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Interstate Investigation Regarding Feasibility of a Demand Management Program in the Upper Colorado River Basin

Upper Division States through the
Upper Colorado River Commission

Investigation Summary Report
December 2022

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List of Acronyms

Abbreviation	Definition
1922 Compact	1922 Colorado River Compact
1948 Compact	1948 Upper Colorado River Basin Compact
2007 Interim Guidelines	2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
Ac-ft	Acre-feet
BO	Biological Opinion
CDL	Cropland Data Layer
CFS	Cubic Feet Per Second
CMIP	Coupled Model Intercomparison Project
CO-RIP	Colorado Riparian Vegetation and Corridor Extent Dataset
CRAU	Colorado River Authority of Utah
CRBPA	1968 Colorado River Basin Project Act
CRSPA	1956 Colorado River Storage Project Act
CCU	Conserved Consumptive Use
CWCB	Colorado Water Conservation Board
DCP	Drought Contingency Plan
DCP Act	Drought Contingency Plan Act
DM	Demand Management
DMC	Demand Management Committee
DMSA	Demand Management Storage Agreement
DROA	Drought Response Operations Agreement

Abbreviation	Definition
DRI	Desert Research Institute
eeMETRIC	Earth Engine - Mapping EvapoTranspiration at High Resolution and Internalized Calibration
EA	Environmental Assessment
EC	Eddy Covariance
EIS	Environmental Impact Statement
ESA	Endangered Species Act
ET	Evapotranspiration
ETo	Reference Evapotranspiration
EToF	Fraction of Grass Reference Evapotranspiration
FTE	Full-Time Employee
GIS	Geographic Information Systems
HLS	Harmonized Landsat Sentinel
Hazen	Hazen & Sawyer
I-O	Inflow-Outflow
IIJA	Infrastructure Investment and Jobs Act
IRA	Inflation Reduction Act
ISC	New Mexico Interstate Stream Commission
LEM	Lake Evaporation Model
LFDO	Lee Ferry Deficit Object
MAF	Million Acre-Feet
M&I	Municipal and Industrial
METRIC	Mapping EvapoTranspiration at High Resolution and Internalized Calibration
NDVI	Normalized Difference Vegetation Index
NEPA	National Environmental Policy Act
PPT	Precipitation
ROD	Record of Decision
RFP	Request for Proposals

Abbreviation	Definition
RMSE	Root Mean Squared Error
RSM	Remote Sensing Method
RTMA	Real-Time Mesoscale Analysis
Reclamation	United States Bureau of Reclamation
Reserve	New Mexico Strategic Water Reserve
SCPP, Pilot	System Conservation Pilot Program
UCRC	Upper Colorado River Commission
UDS	Upper Division States

Disclaimer

This summary report of the *Interstate Investigation Regarding Feasibility of a Demand Management Program in the Upper Colorado River Basin* is the culmination of a multi-year investigation guided by the Upper Division States (Colorado, New Mexico, Utah, and Wyoming) (UDS) through the Upper Colorado River Commission (UCRC), to study and evaluate the feasibility of a Demand Management Program (DM Program) consistent with the Demand Management Storage Agreement (DMSA).

The investigations summarized in this report are focused on the interstate components related to the consideration of the feasibility of a DM Program in the Upper Basin. Each UDS is conducting parallel and independent investigations related to feasibility, and each UDS has individual considerations regarding a potential DM Program. Nothing in this report interprets, precludes, or replaces any of the intrastate investigations.

This report and related materials and data are intended to inform the future consideration of a potential DM Program by the UDS through the UCRC. The future consideration of a potential DM Program will adhere to and conform to the steps and processes outlined in the DMSA. This report and related materials and data are unique to the investigation, to the hired contractors, and the assumptions, parameters, and purposes of this study, and therefore are not intended to be applied to or utilized for any other application, function, or concern outside the context of the investigation.

The information presented herein does not establish any precedent or formal position, or declaration of the UDS or the UCRC. The modeling and analysis conducted in this investigation are in no way indicative of any policy, procedure, or precedent regarding any interpretation of the "Law of the River" [1] and should not be construed as such.

In conjunction with this summary report, the DMC has developed an associated "Key Findings and Recommended Next Steps"[2] document for consideration by the UCRC Commissioners.

[1] The "Law of the River" refers to the body of law existing on the Effective Date of the execution of the Drought Contingency Plan (DCP) Companion Agreement and affecting the interstate and international use, management, and allocation of water in the Colorado River System, including the 1922 Colorado River Compact, the Mexican Water Treaty of 1944, the 1948 Upper Colorado River Basin Compact, several United States Supreme Court decisions, the Consolidated Decree of the Supreme Court in Arizona v. California, and a host of federal laws and administrative regulations..

[2] Upper Colorado River Commission. *UCRC Demand Management Investigation*. Webpage: http://www.ucrcommission.com/ucrc-demand-management-investigation/.

1. Introduction

1.1 Colorado River Drought Contingency Plans

Figure 1-1: Conceptual Map of the Colorado River and the Upper and Lower Colorado River Basins

In response to ongoing dry conditions and depleted storage in the Colorado River Basin, the seven Colorado River Basin States and the Department of the Interior developed a series of Drought Contingency Plans (DCPs) as additional actions beyond those contemplated in the 2007 Interim Guidelines which became effective on May 20, 2019. The DCPs were developed with the intent of reducing the risk of reaching critical elevation levels in Lake Powell and Lake Mead through the Interim Period (through 2026). The Republic of Mexico agreed to participate in drought contingency efforts through its commitments under Minute 323 to the 1944 U.S.-Mexico Water Treaty.

The Upper Basin DCP (consisting of ongoing weather modification programs, the Drought Response Operations Agreement[3] (DROA), and the Demand Management Storage Agreement[4] (DMSA)) marked the culmination of negotiation efforts dating back to 2014.[5]

The Lower Division States of Arizona, California, and Nevada, together with key water users in those states, developed the Lower Basin DCP (consisting of the Lower Basin Drought Contingency Plan Agreement[6] and the Lower Basin Drought Operations Exhibit[7]) to require additional reductions in water use beyond those specified in the 2007 Interim Guidelines to protect Lake Mead elevations and to incentivize additional voluntary conservation and storage at Lake Mead.

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[3] Upper Colorado River Commission. *Drought Response Operations Agreement*. Webpage: http://www.ucrcommission.com/wp-content/uploads/2019/09/Attachment-A1-Drought-Response-Operations-Agreement-Final.pdf.
[4] Upper Colorado River Commission. *Demand Management Storage Agreement*. Webpage: http://www.ucrcommission.com/wp-content/uploads/2020/04/Attachment-A2-Demand-Managment-Storage-Agreement-Final.pdf.
[5] Upper Colorado River Commission. December 10, 2014. *Regarding Development of an Emergency Upper Basin Drought Contingency Plan*. Webpage: http://www.ucrcommission.com/wp-content/uploads/2019/09/Upper_Basin_Drought_Contingency_Plan.pdf.
[6] Upper Colorado River Commission. *Lower Basin Drought Contingency Plan Agreement*. Webpage: http://www.ucrcommission.com/wp-content/uploads/2019/09/Attachment-B-LB-DCP-Agreement-Final.pdf.
[7] Upper Colorado River Commission. *Exhibit 1 to the Lower Basin Drought Contingency Plan Agreement*. Webpage: http://www.ucrcommission.com/wp-content/uploads/2019/09/Attachment-B-Exhibit-1-LB-Drought-Operations-1.pdf.

The Upper and the Lower Basins executed a "Companion Agreement," an agreement to "link" the Upper and Lower Basin DCPs into a coordinated Basin-wide approach.[8]

Figure 1-2: Signing of the DCP Agreements, May 20, 2019

The Upper Division States (UDS) of Colorado, New Mexico, Utah, and Wyoming, through the Upper Colorado River Commission (UCRC), consistent with the DMSA, are investigating the feasibility of a potential DM Program. This report is a summary of the work conducted by consultants hired by the UCRC to support the interstate investigation. In addition, each UDS is conducting its own investigations regarding the feasibility of a potential DM Program. The consideration of feasibility of a DM Program will necessarily require the consideration of both interstate and intrastate issues. Each UDS would have to agree that a DM Program is feasible before such a program could be established.

1.2 Demand Management Storage Agreement (DMSA)

The DMSA requires the UDS and the UCRC to investigate the feasibility of a DM Program in the Upper Basin. Conceptually, a DM Program relies on the conservation of water that would have otherwise been consumptively used. The DM Program would propose voluntary, temporary, and compensated reductions in water use and store the conserved water in certain Upper Basin reservoirs for the purpose of maintaining compliance with the 1922 Compact. The DMSA authorizes the storage of up to 500,000 ac-ft of water in the Colorado River Storage Project Act (CRSPA) Initial Units of Lake Powell, Flaming Gorge, the Aspinall Unit, and Navajo Reservoir through 2057.

The DMSA does not in and of itself establish a formal DM Program. It provides the minimum conditions and requirements necessary to store water conserved through a DM Program. It also secures the authorization for storage capacity in the CRSPA Initial Units at no charge to the Upper Division States and provides the foundation for the legal and policy mechanisms and processes to investigate, establish, and implement a DM Program, if the UDS, through the UCRC, (1) agree to program feasibility, (2) elect to develop a program, and (3) agree to implement the program. The DMSA also requires consultation with the Lower Division States and agreement with the Secretary of the Interior on DM Program operations.

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[8] Upper Colorado River Commission. *Agreement Concerning Colorado River Drought Contingency Management and Operations.* Webpage: http://www.ucrcommission.com/wp-content/uploads/2019/09/Companion-Agreement-Final.pdf.

1.2.1 DM Feasibility

The DMSA sets forth sequential steps for considering, approving, and implementing a DM Program. Specifically, the DMSA requires an investigation of and consensus among the UDS on the following in the assessment of feasibility:

- Verification of and accounting for the actual volume of Conserved Consumptive Use (CCU);
- Conveyance of the conserved water to appropriate destinations and accounting for associated conveyance losses;
- Providing for storage at and release from the CRSPA Initial Units of any CCU;
- Administration of an Upper Basin DM Program;
- Funding of an Upper Basin DM Program; and
- Compliance with federal and state laws within each UDS.

1.2.2 DM Program Development

In addition to the consideration of DM Program feasibility, the framework for a DM Program must include the following requirements:

1) Water conserved will only be recognized as part of a DM Program if:
    a. The source of conserved water is Upper Colorado River System water or imported water;[9]
    b. The water is conserved, stored, and released for the specific purpose of helping the UDS assure continued compliance with Article III of the 1922 Colorado River Compact;
    c. The water must have been beneficially and consumptively used under valid water rights before the year in which the water is being conserved as part of an Upper Basin DM Program (this requirement does not apply to imported water);
    d. The water must have been physically available for diversion in the year it is conserved and would have been beneficially and consumptively used within a UDS but for the conservation for the benefit of an Upper Basin DM Program (this requirement does not apply to imported water); and
    e. The conserved or imported water has arrived at a CRSPA Initial Unit after accounting for any transit and associated losses.

2) Any conserved or imported water to be stored in a CRSPA Initial Unit for the purposes of an Upper Basin DM Program shall be subject to the following:
    a. Assessment of its proportionate share of evaporation during storage;
    b. Available unfilled storage capacity;
    c. An annual creation limitation at the CRSPA Initial Units combined;
    d. A maximum combined storage limitation of 500,000 ac-ft at the CRSPA Initial Units;

[9] Per the DMSA, "Imported Water" means water introduced to the Upper Colorado River System from outside the Colorado River System for the specific purpose of augmenting the supplies available for, or storing water as part of, an Upper Basin DM Program. Such Imported Water need not have been previously consumptively used in its basin of origin.

e. Reduction, in any year in which water flows over or through the spillway at Glen Canyon Dam, by the amount of that flow on an acre-foot for acre-foot basis up to the full amount of water stored under an Upper Basin DM Program; and
f. Annual verification by the UDS, through the UCRC, and the Secretary of Interior, of the volume of conserved water, created, conveyed, and stored at the CRSPA Initial Units.

3) Any conserved water stored and released from a CRSPA Initial Unit under an Upper Basin DM Program shall:
    a. Be accounted for consistent with the provisions in the section above and within this section;
    b. Through the year 2057, not be released or cause a different release from Lake Powell than would have otherwise occurred under the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines) or post-2026 operational rules. This provision survives termination of the DMSA through 2057; and
    c. Be subject to release from any of the CRSPA Initial Units only at the request of the UCRC to help assure continued compliance with Article III of the 1922 Colorado River Compact. This provision survives the termination of the DMSA through 2057.

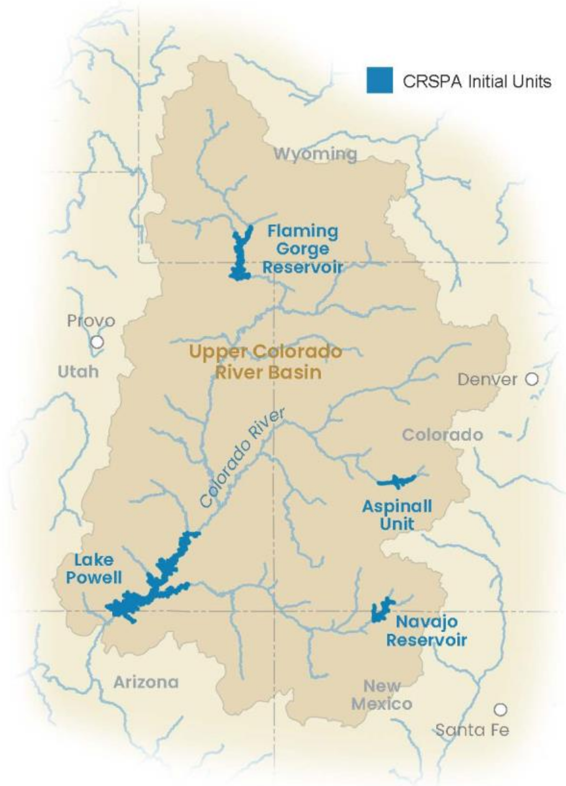

Figure 1-3: Conceptual Map of the Upper Basin and CRSPA Initial Units (Not to Scale)

This investigation includes and explores several DM Program design parameters and scenarios in an effort to inform consideration of potential program development.

1.2.3 DM Program Process

This report is focused on the feasibility investigation, which is the first of several required steps outlined in the DMSA. Subsequent steps are dependent on the consideration of feasibility. The process of implementing a DM Program includes the following:

- A UCRC Finding – As stipulated in the DMSA, the purpose of a DM Program shall be to accomplish a temporary, voluntary, and compensated reduction in consumptive uses in the Upper Basin, if needed in times of drought, and to help assure continued compliance with the 1922 Colorado River Compact. As a first step, the UCRC must make findings that a DM Program is necessary for continued compliance.
- Agreement and Consultation – Through the UCRC, the UDS and the Secretary of Interior must enter into agreements regarding the methodology, process, and documentation for verification and accounting for the creation, conveyance, and storage of conserved water to be stored in and

released from a CRSPA Initial Unit as part of a DM Program. Consultation (on a consensus basis) with the Lower Division States is required before entering into such agreements.

- UCRC Approval: The UCRC must approve the proposed Upper Basin DM Program; and
- State Approval: each UDS, acting through its UCRC representative, must approve the proposed Upper Basin DM Program.

Figure 1-4: Process Outlined by the DMSA for DM Program Consideration

1.2.4 Additional Considerations Post-2026

On December 31, 2025, the Upper Basin DCP, which includes the DMSA, and the 2007 Interim Guidelines, are set to expire. However, they will guide operations through 2026, and certain specific provisions of the DMSA will survive their termination and control the management of stored water through 2057. As noted above, water stored pursuant to the DMSA prior to December 31, 2025, is not subject to release from Glen Canyon Dam as promulgated in the terms of the 2007 Interim Guidelines and any post-2026 reservoir operating rules through 2057.

1.3 Approach to UCRC's Interstate DM Investigation

In 2019, the U.S. Bureau of Reclamation (Reclamation) provided the UCRC with a grant to investigate the feasibility of a DM Program. The UCRC began the effort in the summer of 2019 after the passage of the DCP. The investigation process was conducted through the UCRC's Demand Management Committee (DMC) – a body of representatives from each UDS and UCRC staff that guided the effort. The DMC's interstate effort operated in tandem but separate from the UDS' respective intrastate investigations and began with UCRC issuing a Request for Proposals (RFP)[10] for contractors that could assist the DMC in better understanding the legal, economic, and technical challenges related to interstate aspects of a DM Program.

Figure 1-5: Sequencing of the UCRC Interstate Investigation of a DM Program

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[10] Upper Colorado River Commission. *Request for Qualification-Based Proposals for Professional Services [for the UCRC Demand Management Investigation]*. Webpage: http://www.ucrcommission.com/wp-content/uploads/2019/10/UCRC-Demand-Management-RFP.Final_.pdf.

Awards were made to selected contractors in the summer of 2020, and contracting and development of scopes of work proceeded through the remainder of that year.[11] In 2021, the work assignments related to the investigation began (detailed below). As described in the RFP, the work fell under four general categories proposed for analysis - Legal, Technical, Economic, and Stakeholder Facilitation and Outreach. Consistent with the RFP, the DMC assigned discrete task orders, including the following:

1.3.1 Legal Analysis Scope

The legal analyses contractor was assigned the following tasks related to legal research and review:

1) Identification of existing State and Federal legal authorities that may allow, facilitate, prevent, or constrain DM storage, as well as the potential need for legislative assistance to obtain such storage;
2) Research and review legal and administrative mechanisms necessary to “shepherd” CCU volumes to Lake Powell or other upstream CRSPA Initial Units;
3) Conduct a review of UDS laws related to longer-term participation in a DM Program related to non-impairment of water rights and/or forfeiture or abandonment statutes (e.g., does participation in a DM Program make water rights vulnerable under the laws of each or any State); and
4) Review and document “key findings” of the analysis and provide a listing of “next steps” that could be potentially undertaken to facilitate a successful implementation of a DM Program related to legal authorities and administrative frameworks that accomplish the effective storage and shepherding of DM volumes and flows.

1.3.2 Technical Analysis Scope

The technical analyses were developed by multiple contractors who were assigned the following tasks within three main lines of inquiry: 1) modeling of water supply, reservoir storage, and river/streamflow routing related to DM Program scenarios; 2) conserved consumptive water use monitoring, estimation, verification, and related accounting techniques; and 3) DM Program duration and extent.

1) Investigations of (or related to) water supply, storage, and routing:
    a. Research issues related to storing DM water at Lake Powell and other CRSPA Initial Units relative to a set baseline and potential DM scenarios;
    b. Identify storage potential that may be available in each CRSPA Initial Unit considering the frequency of filling and the likelihood of available capacity to store DM volumes for a significant period;
    c. Identify the technical and legal feasibility of maintaining accounting for storage volumes and system assessments within Lake Powell and other CRSPA Initial Units for storage of conserved water/DM volumes to maintain compliance with the 1922 Compact;
    d. Per the existing authorities and obligations of each UDS to administer waters within the state for purposes of compact compliance, work with the States to evaluate the necessity for and means of monitoring diversion activities to ensure that conserved water can be shepherded to the place of storage; work with the UDS to estimate the likelihood that

[11] UCRC made awards at their Regular Meeting held on May 19, 2020, and at a Special Telephonic Meeting on June 16, 2020. The contractors included Smith Hartvigsen (legal analysis), Desert Research Institute (technical analysis), AMP Insights (economic analysis), JUB Engineers (stakeholder engagement and outreach), and Hazen & Sawyer (project management and technical analysis).

such resources are available now and what might be required for future state resource additions to accomplish such monitoring and shepherding.

2) Monitoring, Accounting, and Verification of Conserved Consumptive Use (CCU) Volumes:
    a. Research methods for measurement and verification of, accounting for, and monitoring of the amount of CCU that could potentially be generated by each of the UDS in a DM Program;
    b. Research techniques or processes to assess CCU volumes related to field fallowing and related conserved volumes traveling from places of historical use to delivery at a designated CRSPA Initial Unit and/or ultimately to Lake Powell, including transit losses;
    c. Research appropriate methods for evaluating evaporation at the CRSPA Initial Units and charging evaporation losses to stored water in Lake Powell or other CRSPA Initial Units;
    d. Evaluate the cost-effectiveness of DM storage for various periods. For example, is there a cost-effective amount of storage beyond which evaporation losses are cost-prohibitive?

3) Duration and Extent of a DM Program:
    a. Research the pros and cons (including economic and environmental considerations) of a DM Program being continuous or “interruptible” (e.g., whether the program should idle in years when the hydrology improves, when certain target elevations at Lake Powell are achieved, or when full DM storage is achieved);
    b. Research and model DM volumes to assess their impact on Lake Powell elevations for the purpose of helping assure continued compliance with the 1922 Compact.

1.3.3 Economic Analysis Scope

The contractor hired to conduct economic analyses was assigned the following tasks related to the compilation and review of economic data and other considerations concerning the range of potential impacts stemming from a DM Program in the Upper Basin.

1) Conduct an extensive literature review of related system conservation, water pricing, and other water conservation studies that could initially inform the investigation as to the state-of-the-science;
2) Develop a detailed description of the baseline/current economic conditions and recent trends in the Upper Basin, with particular emphasis on the direct and secondary relationships between the region’s economic and water use sectors. The baseline was established to assist with the development of DM Program scenarios and as a comparative tool that could help define the potential effects of those scenarios on the economic productivity and health of the Upper Basin;
3) Using the generated baseline and economic models, identify and analyze the nature and magnitude of possible direct and secondary economic impacts across sectors and geographies resulting from the provided DM Program scenarios within the Upper Basin;
4) Provide an array of potential strategies for minimizing negative impacts to water users, rate-payers, and regional and urban economies;
5) Conduct interviews with UDS agency staff and the UCRC to understand the range of potential administrative or transactional (non-participant-compensation) costs related to standing up a DM Program in the Upper Basin;
6) Provide a review of potential funding sources, including Federal, State, and intrastate programs, appropriations, and other funding mechanisms related to or that could be utilized to provide DM Program participant compensation;

7) Conduct a voluntary survey of Municipal and Industrial (M&I) water providers/users in the Upper Basin to understand their interest, willingness, or objections to participating in a potential DM Program.

1.3.4 Stakeholder Facilitation and Outreach Scope

A contractor was assigned tasks related to stakeholder engagement and outreach activities. The contractor developed materials to provide an online central repository for information on the UCRC website where interested parties could look for updates on the investigation timeline and process and also direct such parties back to state-maintained studies and other resources. This work was finalized in the summer of 2022.[12]

2. UCRC Interstate Investigation of Demand Management

2.1 Verification and Accounting for Conserved Consumptive Use (CCU)

Accurate, reliable, and cost-effective CCU estimation is a significant component of a DM Program. There is a range of tools that can assist with this task, including those utilized during prior system water conservation pilots, those explored within this investigation, and ongoing pilots and field studies in the Upper Basin. The System Conservation Pilot Program (SCPP, Pilot) conducted by UDS through the UCRC from 2015-2018 provided valuable lessons relating to the quantification of temporary, voluntary, and compensated reductions in consumptive use and has helped to inform discussions and this investigation on approaches for estimating water conservation efforts at field scale.[13] Likewise, intrastate studies and pilot efforts to quantify CCU using remote-sensing tools in the Upper Basin have provided informative data and results.[14] This summary report on the UCRC's feasibility investigation restates some of the known tools for this quantification step and further explores some of the nascent remote-sensing-based approaches that allow for CCU quantification at scale.[15] An exploration of the possible transactional costs related to verification and accounting can be found in Section 2.5.3.

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[12] Upper Colorado River Commission. *UCRC Demand Management Investigation*. Webpage: http://www.ucrcommission.com/ucrc-demand-management-investigation/.

[13] The Colorado River System Conservation Pilot Program (SCPP, Pilot) was part of a larger basin-wide program supported by M&I and NGO partners interested in pursuing water conservation initiatives. The goals of the SCPP were to explore and understand whether voluntary, temporary, and compensated reductions in consumptive use in the Upper Basin were feasible to partially mitigate declines in elevation seen at Lake Powell and be utilized as a drought mitigation tool. From 2015-2018, the SCPP funded 64 projects for an estimated CCU of approximately 47,213 ac-ft at a total cost of $8.52M. The SCPP established that there was interest in participating in voluntary reduction in consumptive use, and demonstrated the ability to administer a program, but also highlighted some of the difficulties of such an approach. This investigation builds on the lessons learned from SCPP to inform a potential DM Program in the Upper Basin. For more about SCPP, access the UCRC's webpage at: http://www.ucrcommission.com/system-conservation-pilot-program/.

[14] Cabot, P., Derwingson, A., Torres-Rua, A. (2020). *Evaluating Conserved Consumptive Use in the Upper Colorado – 2020 Report*. Website: https://www.waterinfo.org/wp-content/uploads/2021/12/Evaluating-Conserved-Consumptive-Use-in-the-Upper-Colorado-Basin_2020-Project-Report-00484067xC13E4.pdf.

[15] In November of 2021, the U.S. Congress passed the Investment in Infrastructure and Jobs Act (IIJA) also known as the Bipartisan Infrastructure Law (BIL) with funding allocated for Colorado River Basin DCP implementation. The UDS and UCRC requested support for the Upper Basin DCP in the form of additional measurement, monitoring, and verification instrumentation that could be used for both DROA and a potential DM Program. These infrastructure components include an expanded eddy-covariance (EC) tower and weather station network, soil moisture and snow monitoring, field-scale water balance and transit loss studies, and reactivation and installation of streamgages. The preliminary siting/scoping for this instrumentation is underway.

2.1.1 Estimation of Historical Consumptive Use

Per the DMSA, all water considered for conservation in a DM Program is required to have been placed to beneficial consumptive use and be available for use in the year of participation. Program administrators will need to establish historical consumptive use by the participants and the status of the user's entitlement during the period of proposed conservation. Depending on the monitoring, reporting, and historical information compiled for the participant, this may be a straightforward process, or it may require extra verification steps before application or proposal approval. As further described in section 2.1.3, Desert Research Institute's (DRI) assigned task was to perform an analysis of remote-sensing applications to evaluate participating SCPP fields. DRI was able to determine whether ET (and subsequent estimates of consumptive use related to irrigation) could be measured over a specified time period and a detectable pattern of ET and irrigation consumptive use be established, with the caveat that other variables (e.g., weather, field management, etc.) may also need to be evaluated. They acknowledged that their approach may be insufficient and require other steps for verification. They also reviewed remote-sensing applications for evaluation of historical use patterns, further described below.

2.1.1.1 Historical Consumptive Use Review

All UDS maintain extensive data related to water rights administration and water-related land-use, including agricultural Geographic Information System (GIS) data. The DM Program application or proposal phase may require review, in coordination with the relevant State Engineer's Office or other agency, to ascertain the historical usage of the water right(s) in question. This would be a required step for all applicants, including both M&I and agricultural enrollees. Along with other application criteria and submission requirements, an important DM Program design element will be to establish relevant timeframes and approaches for estimating water use for the years prior to participation. Expedited water use reporting may be required for applicants that are interested in participating in an upcoming season, year, or relevant timeframe if the data for an immediately prior year are not yet available. In such cases, it may be necessary that the applicant develop supplementary information (e.g., metered data, field surveys, imagery, pumping records, etc.) that can be used as supporting evidence for a pattern of historical use.

For applicants that wish to enroll agricultural lands in a DM Program, remote-sensing tools that have been developed to estimate water use can be useful as either a primary or supplementary source of information for establishing historical trends of use. Relevant ET data can be extracted for the area of interest and included in an applicant package as a preliminary or expedited step toward establishing historical use patterns. This approach can be used in tandem with the relevant State Engineer's Office or other agency verification steps to provide a comprehensive and vetted picture of historical water use as a baseline for participation in a DM Program. As mentioned in SCPP documentation,[16] it will be important to solicit the right set of information from applicants to capture the necessary level of detail for each proposed project.

2.1.1.2 Water Availability in Year of Participation

Similar to the steps outlined above, there may need to be a consideration of whether the conserved water would have been available to the water user during the year of participation in a DM Program. There may be additional supplementary data and information required for this analysis as proof of eligibility. This second review would likely need to occur in the early spring timeframe for both types of enrollees as the coming year's hydrologic situation develops. There may also be a need for continued monitoring of water availability throughout the participation period.

2.1.2 On-site Direct Monitoring and Measurement of CCU

During the SCPP, program administrators worked with participants or their representatives to establish project-specific verification plans that were included in their final contracts. Each plan contained procedures to verify and document that the participant had complied with their individual plan. These included the use of existing measurement devices as well as sufficient and controllable diversion structures (these were required for participation), combined with field site visits during the irrigation season. Field visits and metering data were used to verify that each Pilot participant had adhered to their plan. Measurement of CCU was done via post-processing using various estimation approaches available at the time of the Pilot.[17]

For larger diversions (transmountain diversions, metered diversions related to M&I entities, or agricultural canals), there is an existing network of measurement infrastructure that can serve to establish historical water use trends and also serve to document a corresponding reduction in requested water deliveries that result in CCU. There may be regions where this degree of instrumentation and monitoring capability is not feasible. In these cases, remote-sensing approaches may be helpful.

2.1.3 Remote-Sensing Approaches to Monitoring and Measurement of CCU

The Desert Research Institute (DRI) specializes in remote-sensing approaches for the estimation of actual cropland ET and related agricultural irrigation consumptive water use (a fraction of the actual ET estimate). DRI collaborated with OpenET, a satellite-based ET cloud-computing, and data services platform,[18] to evaluate the following:

1) Investigate any correlations and/or relationships between a proxy for crop water demand (Net Reference ET[19]) and the difference between ET rates for fully irrigated versus fallowed fields;

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[16] Upper Colorado River Commission. (2018) *Appendix C: 2018 System Conservation Pilot Program Update*. Website: http://www.ucrcommission.com/RepDoc/SCPPDocuments/2018_SCPP_RUFinal.pdf.

[17] Related post-project estimates of CCU were developed using climate data from nearby weather stations and each State's preferred method (Modified Blaney-Criddle for New Mexico, Utah, and Colorado, METRIC for Wyoming). These results were then adjusted to account for water supply limitations related to the relative wetness or dryness experienced in the Upper Basin for each year of the Pilot. These estimation approaches pre-date the adoption of a unified interstate remote-sensing-based method for estimating CCU by the Upper Division States and the UCRC in June of 2022, as discussed in later sections of this report.

[18] Melton, F., Huntington, J.L., Grimm, R., Herring, J., Hall, M., Rollison, D., Erickson, T., Allen R., Anderson, M., Blankenau., P., et. al. 2021 (in proof). *OpenET – Filling the Biggest Data Gap in Water Management for the Western U.S*. Journal of the American Water Resources Association. OpenET builds upon decades of research by NASA, USGS, USDA and university partners, and involves more than 45 scientists and software engineers from four NASA Research Centers, USGS, USDA, seven universities including DRI, NGOs, and private sector partners. OpenET provides monthly and annual ET data at 30m using Landsat imagery, weather data, and well-established ET models on the Google Earth Engine cloud-computing platform.

[19] Net Reference ET refers to the evapotranspiration rate from a fully watered reference surface, in this case grass-alfalfa.

2) Summarize ET data across the Upper Basin for recent sample years that could serve as a baseline comparison against conservative DM Program participation assumptions;
3) Analyze and review historical ET data for SCPP participant fields to detect reduced ET and identify data requirements or "lessons learned" needed to effectuate a remote-sensing approach;
4) Evaluate remote-sensing approaches to estimating the ET associated with riparian corridors in Upper Basin tributaries and the Colorado River mainstem to assist with the estimation of transit loss (provided in Section 2.3.1); and
5) Using riparian ET and other factors, assist with the development of strategies to optimize CCU conveyance and DM storage and release timing (further presented in Section 2.4.3).

2.1.3.1 Net Reference ET vs. Difference in Fully-Irrigated, Partially-Irrigated, and Fallowed Fields

State-by-state comparisons of ET rates were developed for 2016-2020 to provide average differences between fully-irrigated, partially-irrigated, and fallowed conditions throughout the Upper Basin. These estimates showed variability in ET related to management practices, such as irrigation and crop type, as well as climate and hydrology. This was confirmed by completing a regression analysis for both fully-irrigated and partially-irrigated fields minus fallowed-field ET rates.[20] The regression analysis for the state-level average growing season ET rates shows differences between fallowed and fully-irrigated conditions ranging from 0.93-2.0 feet and differences between partially-irrigated and fully-irrigated conditions ranging from 0.45-1.45 feet (Figure 2-1, next page).

[20] In line with recommendations made by the Upper Colorado River Basin Assessment for Agricultural Consumptive Use Study - Phase III Report and the adoption of the Earth Engine Mapping EvapoTranspiration at High Resolution and Internalized Calibration (eeMETRIC) remote sensing method (RSM) by the UCRC in June of 2022, eeMETRIC-based ET estimates were used for all comparisons, etc. during this investigation. Irrigation classifications were made using the NDVI-based Harmonized Landsat Sentinel-2 Mapper (publication pending) developed in conjunction with the Consumptive Use Study. Study reports may be accessed on the UCRC webpage: http://www.ucrcommission.com/reports-studies/.

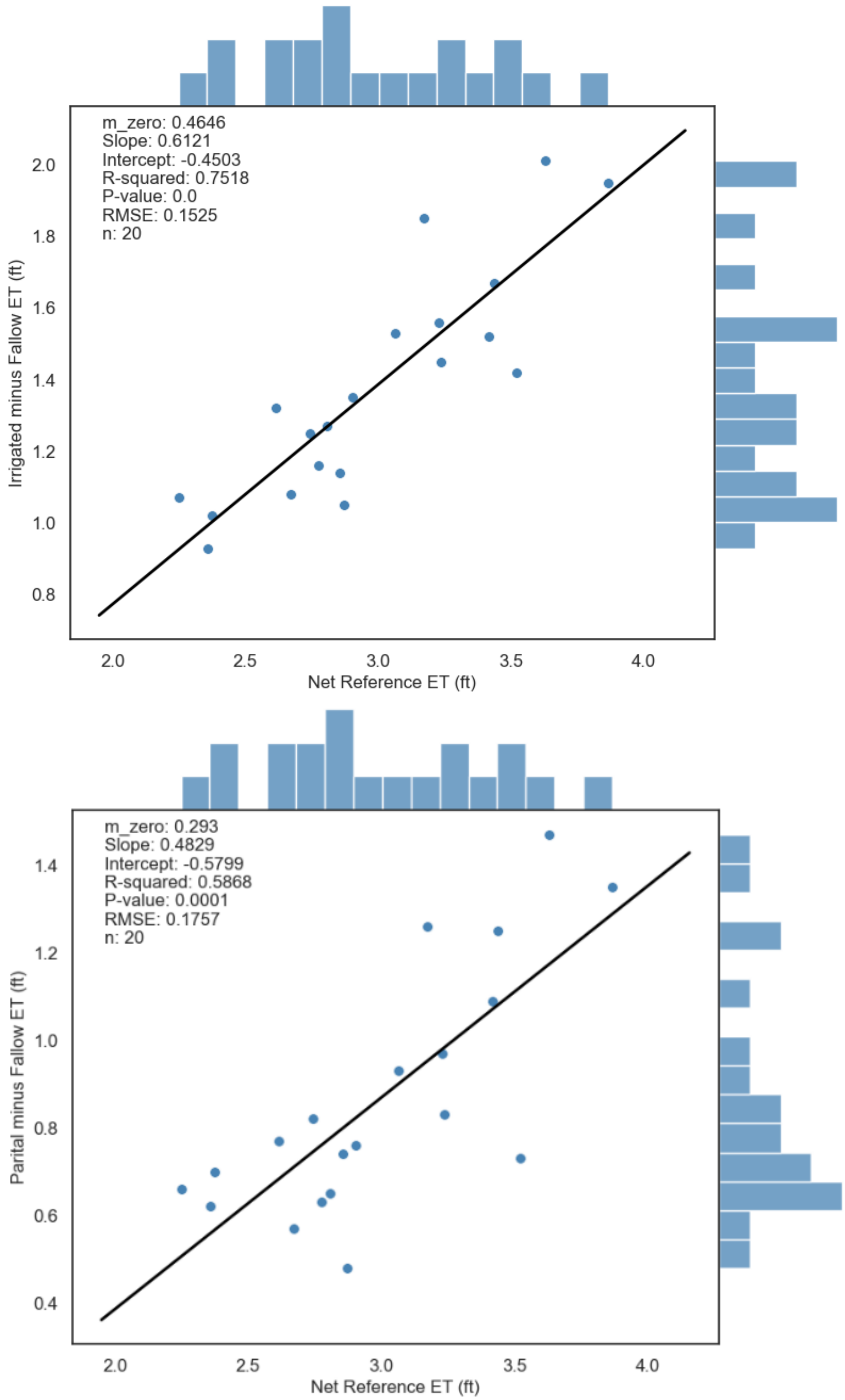

Figure 2-1: Regression analysis between top) Fully-Irrigated – Fallowed ET rate and bottom) Partially-Irrigated – Fallowed ET versus Net Reference ET. Each point represents an estimate from a state for 2016-2020. Irrigation classifications are based on the Harmonized Landsat Sentinel-2 (HLS) classification method. Blue bars along each axis represent the distribution of values for that parameter.

Observed differences between irrigated and fallowed-field ET rates are a function of water availability, climate, crop type, and location (e.g., latitude, elevation, and/or riparian vs. upland). Comparison of state-level, well-watered (i.e., 75th percentile) ET rates from alfalfa, grass hay, and corn crops indicate that alfalfa fallowing has the highest CCU potential, followed by grass-hay, and finally corn (Table 2-1).

Table 2-1: 2016-2020 Average 75th percentile Growing Season and Annual ET Rates Aggregated by State and USDA Cropland Data Layer (CDL) Crop Type. The standard deviation is shown in parentheses.

	Q75 Growing Season ET Rates (inches/growing season)			
	Alfalfa	**Grass Hay**	**Corn**	**Other**
Colorado	35.5 (1.2)	32.2 (1.4)	30.8 (2.9)	30.8 (2.1)
New Mexico	42.7 (2.3)	36.2 (2.3)	35.9 (2.7)	33.4 (3.5)
Utah	34.8 (1.4)	32.9 (1.6)	31.4 (2.4)	24.9 (3.4)
Wyoming	31.2 (1.5)	30.2 (0.7)	24.3 (5.2)	27.0 (2.1)
	Q75 Annual ET Rates (inches/year)			
	Alfalfa	**Grass Hay**	**Corn**	**Other**
Colorado	39.2 (1.0)	34.9 (1.2)	33.7 (2.6)	34.6 (2.0)
New Mexico	48.1 (2.3)	42.0 (2.8)	40.3 (2.6)	38.3 (3.5)
Utah	37.3 (1.3)	35.3 (1.5)	33.3 (2.4)	27.8 (2.8)
Wyoming	32.5 (1.4)	31.7 (1.0)	25.8 (6.4)	28.2 (2.0)

2.1.3.2 Summary of Upper Basin ET Rates and Potential CCU of a DM Program

Utilizing the estimates of ET for fully-irrigated, partially-irrigated, and fallowed fields for the three primary crop types (alfalfa, grass hay, and corn), average CCU by state can be used to frame a range of potential CCU savings. For example, if a hypothetical DM Program yielded 100,000 acre-feet fo water, the data from 2016-2020 suggests a 10% fully irrigated-to-fallowed conversion scenario. CCU estimates produced by this hypothetical scenario were based on average rates and generalized conditions; the actual application of a DM Program would require more detailed site-by-site considerations. The above illustrates how DM Program design criteria that consider crop type, climate, and other hydrology factors will necessarily influence actual CCU results.

2.1.3.3 SCPP Field Investigations

Investigations into all participating SCPP field ET rates showed a range of responses to fallowing. Evident decreases in ET and consumptive use were observed in upland settings where direct irrigation provided the primary source of water for the crop (Figure 2-2, bottom figure, next page). No consistent, measurable response was detected for fields located in riparian areas where continued access to shallow groundwater or sub-irrigation from adjacent fields likely mitigated irrigation removal to varying degrees (Figure 2-2, top figure, next page).

The comparison of SCPP field ET data with participation timeframes revealed the need to confirm baseline water usage prior to fallowing in order to identify and exclude fields where regular historical fallowing has occurred. Furthermore, consistent, accurate field boundary delineation was identified as a necessity to track the true extent of participation and to reliably monitor and quantify the impacts of fallowing on CCU from year to year.

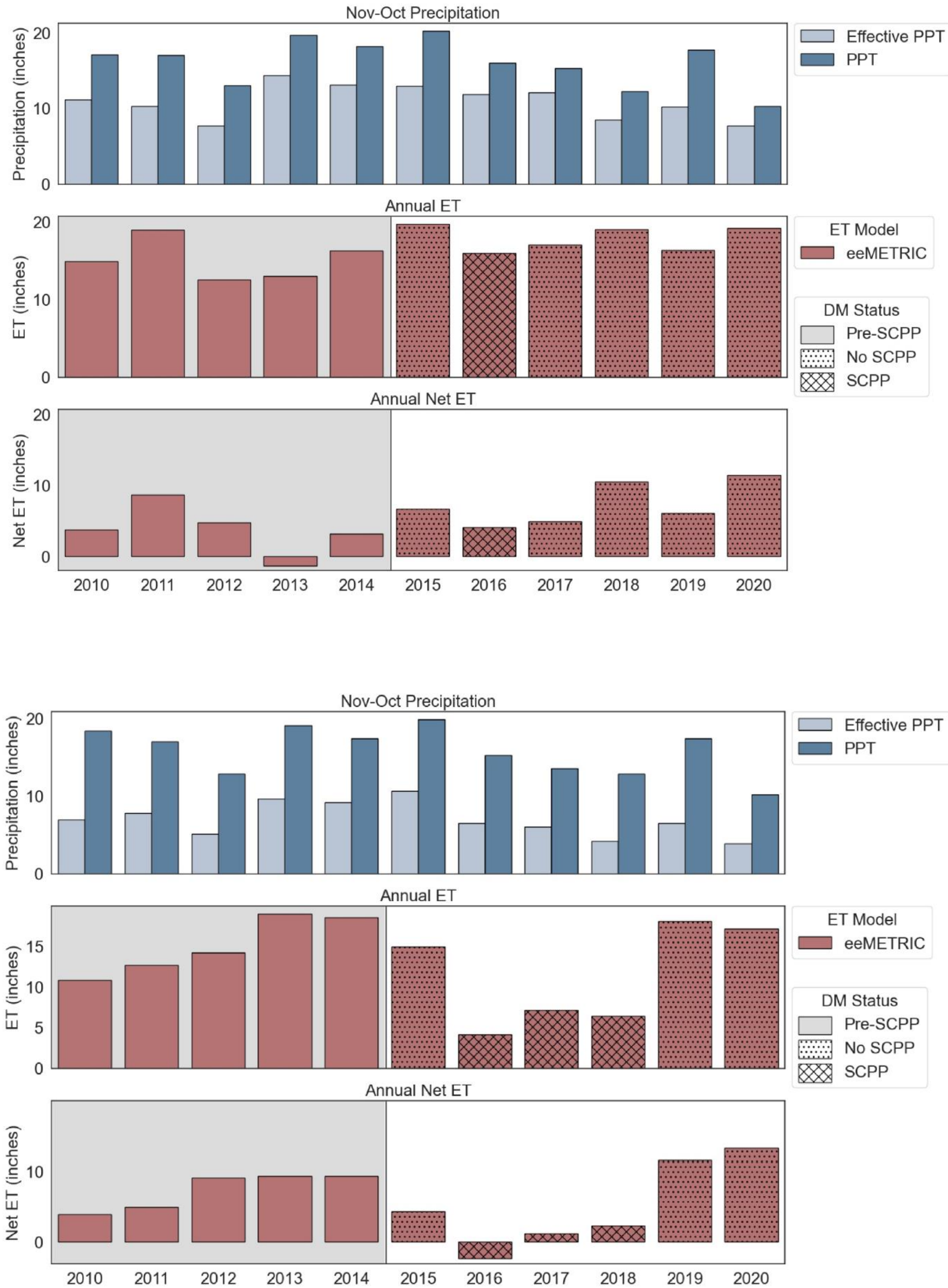

Figure 2-2: Time Series Plot of Annual Precipitation, Actual ET, and Net ET for Two Example SCPP fields located in Top) Riparian and; Bottom) Upland Setting. Clear reductions in ET and Net ET are observed during SCPP participation years at the upland site, while no significant change was seen at the riparian location. Negative ET values indicate groundwater storage used in subsequent time-step analyses.

Effective precipitation influences agricultural field management and related irrigation, making temporal comparisons difficult without clear information on irrigation type, irrigation rate (e.g., deficit irrigation), crop type, and planting dates and extent. Field-scale effective precipitation estimates do not currently exist; therefore, temporal comparisons made during this investigation relied on crop modeling based on historical management practices and growth under well-watered conditions. Spatial comparisons of ET rates from irrigated, partially-irrigated, and fallowed fields may provide another method for estimating CCU if field-scale effective precipitation estimates are not readily available.

RSM estimates can provide average ET rates for different irrigation classes and crop types, which in turn can be used to assess differences in water use between fully-irrigated, partially-irrigated, and fallowed fields on a year-to-year basis. Unlike temporal approaches, spatial comparisons eliminate the use of gridded precipitation datasets which have significant spatial and temporal uncertainty in areas of complex terrain, as is evident in the Upper Basin. Spatial comparisons made during this study used average fallowed field ET as a proxy for effective precipitation; however, the use of other reference surfaces, such as natural vegetation or shrublands, may provide more representative estimates of effective precipitation and should also be evaluated.

2.2 Tools for Estimating Evaporation at CRSPA Initial Units

DRI was also tasked with evaluating any existing or new tools that can be used to estimate evaporation losses at the CRSPA Initial Units for the purposes of assessing potential losses and optimizing storage.

The Lake Evaporation Model (LEM) developed by Zhao and Gao[21] produces reservoir evaporation estimates at daily and monthly time steps using near-surface weather data with the Penman combination equation. The LEM model was applied to Lake Powell and the upstream CRSPA Initial Units using RTMA data from 2016-2020. Estimates of total evaporation for each of the six reservoirs are shown below in Table 2-2, next page.

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[21] Zhao, G., & Gao, H. (2019). *Estimating reservoir evaporation losses for the United States: Fusing remote sensing and modeling approaches*. Remote Sensing of Environment, 226, 109-124.

Table 2-1: LEM Annual Evaporation Estimates for 2016-2020

	Annual Evaporation Estimates from LEM (inches/year)					
Reservoir	**2016**	**2017**	**2018**	**2019**	**2020**	**Average**
Lake Powell	52.5	52.4	52.0	50.3	51.1	51.7
Flaming Gorge Reservoir	40.1	39.6	40.7	37.2	41.8	39.9
Navajo Reservoir	46.5	48.9	48.4	45.4	47.5	47.3
Blue Mesa Reservoir	40.3	41.4	39.8	37.9	39.4	39.8
Morrow Point Reservoir	43.5	43.3	42.9	39.7	42.6	42.4
Crystal Reservoir	45.7	44.3	45.1	42.9	46.0	44.8

Detailed comparisons of daily and monthly LEM estimates to eddy-covariance (EC) data collected at Lake Powell from 2019-2020 generally show good agreement. For daily data, results indicate slope values of 0.96 and 0.91, r-squared values of 0.26 and 0.53, and Root Mean Squared Error (RMSE) values of 0.047 and 0.039 inches per day for Warm Creek and Padre Bay, respectively. For monthly data, results were slightly better with slope values of 1.07 and 0.97, r-squared values of 0.89 and 0.94, and RMSE of 0.98 and 0.72 inches per month with comparisons at Warm Creek and Padre Bay, respectively.

Other locations show similar temporal patterns to Lake Powell with generally lower evaporation rates due to reservoir location (higher elevation and latitude), causing colder air and water surface temperature and reduced evaporative demand (Figure 2-3, next page). Generally, peak evaporation from LEM occurs in late summer and fall time periods. This was also observed to some degree with in-situ estimates of evaporation at Lake Powell. Heat storage within the water body alters the timing and magnitude of available energy for latent and sensible heat flux.

Conversely, shallow water bodies warm more quickly than deeper systems and exhibit less heat storage, and demonstrate evaporation timing patterns more in line with annual temperature and incoming solar radiation patterns. Peak evaporation at Crystal Reservoir occurs earlier than other locations due to the average depth of the reservoir falling below 65.6 ft (a critical depth threshold in the evaporation calculations) during the 2016-2020 study period. All other reservoirs had depths consistently greater than 65.6 ft from 2016-2020. Incorporating depth information, especially during low storage periods when average depths are less than 65.6 ft, is critical for accurately estimating reservoir evaporation using this method.

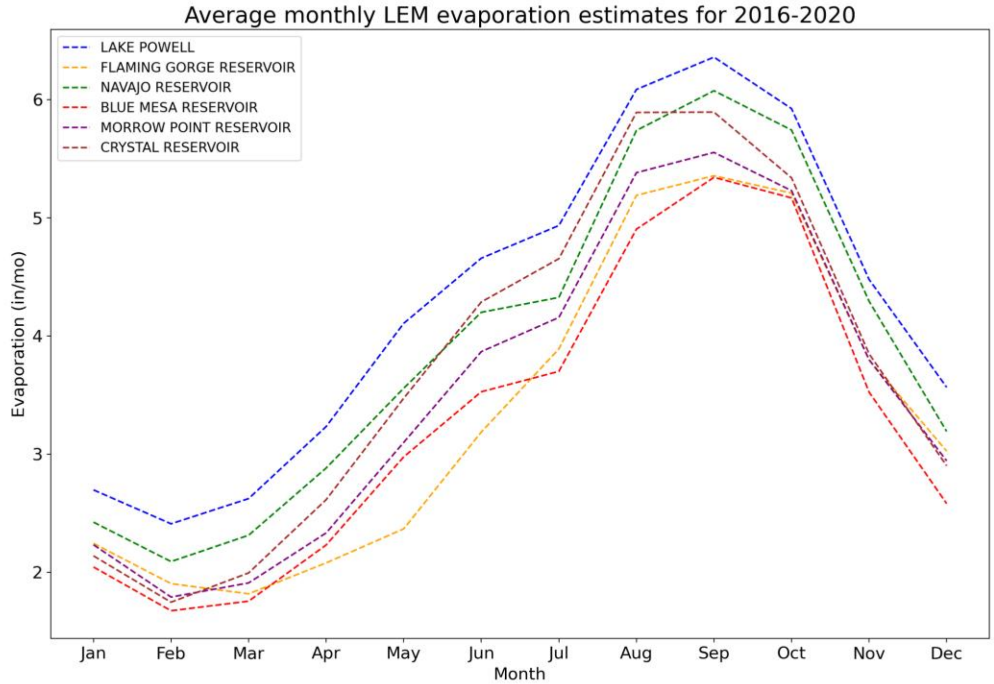

Figure 2-3: Average Monthly LEM Evaporation Estimates for 2016-2020 for all CRSPA Initial Units.

Additionally, consideration of heat advected into and out of the reservoir through inflows and outflows will be different for each reservoir depending on location and operations, such as the timing and magnitude of releases or penstock elevations. Validation using in-situ or remotely-sensed surface temperature data may help reduce the uncertainty of simulated heat storage within the LEM model.

2.3 Estimation of Riparian ET Losses

DRI and Hazen & Sawyer (Hazen) were tasked to work in tandem to address investigation questions concerning the estimation of transit losses associated with CCU volumes shepherded downstream to CRSPA Initial Units. Figure 2-4, next page, illustrates a model of conceptual gains and losses during transit through a hypothetical reach. Transit losses are highlighted in yellow in Figure 2-4 and are further described in Table 2-3 on the following page.

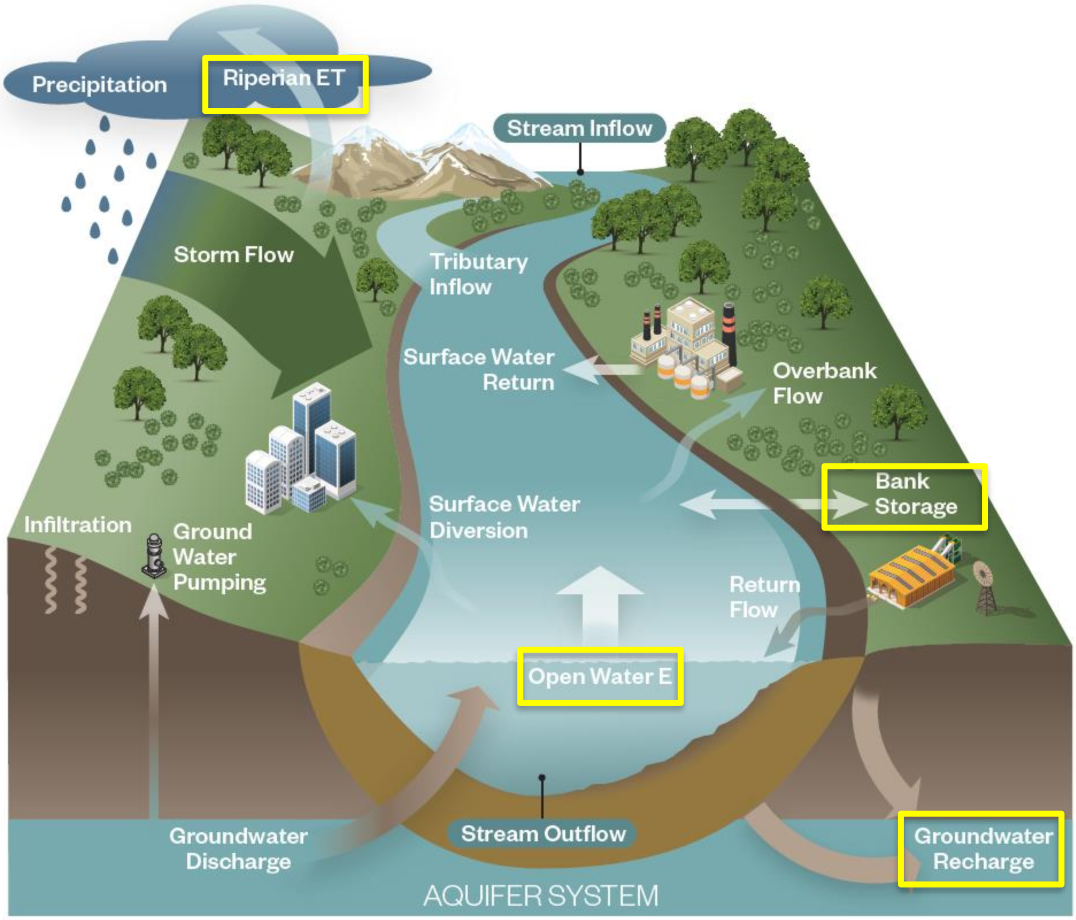

Figure 2-4: Conceptual Model of Reach Gains and Losses (Hazen, 2022)

Table 2-3: Summary of Conceptual Losses During Transit

Source of Transit Loss	Description
Riparian Evapotranspiration (ET)	• Reflects depletions resulting from ET associated with riparian vegetation • Influenced by temperature, precipitation, net irradiance, vegetative cover, and water availability • Recent advances in remote-sensing have increased the ability to efficiently calculate and scale estimates of riparian ET for river basin scale applications • *Current research suggests this is the largest source of natural surface water losses during transit, although this varies by location and site characteristics.*[22]
Open Water Evaporation	• Accounts for direct evaporative losses from the water surface • Influenced by temperature, wind, precipitation, net irradiance, river stage, and reach geometry • *Expected to be a smaller loss than riparian ET but to occur with a similar seasonal cycle*
Bank Storage	• Defined as water that is stored in the reach bank/channel reach resulting from an increase in stage • Influenced by flow volume, duration of high flow event, and amount of time between subsequent high flow events • Only a portion of bank storage is considered "lost" since water is eventually returned to the reach after flows have receded (generally within days to months) • *Losses from bank storage accounted for within riparian ET and/or groundwater recharge/infiltration*
Groundwater Recharge	• Reflects surface water seepage to deep aquifers • Influenced by local soil moisture, geologic conditions, differential head between groundwater and surface water, and groundwater pumping • *Significant uncertainty associated with the magnitude of these losses given geological heterogeneity and inability to measure groundwater storage and pumping at scale*

The contractors reviewed documentation and, where possible, quantified transit losses that CCU may experience in the process of being shepherded from its place of origin to an upstream CRSPA Initial Unit and/or to Lake Powell. Of the sources of transit losses described in Table 2-3, riparian ET was the only component that could be quantified, given existing data. Other elements of transit loss were not quantified for the following reasons:

- Channel open water evaporation was not quantified, given the need for reach-specific geometries and the general assertion that it is expected to be a smaller contributor to transit losses when compared to riparian ET.

[22] Zipper, Samuel C., et al. "Quantifying Streamflow Depletion from Groundwater Pumping: A Practical Review of Past and Emerging Approaches for Water Management." *JAWRA Journal of the American Water Resources Association* 58.2 (2022): 289-312.

- Bank storage was not quantified, given that most losses are eventually returned to the reach and that real losses are accounted for within riparian ET and groundwater recharge.[23]
- Groundwater recharge was not quantified, given the lack of observational data availability and relative complexity required to model losses and/or gains.[24]

This task also discussed approaches the UDS may employ to account for transit losses in their routine water administration. Lastly, a proposed approach was explored to incorporate transit losses into existing modeling tools for the Upper Basin.

2.3.1 Quantification of Riparian ET

Riparian ET[25] is a key component of water loss during transit from one storage location to another; however, it is seldom quantified. While streambed seepage losses may be significant in some areas (e.g., due to groundwater withdrawals for irrigation and subsequent ET), such losses are difficult to quantify and likely minimal compared to riparian ET losses that can be more readily and accurately estimated at scale.[26] Given these challenges, subsequent analyses focused on riparian ET variability and magnitude at six Upper Basin catchments to better understand the controls and drivers of transit-based evaporative losses (Figure 2-5).

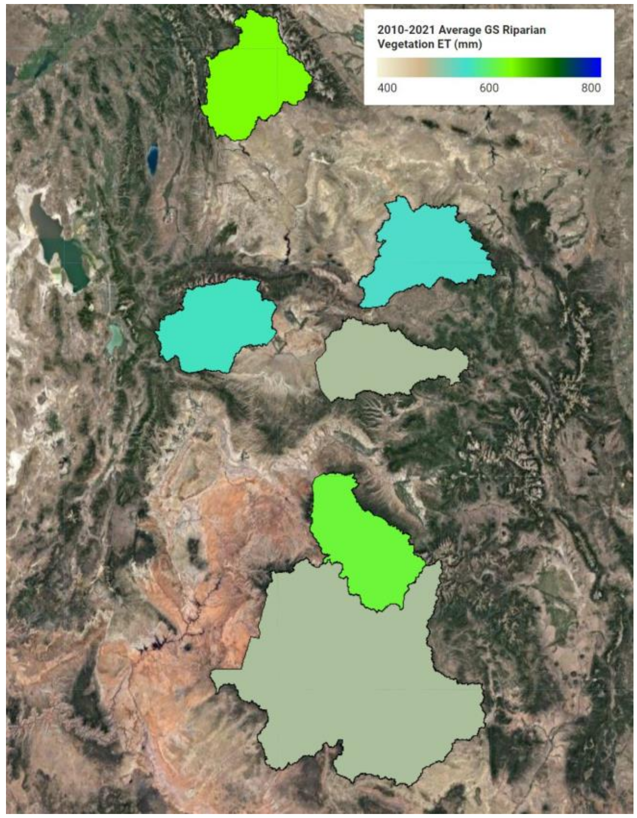

Figure 2-5: Map of 2010-2021 Growing Season ET Rates for Riparian Areas in the Study Catchments

The combination of evaporative demand, plant type, and water availability in this study governed riparian ET rates for each study catchment area. The highest average growing season and annual riparian vegetation ET rates

[23] Livingston, Russell K. *Transit losses and travel times of reservoir releases along the Arkansas River from Pueblo Reservoir to John Martin Reservoir, southeastern Colorado*. No. 78-75. US Geological Survey, 1978. Also see Pahl, 1985, Page 19 of citation below: "Livingston argues that the evaporation loss is the only true loss to the system; therefore, conveyance losses to a downstream on-channel reservoir, which has the capability of collecting virtually all water in bank and channel storage in the recession of a release from an upstream reservoir, should be only those losses from evaporation, transpiration, and groundwater withdrawals."

[24] Groundwater/surface water interactions in the Upper Basin are an area of active research involving complex modeling using coupled hydrologic-groundwater flow models (e.g., Rosenberg et al., 2013; Tran et al., 2020).

[25] ET is actual ET (mm), Net Reference ET (ETo) is grass reference ET (mm), and EToF is the fraction of Reference ET (unitless). Actual ET from eeMETRIC represents water flux from both evaporation and transpiration. ET is a function of both atmospheric and plant water demand as well as water availability. Atmospheric water demand is driven by both regional and local climate with specific links to the vapor pressure deficit (i.e., air temperature and humidity), solar radiation, and wind speed, while plant water uptake is a generally driven by plant type, leaf density, and productivity. During water limited periods, EToF decreases due to plant stress from insufficient available soil moisture.

[26] Pahl, Randall A. *Conveyance losses due to reservoir releases in natural streams in Wyoming*. U of Wyoming, 1985.

were seen in the Green River and Dolores River catchments, while the lowest riparian vegetation ET rates were seen in the San Juan and White River catchments (Table 2-4).

While evaporative demand was relatively high in the San Juan and White River catchments, water availability and vegetation vigor throughout the riparian zone were low, and therefore actual ET rates were low (i.e., maintained a complementary relationship). Higher Normalized Difference Vegetation Index (NDVI) values observed in the Green River catchment reflected generally healthy grasses that are typical throughout riparian areas of Wyoming. Conversely, the San Juan catchment showed predominantly lower NDVI values throughout the riparian zone. Lower NDVI is reflective of the lower-density sage and black brush that is typical of riparian areas in southern Utah and New Mexico.[27]

Table 2-4: 2010-2021 Growing Season (GS) Riparian ET Statistics for Each Study Catchment Area
The table is sorted with the lowest ET rate catchments at the top and the highest at the bottom. Standard deviation values are shown in parentheses.

Catchment Area Average	Growing Season ET (mm)	Growing Season EToF	Growing Season ETo (mm)
WHITE RIVER NEAR WATSON, UTAH	504 (33)	0.54 (0.05)	963 (50)
SAN JUAN RIVER NEAR BLUFF, UT	509 (27)	0.47 (0.04)	1117 (56)
LITTLE SNAKE RIVER NEAR LILY, CO	546 (42)	0.60 (0.06)	925 (46)
DUCHESNE RIVER NEAR RANDLETT, UT	557 (36)	0.59 (0.04)	952 (53)
GREEN RIVER NEAR LA BARGE, WY	621 (46)	0.73 (0.05)	852 (45)
DOLORES RIVER NEAR CISCO, UT	630 (28)	0.63 (0.03)	1016 (61)

EToF distributions for each catchment follow similar patterns to NDVI but also reflect water availability and soil moisture since EToF incorporates both ET's evaporation and transpiration components. Unlike NDVI, wet soil or exposed surface water has high EToF due to evaporation (not transpiration).

Figure 2-6, next page, shows three observed riparian zones in the Upper Basin that highlight the different vegetation/moisture scenarios, which strongly affect the associated EToF and NDVI values.

[27] Woodward, Brian D., et al. (2018*) CO-RIP: A riparian vegetation and corridor extent dataset for Colorado river basin streams and rivers*. ISPRS International Journal of Geo-Information 7.10: p 397.

Figure 2-6: Left) Aerial photo of Green River, WY riparian zone, Middle) Aerial photo of White River, CO riparian zone, Right) Aerial photo of San Juan River, NM riparian zone.

- High NDVI, High EToF
    - Dense, vigorous riparian vegetation with relatively high soil moisture
    - High transpiration
    - Left example of Figure 2-6: Green River, WY
- Low to moderate NDVI, High EToF
    - Sparse and or stressed vegetation with relatively high soil moisture
    - Potential for exposed surface water if NDVI values are negative
    - High evaporation
    - Middle example of Figure 2-6: White River, CO
- Low NDVI, Low EToF
    - Sparse and or stressed vegetation with relatively low soil moisture
    - Low transpiration and evaporation
    - Right example of Figure 2-6: San Juan River, NM

Regression analysis between ET, EToF, and ETo shows a strong correlation between growing season EToF and ET (r-squared=0.67, Figure 2-7, next page), while ETo is not significantly correlated with riparian ET rates (r-squared = 0.07, not shown). ETo represents the potential ET from a well-watered grass surface and is considered a proxy for atmospheric evaporative demand. Results indicate that interannual variability in riparian ET rates throughout the Upper Basin is more closely tied to vegetation vigor and water availability than to climate.

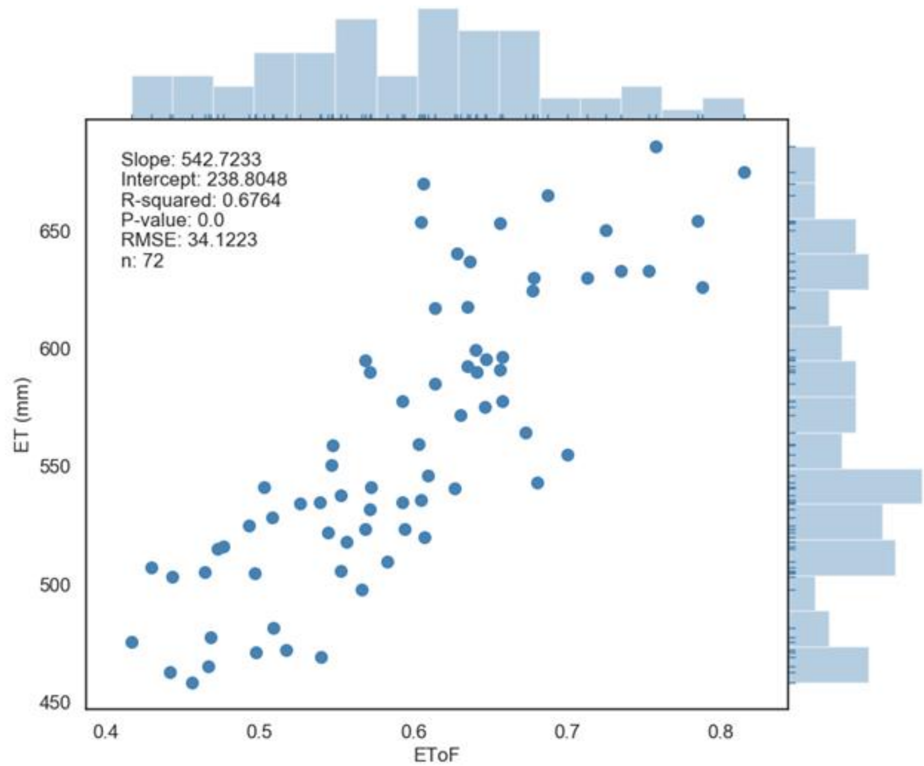

Figure 2-7: Scatterplot between Growing Season Riparian EToF and ET within the Catchment Areas between 2010-2021. Each point represents a single catchment for a single year between 2010-2021 (6 catchments, 11 years, 72 observations)

Regression analysis between average growing season streamflow and riparian EToF show positive relationships for all catchment areas. This finding suggests that increases in streamflow result in higher ET through increased water availability and plant productivity throughout the riparian zone. Notably, most catchment areas demonstrate breakdowns in the linear relationship between flow and EToF at lower flows. This low-end scatter is likely related to substantial vegetation stress and potential reduction in the extent of riparian vegetation growth during low-flow periods.

Increases in EToF indicate more vegetation vigor and, or surface evaporation; however, overall ET is a function of both plant productivity and atmospheric demand. Analysis between streamflow and actual ET rates did not demonstrate significant relationships. The complementary nature of atmospheric demand and moisture availability drives actual ET rates. This complementary feedback is especially true for the Upper Basin, where clear hot/dry, and cool/wet seasonal climate patterns prevail.

Analysis between monthly streamflow and EToF showed clear seasonal patterns, with most sites exhibiting stronger correlations during summer months than winter. Higher correlations during summer are likely driven by increases in atmospheric and plant water demand. Relationships during winter are less prominent due to dormant vegetation. Results from the remotely-sensed riparian ET analysis show that the lowest ET rates occur during the winter and spring. In agreement, Livingston found that releases during periods of lower antecedent streamflow resulted in more significant losses to bank and channel storage but notes these are not actual losses since they are recoverable at some time scale unless extracted by riparian vegetation for transpiration.[28] Low ET rates and high flow conditions make late winter and early spring the most efficient time for conveying stored water from one location to another (with site-specific exceptions). ET rates and streamflow relationships established by this analysis apply to other areas throughout the Upper Basin and provide a path forward for the incorporation of actual ET rates within integrated modeling and planning studies related to transit loss and optimization of storage and release.

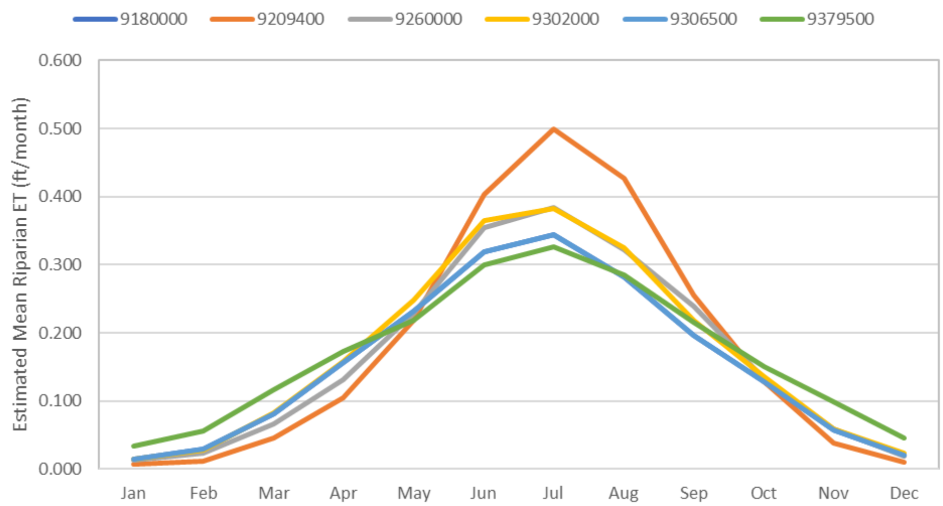

Figure 2-8: Summary of Monthly Average Riparian ET in Catchments above Selected Gages

Figure 2-8 shows that, on average, 89% of annual riparian ET calculated at the gage locations occurs between April and October.[29] The seasonal timing and estimated rate of the riparian ET are generally consistent with reservoir evaporation in the Upper Basin (see Figure 2-3), with annual peaks occurring in July and the majority of ET occurring between April and October.

An average volume of riparian ET for each catchment was estimated by multiplying the ET rate by the riparian corridor vegetation area. This information was used to estimate annual volumetric riparian ET losses in the six catchment areas, summarized in Figure 2-9, next page. Estimated volumetric losses from riparian ET are in a similar order of magnitude to reservoir evaporation for the CRSPA Initial Units examined in Section 2.2.

[28] Ibid. pg. 20.

[29] On average, 75% of annual riparian ET calculated at the gage locations occurs between May and September.

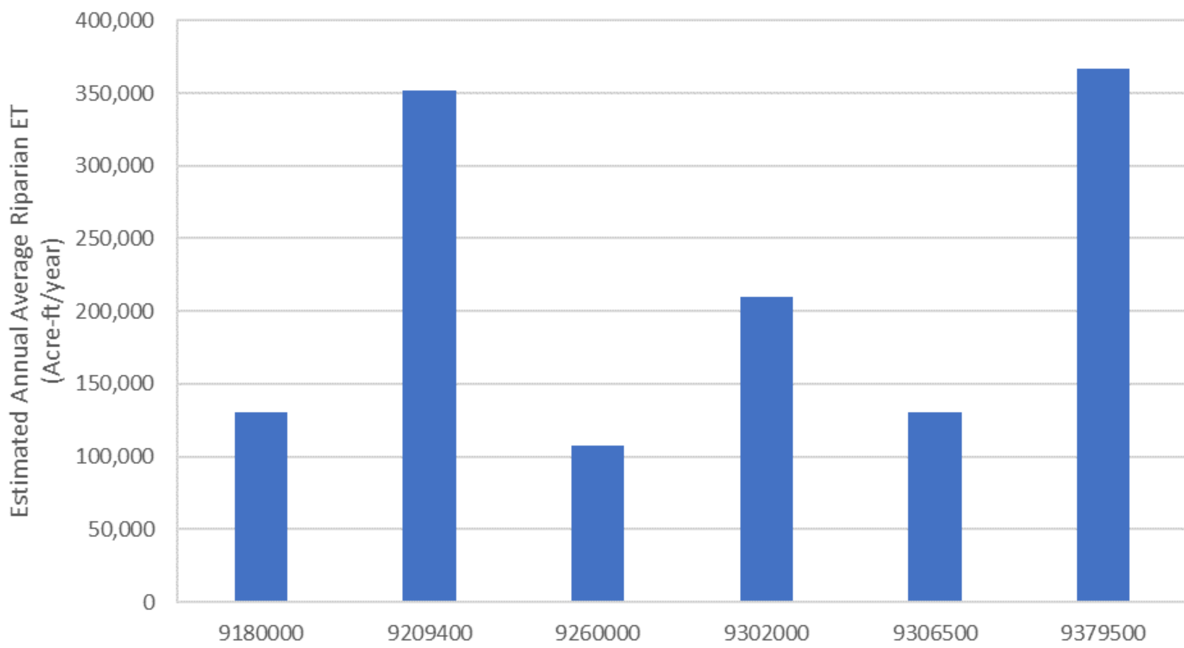

Figure 2-9: Estimated Annual Average Riparian Corridor ET for Study Catchments

2.3.2 Approaches to Quantifying Transit Loss Employed by UDS

UDS DMC members were interviewed regarding state calculation or estimation of transit losses and approaches to estimating transit losses for CCU (Table 2-5).

Table 2-5: Summary of UDS' Approaches to Quantifying Transit Losses

State	Approach to Quantifying Transit Losses
Colorado	• Daily transit losses tracked for all reservoir releases • Losses are highly dependent on short-term factors such as bank storage, attenuation, and travel time that tend to "even out" over longer time scales
New Mexico	• Currently working on several initiatives, including the development of a RiverWare™ model for the San Juan Basin that includes estimated transit losses.
Utah	• Static losses applied to reservoir releases specific to each administrative basin and date back to original decrees • Generally, on the order of 1-2%, but can vary by basin and seasonally • Little documentation defining the quantification methodology
Wyoming	• Some basins within the state have established transit loss rates. • Commissioned earlier studies that attempted to look at losses within managed basins.[30,31] These studies are not currently used operationally.

[30] Hasfurther, V.R. (1985). *The Use of Meander Parameters in Restoring Hydrologic Balance to Reclaimed Stream Beds.* Book Chapter 5 in The Restoration of Rivers and Streams Theories and Experience. Wyoming Water Research Center, University of Wyoming, Laramie, WY.

[31] Turner, J.P., Hasfurther, V. (1992). *Modeling of hydrologic conditions and solute movement in processed oil shale waste embankments under simulated climatic conditions*. Environmental Simulation Lab, University of Wyoming, Laramie, WY.

2.4 Storage and Release from the CRSPA Initial Units of CCU

To better understand the potential range of storage and release resulting from a potential DM Program Hazen was asked to conduct a baseline vs. DM scenario analysis using CRSS. For the study, Hazen used the CRSS version released by Reclamation in April 2021 and then repeated the analysis with the January 2022 release (with no specified DROA operations). The analyses relied on a comparison of baseline CRSS simulations of specified supply, demand, and operational scenarios with potential hypothetical DM Program scenarios developed by the DMC for selected metrics. As part of this modeling effort, DM scenarios and related impacts to storage and releases were simulated by adjusting CRSS rulesets. Similarly, the simulations run by Hazen included the development of DM accounts, scenario-specified DM CCU contributions, and accrual parameters, rules for the assessment of evaporative losses within the DM account, and DM water conveyance rules.

2.4.1 DM Program Hypothetical Scenarios

The modeled baseline included a range of water supply, demand, and operations described in

TableTable 2-6 through the end of the modeling period of 2057 (the expiration of some of the provisions of the DCP).

Table 2-6: Assumptions for Modeled Future Baseline Conditions

Hydrologic Ensembles	Description
Full Hydrology (i.e., "Historical")	Historical hydrology from1906 to 2019, re-sampled using the index sequential method[32] to produce 114 traces[33]
Stress Test Hydrology	"Stress test" hydrology based on the recent 30-year period from 1988-2019, re-sampled using the index sequential method to produce 32 traces
CMIP3 Hydrology	112 traces derived from the Coupled Model Intercomparison Project 3 (CMIP3) – a dataset based on climate models
Demand	
2016 UCRC Depletion Demand Schedule[34]	A series of estimated current and future depletion demand projections used for planning purposes by the UCRC and the UDS. This is the default demand variable in CRSS.
Operations	
2007 Interim Guidelines (Early CRSS Models and then with No DROA Operations)	2007 Interim Guidelines and the 2019 Drought Contingency Plan are extended through the end of the simulation period – with and without DROA Operations

[32] An index sequential method repeats historical hydrology as a continuous sequence changing the starting year with each simulation.
[33] A "trace" is one instance or sequence of hydrology. For example, the measured historical record from 1906 – 2019 represents a single trace.
[34] Upper Colorado River Commission (2017). *2016 Depletion Demand Schedule. The schedules used in these analyses was incorporated into the CRSS versions in use at the time of the model release, and pre-date the Updated 2016 Depletion Demand Schedule released by UCRC in June of 2022*. Webpage: http://www.ucrcommission.com/upper-colorado-river-division-states-depletion-demand-schedules/.

To evaluate a potential DM Program, the DMC provided Hazen with a range of potential hypothetical DM contributions modeled over varying accrual timeframes. Modeled CCU contributions for each state were distributed geographically and by agriculture, export, and M&I sectors based on 2020 pro-rata depletions as outlined in the 2016 UCRC Depletion Demand Schedule.[35]

The DMC further provided model conditions that would initiate a DM Program and specify when it would become dormant. For practical modeling purposes, it was assumed that once a DM Program was begun, it would remain active through at least one entire irrigation season, regardless of changing conditions.

Resulting CCU was modeled to ultimately reside in Lake Powell, accruing losses due to evaporation. For the purposes of modeling, if model flows at the Lee Ferry Deficit Object (LFDO) were reduced below 75 maf over a ten-year period, the DM storage volume was modeled as a release. In some hydrologic scenario traces, the DM storage volume was also released as a “spill” due to high runoff.[36]

2.4.2 DM Hypothetical Scenario Modeling Results

The following sections review the modeling results detailing the frequency of DM Program initiation and related volumes of CCU stored, the storage potential in upstream CRSPA Initial Units, and sample trace analyses of DM storage releases.

2.4.2.1 Modeled Frequency of DM Program Initiation and Volume of CCU

The potential frequency of hypothetical DM Program implementation and the volume of CCU accumulated is dependent on the assumed conditions for initiation, hydrologic scenario, accrual period of the DM Program (e.g., how long it takes to accrue CCU), and specifics of CCU contributions by state and sector. The scenarios provided by the DMC resulted in conditions that initiated a hypothetical DM Program in about 35% of the CMIP3 and Stress Test hydrology traces within the first five years of the simulation periods compared to less than 25% of the traces in the Full Hydrology ensemble (Figure 2-10, next page).

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[35] Ibid.
[36] The LFDO object in Reclamation’s CRSS model is a component for measuring flow at a specific location in the Colorado River Basin but in no way is indicative of any policy, procedure, or precedent regarding any interpretation of the “Law of the River” and should not be construed as such.

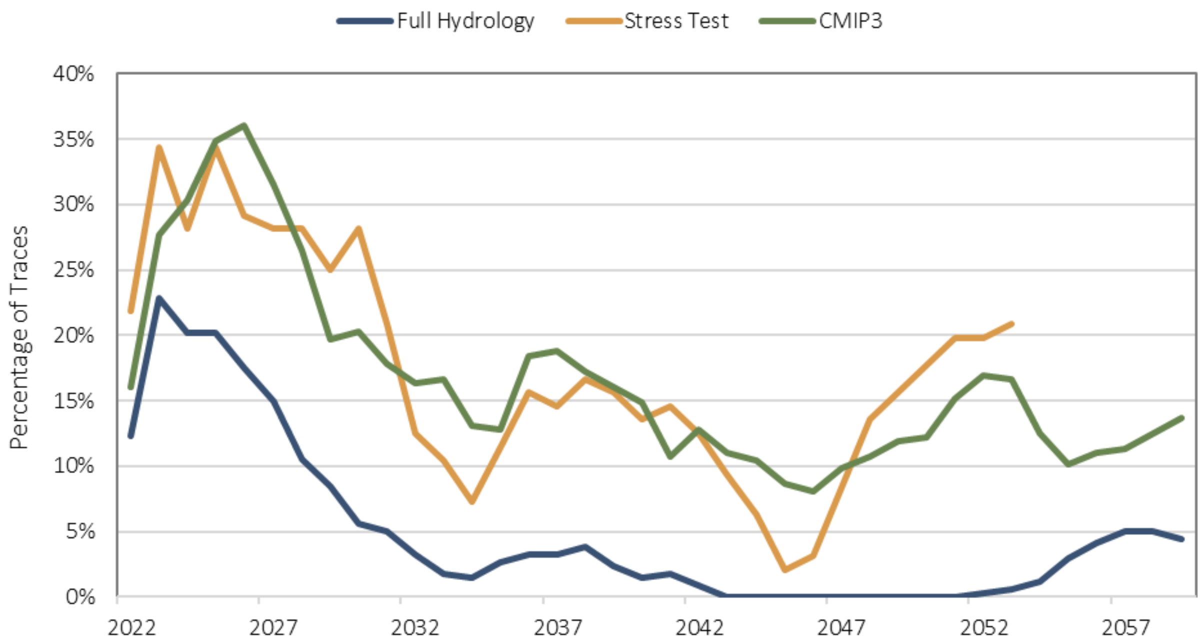

Figure 2-10: Percentage of Traces with Initiation of a DM Program per Hydrology Ensemble

The frequency of DM Program initiation within any given trace depended on Lake Powell storage and elevation and the frequency and volume of modeled subsequent DM-related releases (e.g., where DM storage was called upon to sustain flows at the LFDO). DM releases were made in 0% of traces under the Stress Test and Full Hydrology ensembles but were present in over 25% of the CMIP3 traces after 2043 (Figure 2-11, next page).

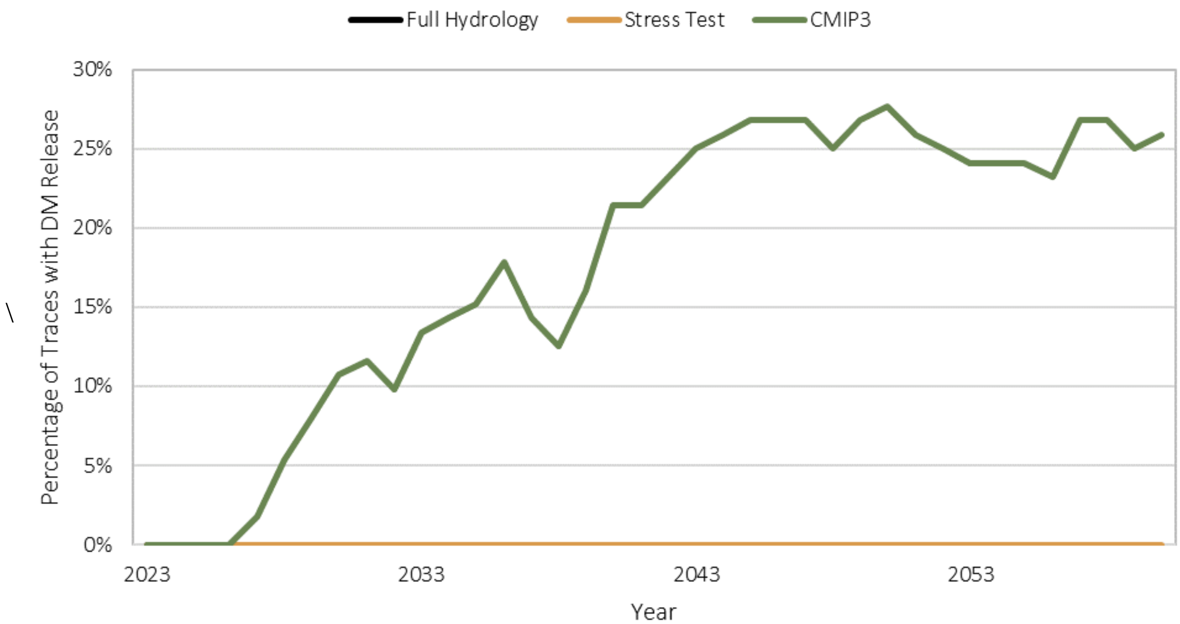

Figure 2-11: Percent of Traces with DM Release per Hydrology Ensemble

In the model results, the frequency of the initiation of a hypothetical DM Program and the amount of CCU stored were more sensitive to hydrology and length of the accrual window than various CCU contribution levels from the states. More CCU was conserved in traces of drier hydrologic ensembles because the DM Program was initiated more frequently, sometimes coupled with DM releases.

As illustrated in Figure 2-12, next page, on a temporal basis, more DM water was stored in scenarios with shorter accrual timeframes. The shorter accrual scenario differed from longer durations of the same in part because longer accrual durations resulted in smaller storage volumes before DM releases were required to be made. Generally speaking, more DM water was stored and released in scenarios with shorter accrual timeframes and drier hydrology ensembles.

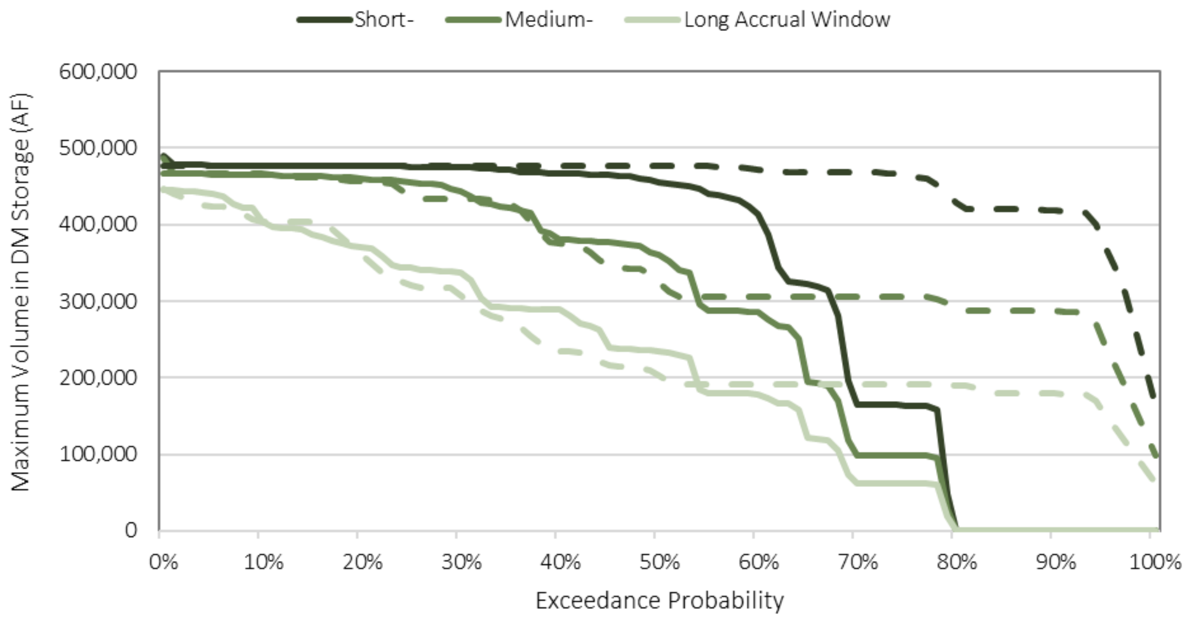

Figure 2-12: Distribution of Maximum DM storage by Trace (inc. Evaporative Losses) for CMIP3 hydrology ensemble (solid lines) and Stress Test hydrology ensemble (dashed lines)

2.4.2.2 Modeled Storage Potential in Upstream CRSPA Initial Units

Storage potential in upstream CRSPA Initial Units was examined by comparing CRSS-modeled storage (across the Full, Stress Test, and CMIP3 hydrology ensembles) to the following parameters:

- Live storage capacity identified for each upstream CRSPA Initial Unit in CRSS;
- Modeled volume of CCU above and below each upstream CRSPA Initial Unit.[37]

Table 2-7 summarizes the DM scenario volumes of CCU water (totaled across all traces) conserved above upstream CRSPA Initial Units. The total volume of potential CCU storage potential differs based on the hydrology ensemble; however, consistently 20% of the CCU volume occurs above the upstream CRSPA Initial Units.

[37] Blue Mesa is assumed to be representative of conditions in the Aspinall Unit.

Table 2-7: Summary of Potential DM Storage in Upstream CRSPA Initial Units. Summary Statistics are Calculated Across All Modeled Traces for Each Hydrology Ensemble

Initial Unit	% of Months All CCU Can be Stored	Total Potential CCU Storage (AF)	Total CCU Bypassed to Lake Powell (AF)	% of CCU Bypassed to Powell
Full Hydrology				
Flaming Gorge	100%	1,958,736	0	0%
Blue Mesa	99.2%	523,107	55,763	10.7%
Navajo	99.5%	965,077	68,316	7.1%
Stress Test				
Flaming Gorge	100%	1,775,883	0	0%
Blue Mesa	100%	468,365	0	0%
Navajo	99.9%	874,709	22,415	2.6%
CMIP3				
Flaming Gorge	99.9%	7,203,215	50,504	0.7%
Blue Mesa	99.3%	2,110,106	403,147	19.1%
Navajo	99.5%	2,838,577	950,796	33.5%

In most months in which a DM Program was active, there was sufficient physical space to store CCU in the upstream CRSPA Initial Units. However, in months where storage was limited, significant volumes of the conserved water would need to be bypassed to Lake Powell. Flaming Gorge was in the best position of the upstream CRSPA Initial Units to retain CCU water on both a volume and percentage basis. The capture of CCU in excess of the available storage in Blue Mesa was likely limited due to modeled operations of Morrow Point and Crystal reservoirs downstream. Navajo Reservoir was slightly more constrained than Blue Mesa. Other operational considerations, such as environmental flows, hydropower operations, operational spill, and rule curves, have the potential to impact the ability to store CCU in upstream CRSPA Initial Units; however, additional modeling would be required to further quantify these impacts.

2.4.2.3 Modeled Analysis of DM Releases

The risks and mitigation related to a hypothetical DM Program and theoretical compliance with provisions of the 1922 Compact were considered using three modeling metrics. These modeling metrics are solely for discussion purposes and are not intended to be viewed as a policy consideration relative to compliance with provisions of the 1922 Compact.

1. The number of subsequent months that DM releases were requested by the model versus the baseline;
2. The modeled frequency of DM releases versus the baseline (measured as a percent of hydrologic traces modeled); and
3. The modeled DM release volume versus the baseline. Modeling showed that there was a marginal improvement in DM release volume requests (results not shown).

Figure 2-13, next page, illustrates the difference in the number of months in which DM releases were requested by the model versus the baseline. The figure shows that the initiation of a DM Program reduces the number of months where DM releases are requested by the model for up to 27 months within the most impacted trace as compared against all traces in the ensemble. The number of months with DM releases was not particularly sensitive to the scenario program accrual window or relative contribution amounts from various states. Conceptually, this finding indicates that a hypothetical DM Program could successfully reduce risk related to compliance with the 1922 Compact within the model space by reducing the duration and/or frequency of requested DM releases in CRSS.

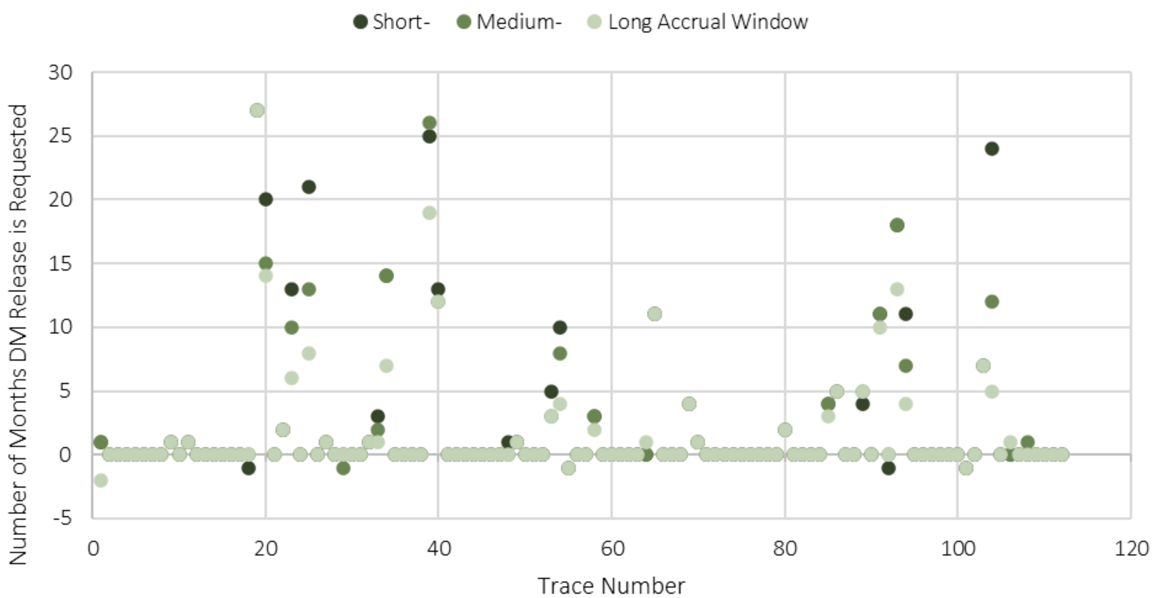

Figure 2-13: Difference in the Number of Months of hypothetical DM Release Requested by the Model Relative to the Baseline with the CMIP3 Hydrology Ensemble

Figure 2-14, next page, shows the modeled frequency of requested DM releases versus the baseline. The figure shows that the initiation of a DM Program can reduce the percentage of traces where DM water is released but does not have a significant impact on the total volume of the requested DM release.

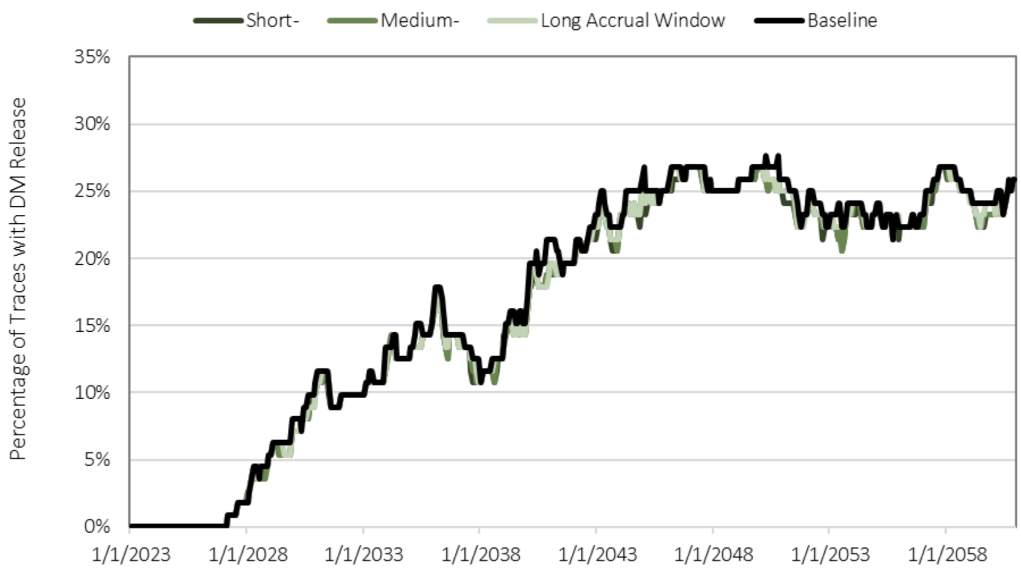

Figure 2-14: Percentage of Modeled Traces with Requested DM Releases within the CMIP3 Hydrology Ensemble and Varying Accrual Windows

2.4.2.4 Modeled DM Storage Evaporation

Hazen also provided an analysis of the expected losses of stored CCU due to reservoir evaporation and examined the potential effectiveness of reducing evaporative losses by maintaining DM storage in upstream CRSPA Initial Units (see also Section 2.4.3 on Optimization).

Higher evaporative losses were associated with scenarios in which more water was stored but not required for later release by the model (e.g., in the Full Hydrology ensemble) or for scenarios where DM water is stored at the beginning of the simulation and released at the end of the simulation (e.g., in the Stress Test Hydrology Ensemble). Figure 2-15, next page, shows DM storage and related evaporative losses as an exceedance distribution for the CMIP3 hydrology ensemble and varying accrual windows. In the figure, 50% of the traces result in a storage volume of approximately 250,000-480,000 ac-ft with attendant losses of approximately 40,000-100,000 ac-ft.

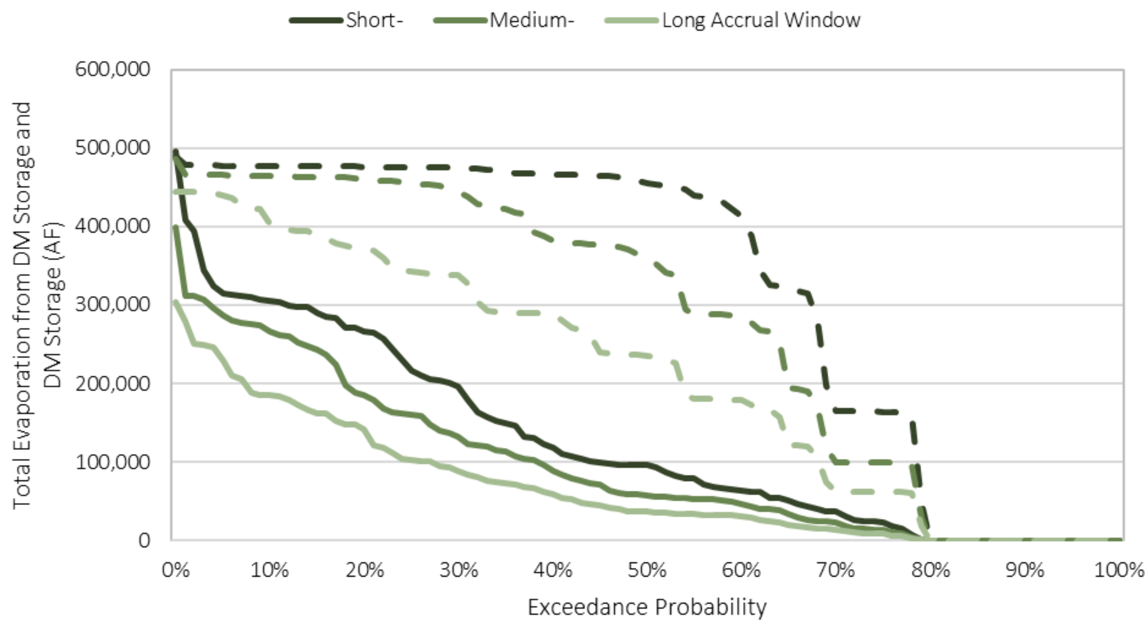

Figure 2-15: Distribution of Total DM storage evaporation (solid) and Total DM storage (dashed) for CMIP3 Hydrology Ensemble and Varying Accrual Window

CRSS represents evaporation in the upstream CRSPA Initial Units based on the product of a monthly varying evaporation rate and the modeled reservoir surface area. The evaporation rate is distinct for each reservoir in the model; Figure 2-16, next page, plots the modeled evaporation rates for each of the CRSPA Initial Units analyzed in the above section. Blue Mesa, Flaming Gorge, and Navajo Reservoir had significantly lower evaporation rates (45-94% of Lake Powell's rates by month).

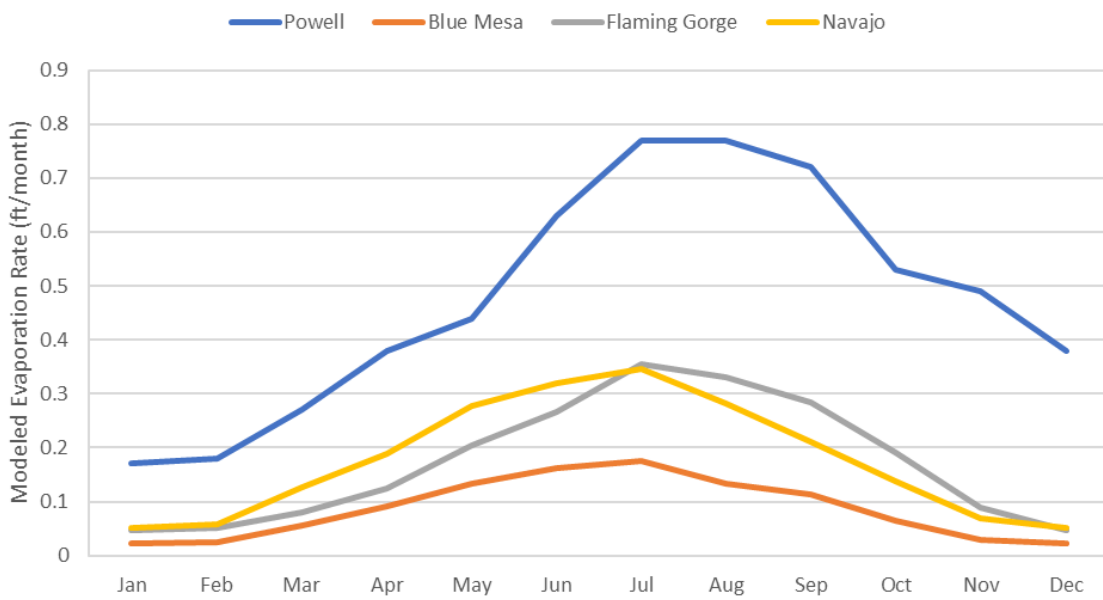

Figure 2-16: CRSS Evaporation Rates for Upstream CRSPA Initial Units

CRSS modeling suggested that, on average, 20% of expected CCU (approximately 100,000 ac-ft out of the total 500,000 ac-ft) may be conserved in upstream CRSPA Initial Units. An estimated breakdown of the total modeled CCU above each upstream CRSPA Initial Unit is presented in Table 2-8. Available storage in the upstream CRSPA Initial Units varies based on modeled hydrologic conditions; however, under most conditions, there was sufficient void space to capture the majority of CCU.

Table 2-8: Distribution of CCU in CRSPA Initial Units

CRSPA Initial Unit	Modeled Approximate Max. CCU (ac-ft)
Flaming Gorge	58,051
Blue Mesa	16,270
Navajo	25,679
Lake Powell	400,000
Total	**500,000**

Based on these findings, and if all available CCU[38] upstream could be stored in the upstream CRSPA Initial Units, rough calculations estimate that annual evaporative losses from the upstream CRSPA Initial Units would be approximately 1,867 ac-ft per year on average.[39] If the same volume of CCU were stored only in Lake Powell, annual evaporative losses would be 3,474 ac-ft per year on average. Under these assumptions, maximizing storage of CCU in the upstream CRSPA Initial Units could result in up to 46% less evaporative loss than if all CCU were stored in Lake Powell.

[38] Available CCU in this context refers to all CCU generated above the upstream CRSPA Initial Units equivalent to 20% of the total 500,000 ac-ft or 100,000 ac-ft.
[39] Assumes long-term average reservoir storage and annual average evaporation rates.

2.4.3 Optimization Strategies for Hypothetical DM Storage Release and Conveyance

DRI and Hazen analyzed potential DM storage and release strategies. Analyses showed that a potential strategy for storage, release, and conveyance of CCU would be to:

1. Hold CCU storage in the upstream CRSPA Initial Units for as long as possible in order to minimize evaporative losses during said storage; and

2. Prioritize CCU releases to Lake Powell during winter months to take advantage of relatively low riparian ET and water demand (see Section 2.3.1). (However, this is not always the case in all locations.)

Consistent with this potential strategy, CCU would need to be released from the upstream CRSPA Initial Units at appropriate times. Storing CCU in upstream CRSPA Initial Units provides flexibility in the timing of DM releases. Given this flexibility, CCU releases may be prioritized during the winter months as:

- Riparian ET, which is expected to make up the largest measurable transit loss, is at an annual minimum during these months (see Figure 2-8); and

- Water demand is also expected to be the lowest during these months, which decreases the need for water administration activities.

2.5 Primary and Secondary Economic Impacts of a DM Program

AMP Insights provided a comprehensive study at an interstate scale of an economic baseline and primary and secondary economic impacts associated with a potential DM Program with three components:

1. Quantitative analysis of potential impacts on agricultural water users;
2. Qualitative analysis of potential impacts on M&I water users, and
3. A review of potential programmatic risks that could result in adverse economic impacts to participants and/or DM activities as well as options to mitigate those risks.

2.5.1.1 Economic Analysis Methods

Relevant baseline information on agricultural production in the Upper Basin, combined with the key assumptions of each DM scenario, was used to estimate the potential adverse direct and secondary economic impacts of a DM Program on gross crop revenues at a state and interstate scale. That analysis did not include estimates of direct participant compensation or the potential positive secondary impacts of participant compensation on the regional economy, which may offset adverse impacts to both individual participants and the broader regional economy.

Participation in a potential DM Program by agricultural producers would require reducing consumptive water use otherwise used for irrigating crops. Fallowing, in turn, results in decreased crop production and the need for variable inputs such as seed, fertilizer, water, and labor. The analysis proved by AMP made several high-level assumptions that were applied to the DM scenarios provided by the DMC.[40]

- Participating acres were fallowed for the full irrigation season;
- Fallowing was temporary and rotational;
- Any potential injury to other water users from fallowing would be assessed and mitigated if needed before an individual agricultural producer would be allowed to legally participate; and
- Only decreases in consumptive water use were considered.

Participation by crop type was assumed to be proportional to current production levels (measured in acres). No assumptions were made regarding the type of irrigation method (and resulting efficiency), farm size, ownership structure, or geographic location; however, findings from various conservation projects and other recent publications on the potential economic impacts of a DM Program suggest that not only likeliness to participate, but also the cost-effectiveness of water acquired may vary based on these (and other) key variables.

The starting point for estimating the direct impacts of each DM scenario was the remaining water available for agriculture annually in each state after that state's modeled DM contribution for the year was met per the DM scenarios provided. This was calculated by subtracting the modeled annual DM water savings volume from the estimated average annual historic amount of water consumptively used by agriculture.

Dividing this total amount of water by the estimated average consumptive use per acre for each UDS resulted in an estimate of the total number of acres within each state that could be irrigated in that year. Subtracting this number from the average or "typical" historical average number of acres irrigated annually provided a representative estimate of the number of acres that would need to be fallowed annually in each state to provide the water that could meet that state's modeled DM scenario contribution.

Next, the fallowed acres were "assigned" a crop — based on the predetermined crop mix for the Upper Basin region of each state — as well as an estimated loss in yield for both the enrollment year and the subsequent year. In order to estimate the total value of gross revenue from crops lost annually, the total units (i.e., tons for alfalfa and bushels for corn and wheat) of yield lost were multiplied by the average price per unit.

The secondary economic impacts were estimated using input-output (I-O) modeling — a method commonly used to model the interrelationships of economic sectors/industries and describe the multiplier effect of changes in one sector/industry across a broader economy. I-O modeling is frequently used to assess the potential economic impact of a new program, such as a DM Program, or investment in a particular industry. Results of I-O analyses are typically expressed as multipliers that represent the additional economic impact above the direct effects on the industry of focus.

[40] The DM scenarios referenced here were also used in the Technical Analysis section.

2.5.1.2 Agricultural Impacts

For the Upper Basin as a whole (if it is assumed that 100% of modeled CCU for a DM Program were to come from agriculture – see M&I section below for alternate assumptions), projected direct economic impacts (i.e., reduction in crop revenue) ranged between -$173.6 million and -$176.2 million across the scenarios considered. The estimated annual impact varied by the assumed duration of the program under a given DM scenario. The inclusion of secondary economic impacts increased this result by approximately 1.6 times to -$277.7 million and -$281.9 million. Results also demonstrated that for a given set of assumptions, the choice of DM scenario (e.g., length of accrual window) had minimal effects on the projected total impact on gross crop revenues, although participant crop selection would impact the extent of the economic impact. These results did not factor in economic benefits, including direct compensation to producers.

In order to approximate the minimum compensation agricultural producers might need in order to participate in a DM Program, the per unit impacts were also estimated. Estimated reductions in crop revenue based on a representative crop mix and all non-alfalfa hay ranged from $303-$409/ac-ft and $142-$212/ac-ft, respectively. These values are estimated reductions in gross revenue, not net revenue, and do not include potential savings on variable costs, such as seed or fertilizer, that DM participants may not need to purchase for that year. Recognizing that, these values could be considered a rough approximation of the minimum "break-even" compensation agricultural producers would need in order to consider participating in a DM Program. Slightly different assumptions regarding yield, consumptive water use, and price contributed to the difference in values.

2.5.1.3 M&I Impacts

A diverse set of strategies could potentially be used by the M&I sector to participate in a DM Program, including, but not limited to, increasing conservation/efficiency measures to reduce consumptive use, utilizing redundant water supplies or water supplies from different basins, and/or changing rate structures or rates to incentivize consumer conservation. For the M&I sector, the potential economic impacts of participating in a DM Program may be much greater for water providers, given that the rate structure for many providers is set such that a portion of revenue comes from the volume of water delivered. For example, an analysis of potential revenue losses for three large water providers in the Upper Basin on a per unit basis ranged from $204-$1,577/ac-ft.

2.5.1.4 Risks and Potential Mitigation

A variety of potential risks exist for individual agricultural producers, the regional economy, and for the DM Program itself. Risk at all levels, from the individual farm to regional to basin-wide, can be minimized or mitigated through appropriate program design choices and implementation success. It is critical to recognize, however, that there are no iron-clad design options to remove all risks completely. Markets for irrigated crops and livestock and M&I water use patterns and needs are subject to both hyper-local and global influences, neither of which are predictable.

Key farm-level risks identified include inadequate compensation, changing property tax status, and challenges related to maintaining land health on fallowed fields. State-specific mechanisms may be considered to help mitigate some of these risks. The risk of inadequate compensation could be minimized by using up-to-date, regionally specific enterprise budgets and premium payments on top of break-even payments to encourage optimal levels of participation. A DM Program could provide early outreach and education on the common changes that could occur to land health during and after fallowing and provide mitigation measures on how to maintain land health during and after the fallowing period.

The cumulative toll of potential farm-level impacts also creates risk at the local/regional level. Regional risks include overdependence on one crop type, geographic area, or farm size and other impacts on small rural communities. Regional-level risks to consider include disproportionate impacts (i.e., potentially overburdening some producers or geographic areas while sparing others from negative impacts), impacts to small, rural communities, and impacts to irrigation ditch companies.

2.5.2 Approaches for Funding a DM Program

A wide range of private and public funding sources are potentially available to support a DM Program. These funding sources vary in terms of which aspects of a DM Program they might support, with some more appropriate for covering landowner compensation while others may be better for covering one or more types of transaction costs (e.g., deal development and negotiation, administrative processing, or accounting and verification). This section summarizes relevant federal and state government funding sources as well as potential municipal, corporate, philanthropic, and other investment sources. The assessment was informed by various funding program reviews (as further described in sections below), research on previous voluntary and compensated conservation programs and other conservation efforts, as well as interviews with conservation program managers and other experts.

2.5.2.1 Federal

Congress primarily appropriates federal funding related to water management and agricultural water use through Reclamation and the Department of Agriculture’s Natural Resources Conservation Service. Numerous established grant programs in both agencies are potentially viable funding sources for one or more elements of a DM Program. In general, however, these grant programs are not a good source of funding to compensate landowners for their consumptive water use due to the objectives of both agencies to advance and support agricultural water development and management while also reallocating water savings to other uses. Thus, a key challenge is to determine how best to utilize and/or modify provisions of the authorizing legislation (i.e., Secure Water Act and Farm Bill) for both agencies to shape these existing programs to be more useful for a DM Program.

Congress can also directly authorize the appropriation of funds for water-related issues through large omnibus bills such as the Farm Bill, the 2021 Infrastructure Investment and Jobs Act (IIJA), or the recently enacted 2022 Inflation Reduction Act (IRA). These bills may be more appropriate for funding landowner compensation under a DM Program as opposed to other program components.

2.5.2.2 State

Each UDS has a different perspective on potential sources and uses of state funding to support a DM Program. In Colorado, certain state water efforts have been funded through general fund appropriations and collection of fees. However, these efforts are distinct from a potential DM Program in a number of ways.

New Mexico periodically requests and sometimes receives appropriations from their state legislature towards the New Mexico Strategic Water Reserve, a statewide program that could be used for the purpose of a DM Program in the San Juan River Basin in the future.

The Utah state legislature has made significant investments in water conservation activities in the state, most recently appropriating approximately $500 million in 2022 toward these efforts. This funding includes support for the Colorado River Authority of Utah's (CRAU) five-year strategic (management) plan, which contemplates DM pilot programs in the Colorado River Basin in Utah, as well as the development of tools to monitor, account for, and verify intra- and interstate DM activities.

Wyoming's Water Development Program provides for the planning, selection, financing, construction, acquisition, and operation of water projects. This can include projects for the conservation, storage, transmission, supply, and use of water. Projects are developed and recommended each year to Wyoming's state legislature by the Wyoming Water Development Commission. Additionally, Wyoming's state legislature has previously provided funding to assure compliance with interstate water compacts and decrees in some of Wyoming's other river basins. However, programs like a potential DM Program have not previously been presented for consideration or funding.

2.5.2.3 Municipal

There is the potential for municipalities and other water providers to participate in funding a potential DM Program. Several Upper Basin municipalities have expressed interest in helping to fund a DM Program in order to reduce the risk to their water supply that may result from involuntary water supply cuts. Within each UDS, municipal participation in a potential DM Program may impact and influence local financing options.

2.5.2.4 Funding Review Results

Passage of the IIJA in 2021 and the IRA in 2022 may make substantial federal funding available for water conservation efforts across the western United States, which may include reauthorization of the SCPP and other water conservation measures. Because of this substantial infusion of federal funding, it is likely less compelling to seek funding from WaterSMART or other programs in the near term; however, there could be an opportunity to develop U.S. Department of Agriculture funding for landowner compensation under the next Farm Bill, expected to be developed by Congress in 2023. State funding may also be further explored to support the implementation of a potential DM Program. Finally, philanthropic funding could provide support in gauging local interest and educating water users about a DM Program. Table 2-9, next page, provides a more comprehensive summary of the potential funding sources for a DM Program.

Table 2-9: Summary of Potential Funding Sources for a DM Program

Source	Agency/ Entity	Opportunity	Funding Focus				Ripeness	
			Water Costs	Transaction Costs (UCRC, State)	Transaction Costs (NGO)	Planning/ Technical Assistance	Current or Past (SCPP) DM Funder	Current/ Timely Funding Available
Federal	Congress	Infrastructure Investment and Jobs Act of 2021	X	X			X	X
		Inflation Reduction Act of 2022	X	X				X
		Interest Bearing Account	X	X	X	X		
		Earmarks	X	X	X	X		
	Bureau of Reclamation	Operational Budget		X		X	X	
		WaterSMART		X		X		X
	Natural Resources Conservation Service	Conservation Innovation Grants (CIG)				X		X
		Environmental Quality Incentives Program (EQIP)	X*					X
		Conservation Reserve Program (CRP)	X*					X
		Conservation Stewardship Program (CSP)	X*					X
		Regional Conservation Partnership Prorgam	X*					X
		Watershed & Flood Protection Program (PL-566)	X*			X		X
State	Colorado	New Fees or Taxes	X	X		X		N.A.
		General Fund Appropriations	X	X		X	X	
		Ballot Measure	X	X		X	X	
	Utah**	General Fund Appropriations	X	X		X	X	
	New Mexico**	General Fund Appropriations	X	X		X	X	
	Wyoming**	General Fund Appropriations	X	X		X	X	
Municipal	Lower CRB	Direct Funding (like SCPP)	X	X	X		X	
	Upper CRB	Direct Funding (like SCPP)	X	X	X		X	
Other	Philanthropic	Various Grant and Direct Funding Options	X		X	X	X	X
	Corporate	Bonneville Environmental Foundation	X	Case-specific; most of these sources prefer to fund water costs rather than transaction and/or planning costs			X	
		California Water Action Collaborative	X					
		Individual Companies	X					X
	Private Capital	Impact Investing	X					X
		Quantified Ventures CRB Water Scarcity	X					
		TNC NatureVest	X					

* These funding sources do not directly state whether or not they will fund water costs, but also do not rule out such funding

**New fees/taxes or a ballot measure to support a DM Program would require political support in each of the UDS.

2.5.3 Costs Related to DM Program Administration

This section discusses the need for and scale of programmatic or transaction costs that may be required to implement and manage a DM Program apart from the costs of compensating participants (i.e., paying water users to forgo their use). At a high level, transaction costs are an array of administrative and operational expenses like outreach to water users, drafting and reviewing applications, contracting with water users, monitoring and verifying projects once approved and implemented, shepherding water, and other DM Program activities. These costs are distinct from money paid to water users for actions like fallowing irrigated fields. Table 2-10, next page, shows a breakdown of transactional costs for a potential DM Program into five broad categories.

Table 2-10: Categories of Transaction Costs for a DM Program

High-Level Category (from Garrick et al., 2013)		Category	Description
Institutional Lock-in Costs*	Static Transaction Costs	Education & Outreach	Promote the program to the general public and, more importantly, to water users to encourage participation
		Project Design & Development	Identify projects/water user partners, design specific projects (i.e., partial vs. full season fallow, etc.), hold initial contract negotiation, draft DM program application and any necessary state water right applications, and other tasks
		Project Implementation	Finalize and receive approval for DM and water right applications, finalize contracting
		Verification, Monitoring & Shepherding	Conduct verification during irrigation/water use season, coordinate/manage reservoir releases
	Institutional Transaction Costs	Adaptive Management & Policy	Fundraise and promote policies to lower barriers and other lock-in costs and sources of inefficiency for DM program operation
*Law/policy/other institutional dynamics that can increase all categories of transaction costs			

Efforts to better understand the costs of a DM Program highlighted that little information about individual transaction costs is available. The summarized findings included in this report, therefore, are focused on the potential scale of costs rather than a specific program cost.

Colorado's ongoing intrastate DM feasibility effort has attempted to estimate transaction costs for three scenarios with differing levels of effort and complexity, and this provides the most useful starting point for the Upper Basin as a whole. Depending on a wide range of factors, Colorado's estimates range from $300,000 in "program costs" up to $19.5 million. Reported spending on the administration of the SCPP, including the costs of detailing a Reclamation employee to the UCRC, from 2015-2018 totaled at least $327,000, or roughly $81,750 per year. These costs do not include additional UCRC and state staff costs or costs borne by NGOs who actively participated in the Pilot.

Another way to think about transaction costs is based on the total transaction costs incurred per unit of water transacted. In an examination of transaction costs in a large-scale water transactions program in the Columbia River Basin, Garrick and Aylward (2012) found that transaction costs ranged from approximately $400 to $13,300 per discounted cubic feet per second (cfs) transacted, with a median value of $2,225/discounted cfs (in 2007 dollars). Depending on the DM Program design and implementation, the amount of water transacted in any year could vary greatly. Based on experience with Columbia River Basin transactions, transaction costs in the Upper Basin would likely be higher in general; the increased costs would primarily come from law and policy that is less conducive to water markets/transactions, and also the potentially high verification and shepherding costs predicted for an Upper Basin DM Program.[41,42]

The final way to summarize possible cost information is by using qualitative information provided during interviews with UDS personnel. For example, there were two staff members in New Mexico who spent some of their time on SCPP. New Mexico also predicted that a DM Program would require between 1.5-2.0 full-time equivalents (FTE) in their state. This estimate was for all possible DM Program-related work, primarily reviewing DM project applications, contracting, verification, monitoring, and limited shepherding (representatives noted that capacity requirements could increase if projects involved complex water rights administration). Unlike New Mexico, where there were no NGO employees supporting SCPP efforts, Wyoming, Colorado, and Utah all had active NGO partners supplementing state capacity. The number of FTEs required for each state would vary depending on the amount of water each state would eventually contribute to a DM Program and the level of complexity of DM projects (especially the complexity of calculating consumptive use reductions, verification processes, and monitoring/ shepherding requirements). It is likely that the estimate of 1.5-2.0 FTEs per state is a lower-bound estimate.

2.5.3.1 Administration Costs Review and Results

Transaction costs are difficult to define fully and enumerate. Despite this difficulty, transaction costs, and the extent to which they are understood and planned for, are significant drivers of DM Program success. For example, in markets for goods with public-resource characteristics like water, high transaction costs and failures to account for and fund them are some of the most common barriers to success.

A specific cost estimate of transaction costs for a potential DM Program was beyond the scope of this effort. Also, if developed, the eventual cost of a DM Program is likely to be heavily influenced by UDS and UCRC policy-maker decisions and program design.

Most of the information available and provided here focuses on the transaction costs associated with participation in a DM Program by agricultural water users. It is important to note, therefore, those transaction costs are likely to vary by water use sector.

Costs for project verification and determination of CCU are among the most critical transaction costs because they directly affect the Upper Basin's ability to move water into DM storage. Prioritizing analysis and spending on these transaction costs will be important; however, such is the nature of transaction costs that underfunding education and outreach, for example, could result in fewer projects to verify and less CCU. The most important message of the research conducted is that failing to adequately account for and then fund the full range of transaction costs could result in fewer participants in a potential DM Program.

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[41] Szeptycki, Leon F.; Forgie, Julia; Hook, Elizabeth; Lorick, Kori; and Womble, Philip. (2015). *Environmental Water Rights Transfers: A Review of State Laws*. All In-stream Flows Material. Paper 3.
[42] Szeptycki, L. & Pilz, D. (2017). *Colorado River Basin Environmental Water Transfers Scorecard*. Stanford Woods Institute for the Environment.

2.5.4 Costs Related to Participant Compensation

Participation in a DM Program is, by definition, "temporary, voluntary, and compensated." Therefore, an important aspect of program design is to determine the appropriate level(s) of compensation for participating individuals or entities. Selection of too low a value could result in low participation levels, while too high a value could result in overpayment for water. To better inform any strategy employed by the UDS and UCRC, this section reviews how participant compensation levels have been determined elsewhere (e.g., pilot projects, economic modeling), as well as any lessons learned that might inform DM Program design in the Upper Basin.

Overall, employed methods for determining participant compensation in previous voluntary and compensated conservation programs are inconsistent and variable. Reasons cited for this include geographic limitations; difficulties associated with transacting and moving water; the global economy's inelasticity to changes in crop production; and a disinclination for the program to set the market price of water in the region.

Instead, compensation used in water conservation pilot programs and studies to date has been determined through a variety of methods, including stakeholder interviews, direct negotiations with participants, and break-even or incentive compensation associated with assumed behaviors resulting from participation (e.g., full season fallowing of a crop). Regardless of the method, the unit for which participants were compensated was typically the volume of CCU. CCU, particularly for agriculture, however, is difficult to ascertain as a standardized measure — variables like geographic region, climate variability, crop mix, irrigation technology, and DM Program-related activity (i.e., full season fallow, split season fallow, crop switch, etc.) – all have the potential to affect this measure.

Some of the previous temporary and compensated conservation measures that relied on stakeholder interviews and negotiations with participants cited a reluctance by those involved to establish a fixed compensation level, and instead, the proponents negotiated compensation on an individual-by-individual basis. A rough estimate of the value of agricultural output per ac-ft of CCU typically served as the starting point for negotiations. Other factors that informed negotiations included expressed interest from potential participants, budget availability for the program, and participant willingness to accept certain levels of compensation. In addition, a previous literature review found that participant compensation "always exceeded the loss in profit on lands participating in temporary water leasing programs."[43]

The following section presents summarized findings from a review of pilot projects and economic impact analyses of a potential DM Program. Note that all reported values are per year and shown in constant 2020 dollars.

[43] WestWater Research. (2018). *Secondary Economic Impacts & Mitigation Strategies. Cited in BBC Research & Consulting et al., 2020.* Webpage: https://swwcd.org/wp-content/uploads/2020/09/upper-basin-demand-management-economic-study-in-western-colorado.pdf.

2.5.4.1 Compensation Costs Review and Results

The following bullets summarize estimated participant compensation from prior studies and pilots; however, they are not to be misconstrued as proposed or estimated for any future potential water conservation compensation or formal DM Program:

- After the removal of one outlier value, the average compensation for participants in the Grand Valley Water Users Association (GVWUA) Conserved Consumptive Use Pilot Project (2017) and UCRC SCPP (2015-2018) was approximately $220/ac-ft.[44,45]
- Another recent study focused on the potential economic impacts of voluntary conservation measures and involuntary curtailment in Colorado's Upper Gunnison Basin and used a stakeholder survey process as the basis for setting compensation levels. Compensation that considered both direct and residual impacts ranged from $78-$207/ac-ft depending on the length and conditions of participation.[46]
- A study in Colorado on the potential economic impacts of a DM Program used survey results to estimate the annual direct costs for fallowing alfalfa and corn ($75/acre) and grass hay ($35/acre, including residual effects on yield in the year following participation). For break-even and premium incentive compensation, payments of $194-$263/ac-ft (with an average of $236/ac-ft) and $136-$183/ac-ft were calculated, respectively.[47]
- A similar study in Wyoming also used the break-even and premium-based compensation approach but developed a very specific profile for participants, who would respond to reduced water use one of two ways. The first scenario assumed participants would purchase hay to replace hay lost from fallowing and set compensation as the participant's baseline net operating income plus the cost of purchasing replacement hay. Compensation payments under this approach ranged from $266-$418/ac-ft, depending on the crop type. The second scenario set compensation as a participant's baseline net operating income, plus the cost of fallowing under the program, plus a 50% premium on the net operating income. This approach resulted in a range of payments from $202-$261/ac-ft depending on crop mix.[48]

Summarized findings include:

- With regards to agricultural participant compensation, the break-even amount (i.e., the minimum value a participant would likely consider) has the potential to vary based on

[44] Grand Valley Water Users Association and JUB Engineers. (2017) *2017 Conserved Consumptive Use Pilot Project.* Webpage: https://www.coloradomesa.edu/water-center/documents/October13_CCUPP_UteWater_Luke.pdf.
[45] Ibid. pg. 10.
[46] Harvey Economics. (2020). *Economic Impacts of Irrigation Water Curtailment Scenarios for the Upper Gunnison Basin.* Accessed at: https://ugrwcd.org/wp-content/uploads/2021/03/Harvey-Economics-Study-of-Gunnison-Basin-October-2020-Board-Meeting.pdf.
[47] Ibid. pg. 44.
[48] Hansen, K., R. Coupal, E. Yeatman, and D. Bennett. (2021). *Economic Assessment of a Water Demand Management Program in Wyoming's Portion of the Colorado River Basin*: Summary. Bulletin B-1373. Laramie, WY: University of Wyoming Extension. Available at: https://www.wyoextension.org/agpubs/pubs/B-1373-1-web.pdf.

a number of factors, such as current water use, geography, crop type, irrigation technology, farm size, etc.

- Participant compensation may need to be higher than the break-even value of the water — to cover additional costs (e.g., the cost of fallowing fields) and/or a premium over and above the value of the water and costs of participation to the producer.
- Lower commitments of CCU may attract more participants than full-season fallowing projects or higher levels of conserved water commitment.
- When establishing participant compensation, there are pros and cons to setting a fixed compensation level versus conducting a reverse auction or engaging in individual negotiations. While actual compensation per acre-foot paid to participants would likely be lower under a strategy using a reverse auction or individual negotiations, these strategies would likely result in higher transaction costs as compared to a fixed compensation strategy. Ditch companies also may need to be compensated for lost revenue resulting from ditch member participation.

2.5.5 Survey of M&I Water Providers Regarding Participation in a DM Program

While there is a growing repository of research and literature focused on the potential incentives for and impacts of participation by agricultural producers in DM, similar efforts related to M&I users are relatively limited. A voluntary online survey of M&I users in the Upper Basin identified by the DMC was conducted with the goal of assessing the potential for these water users to participate in a DM Program. The survey included questions on existing programs or plans to address water supply shortages, potential participation in a DM Program, and characteristics of the agency/entity.

2.5.5.1 M&I Survey Methods, Demographics, and Results

A total of sixteen entities completed the survey, resulting in a response rate of approximately 32%. Responses by state were as follows: Colorado (4), New Mexico (3), Utah (3), and Wyoming (5), Unknown State (1). All but two respondents reported that they work for a publicly owned agency/entity. One respondent worked for a private water provider, while the other worked for an entity that operates industrial power plants. Eleven of the fifteen water providers (73%) used a tiered-rate structure, as opposed to a flat rate (3) or a flat rate combined with a tiered structure (1).

The size of the populations served by respondent agencies ranged from 2,000 to 1.5 million. Five of the twelve respondents (40%) answering this question worked for agencies serving populations of 10,000 or fewer individuals.

The percentage of direct water supply coming from the Colorado River varied substantially across respondents, with results ranging from 0% to 100%. Five of the twelve respondents answering this question stated that 100% of their entity's primary water supply came from the Colorado River. Three responding entities relied on the Colorado River for supplemental water supply, from which all of their supplemental supply is derived.

Respondents were asked how secure, in terms of providing a reliable volume of water, they perceived their current primary and supplemental water supply sources to be. Responses varied by both respondent and source type (i.e., primary versus supplemental); however, nearly all respondents perceived their entity's primary water supply sources to be at least "somewhat secure." Generally, supplemental sources were perceived as less secure than primary water supply sources, and a few respondents believed their supplemental water sources were "not at all secure." When shifting the focus from the security of current water supply sources to potential future water shortages, the majority of respondents (15 of 16) stated that their entity is "very" or "extremely" concerned about the potential for future water supply shortages/scarcity.

To better understand whether respondents had already implemented programs or initiatives to proactively address potential water shortages, a question about the number and types of such programs/initiatives was asked. A total of ten different programs or initiatives were listed as responses, along with an "other" option. All respondents had at least one program or initiative in place to proactively address potential water shortages. The number of programs/initiatives implemented by a single agency ranged from one to eleven, with a median number of four per respondent. Distribution system leakage detection and repair was the most reported program/initiative, followed by the use of a tier-rate structure (Figure 2-17).

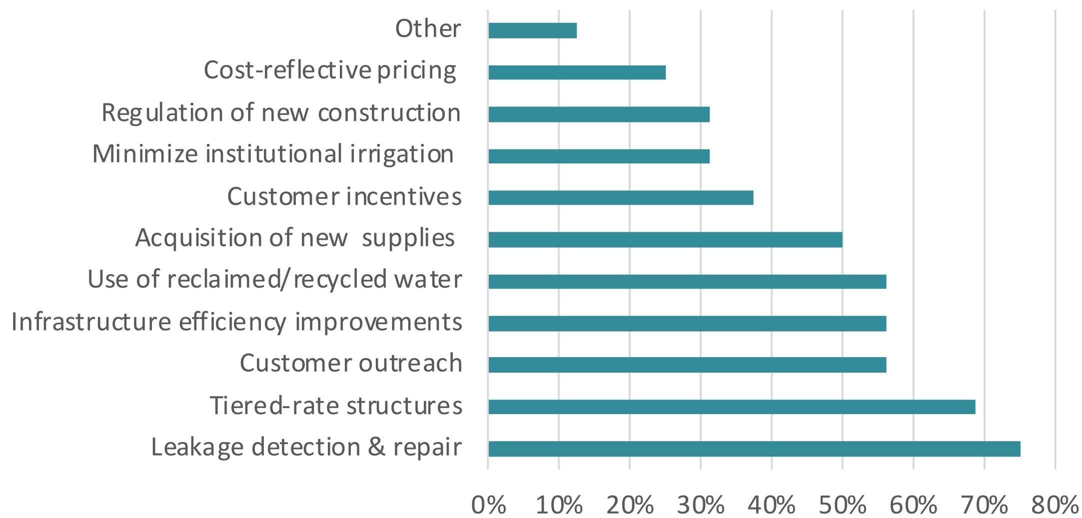

Figure 2-17: Municipal Water Provider and Industrial Use Programs & Initiatives

Seven of the sixteen respondents (44%) stated that their entity tracks the amount of water that could be/had been saved by these programs/initiatives, and five of those seven also tracked the cost per unit of water saved.

Just over half of the respondents (9 of 16) stated their agency has a formal drought response or water scarcity contingency plan. Six of those nine respondents' plans include additional programs or initiatives were are not in place but would be implemented as part of the plan. These additional programs included real-time monitoring of water use, watering restrictions, audits of more significant water users, outreach to property managers, regulation of new construction, and implementation of a tiered rate structure.

In response to a question on how respondents plan for or respond to costs associated with water supply shortages, three respondents stated their agency does nothing. Across the other thirteen respondents, the most common actions reported were adjusting rates, use of reserve funds, and additional scenario planning.

In terms of potential willingness to participate in a temporary, voluntary, and compensated Upper Basin DM Program, responses were as follows: No (3), Maybe (10), Yes (2), No Response (1).

Respondents who answered “Maybe” or “Yes” were asked to elaborate on any interests and/or concerns related to a DM Program, as well as whether there were specific DM Program design elements (e.g., pricing, conditions, incentives) that might help mitigate those concerns. Primary concerns expressed included soil health, increased rates for customers, safeguarding against speculators, and use of water by Lower Division States. Possible DM Program design elements listed included pricing, conditions, incentives, safeguards, and credits for future water needs.

Finally, respondents were asked whether they had any other thoughts or recommendations for how their entity and/or others might effectively participate or interact with a DM Program. A wide variety of responses were submitted — with some respondents reiterating their willingness to participate and support a DM Program and others requesting more information.

2.6 Intrastate and Interstate Legal Authorities and Administrative Frameworks Regarding the Storage and Release of DM Water

This section analyzes the intra- and interstate legal authorities and administrative frameworks that the UDS and the UCRC may use or that do not prohibit the storage and release of DM water from the CRSPA Initial Units for a DM Program. It does not, however, offer any opinion on whether the UCRC or the UDS should or should not pursue a DM Program.

2.6.1 Federal Authorities

Any discussion on Federal authorities and a DM Program must begin with the Colorado River Drought Contingency Plan Authorization Act (DCP Act), which Congress passed in 2019.[49] In enacting the DCP Act, Congress directed the Secretary of the Interior to operate Colorado River System reservoirs in accordance with the DCPs. By ratifying the DCPs, including the DMSA, Congress codified the ability of the UDS, through the UCRC, to store up to 500,000 acre-feet in the CRSPA Initial Units for a DM Program. However, the DCP Act states that any DM Program must comply with applicable Federal environmental laws and must not affect water rights. The legal authorities embodied in the “Law of the River” appear to be broad and flexible enough to not prohibit a DM Program. Nothing in the 1922 Compact or the 1948 Upper Colorado River Basin Compact (1948 Compact) prohibits a DM Program.

In addition, the following subparagraphs from Article VIII of the 1948 Compact vest the UCRC with sufficient authority to perform the tasks contemplated in the DMSA:

> (3) “Make estimates to forecast water run-off on the Colorado River and its tributaries;”
>
> (4) “Engage in cooperative studies of water supplies of the Colorado River and its tributaries;”
>
> (5) “Collect, analyze, correlate, preserve and report on data as to the stream flows, storage, diversions and use of the waters of the Colorado River, and any of its tributaries;”
>
> (7) “Make findings as to the quantity of water deliveries at Lee Ferry during each water year;”

[49] Pub. L. No. 116-14, 133 Stat. 850 (2019).

> (9) "Make findings to the quantity of reservoir losses and as to the share thereof chargeable under Article hereof to each of the States;"
>
> (10) "Make findings of fact in the event of extraordinary drought…in the Upper Basin, whereby deliveries by the Upper Basin of water which it may be required to deliver in order to aid in fulfilling obligations of the United States of America to the United Mexican States arising under the Treaty between the United States of America and the United Mexican States, dated February 3, 1944."
>
> (12) "Perform all functions required of it by this Compact and do all things necessary, proper or convenient in the performance of its duties hereunder, either independently or in cooperation with any state or federal agency."

Given this authority, the UCRC would likely be able to make findings and perform functions related to the implementation of a DM Program, including playing an administrative role like the one it played in implementing the SCPP.[50]

Similarly, the CRSPA and Colorado River Basin Project Act (CRBPA) would not prohibit the Secretary from operating the CRSPA Initial Units in cooperation with the UDS and with agreement from the UCRC to facilitate the storage and release of water for a DM Program if such a program is established and implemented under the DMSA.

The DCP Act requires compliance with federal environmental laws, where applicable. Such laws include, but may not be limited to, the Endangered Species Act (ESA) and the National Environmental Policy Act (NEPA) in the context of the storage and release of water conserved for DM purposes from the CRSPA Initial Units. NEPA requires federal agencies to prepare an environmental assessment (EA) or Environmental Impact Statement (EIS) depending on the degree and nature of the impacts that an action with a federal nexus has on the human environment. An EA determines whether said federal action has the potential to cause significant environmental impacts. If the federal agency conducting the EA determines that the federal action will not result in significant environmental impacts, the agency will issue a "finding of no significant impact," and the NEPA process will conclude. If, however, the EA determines that the environmental impacts of a proposed federal action will be significant, it will prepare an EIS. The EIS process can include the development of baseline investigations, alternative action considerations, and impact analyses. The EIS process ends with the issuance of a Record of Decision (ROD) that includes provisions intended to mitigate impacts on the environment and to ensure compliance with any ESA requirements.[51]

Reclamation has issued RODs and biological opinions (BO) for each of the CRSPA Initial Units that include provisions intended to ensure their operations satisfy the authorized purposes of the project and meet ESA requirements for ESA-listed species. Operating a DM Program outside of the existing RODs could require additional analysis, including potentially another EIS, which could take years and would likely present a significant constraint on a potential DM Program. Nevertheless, each ROD appears to include operational flexibility, meaning that it may be possible to operate a DM Program within the parameters of the existing RODs, thereby avoiding the need for further EIS development.

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[50] For more on the SCPP, see: http://www.ucrcommission.com/system-conservation-pilot-program/.
[51] 16 U.S.C. § 1531 *et seq.*

2.6.2 State Authorities

How each UDS would administer a DM Program would depend on the individual laws of each state. Multiple approaches are available for the intrastate administration of a DM Program. Such approaches may include but are not limited to, treating DM water as a beneficial use or administering a DM Program pursuant to each state's water rights administration and supervision authorities. The feasibility of any given approach would depend on the laws and requirements of each state.

2.6.2.1 Colorado

Colorado provided its own legal research on a potential DM Program. More specifically, the Colorado Water Conservation Board (CWCB) adopted Colorado's 2019 Work Plan to help guide the initial stage of the intrastate feasibility investigation in Fiscal Year 2019-2020. One component of the Work Plan was to establish workgroups comprised of subject-matter experts and key Colorado River stakeholders, which were directed to meet at least four times publicly in Fiscal Year 2019-2020, and to identify key threshold issues for consideration. One such workgroup was the Law and Policy Workgroup, which prepared a full report available on the CWCB's website.[52]

There are several outstanding legal and policy questions relating to a potential DM Program in Colorado, and the conclusions drawn could impact how such a program operates and whether it works within existing law. These key legal and policy issues include, but are not limited to:

- Would participation in a potential program be considered a beneficial use under Colorado law?
- What is the definition of Compact compliance?
- How is program eligibility determined?
- How is CCU defined for purposes of participation in a potential DM Program?
- What is the appropriate definition of "temporary" in the context of a potential DM Program?
- What is the appropriate procedure for DM Program project review and approval?

2.6.2.2 New Mexico

There are a number of provisions within current New Mexico law that would allow and possibly facilitate a DM Program. However, none of these provisions are specific to a DM Program, and there are questions as to how exactly New Mexico would implement a DM Program.

New Mexico's Interstate Stream Commission (ISC) ensures compliance with the state's interstate compacts. As such, it has broad authority to negotiate compacts, conduct investigations, and "do any and all other things necessary to protect, conserve, and develop the waters and stream systems of [New Mexico], interstate or otherwise."[53] Among other authorities, the ISC operates the New Mexico Strategic Water Reserve (Reserve), by which the ISC can acquire water rights to "assist the state in complying with interstate stream compacts and court decrees," among other purposes.[54] New Mexico law specifies that water rights the ISC acquires for the Reserve "shall remain in their river reach or

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[52] Colorado Water Conservation Board. (2020). *Demand Management Feasibility Investigation Update*. CWCB Website: https://dnrweblink.state.co.us/CWCB/0/edoc/212913/Demand%20Management%20Update_20200723.pdf.

[53] N.M. STAT. ANN. § 72-14-3. The ISC consists of the State Engineer and eight unsalaried members appointed by the Governor.

[54] *Id.* § 72-14-3.3(B) (1978); N.M. CODE R. § 19.25.14.9.

ground water basin of origin," and the cumulative impacts of reserve acquisitions "shall not adversely affect existing users or delivery systems."[55]

Given the Reserve's express statutory purpose of "complying with interstate stream compacts," the Reserve might be a possible mechanism that New Mexico could use to implement a DM Program. New Mexico law requires applications to the New Mexico State Engineer to change the purpose or place of use of a water right.[56] A DM Program in New Mexico will likely involve Navajo Reservoir, so water conserved pursuant to a DM Program could be stored in Navajo Reservoir and released to Lake Powell at the most appropriate time. If water were already stored in Navajo Reservoir pursuant to a contract prior to its participation in a DM Program, it could be administratively easy to change from the authorized purpose of storage to DM purposes.

Forfeiture for non-use can occur following four consecutive years of non-use in New Mexico,[57] but a water right placed in the Reserve is protected against forfeiture.[58] Because forfeiture only applies after the water has not been used for a period of four years, any water leased for a DM Program without an approved change application for DM purposes would not be at risk of forfeiture as long as the lease is for less than four consecutive years.

A change application would likely be needed, however, to authorize the storage and release of DM Program water.[59] For such applications to be approved, the storage and release of DM Program water would likely need to qualify as a beneficial use. New Mexico's Constitution states that "beneficial use shall be the basis, the measure and the limit of the right to the use of water."[60] New Mexico's statutes, however, do not define beneficial use.[61] Instead, New Mexico's courts have recognized a flexible interpretation of beneficial use.[62] Some New Mexico court cases have held that a physical diversion is required for a use to be beneficial.[63]

Currently, there appears to be a question as to whether DM Program water would qualify as a beneficial use under New Mexico law. Nevertheless, two recent instream flow approvals may provide guidance on how the State Engineer might review and administer DM Program applications. In 2019, the State Engineer approved a temporary instream flow permit for Audubon, New Mexico, to use

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[55] *Id.* § 72-14-3.3(F) and (H). The ISC cannot acquire water rights served or owned by an acequia or community ditch, nor can it acquire water rights served by an irrigation district, except through contractual arrangement with the district board or as a special water users association. *Id.* § 72-14-3.3(A). It also cannot acquire water rights through condemnation can only acquire water rights that have sufficient seniority and consistent historic beneficial use to effectively contribute to its purposes. *Id.*
[56] *Id.* §§ 72-5-24, 72-5-23.
[57] *Id.* § 72-5-28(A).
[58] *Id.* § 72-14-3.3(A).
[59] *Id.*
[60] N.M. CONST. art. XVI, §. 3.
[61] N.M. STAT. ANN. § 72-12-2; N.M. STAT. ANN.§ 72-1-2 (1978) (governing water rights that are appropriated for irrigation purposes and stating: "Beneficial use shall be the basis, the measure and the limit of the right to the use of water, and all waters appropriated for irrigation purposes, except as otherwise provided by written contract between the owner of the land and the owner of any ditch, reservoir or other works for the storage or conveyance of water, shall be appurtenant to specified lands … so long as the water can be beneficially used thereon, or until the severance of such right from the land in a manner hereinafter provided in this article.").
[62] *See e.g., Carangelo v. Albuquerque-Bernalillo Cnty. Water Util.* Auth., 2014-NMCA-032, ¶ 41, 320 P.3d 492, 505 (N.M.App. 2013); *State ex. rel. Off. of State Eng'r v. Romero*, 2020-NMCA-001, ¶ 28, 455 P.3d 860, 868 (N.M.App. 2019); *State ex rel. Martinez v. McDermett*, 1995-NMCA-060, ¶ 10, 901 P.2d 745, 748 (N.M.App. 1995).
[63] *State ex rel. Erickson v. McLean*, 308 P.2d 983, 987 (N.M. 1957) (emphasis added). *See also State ex rel. Reynolds v. Miranda*, 1972-NMSC-003, 493 P.2d 409 (N.M. 1972) and *Hagerman Irr. Co. v. Murray*, 1911-NMSC-021, 113 P. 823 (N.M. 1911) (including similar language regarding the physical diversion of water as a requirement for beneficial use).

water rights for instream flow in a specified stream segment of the Rio Gallinas for fish and wildlife purposes. In 2020, the State Engineer approved a temporary instream flow permit for Trout Unlimited to use water rights for instream flow in a specified stream segment of a tributary to the Rio Chama. In both cases, the water or a portion of the water is temporarily unavailable for its original irrigation purpose and is instead used for instream flow. The New Mexico Office of the State Engineer also imposed conditions in both approvals to ensure that the new purpose of use will be monitored and metered and will not impair the water rights of other users in the system. Both permits require points of diversion where the water enters the stream, along with measuring devices to show control of the water permitted for instream use. In other words, the installation of measuring devices appears to satisfy the physical diversion requirements discussed above.

2.6.2.3 Utah

DM Program water likely qualifies as a beneficial use under Utah law, in which case it would be treated similarly to other water rights for administration and distribution purposes, notwithstanding practical and technical considerations. Although beneficial use is the "basis, the measure and the limit of all rights to the use of water," there is no statutory definition of beneficial use in Utah.[64] Instead, Utah courts have held that the concept of beneficial use is not static and "is susceptible to change over time in response to changes in science and values associated with water use" and that what qualifies as a beneficial use depends on the facts and circumstances of each case.[65] Given Utah's recognition that beneficial use depends on the circumstances of each case, the DMSA and the DCP Act could create the context by which DM Program water qualifies as a beneficial use under Utah law.

If DM Program water qualifies as a beneficial use, the Utah State Engineer would need to approve a change application to convert a water right to DM Program water use. The required conditions for State Engineer approval of a change application do not inherently prohibit a change for DM Program water use.[66]

Recent changes in Utah law could facilitate a DM Program. In 2020, the Utah Legislature passed H.B. 130, which expressly recognized what are known as "fixed-time" change applications that can be filed to authorize a change in an underlying water right for periods of time that exceed one year but do not exceed ten years.[67] H.B. 130 further specified that proof requirements do not apply to fixed-

[64] UTAH CODE ANN. §§ 73-1-3 and 73-3-1(4).
[65] *In the General Determination of the Waters of Utah Lake and Jordan River. Butler, Crockett & Walsh Develop. Corp. v. Pinecrest Pipeline Operating Co.*, 2004 UT 67, ¶ 46, 98 P.3d 1 (quoting *Jeffs v. Stubbs*, 970 P.2d 1234, 1245 (Utah 1998). This decision also quotes portions of *Beneficial Use, Waste, and Forfeiture: The Inefficient Search for Efficiency in Western Water Use*, 28 Envtl. L. 919, 942 (1998), including: "What is a beneficial use, of course, depends upon the facts and circumstances of each case. What may be a reasonable beneficial use, where water is present in excess of all needs, would not be a reasonable beneficial use in an area of great scarcity and great need. What is a beneficial use at one time may, because of changed conditions, become a waste of water at a later time?" *See also Delta Canal Co. v. Frank Vincent Family Ranch, LC*, 2013 UT 69, ¶ 22, 420 P.3d 1052 (stating, "Over time, the types of use considered to be beneficial have expanded to encompass not only economically beneficial uses, but also uses that promote conservation, recreation, and other values deemed to be socially desirable.") (internal quotations and citations omitted).
[66] *Id.* § 73-3-8(1)(a) (stating in relevant part that "it shall be the duty of the State Engineer to approve an application if there is reason to believe that…(ii) the proposed use will not impair existing rights or interfere with the more beneficial use of the water; (iii) the proposed plan: (A) is physically and economically feasible…(B) would not prove detrimental to the public welfare; (iv) the applicant has the financial ability to complete the propose works; (v) the application was filed in good faith and not for the purposes of speculation or monopoly."
[67] *Id.* § 73-3-3(1)(b).

time and temporary change applications, meaning that the holder of an approved fixed-time application is not required to show that the right is diverted.[68]

H.B. 130 also authorized split-season use of water rights in which "the holder of a perfected water right grants to a water user the right to make sequential use of a portion of the water right." Relatedly, if DM Program water is a beneficial use, water rights leased by the State of Utah for a DM Program would not be subject to abandonment and forfeiture. Utah law also includes further protections, providing that a water right is not subject to abandonment or forfeiture "if its place of use is contracted under an approved state agreement or federal conservation fallowing program."[69] A DM Program would likely satisfy both the "state agreement" component of this protection because Utah will likely need to lease water rights to use them in a DM Program. A DM Program may also qualify as a "federal conservation fallowing program" under Utah law since a DM Program will require additional agreements with the United States.

2.6.2.4 Wyoming

Wyoming law would not easily accommodate DM Program water as a beneficial use. Wyoming law provides in relevant part that "[b]eneficial use shall be the basis, the measure and limit of the right to use water at all times …."[70] Although Wyoming's statutes do not define beneficial use, Wyoming's statutory framework has historically required a physical diversion of water for the use to be considered beneficial. For instance, in 1900, the Wyoming Supreme Court noted that an "appropriation consists in a diversion of the water by some adequate means, and its application to a beneficial use."[71] The only use that does not require a diversion that Wyoming law recognizes as a beneficial use is an instream flow right held by the State of Wyoming to establish or maintain fisheries – a purpose that is separate from DM.[72] Wyoming's temporary water right transfer statute is also limited to uses that involve a physical diversion of water – "highway construction or repair, railroad roadbed construction or repair, drilling and producing operations, or other temporary purposes" – which are not of the same kind or character as DM Program water or DM.[73]

Instead, Wyoming would likely need to administer a DM Program pursuant to its water rights administration and supervision authorities. The Wyoming State Engineer has broad constitutional authority[74] that may provide the basis to implement a DM Program similar to how they curtail and shepherd water to ensure compliance with Wyoming's other interstate compacts and decrees. The Wyoming Constitution vests the State Engineer, who administers Wyoming's interstate compacts and decrees, with "general supervision of the waters of the state and of the officers connected with its distribution."[75] It also authorizes the Wyoming Board of Control, which adjudicates and finalizes water rights and considers other related matters, to supervise the waters of the state, "their

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[68] *Id.* § 73-3-16(8).
[69] *Id.* § 73-1-4.
[70] *Id.* § 41-3-101
[71] *Farm Inv. Co. v. Carpenter*, 61 P. 258, 265 (Wyo. 1900) ("Private ownership of water in the natural streams is not recognized. The right to divert water therefrom and apply the same to beneficial uses, is, however, expressly guarantied [*sic*]. By such diversion and use a priority of right to the use of the water may be acquired.").
[72] WYO. STAT. §§ 41-3-1001 (41-3-1002(e).
[73] WYO. STAT. ANN. § 41-3-110(a). Although the term "temporary purposes" is not defined, the Wyoming Supreme Court has held that "[u]nder the rule of statutory construction, *ejusdem generis*, a general term which concludes a list of specifically enumerated terms should be restricted to the same genus as the things enumerated. *Reliance Ins. Co. v. Chevron U.S.A. Inc.*, 713 P.2d 766, 770 (Wyo. 1986).
[74] *John Meier & Son, Inv. V. Horse Creek Conservation Dist. of Goshen Co.*, 603 P.2d 1283 (Wyo. 1979).
[75] WYO. CONST. art. 8, § 5.

appropriation, distribution and diversion," and "the various officers connected therewith."[76]

The Wyoming Supreme Court has also held that because the State Engineer and the Board derive their authority from the Wyoming Constitution rather than from legislative action, they can act in accordance with their constitutional authority unless the Legislature or the courts direct otherwise.[77] The authority of the State Engineer and the Board is not unlimited, as both authorities must comply with court decrees and statutes passed by the Legislature.[78] Nevertheless, the opposite also appears to be true: unless limited by a court order or statute, the State Engineer and the Board have broad authority to fulfill their constitutional duties.

The Wyoming Legislature or the courts have not limited the authority of the State Engineer and the Board. They have the authority to regulate the waters of the state in accordance with state laws, which include Wyoming's interstate compacts and court decrees.[79] For instance, the State Engineer's office is already utilizing its constitutional authority to enforce and implement the requirements of Wyoming's other interstate compacts and decrees, including the Bear River Compact and the Yellowstone River Compact, where the State Engineer has regulated water rights.

The State Engineer's administration of the U.S. Supreme Court's 2001 modified North Platte Decree and its related stipulations provides another example of how the State Engineer is exercising interstate stream authority. By stipulation, Nebraska, Wyoming, and the United States have jointly agreed to a method of allocating water during periods of shortage, under which Reclamation must follow certain procedures and guidelines when allocating storage water from the Pathfinder and Guernsey Reservoirs and the Inland Lakes. Under these guidelines, each spring, Reclamation must advise the other parties whether the current year is likely to be an "allocation year," meaning that there will be an automatic priority call if storage and forecasted water supplies are less than 1,100,000 acre-feet.[80] Such a call, in turn, requires the State Engineer to determine whether the call is valid and warrants upstream regulation. If regulation is needed, the State Engineer regulates junior diversions from the North Platte River above Guernsey Reservoir. [81]

Wyoming may want to structure its approach to a DM Program so that participating water rights are protected from abandonment and forfeiture. Under Wyoming law, a water right holder will be "considered as having abandoned [a] water right and shall forfeit all water rights and privileges appurtenant thereto" if the right holder fails, either intentionally or unintentionally, to use the water for a beneficial use for five successive years. Because participation in a DM Program is temporary, water rights that participate in a DM Program for less than five successive years would arguably not

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[76] *Id.* art. 8, § 2. The Board's discretion is also subject to court review.
[77] *John Meier & Son v. Horse Creek Conservation Dist.*, 603 P.2d 1283, 1288 (Wyo. 1979) (emphasis added). *See also White v. Wheatland Irrigation Dist.*, 413 P.2d 252, 258 (Wyo. 1966) (holding that "the board's authority to entertain and decide the … proceeding [cannot] be subject to doubt, notwithstanding the lack of a statutory provision relating to a change in point of diversion such as is now prescribed …. [i]t has long been recognized that orders of the board establishing such rights are clothed with the dignity of decrees entered by the courts.").
[78] *See e.g., Green River Development Co. v. FMC Corp*., 660 P.2d 339, 349 (Wyo. 1983).
[79] Wyoming law authorizes the governor to appoint any commissioners needed to represent Wyoming on any joint commission with other adjoining states for the purpose of negotiating compacts or agreements. WYO. STAT. ANN. § 41-11-201 *et seq*. Although such commissions may negotiate compacts and perform other such duties, including conducting certain investigations, this authority does not appear to affect the State Engineer's constitutional duty to administer Wyoming's interstate and intrastate water resources under WYO. CONST. art. 8, § 5.
[80] *See* Interstate Streams Division, Wyoming State Engineer's Office, *Summary of North Platte River and Laramie River Court Decrees* (Dec. 1, 2004), https://waterplan.state.wy.us/plan/platte/2006/atlas/overview/Basin_Decrees_Agreements.pdf.
[81] This priority call excludes the Pathfinder Modification Project.

be subject to abandonment and forfeiture. [82]

Notwithstanding the Wyoming State Engineer's constitutional authority to implement a DM Program, there are some ambiguities in Wyoming law regarding how the state would implement the specifics of a DM Program. However, such considerations are beyond the scope of this analysis of legal authorities.

2.6.3 Potential Legal Approaches for Shepherding Conserved Water to Storage

The DMSA expressly recognizes that each UDS is responsible for regulating within its boundaries the appropriation, use, and control of water apportioned to it by the Compacts. In the context of a DM Program, this means that state law will govern the shepherding of DM water to and from the CRSPA Initial Units, as well as any water right approvals that may be needed for water rights holders to participate in a DM Program.

There are at least two possible approaches that the states could use to administer a DM Program. Under the first, DM water would be considered a beneficial use and would be stored, released, and shepherded like other water rights, consistent with state law. Under the second approach, the state would use its water rights administration and supervision authorities to convey water. While each state retains the right to regulate the appropriation, use, and control of Compact water within its boundaries, a DM Program will require the shepherding of DM water across state boundaries as well.

2.6.4 Legal Considerations for the Facilitation of a DM Program

If the UDS elect to create a DM Program, there are a few key legal considerations or "ground rules" that will be necessary.

First, only the UDS, through the UCRC, have access to the unfilled storage capacity of the CRSPA Initial Units under Section III.B of the DMSA to store DM water. This means that only the UDS, in conjunction with the UCRC, can operate a DM Program. The Upper Division's compliance with the 1922 Compact is also specific to the states and cannot be fulfilled by non-state entities, including political subdivisions of a state. More specifically, in those states that elect to pursue a beneficial use approach as part of the DM Program, DM water could only qualify as a beneficial use if the state is the entity securing the water for the DM Program through a lease with the right holder, a water right application filed in conjunction with the right holder, or some other state-approved process. Because a non-state entity lacks the authority to provide compliance with the 1922 Compact, this is the only way such use could be considered beneficial. The same is true under a water right administration/supervision approach because the state, rather than the right holder, would store and release the water at issue.

Second, the DMSA requires a consensus approach to the development and implementation of a potential DM Program. However, a one-size-fits-all approach to DM will not work, and each Upper Division State must have sufficient flexibility to implement a DM Program in accordance with their respective intrastate authorities and policies.

Third, a collaborative approach to the development of a DM Program is required. Section III.B.3.d of the DMSA expressly requires each UDS, acting through the UCRC, to approve any Upper Basin DM

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[82] WYO. STAT. ANN. § 41-3-401(a).

Program. Moreover, collaboration will also be needed with the Federal Government and the Lower Division States because, as noted previously, Section III.B.3.b requires further agreements between the Upper Division and the Secretary of the Interior to create a DM Program. In turn, this Section of the DMSA also requires the UCRC and the Secretary to consult with the Lower Division States using a “consensus-based approach.” While the DMSA only calls for a consultation with the Lower Basin, it is unlikely the Secretary would approve the additional agreements the Upper Division States need to enter into with the U.S. to create a DM Program if Lower Division States object to the proposed program.

2.7 Approaches for Administration of an Upper Basin DM Program

The DMSA specifies that approaches for the administration be evaluated as part of the DM Program investigation. Framing for this component of the feasibility investigation is ongoing and being developed and will be subject to the further direction of the UDS and the UCRC Commissioners.