Evaluation of stream capture related to groundwater pumping, Lower Humboldt River Basin, Nevada: U.S. Geological Survey Scientific Investigations Report 2023–5110, and Nevada Division of Water Resources Bulletin 50, 77 p., https://doi.org/10.3133/sir20235110.

Rothberg, Daniel. (2024). “Nevada Supreme Court issues major water ruling.” Western Water Notes. Link: https://www.westernwaternotes.com/p/nevada-supreme-court-issues-major (Accessed 1 November 2024)

Schumacher, Havala. The Fox Canyon Water Market: A Market-Based Tool for Groundwater Conservation Goes Live. 2020. https://www.usda.gov/media/blog/2020/05/08/fox-canyon-water-market-market-based-tool-groundwater-conservation-goes-live (Accessed 05/28/2024).

Smith, D., and Dixon, J. Groundwater pumping from distant locations for flow augmentation the Humboldt River. Presented at the NDWR Stakeholder Workshops on Conjunctive Management Concepts and Ideas for the Humboldt River Region. September 26, 2023. Carson City, Nevada and Virtual.

Sullivan, A., Kryder, L., Benedict, J., and Allander, K. Humboldt River Region Water Management Informational Update. Presented March 28th, 2023. Carson City Nevada and Virtual.

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Trends in flow of the Humboldt River, North-Central Nevada, 1945 to 2020

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ABSTRACT

The Humboldt River flows from its headwater areas east of Elko to the Humboldt Sink southwest of Lovelock. Water in the river is used primarily for irrigation of crops and the river has been fully appropriated and adjudicated since the 1930's. Groundwater pumping for irrigation began increasing in the 1960's. Dewatering of mines began in the early 1990's. Pumping of groundwater has raised concerns over its effects on flow in the river, particularly during periods of drought. Five continuously operated gaging stations on the Humboldt River were used to evaluate if groundwater pumping since the 1960's could be causing a decrease in flow.

Various analysis using annual, monthly, and daily flows at Humboldt River gaging stations indicate flow between the Comus and Imlay gaging stations showed an increase in loss that exceeded estimated measurement errors. The mean difference in flow between gaging stations during two droughts—water years (WYs) 1953 to 1955 and 2012 to 2015 also indicate increased loss between the two gaging stations. Daily mean flows at the gaging stations show little difference between October 1945 to September 1969 and January 2007 to September 2020 except for the Imlay gaging station where the daily mean flow for the latter period was less 90 percent of the time than the earlier period. The lack of a change in flow at the Comus gaging station is consistent with the number of days when daily mean flow at the gaging station was less than 1 cubic foot per second (cfs) for two 13-year periods with nearly the same mean flow (1,297 days during WYs 1951 to 1964 and 1,291 days during WYs 2007 to 2020). However, the number of days when the daily mean flow at the Imlay gaging station was less than 1 cfs increased from 64 days during the earlier period to 941 days during the later period. In conclusion, flow at gaging stations upstream of Comus indicates no measurable decrease that could be attributed to groundwater pumping, whereas a measurable decrease in flow at the Imlay gaging station is best explained by groundwater pumping near the river downstream of Comus.

Prudic, David E. 2024, Trends in flow of the Humboldt River, North-Central Nevada, 1945 to 2020. Journal of the Nevada Water Resources Association, Winter 2024, p. 43-64. DOI: 10.22542/jnwra/2024/1/3.

INTRODUCTION

The Humboldt River Basin encompasses an area of about 17,000 square miles (mi^2) in north-central Nevada. It lies wholly within Fremont's Great Basin—a region in the arid west that drains internally and has no outlet to the oceans (Grayson, 1993). The Great Basin itself lies within the larger Basin and Range Physiographic Province (Fenneman and Johnson, 1946), which is characterized by a series of generally north trending mountain ranges 5 to 15 miles (mi) in width and 40 to 80 mi long separated by valleys of similar dimensions. The ranges are commonly 1,000 to 5,000 feet (ft) higher than the neighboring valleys (Harrill and Prudic, 1998).
The Basin and Range Province formed because of extensive faulting that raised the numerous mountain ranges relative to the neighboring valleys. The mountain ranges generally consist of rocks that are older than 20 million years (Stewart, 1980). The rocks include all types ranging from igneous (granite and volcanic) to sedimentary (limestone and sandstone). Some of the sedimentary rocks have been altered to marble and quartzite through metamorphism.

The Humboldt River begins at a spring near the northern end of the East Humboldt Range (Horton, 2000). The river's course is generally across the fabric of the Basin and Range topography but overall, the course is from east of Elko to southwest of Lovelock where it empties in the Humboldt Sink (**Figure 1**). During years of exceptional precipitation and flow, the Humboldt River fills the sink, which then overflows into the Carson Plain to the southeast of the sink. Eventually, the overflow can reach the Carson Sink north of Fallon during years of exceptional runoff.

Water diversions from the Humboldt River for agricultural irrigation began as early as the 1860's. Because of increased water diversions that diminished flow further downstream, surface-water rights were adjudicated in the 1930's (Mashburn and Mathews, 1943). During this period, agriculture sustained by surface-water diversions was the dominant economy. Groundwater was little used in the numerous valleys within the Humboldt River Basin prior to the 1950's (Prudic et al., 2006). Groundwater pumping for irrigation increased rapidly during the 1960's to early 1980's, primarily in tributary valleys and resulted in a greatly expanded area of agricultural productivity. Since the late 1980's, mining for gold primarily in Elko, Eureka, and Humboldt Counties has resulted in mining becoming the principal economy (Nevada Division of Water Planning, 2019).

Pumping of groundwater in the Humboldt River Basin has raised concerns over its effects on flow and surface-water rights, particularly during periods of drought. Most of the early groundwater pumping was used to augment stream diversions during dry periods. Pumping for irrigation in areas not supplied by surface water diversions increased rapidly beginning in the 1960's (Prudic et al., 2006). Many large capacity wells were drilled into a productive sand and gravel aquifer near Winnemucca between the 1960's and 1980's. The aquifer connects directly to the Humboldt River and extends into southern Paradise and northern Grass valleys (Cohen, 1966). Irrigation wells upstream of the Comus gaging station are concentrated in tributary valleys distant from the Humboldt River (Prudic et al., 2006). Mine dewatering is mostly in consolidated rocks near the edges of tributary valleys (except Lone Tree Mine) between Carlin and Comus gaging stations (**Figure 1**). Net mine dewatering (total pumping less water returned to rapid infiltration basins) was 52,500 acre-feet in 2015 (Nevada Department of Conservation and Natural Resources, 2017). This is less than 15 percent of the total pumping in the basin whereas, net irrigation pumping was more than 75 percent of the to the total and domestic and municipal pumping was about 6 percent.

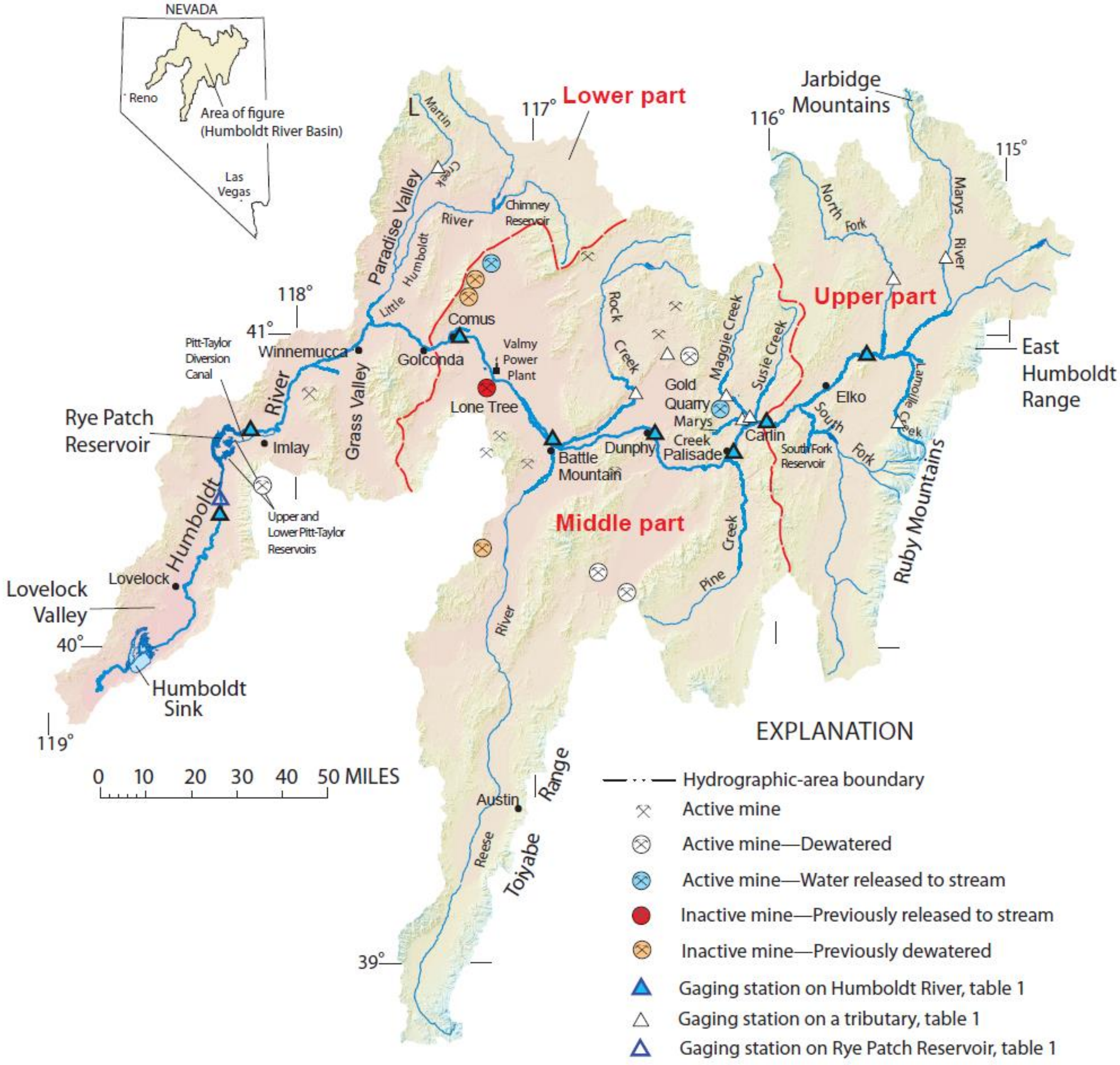

Figure 1—Humboldt River Basin in north-central Nevada showing locations of active and inactive mining operations, major towns and tributary streams.

Flows on the Humboldt River have been continuously monitored at six gaging stations by the U.S. Geological Survey since October 1, 1945. The uppermost gaging station is east of Elko and the lowest is just downstream of Rye Patch Dam. The gaging station at Palisade has a continuous record beginning October 1, 1911 and the gaging station downstream of Rye Patch Dam has a continuous record beginning October 1, 1935. Two additional current gaging stations, one near Dunphy and the other at Battle Mountain, have incomplete records. The continuously operated gaging stations upstream of Rye Patch Reservoir plus the Battle Mountain gaging station were used to evaluate (1) the relation of flow to climate and (2) if groundwater pumping could be causing a decrease in flow at the gaging stations. This paper analyzes trends in Humboldt River flow during the period from October 1, 1945 to September 30, 2020.

Inflow to the Humboldt River is primarily from tributary streams that gather snowmelt runoff in the higher mountains, particularly in mountains upstream of the Palisade gaging station. Much smaller fractions enter the river through (1) direct precipitation on the river, (2) direct runoff from nearby areas, (3) irrigation return flows and pipelines that discharge water directly to the river, and (4) groundwater inflow. Groundwater inflow along the river is limited to small reaches of the river where the geology restricts continued groundwater flow parallel to the river or water that was added to groundwater next to the river during flooding or high flow and later returned back to the river during periods of lower flows (known as bank storage; Cohen, 1966).

Natural outflows (losses) along the Humboldt River include evaporation directly from the river and flow to adjacent groundwater. Evaporation losses directly from the river typically are small but groundwater losses along the Humboldt River were large prior to agricultural diversions because native plants on the floodplain of the river typically caused the water table in the ground to be lower near the river than the water level in the river (Eakin and Lamke, 1966).

The diversion of water from the Humboldt River in the mid- to late-1800's resulted in another loss of flow. The diverted water was and is used to irrigate crops on the floodplain of the river and several of its tributaries. The act of diverting water from the river and its tributaries increased evapotranspiration on the floodplain and reduced downstream flow. However, not all the diverted water is lost to evapotranspiration, some returns back to the river as surface runoff at the end of the fields and some recharges local groundwater that eventually returns to the river during periods of low river flows (Cohen, 1966).

All of the different inflows and outflows from the river vary from year to year and season to season. These variations complicate the actual cause of changes in flow because many of the additional inflows and outflows between gaging stations on the Humboldt River are unknown. Ideally, reliable measurements of all inflows and outflows along the river between gaging stations would provide for a better assessment of effects from groundwater pumping on flows.

METHODS

Daily, monthly, and annual flow data were obtained from the U.S. Geological Survey NWIS database (https://maps.waterdata.usgs.gov/mapper/index.html) for currently active gaging stations on the Humboldt River and selected tributaries. The gaging stations used in the analysis of trends in flow are listed in **Table 1**. Flow at each gaging station has an associated qualitative measurement error. The Elko and Imlay gaging stations are rated "good" by the U.S. Geological Survey (estimated error of ±5 percent), whereas the other stations are rated as "fair" (estimated error of ±8 percent). These errors assume the individual measurements used to determine flows at gaging stations are unbiased (Turnipseed and Sauer, 2010, p. 96).

Table 1. Active U.S. Geological Survey gaging stations on the Humboldt River and selected tributary streams. [Gaging stations active through September 30, 2020. Locations of gaging stations are shown in **Figure 1**. Data for each gaging station can be obtained from http://waterdata.usgs.gov/nv/nwis/. Highlighted gaging stations on the Humboldt River and selected tributaries are the main gaging stations used to analyze trends]

Station Number	**Station Name**	**Drainage area (square miles)**	**Annual flow for period of record (acre-feet)**	**Annual unit flow (acre-feet per square mile)**	**Period of Record (water years)[1]**
10315500	Marys River above Hot Springs Creek near Deeth	415.	44,911	108.2	1944 to 1980, 1981 to 2020
10316500	Lamoille Creek near Lamoille	24.9	32,273	1,296.1	1916 to 1922, 1944 to 2020
10317500	North Fork Humboldt River at Devils Gate near Halleck	830	52,147	62.8	1914 to 1921, 1945 to 1982, 2004 to 2020
10318500	Humboldt River near Elko	2,779	176,180	63.4	1896 to 1902, 1945 to 2020
10319900	South Fork Humboldt River above Tenmile Creek near Elko	898	85,994	95.8	1989 to 2020
10320100	South Fork Humboldt River above Dixie Creek near Elko	1,150	83,590	93.1	1946 to 1982 1988 to 2020
10321000	Humboldt River near Carlin	4,310	263,050	61.0	1944 to 2020
10321590	Susie Creek at Carlin	194	6,324	32.6	1992 to 2020
10321950	Maggie Creek at Maggie Creek Canyon near Carlin	334	15,062	45.1	1990 to 2020
10321950	Maggie Creek at Carlin	396	25,231	63.7	1914 to 1924, 1993 to 2020
10322150	Marys Creek at Carlin	45.4	4,057	89.4	1990 to 2020
10322500	Humboldt River at Palisade	5,053	286,620	56.7	1903 to 1906, 1912 to 2020
10323425	Humboldt River at Old U.S. 40 Bridge, at Dunphy	7,470	279,390	37.4	1992 to 2020
10324700	Boulder Creek near Dunphy[2]	76.7	3,454	45.0	1992 to 2020
10324700	Rock Creek near Battle Mountain	863.8	28,844	33.4	1937 to 2020
10325000	Humboldt River at Battle Mountain[3]	11,200	267,650	23.9	1897, 1922 to 1924, 1946 to 1981, 1992 to 2020
10327500	Humboldt River at Comus	12,220	241,420	19.8	1895 to 1926, 1946 to 2020
10329500	Martin Creek near Paradise Valley	175	24,802	141.7	1922 to 2020
10333000	Humboldt River near Imlay	15,500	194,300	12.5	1936 to 1941, 1946 to 2020
10334500	Rye Patch Reservoir near Rye Patch	16,100	----		1937 to 2020
10335000	Humboldt River near Rye Patch	16,100	174,280	10.8	1897 to 1931, 1936 to 2020

[1] Water year (WY) begins October 1 of previous year and ends September 30 of the designated year.
[2] Boulder Creek gaging station is monitored from January 1 to June 30 each year from 1994 to 2020 and may miss short duration flows following intense rain storms between July and December.
[3] The drainage area now includes the Reese River Valley; drainage area prior to 1991 did not include Reese River (U.S. Geological Survey, 1960, p. 199). The drainage area was previously 8,860 square miles.

The first technique used double-mass curves (Searcy and Hardison, 1960). This technique compares cumulative annual flow at gaging stations on the Humboldt River to cumulative annual precipitation (see **Supplement**) and to cumulative averaged flow at two tributary gaging stations (Lamoille and Martin creeks).

The second technique compared net difference (gain or loss) between two gaging stations on the Humboldt River. Net is used because there are unknown gains and losses that can occur along the river between gaging stations. Error bars related to the net difference in flows between gaging stations are based on the error associated with the measurement of flow at each gaging station. The errors at each gaging station are added when two or more gaging stations are added or subtracted (Winter, 1981). The error bars were used to determine if differences in net increases and decreases between the two droughts exceeded the range in error between net increases or decreases in flow. The net increase or decrease in annual flow between gaging stations was divided into four periods: WYs 1946 to 1969 represent a time of little groundwater pumping; WYs 1970 to 1991 represent a time when groundwater pumping was increasing from agricultural irrigation; WYs 1992 to 2006 represent a time when mine dewatering peaked with water from several mines being discharged to the Humboldt River or one of its tributaries; and WYs 2007 to 2020 represent a period following when Lone Tree Mine stopped discharging water to the Humboldt River.

The third technique compared daily mean flows for gaging stations on the Humboldt River using flow-duration curves (Searcy, 1959). Two periods were compared at each gaging station: October 1946 to September 1969 and January 2007 to September 2020. Flow duration is used to determine the percentage of time that flow equaled or exceeded a particular value. Daily mean flow at a gaging station is first ranked from highest to lowest and then the probability for a particular daily mean flow is determined. Results from such data are then displayed on a log-probability graph.

The fourth and last technique determined the cumulative number of days at the Humboldt River gaging stations since WY 1946 when daily mean flow at a gaging station was less than 1 cubic feet per second (cfs). The analysis then compared the number of days when flow was less than 1 cfs for two periods that had nearly the same mean flow at the Carlin gaging station; WYs 1951 to 1964 and WYs 2007 to 2020. Daily mean flow at Palisade had no days of flow less than 1 cfs.

RELATION BETWEEN HUMBOLDT RIVER FLOWS TO AVERAGED TRIBUTARY FLOW

Flow at a gaging station is an integration of all inflows and outflows in the drainage basin upstream of the station. These sources and losses include natural processes such as precipitation, tributary inflows and evapotranspiration that vary with time and place within the drainage area upstream of a gaging station as well as processes caused by man’s activities such as diversion of flow for irrigation and capture of flow by groundwater pumping. The gaging station on Lamoille Creek that drains the north end of the Ruby Mountains has the highest flow per unit area (**Table 1**). When converted into inches (in.), the average flow per unit area is about 24 in./year(yr) and is about twice the average annual precipitation in northeastern Nevada (see **Supplement**). Mean annual flow at Lamoille Creek was estimated to be about 70 percent of the mean annual precipitation in the drainage area upstream of the gaging station (Prudic et al., 2006). This suggests that mean annual precipitation is 34 in. indicating losses in upstream of the Lamoille Creek gaging station are less than losses in drainage areas upstream of gaging stations on the Humboldt River and its other gaged tributaries (**Table 1**).

Cumulative flow per unit area to cumulative averaged annual flow per unit area of Lamoille and Martin creeks have the same pattern as the comparison of cumulative flow to precipitation (see **Supplement)** except it is less variable (**Figure 2**). The reason is that much of the additional flow during wet years (particularly 1983 and 1984) also was measured at gaging stations on the tributary streams.

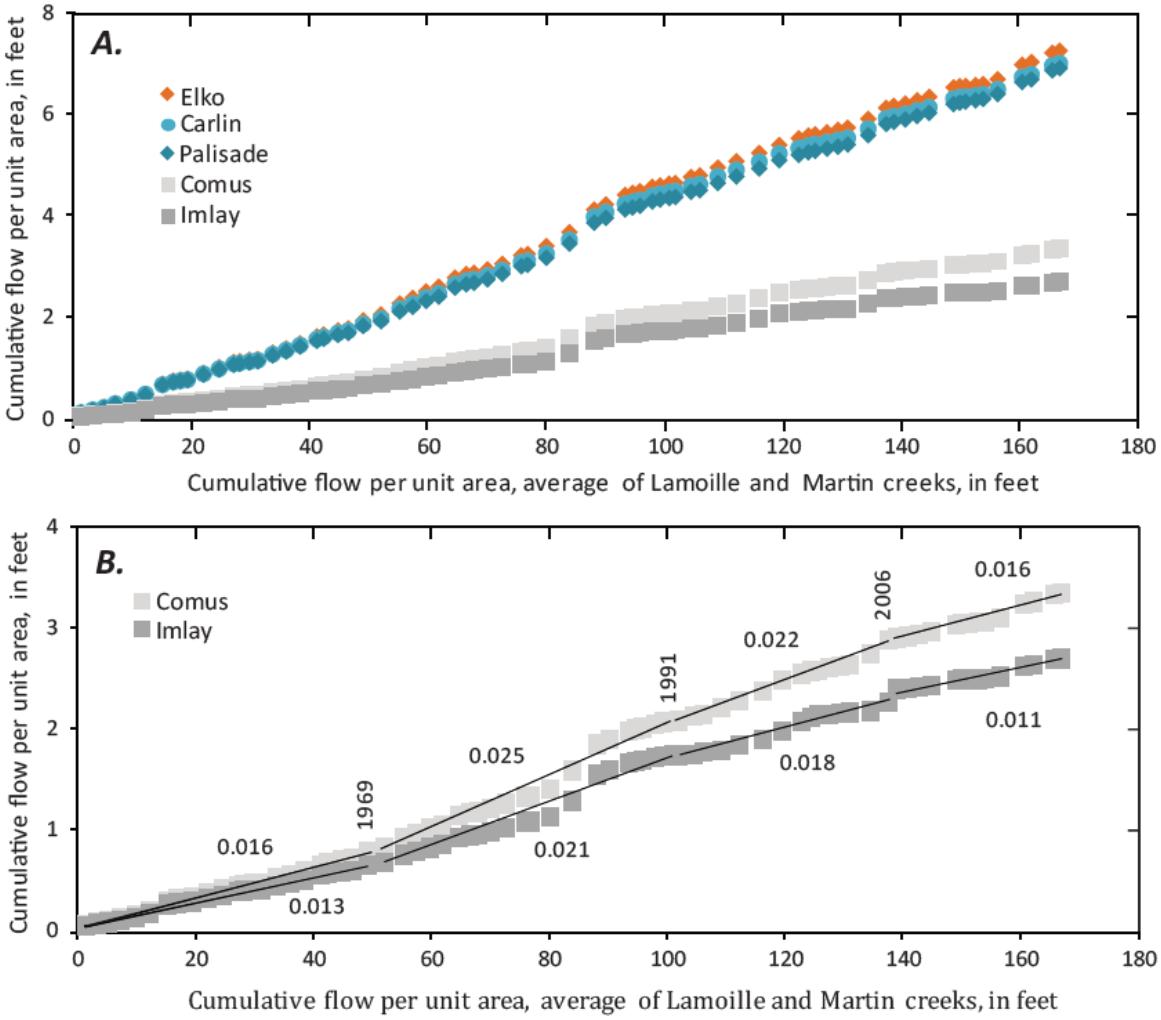

Figure 2—Cumulative annual flow to averaged flow per unit area of Lamoille and Martin creeks for WYs 1946 to 2020 (***A***) at gaging stations on the Humboldt River and (***B***) at Comus and Imlay with ratios of flow to averaged tributary flows for four periods—WYs 1946 to 1969, 1970 to 1991, 1992 to 2006, and 2007 to 2020.

Ratios of flow to averaged tributary flows indicate that much of the tributary flow is lost prior to reaching any of the gaging stations on the Humboldt River. The marked decrease in the ratio of flow to tributary flow between Palisade and Comus and between Comus and Imlay indicates that there is considerable loss in flow downstream of Palisade even prior to groundwater pumping (Prudic et al., 2006).

Dividing cumulative flows and cumulative tributary flows at Comus and Imlay into four periods yielded similar results to those when cumulative river flows were compared with cumulative precipitation (compare **Figure 2*B*** to **Figure S11*B* in supplement**). The differences in the ratios among the four periods at Comus and Imlay were about the same as those for precipitation. The ratio of flow to tributary flow at Imlay, decreased 15 percent ((0.013-0.011)/0.013) between the earliest and latest periods and is slightly less than the 18 percent decrease the decrease in the ratio of flow to precipitation. This indicates that flows at Imlay have decreased more than can be explained by variations in precipitation alone.

NET INCREASE OR DECREASE IN FLOW BETWEEN GAGING STATIONS

The net increase in annual flow between the Elko and Carlin gaging stations varied among the four periods with the highest net increase for WYs 1970 to 1991 and the lowest net increase for WYs 2007 to 2020 (**Figure 3**). The overall variability is in response to changes in precipitation. The net increase is less variable between the Palisade and Carlin gaging stations and the increase ranged from a low during WYs 1946 to 1969 to a high during WYs 1992 to 2006, which in part was the result of dewatering at Gold Quarry Mine being discharged to Maggie Creek via Maggie Creek Reservoir. The net increase for WYs 1946 to 1969 and WYs 2007 and 2020 between the two sets of gaging stations are within the margin of error.

The net decrease in annual flow between the Palisade and Comus gaging stations also varied among the four periods with the lowest net decrease during WYs 1992 to 2006 and the highest net decrease during WYs 2007 to 2020 (**Figure 3**). However, the net decrease is within the margin of error for all four periods when the difference in annual flows for WYs 1983 and 1984 are excluded and when mine water that was discharged to the river is added. WYs 1983 and 1984 were excluded because the annual flow at Comus was more than that at Palisade. The greater flow at Comus compared with Palisade was caused from tributary streams contributing flow to the river during those years when they normally do not. Besides WYs 1983 and 1984, higher annual flow at Comus was recorded for WYs 1997, 1998, 1999, and 2006; years of above average precipitation and when either or both Lone Tree Mine and Goldstrike Mines were contributing flow to the Humboldt River downstream of Palisade.

The net decrease in annual flow between the Imlay and Comus gaging stations was least for WYs 1946 to 1969 and highest for WYs 2007 to 2020 (**Figure 3**). The three periods since 1969 all had much greater decreases in flow ranging from 55,000 acre-ft/yr for WYs 1970 to 1971 to 63,000 acre-ft/yr for WYs 2007 to 2020 then the period for WYs 1946 to 1969. The latest three periods are outside the error bar for WYs 1946 to 1969 and indicates that the increase in net loss of flow downstream of Comus is most likely caused by groundwater pumping from basin-fill deposits near Winnemucca. Its either that or more water is now diverted from the river than had been done previously but that would have resulted in increased groundwater levels near the river and greater late season flows as some of the water that infiltrated beneath irrigated fields during peak flow would have returned to the river at low flows. However, flows in the river had decreased during drought years and during low flow in the late summer and fall as is discussed in the subsequent sections.

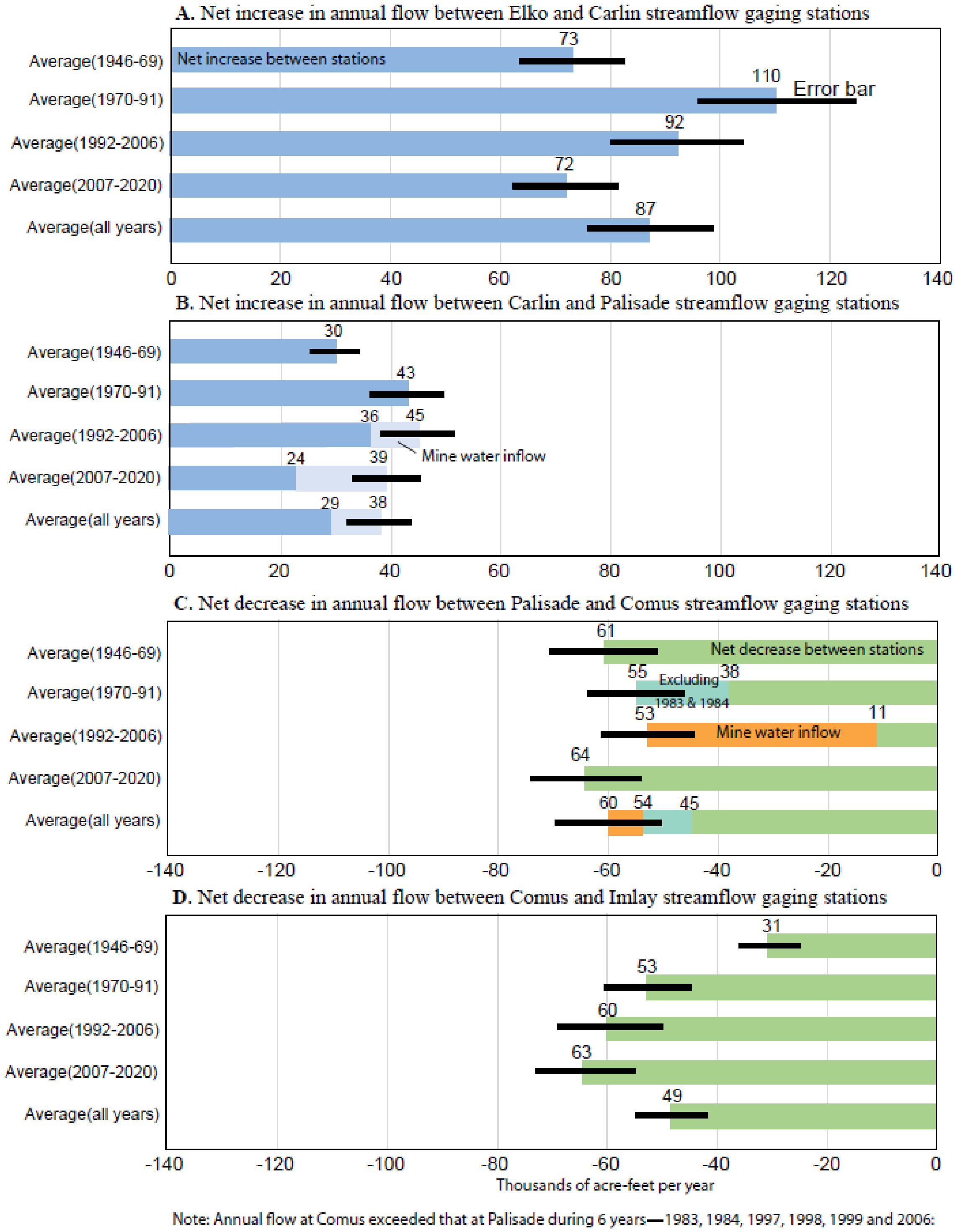

Figure 3—Net change in flow between gaging stations on the Humboldt River from WYs 1946 to 2020. Uncertainty (error bar) in the net change was estimated by adding the error associated with each gaging station (Winter, 1981).

HUMBOLDT RIVER FLOW DURING DROUGHTS

Years of higher flow, precipitation, and tributary flow mask effects during drought years when depletion of flow by groundwater pumping would be most noticeable. Consequently, drought years were separated from other years on the basis of the WY annual PHDI (see **Supplement**) and cumulative flow at Palisade, Comus and Imlay gaging stations were compared with cumulative precipitation and tributary flow for those drought years at each gaging station (**Figures 4**, **5**, and **6**, respectively). The ratio of flow to precipitation during PHDI drought years at the Palisade gaging station does not change during drought years when compared with precipitation whereas there is an 11 percent increase when compared with averaged tributary flows (**Figure 4**). The lack of sensitivity between flow and precipitation even while dewatering at Gold Quarry Mine was adding flow to the Humboldt River via Maggie Creek suggests that the amount of water added is small relative to the uncertainty in the estimate of precipitation. However, the increase in the ratio of flow to averaged tributary flows during the years when Gold Quarry Mine was adding flow to the Humboldt River is consistent with the amount of added water.

Cumulative flow at the Comus gaging station relative to precipitation and averaged tributary flow showed an increase in the ratio during drought years between WYs 1992 and 2006 when Lone Tree and Goldstrike mines discharged water to the Humboldt River compared with the period prior to mine dewatering (**Figure 5**). Once mine dewatering stopped, the ratio of cumulative flow relative to precipitation was slightly less than prior to mine dewatering but the ratio of flow to averaged tributary flows was the same. This suggests that groundwater pumping upstream of Comus has had little effect on the flow during drought years at Comus, even though nearly all the mine dewatering in 2015 was between the Comus and Palisade gaging stations (Nevada Department of Conservation and National Resources, 2017). The ratio of flow compared with precipitation at Imlay was less than 1 percent for all three periods, even prior to when water from Lone Tree and Goldstrike mines added flow to the river upstream of Comus. The ratio of flow to precipitation and averaged tributary flows at Imlay increased during drought years when flow was added to the river by Lone Tree and Goldstrike mines (**Figure 6**).

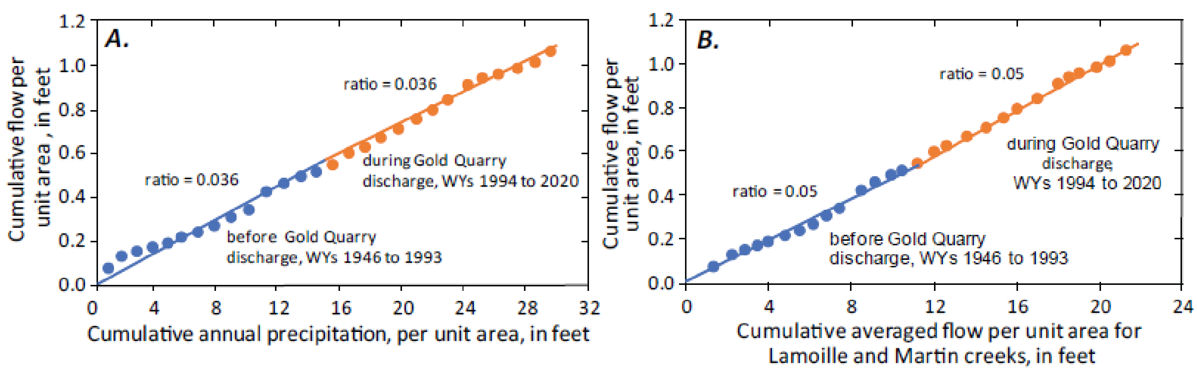

Figure 4—Cumulative annual flows at Palisade for PHDI drought years in relation to (***A***) cumulative precipitation and (***B***) cumulative averaged flow for Lamoille and Martin Creeks.

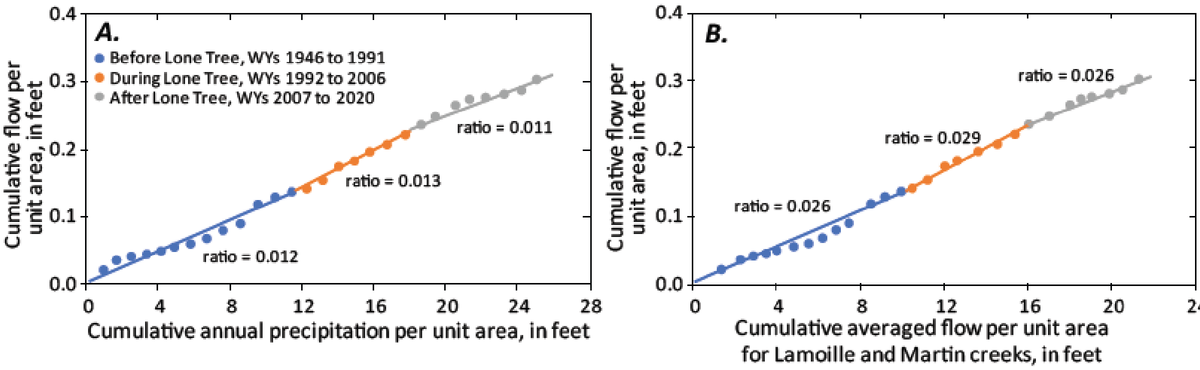

Figure 5—Cumulative annual flow at Comus for PHDI drought years in relation to (***A***) cumulative precipitation and (***B***) cumulative averaged flow for Lamoille and Martin creeks.

Once Lone Tree and Goldstrike mines stopped adding water, the ratio of flow to precipitation during drought years decreased 38 percent from 0.008 prior to dewatering to 0.005 afterwards. The ratio of flow to averaged tributary flows also decreased 25 percent between the two periods. The decrease in the ratios again indicate that more water is being lost between the Comus and Imlay gaging stations than can be explained by natural variations or uncertainties in the estimates of precipitation or the uncertainty in flow either at Imlay or at Lamoille and Martin Creek gaging stations. This analysis supports that the decrease in the ratio of flow to precipitation and to averaged tributary flow at Imlay is increased river losses from groundwater pumping near Winnemucca.

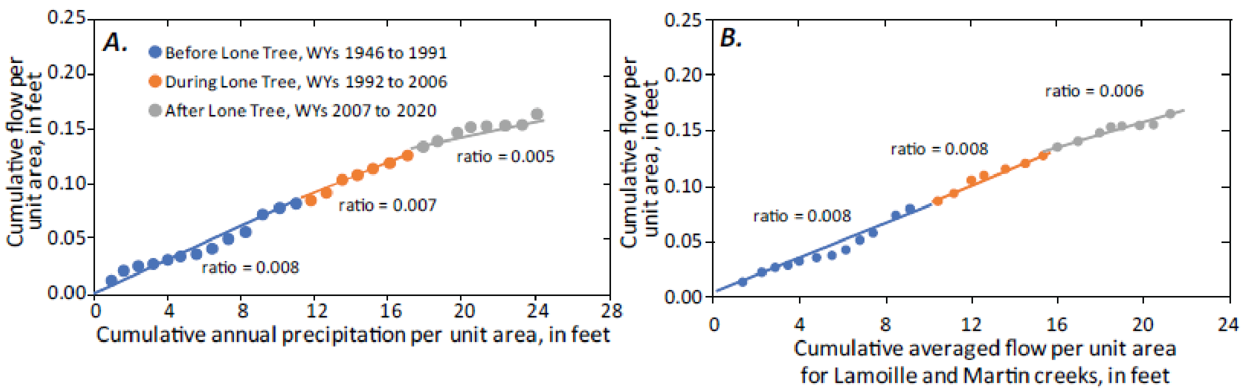

Figure 6—Cumulative annual flow at Imlay for PHDI drought years in relation to (***A***) cumulative precipitation and (***B***) cumulative averaged flow for Lamoille and Martin creeks.

This analysis supports the conclusions of Prudic (2020) in which he compared two multi-year droughts (1953 to 1955 and 2012 to 2015). In this earlier analysis, the net increase for the 2012 to 2015 drought was nearly the same as the 1953 to 1955 drought between gaging stations. Only two reaches had net differences that exceeded the estimated error. The first was between the Carlin and Palisade gaging stations where the net increase during the 2012 to 2015 drought was much more than the 1953 to 1955 drought because of additional flow from Gold Quarry Mine dewatering (Prudic 2020). The second was between the Comus and Imlay gaging stations where the net decrease in flow during the 2012 to 2015 drought was twice as much as that during the 1953 to 1955 drought.

MEAN MONTHLY FLOW PRIOR TO AND AFTER GROUNDWATER PUMPING

Mean monthly flows were analyzed for all gaging stations using two periods. The first was for the period WY 1946 to 1969 and the second was from January 2007 to September 2020. The second period did not include October 2006 to December 2006 because Lone Tree was still discharging a small amount of mine water into the Humboldt River upstream of Comus. The mean monthly flows at Elko and Carlin gaging stations were nearly the same during WYs 1946 to 1969 and January 2007 to September 2020 (**Figure 7**). Peak monthly flows were in June and minimum monthly flows were in September. The most recent period showed more flow during February and March and less in April and May suggesting earlier snowmelt. The low-flow months are nearly the same at both gaging stations. If groundwater pumping was affecting river flow upstream of these gaging stations, then low flow during August through January should have been less given the similarity of peak flow at both gaging stations. The increased flows during February and March cannot be explained by release from water in the South Fork Reservoir because the Elko gaging station is upstream of the reservoir. The mean flow at each gaging station was nearly the same for both periods.

Mean monthly flows at Palisade have the same pattern of flow for the two periods as that at Elko and Carlin, with the exception that the mean flow from January 2007 to September 2020 was 15 cfs more than the mean flow for WYs 1946 to 1969 and was caused by inflow of Gold Quarry Mine dewatering via Maggie Creek (**Figure 8**). There is a marked difference in flow between the two periods at Battle Mountain. The mean flow at the Battle Mountain gaging station is 49 cfs more from January 2007 to September 2020 compared with the mean flow for WYs 1946 to 1969. Most of the increased flow is during spring runoff with only a slight increase in flow during the low flow months. The increased flow only can be explained if there is additional inflow from tributaries upstream of the Battle Mountain gaging station or if there is less diversion from the river between the gaging stations or a combination of both. The gaging station at Battle Mountain was not in operation between WYs 1982 and 1991 and the estimated drainage area after it began operation during WY 1992 increased more than 2,000 square miles (**Table 1; foot note 3**). Prior to 1981, the Reese River entered the Humboldt River downstream of the Battle Mountain gaging station (confluence was just east of the Valmy Power Plant). The Reese River presently enters the Humboldt River upstream of the Battle Mountain gaging station, hence the reason why the large increase in the drainage area after WY 1991 and perhaps the principal reason for an increase in mean monthly flows during spring snowmelt.

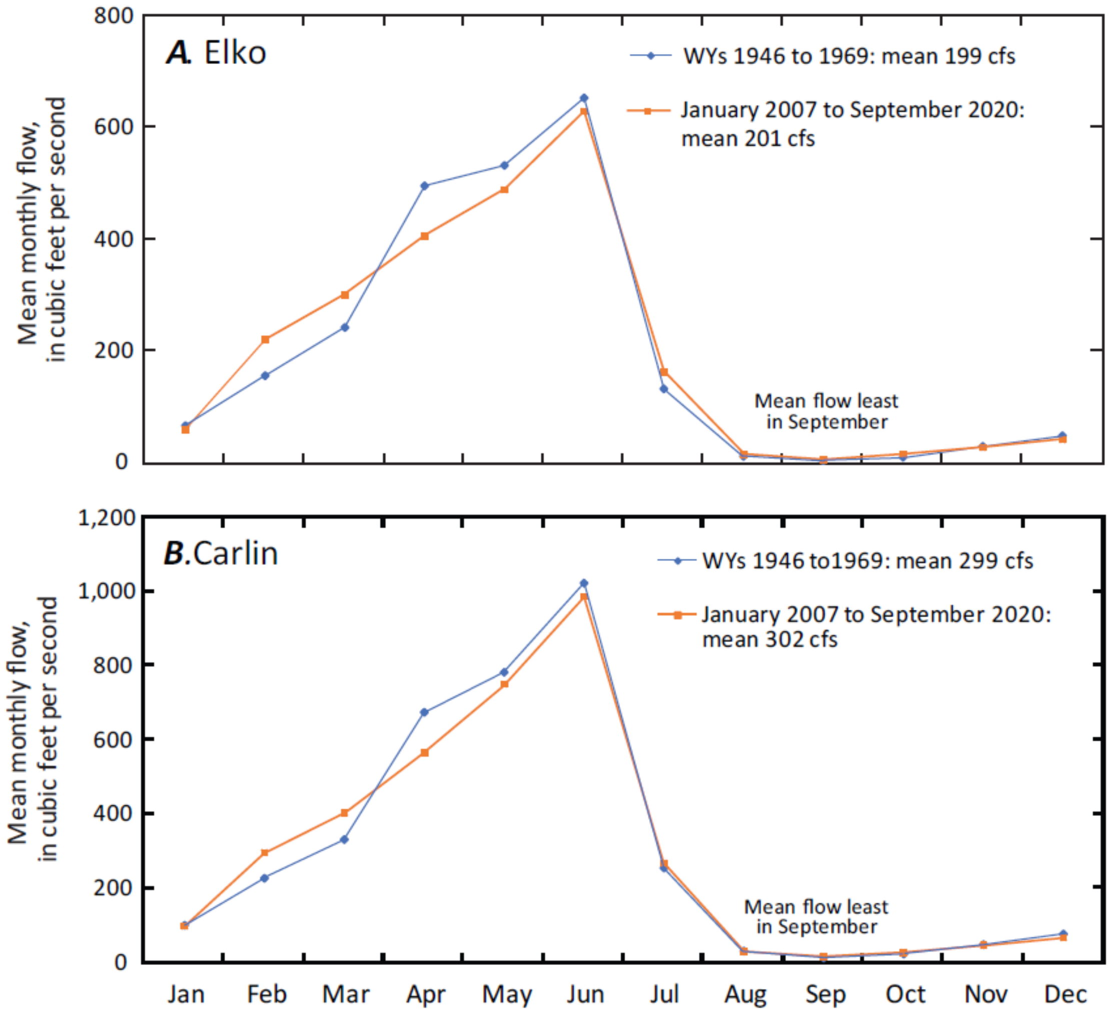

Figure 7— Comparison of mean monthly flows at the Elko and Carlin gaging stations for two the periods: WYs 1946 to 1969 and January 2007 to September 2020.

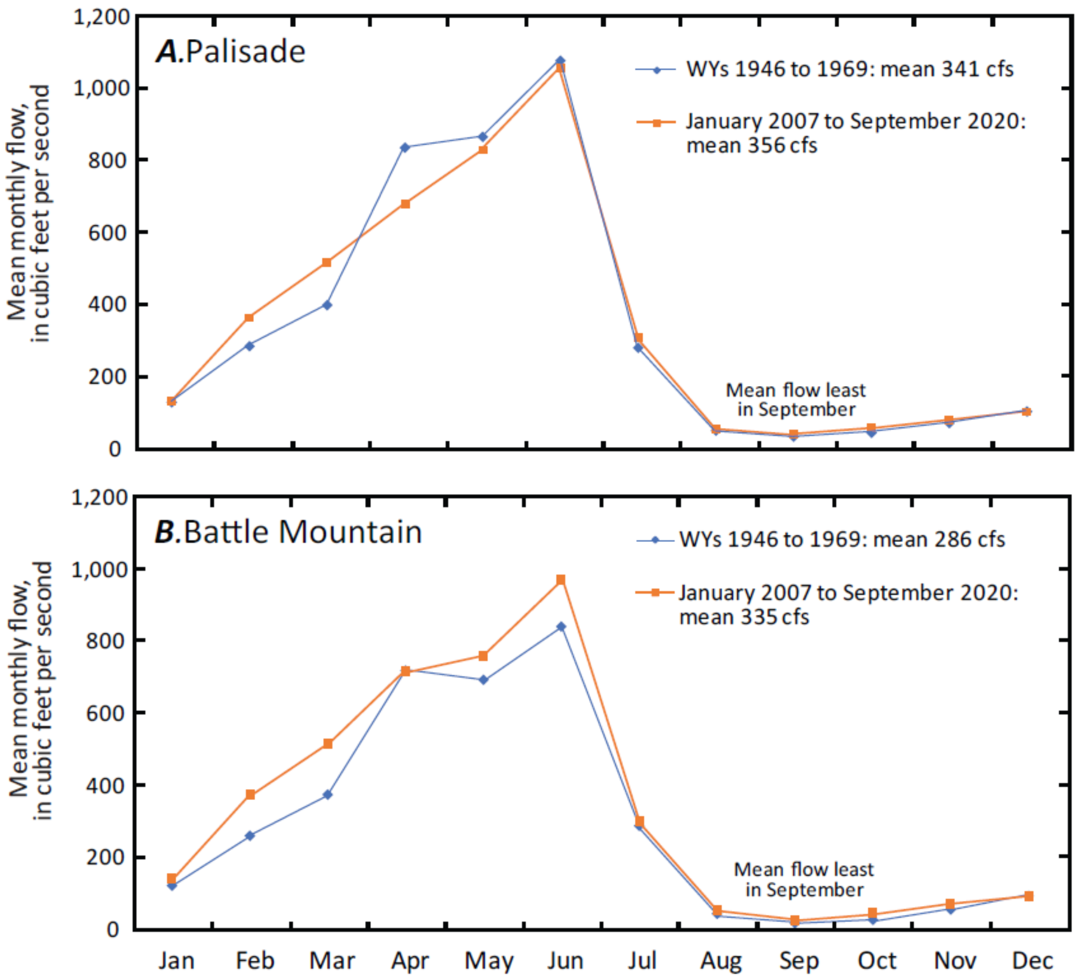

Figure 8— Comparison of mean monthly flows at the Palisade and Battle Mountain gaging stations for the two periods: WYs 1946 to 1969 and January 2007 to September 2020.

The timing of the peak and minimum mean monthly flows at the Comus gaging station was the same as those at upstream gaging stations (**Figure 9**). The mean flow from January 2007 to September 2020 was 9 cfs more than the mean flow for WYs 1946 to 1969 indicating that some of the excess flow at Palisade reaches the Comus gaging station. The timing of peak and minimum flow at Imlay differs from the upstream gaging stations during WYs 1946 to 1969. Peak flow was in May and the minimum flow was in October. Peak flow from January 2007 to September 2020, however, was the same as the upstream gaging stations. Why the difference in the timing of peak flow is unknown but perhaps could be caused by changes in diversions from the river. More important than the timing of peak and minimum flow is that the mean flow at Imlay decreased by 36 cfs during the September 2007 to September 2020 period compared with WYs 1946 to 1969 along with a marked decrease in peak and low flows. The net decrease in mean flow between the Comus and Imlay gaging stations during WYs 1946 to 1969 was 43 cfs (256 cfs less 213 cfs), whereas the net decrease from January 2007 to September 2020 was 88 cfs (265 cfs less 177 cfs), or about twice as much. The marked decrease in mean monthly flow between the two periods at the Imlay gaging station from August to November when surface diversions are typically at a minimum indicate that the decrease in flow at Imlay is caused by losses from groundwater pumping between the two gaging stations.

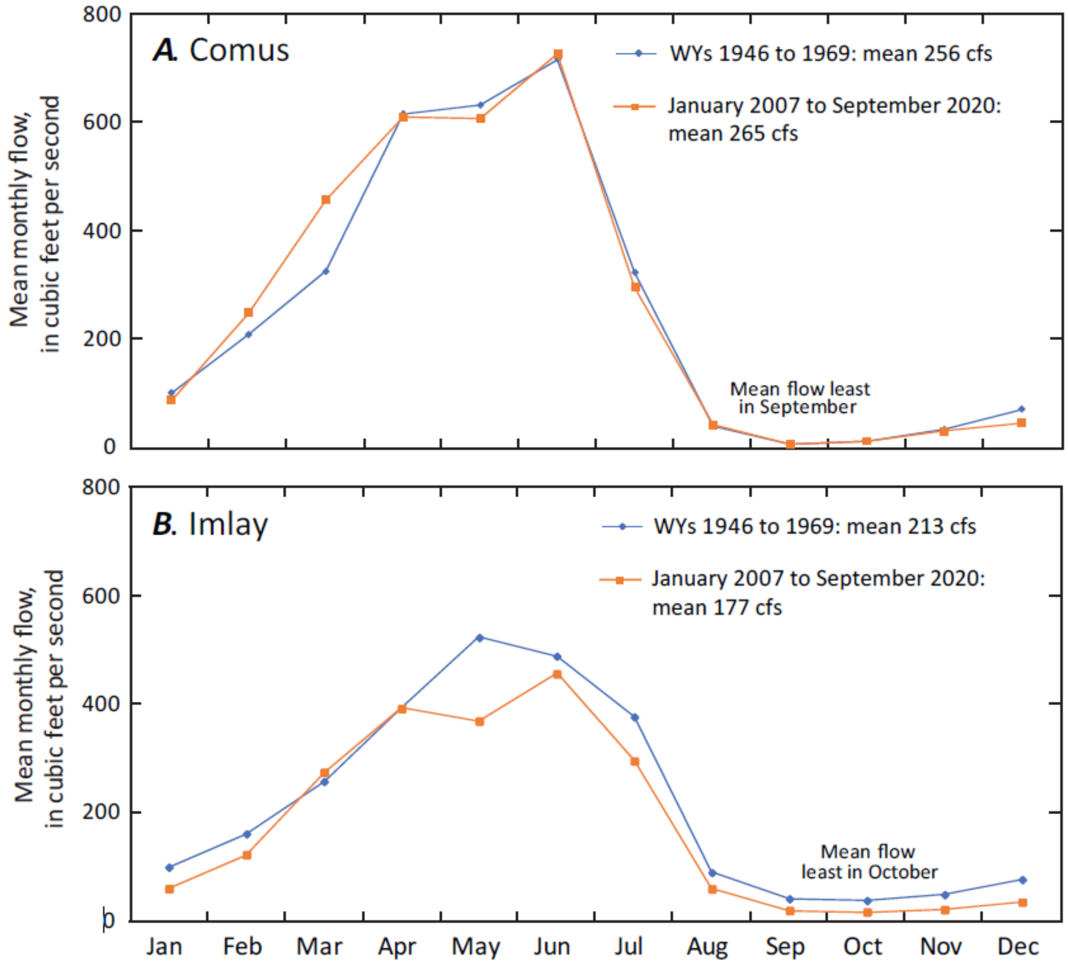

Figure 9— Comparison of mean monthly flows at the Comus and Imlay gaging stations for the two periods: WYs 1946 to 1969 and from January 2007 to September 2020.

CHANGES IN GROUNDWATER CONTRIBUTIONS TO THE HUMBOLDT RIVER

Groundwater does not contribute flow to the Humboldt River along its entire length. Groundwater contributions are limited to a few areas where there is evidence for such inflow. Sections along the river that have been documented to have groundwater contributions to the river include the lower sections of the North and South Forks of the Humboldt River near the confluence with the Humboldt River (Plume and Smith, 2013), the section between the Carlin and Palisade gaging stations (Maurer et al., 1996), two short sections, one upstream and one downstream of Dunphy (Maurer et al., 1996), and a section from Golconda east of Winnemucca to 20 mi west of Winnemucca (Cohen, 1966). A gravel aquifer near Winnemucca was mapped by Cohen that was directly connected to the Humboldt River. Cohen was able to determine the direction of groundwater flow and estimate the amount of groundwater contribution from southern Paradise Valley and northern Grass Valley to the Humboldt River.

September flows on the Humboldt River are on average the lowest monthly flow, which means that contributions from groundwater would be more noticeable than months with higher flows. September flows at Carlin are higher than at Elko and September flows are higher at Palisade than at Carlin. September flows decrease consistently between Palisade and Comus except when Lone Tree and Goldstrike mines discharged water to the river. September flows increased between Comus and Imlay gaging stations until about 1985 (**Figure 10**).

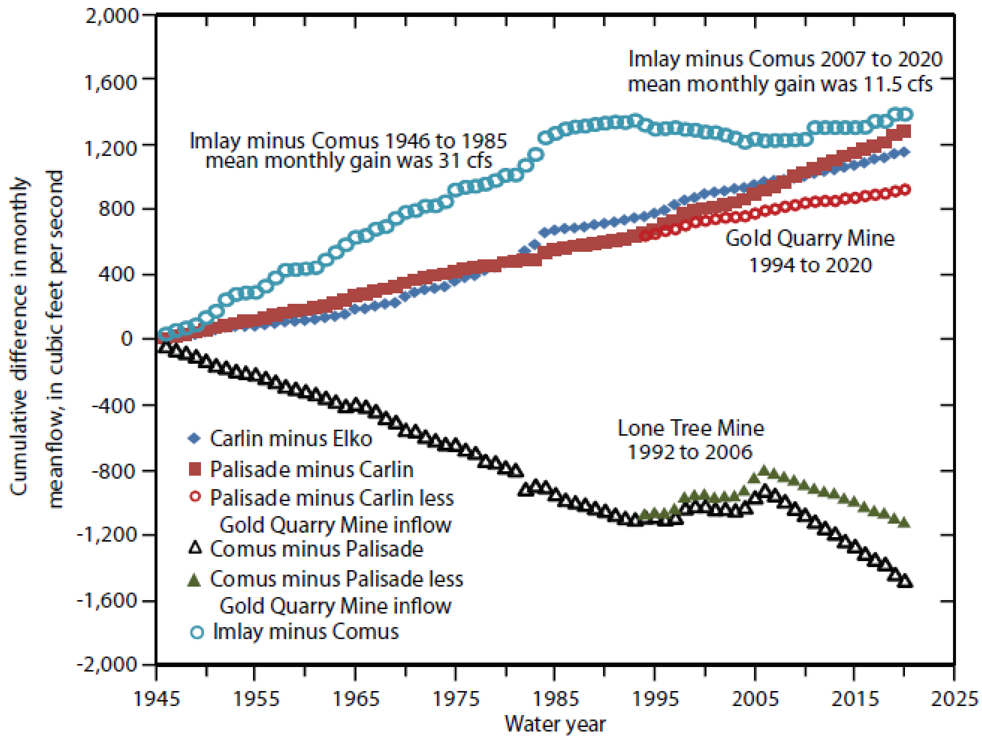

Figure 10—Cumulative net difference in September flows between selected gaging stations on the Humboldt River from 1946 to 2020. Positive values mean a gain in flow between gaging stations and negative values mean a loss in flow.

September flow at Palisade increased more than at Carlin beginning in 1994 when Gold Quarry Mine began discharging water to the Humboldt River via Maggie Creek. Subtracting the inflow from Gold Quarry Mine produced a mean September gain of 12.5 cfs slightly more than the mean September gain of 11 cfs between 1946 and 1993.

Water pumped from Lone Tree Mine was discharged to the Humboldt River from 1992 to 2006 and some of the water pumped at Goldstrike Mines was discharged to the river from 1997 to 1999. These discharges reduced the cumulative net loss in flow at Comus but that reduction was only temporary. Since 2007, after discharge from Lone Tree Mine ceased, the net mean September loss was 21 cfs between Comus and Palisade when inflow from Gold Quarry Mine is subtracted from the flow at Palisade. This net mean loss between the two gaging stations is slightly less than the net mean loss of 23 cfs from 1946 to 1991. The net mean September loss from 2007 to 2020 between Comus and Palisade without subtracting the inflow from Gold Quarry was 37 cfs. This indicates that water added by Gold Quarry Mine is insufficient to reach Comus during periods of low flow because groundwater along most of the reach downstream of Dunphy is and has been lower than the river bed since at least 1946 and is consistent with the large annual loss between the two gaging stations.

The largest change in the cumulative net difference in September flows was between Comus and Imlay. Prior to 1985, the net mean gain in flow between the two gaging stations was 31cfs. Some of this inflow was from tributary streams and some was from groundwater inflow (Cohen, 1966). The cumulative net loss between the two gaging stations actually decreased during 1992 to 2006 because dewatering at Lone Tree Mine added flow at Comus and much of this added flow in September was lost prior to reaching Imlay. Since 2007, there has been a slight net gain in September flows at Imlay of 11.5 cfs or only about a third of what it was prior to 1985. The increase in cumulative net gain of September flow since 2007 is the result of sporadic inflows from tributary streams during the wet years of 2011, 2017 and 2019. Otherwise, the general lack of groundwater contributions since at least 1985 results in many years without September gains between the two gaging stations.

Flow duration of daily mean flows at gaging stations on the Humboldt River can determine changes in flow that may be caused by groundwater pumping. The early period from October 1945 to September 1969 was compared to the latest period from January 2007 to September 2020. Flow duration for the two periods was nearly the same at Elko and Carlin (**Figure 11**). The Humboldt River at both gaging stations is perennial 99 percent of the time. The curves flatten near high flows because of snowmelt runoff with slightly higher flows from January 2007 to September 2020. A slight flattening of the curve during low flow indicates a small contribution from groundwater with more groundwater contribution at Carlin that increased during the most recent period compared with the earlier period. The slight increase might be caused by releases from the South Fork Reservoir.

Flow duration for Palisade differs slightly at low flows between the two periods because of discharge from Gold Quarry Mine during the later period (**Figure 12*A***). The Humboldt River at Palisade is also perennial but the curves flatten more at low flow than those at the upstream gaging stations. The minimum daily mean flow was 10 cfs during the earlier period indicating additional groundwater contributions between Carlin and Palisade. The minimum daily mean flow increased to 20 cfs during the later period because of the addition of water from Gold Quarry Mine.

Flow duration at Battle Mountain differs at both higher and lower flows for the two periods (**Figure 12*B***). More importantly, the Humboldt River at Battle Mountain is intermittent even during the earlier period. The higher flows during the later period is probably caused by flow from the Reese River during wetter than normal years. The channel of the Reese River north of Battle Mountain apparently changed following the large floods of 1983 and 1984 when the Battle Mountain gaging station was not in operation. Previously, the channel flowed west parallel to the Humboldt River until they merged just east of the Valmy Power Plant. The curves differ markedly at lower flows because some of the water discharged by the Gold Quarry Mine into Maggie Creek reached Battle Mountain. However, the sharp decline when daily mean flows are less than 20 cfs indicate little to no groundwater contributions upstream of Battle Mountain that could maintain minimum flows at the gaging station.

The mean flow at Comus was 9 cfs more from January 2007 to September 2020 than during WYs 1945 to 1969 (**Figure 13*A***) and is only slightly less than the increase in mean flow at Palisade caused by Gold Quarry Mine dewatering that entered the Humboldt River via Maggie Creek. The increase in flow during the latest period at Comus is largely from flows greater than 1,000 cfs. Flows less than 1,000 cfs are nearly the same for both periods even at low flows. Like Battle Mountain, the Humboldt River at Comus is intermittent because there is essentially no flow about 10 percent of the time for both periods. The sharp decline when daily mean flows are less than 20 cfs is similar to the rapid decline in flow at Battle Mountain and indicates little groundwater contributions upstream of Comus that sustains flow at the gaging station. The same low flow during both periods indicates that groundwater pumping has had little to no measurable effect on flow.

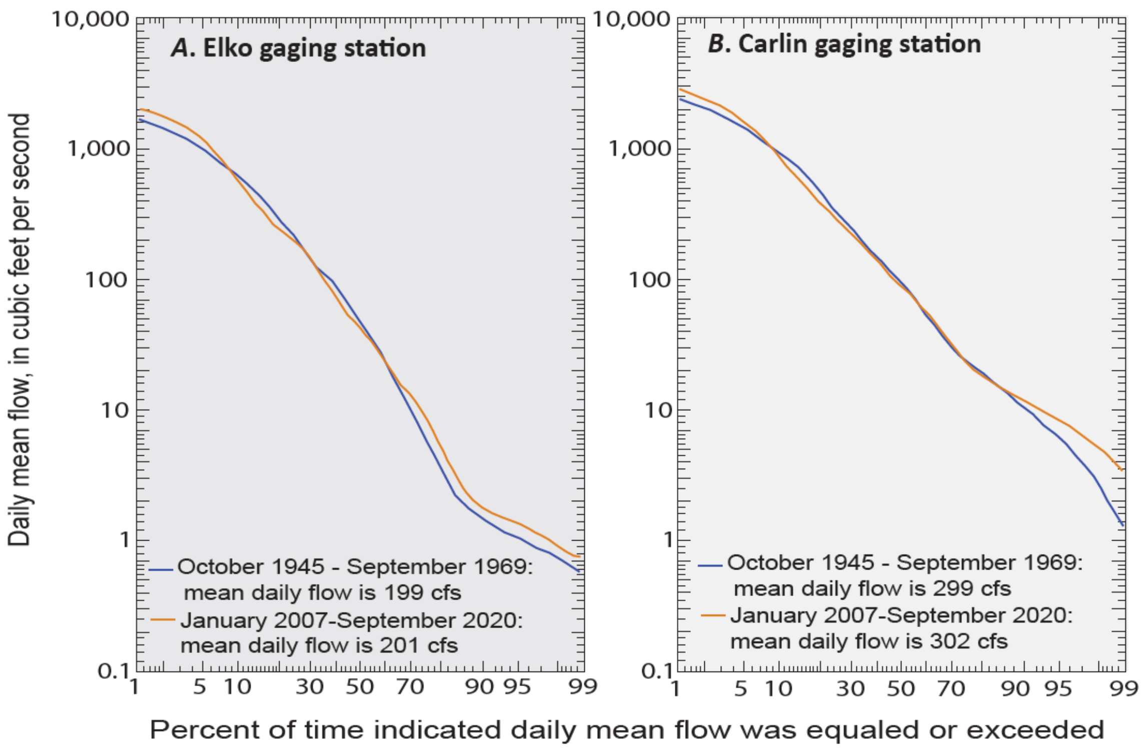

Figure 11—Flow duration of daily mean flows at (***A***) Elko and (***B***) Carlin during October 1945 to September 1969 and January 2007 to September 2020.

Flow at Imlay is markedly different between the two periods (**Figure 13*B***). Mean flows at Imlay decreased from 213 cfs during WYs 1945 to 1969 to 177 cfs from January 2007 to September 2020. The Humboldt River at Imlay was perennial during WYs 1945 to 1969 with flow 1.5 cfs or more 99 percent of the time. Low flow is consistent with the mean net increase in mean September flows of 2.62 cfs from 1945 and 1985 between Comus and Imlay (**Figure 10**) and indicates some groundwater contribution to the Humboldt River between the two gaging stations. The groundwater contribution is consistent with a previous study by Cohen (1966) that measured an increase of nearly 14 cfs during December 5-6, 1961 between Comus and 20 mi downstream of Winnemucca at Rose Creek. At that time, the daily mean flow at Comus was 0.2 cfs while flow at Imlay on December 6, 2020 was 9 cfs suggesting a slight loss in flow between Rose Creek and Imlay. Contrastingly, flow at Imlay was intermittent from January 2007 to September 2020 with flows less than 0.1 cfs (essentially no flow) 18 percent of the time. Daily mean flows from January

2007 to September 2020 are less than those for the earlier period 90 percent of the time suggesting that groundwater pumping in the area between the two gaging stations is the cause of increased river losses (known as capture of flow).

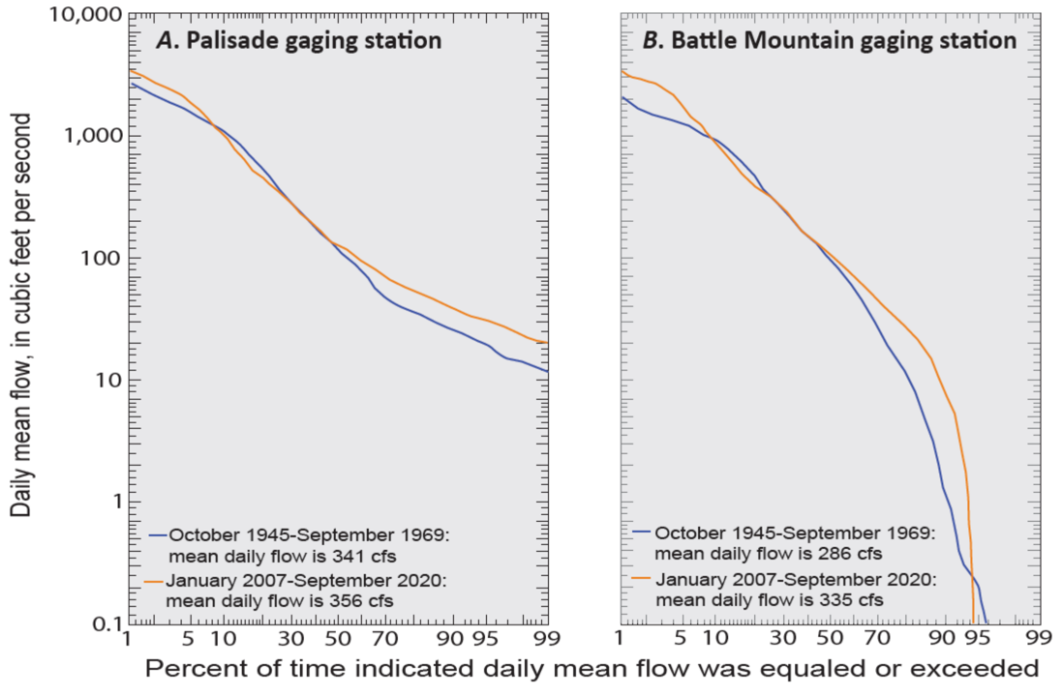

Figure 12—Flow duration of daily mean flows at (***A***) Palisade and (***B***) Battle Mountain during October 1945 to September 1969 and January 2007 to September 2020.

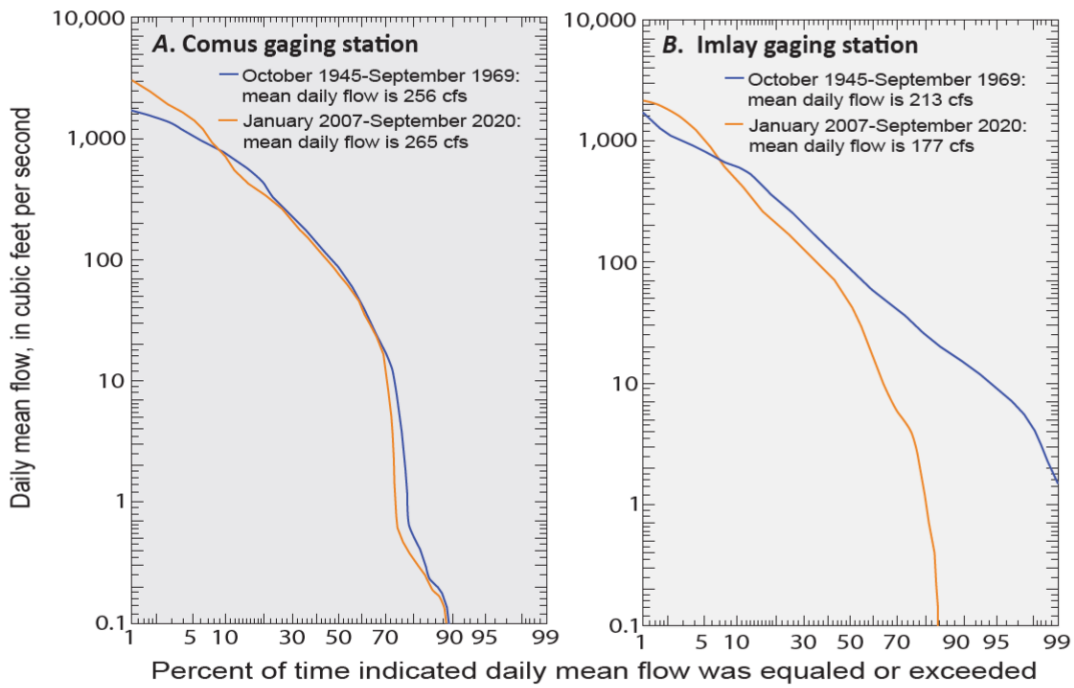

Figure 13—Flow duration of daily mean flows at (***A***) Comus and (***B***) Imlay during October 1945 to September 1969 and January 2007 to September 2020.

Finally, changes in groundwater contributions were evaluated by comparing changes in the number of days when daily mean flow since 1946 was less than 1 cfs. At Elko and Carlin, days when flows were less than 1 cfs has decreased at both gaging stations since the mid 1960's (**Figure 14*A***).

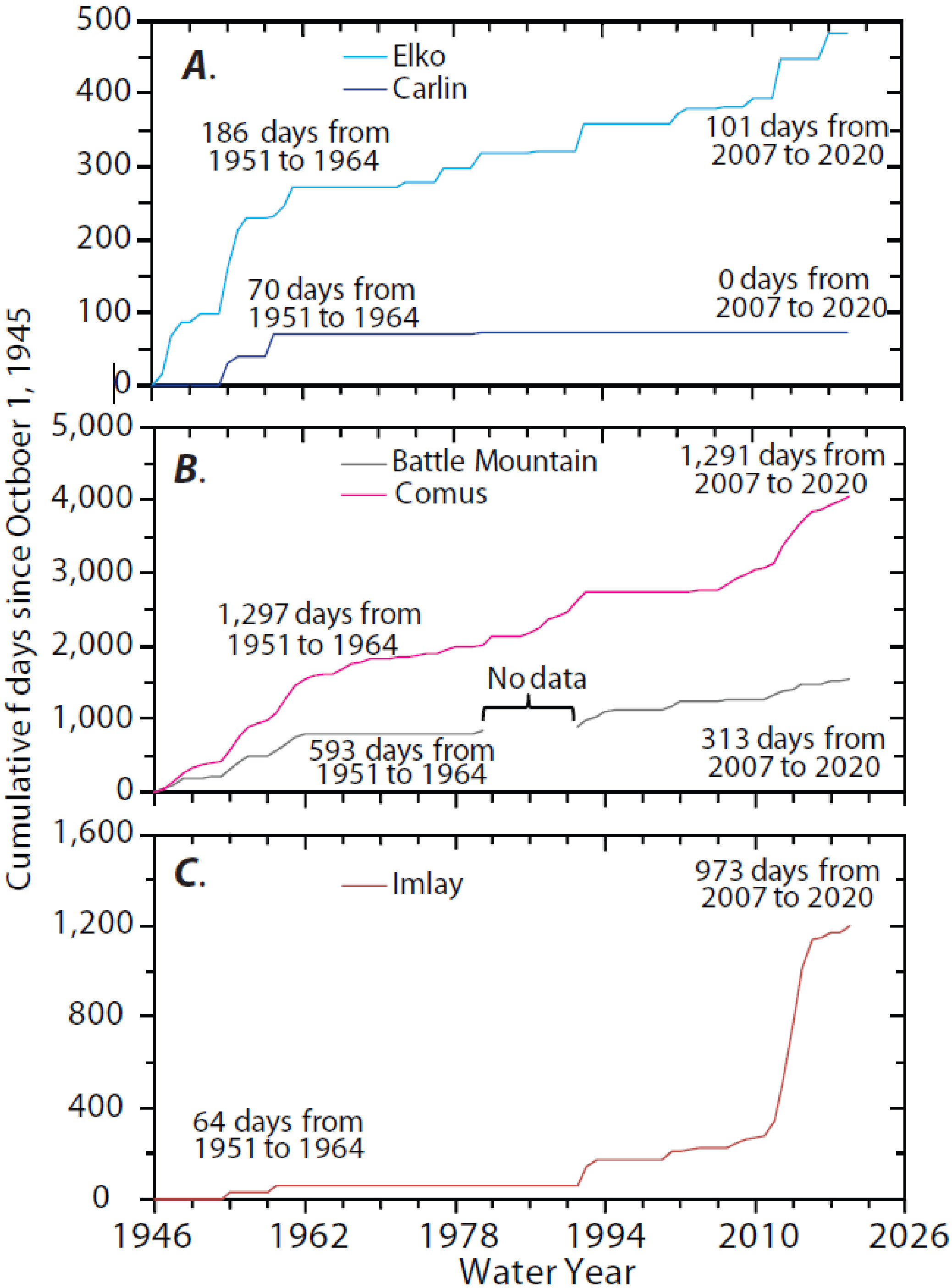

Figure 14—Days when the daily mean flow at a gaging station was less than 1 cfs.

Elko had a total of 483 days when daily mean flows were less than 1 cfs between October 1, 1945 and September 30, 2020. Of those, 186 days were during WYs 1951 to 1964 whereas only

101 days were during WYs 2007 to 2020 when the mean flow at the Carlin gaging station was nearly the same. Carlin had a total of 72 days of which, 70 days were during WYs 1951 to 1964 and none were during WYs 2007 to 2020. These results do not indicate that groundwater pumping in the upper part of river basin has affected flow in the river.

Between October 1, 1945 and September 30, 2020, the daily mean flow at Palisade was always more than 1 cfs but daily mean flows at Battle Mountain and Comus had many days of flow less than 1 cfs (**Figure 14*B***). Battle Mountain was not in operation between WYs 1982 and 1991. Days when flows were less than 1 cfs decreased at Battle Mountain after WY 1991. The decrease in flows less than 1 cfs could in part be explained by Gold Quarry Mine discharge being added to the river via Maggie Creek. The number of days that the daily mean flow was less than 1 cfs exceeded 4,000 days at Comus but was nearly the same when comparing WYs 1951 to 1964 with WYs 2007 to 2020.

Days when daily mean flows were less than 1 cfs increased dramatically at Imlay after 1992 and accelerated once Lone Tree Mine ceased adding flow to the river (**Figure 14*C***). The severe drought during WYs 2012 to 2015 resulted in extended periods of no flow at the gage. During this drought, a total of 740 days had flows less than 1 cfs of which, 677 days were no flow. Prior to 1992, only the drought years of 1954, 1955 and 1959 had a total of 64 days when flows were less than 1 cfs of which, 20 days were no flow, whereas even during the time when Lone Tree Mine contributed flow to the river between 1992 and 2006, 160 days had daily mean flows less than 1 cfs of which, 127 days were no flow.

CONCLUSIONS

The various analyses of Humboldt River flows indicate no measurable decrease that could be attributed to groundwater pumping upstream of the Comus gaging station, whereas a measurable decrease in flow at the Imlay gaging station can best be explained by increased losses to groundwater as a result of groundwater pumping from a productive aquifer near Winnemucca.

REFERENCES

Cohen, Philip, 1966, Water in the Humboldt River Valley near Winnemucca, Nevada: U.S. Geological Survey Water-Supply Paper 1816, 69 p.

Eakin, T.E., and Lamke, R.D., 1966, Hydrologic reconnaissance of the Humboldt River basin, Nevada: Nevada Department of Conservation and Natural Resources, Water-Resources Bulletin 32, 107 p.

Fenneman, N.M. and Johnson, D.W., 1946, Physical division of the United States: U.S. Geological Survey map, scale 1:7,000,000.

Grayson, D.K., 1993, The Deserts' Past—A natural prehistory of the Great Basin: Washington D.C., Smithsonian Institution, 356 p.

Harrill, J.R., and Prudic, D.E., 1998, Aquifer systems in the Great Basin region of Nevada, Utah, and adjacent States—Summary report: U.S. Geological Survey Professional Paper 1409−A, 66 p.

Horton, G.A., 2000, Humboldt River chronology—an overview and chronological history of the Humboldt River and related water issues: Nevada Division of Water Planning Report, Volume 1—Overview, 184 p.

Mashburn, Gray, and Mathews, W.T., [Compilers], 1943, The Humboldt River adjudication: Carson City, Nevada, State Printing Office, 5 sections, 406 p.

Maurer, D.K., Plume, R.W., Thomas, J.M., and Johnson, A.K., 1996, Water resources and effects of changes in ground-water use along the Carlin Trend, North-Central Nevada: U.S. Geological Survey Water-Resources Investigations Report 96‒4134.

Nevada Division of Water Planning, 2019, Humboldt River Chronology, An Overview and Chronological History of the Humboldt River and Related Water Issues—Part 1: Nevada Water Basin Information and Chronology Series I, 179 p.

Plume, R.W., and Smith, J.L., 2013, Properties of basin-fill deposits, a 1971–2000 water budget, and surface-water-groundwater interactions in the upper Humboldt River basin, northeastern Nevada: U.S. Geological Survey Scientific Investigations Report 2013-5077, 38 p., http://pubs.usgs.gov/sir/2013/5077/.

Prudic, D.E., 2020, Estimates of pit-lake evaporation and its potential effects on groundwater interactions with the Humboldt River: Journal of the Nevada Water Resources Association, Winter 2020, p 29-47. DOI: 10.22542/jnwra/2020/1/2.

Prudic, D.E., Niswonger, R.G., and Plume R.W., 2006, Trends in streamflow on the Humboldt River between Elko and Imlay, Nevada, 1950‒99: U.S. Geological Survey Scientific Investigations Report 2005‒5199, 57 p.

Searcy, J.K., 1959, Flow-duration curves: U.S. Geological Survey Water-Supply Paper 1542‒A, p. 1‒33.

Searcy, J.K., and Hardison, C.H., 1960, Double-mass curves: U.S. Geological Survey Water-Supply Paper 1541-B, p. 31‒59.

Stewart, J.H., 1980, Geology of Nevada—A discussion to accompany the geologic map of Nevada: Nevada Bureau of Mines and Geology Special Publication 4, 136 p.

Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods, book 3, chap. A8, 87 p.

U.S. Geological Survey, 1960, Surface water supply of the United States 1958—Part 10, The Great Basin: U.S. Geological Survey Water-Supply Paper 1564, 268 p.

Winter, T.C., 1981, Uncertainties in estimating the water balance of lakes: Journal of the American Water Resources Association, v. 17, no. 1, p. 82‒115.

Next HSWG Agenda

1. **Chris proposal to bring Garret Baxter from Idaho about Snake River**
    a. **Discuss pros/cons of conservancy district**
2. **Discuss water markets in the Humboldt**
3. **Opportunities and constraints from focus groups**
4. **Nature based solution/Conservation as offset credits**
5. **How much consumptive loss in the Middle Section of the Humboldt**
6. **Discuss legal tools and management tools that DWR can use short term and long term.**
    a. **We don't have the data yet to develop management tools. Middle Humboldt Model**
7. **How much consumptive loss due to Stahl Dam?**
8. **How much consumptive loss due to old standing pits along the river?**
9. **Identify the low hanging fruit to mitigate the conveyance loss to downstream users**
10. **Solidify the common issues, as we are constantly discussing the same items**
11. **Decide the definition of offset**
12. **Decide the types of credits for offset beside purchasing decreed water.**
13. **Discuss Prudit model and other works**
14. **Ogallala aquifer discussion (Sam Routson Carry over request)**
15. **Capture mitigation based on pumping vs duty (Mahannah carry over request)**

Next meeting: 4/11/25 8am – noon in Carson City