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Colorado Water Conservation Board
Department of Natural Resources

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Jared Polis, Governor

Dan Gibbs, DNR Executive Director

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TO: Colorado Water Conservation Board Members

FROM: Alexander Funk
Interstate, Federal, and Water Information Section

DATE: May 20th, 2021

AGENDA ITEM: Agenda Item 29. Evaluating Conserved Consumptive Use in the Upper Colorado River Project Update

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Staff Recommendation: This is an informational item only. No Board action is required.

Background:

The Colorado Water Conservation Board approved funding for the Evaluating Conserved Consumption Use in the Upper Colorado River Project through the Alternative Transfer Methods Grant Program. The project aims to explore issues relating to the potential development of alternative transfer methods and other voluntary, temporary, and compensated agricultural water conservation methods to address regional water resource challenges. Despite the implementation of alternative transfer methods in other portions of the state, few alternative transfer methods have been adopted on the Western Slope, given concerns about potential agronomic impacts to higher elevation irrigated grass pasture and hay production and regional socio-economic impacts. Multiple studies and reports, including previously funded ATM grant projects, have identified a need for additional research studies at high elevation sites to investigate the behavior of irrigated grass pasture and hay production under temporary fallowing or deficit irrigation. Various methods for verifying conserved consumptive use savings also face challenges when assessing historical consumptive use in higher elevations.

The Colorado River Basin Roundtable ("CBRT") leads the project team, with support from a collaborative group of organizations, university partners, and ten local agricultural producers with operations near Kremmling, Colorado. In Phase, I of the study, full season or split-season irrigation reduction treatments were applied to over 1,000 acres of irrigated pasture and 200 acres of reference fields. Instruments were installed in both treated and reference fields, and soil and forage samples were taken to begin assessing actual water savings and potential agronomic impacts such as forage quality and yield from the application of irrigation reduction treatments. The project also assesses potential wildlife habitat impacts from changes in irrigation practices and evaluates ranch enterprise budgets to understand regional economic impacts better. Altogether, the project will provide critical information to producers to make informed decisions about participating in ATM programming.

Members of the Upper Colorado Project Management Team, including the Colorado River Basin Roundtable ("CBRT"), Trout Unlimited, American Rivers, the Nature Conservancy, Colorado State University, will provide an overview of progress to date.

Progress Report:
Evaluating Conserved Consumptive Use in the Upper Colorado

To:	Alex Funk, CWCB Agricultural Water Resources Specialist
From:	Upper Colorado Project Management Team
CC:	Jason Turner, Colorado Basin Roundtable
Date:	March 15, 2021
Re:	March 15 Progress Report for ATM Grant – CTGG1 2020-2976

On behalf of the Upper Colorado Project Management Team, we are pleased to offer this progress report for our "Evaluating Conserved Consumptive Use in the Upper Colorado" project funded from the Alternative Transfer Mechanism grant program. This report covers project updates on tasks, budget, and schedule that have occurred since our last report on December 15th, 2020.

Task Updates

Task 1: Contract with participants and selection of research locations.

Deliverables: Final table of participating lands with acreages, associated conservation measure(s), and indication of signed contract with participant (identities will be kept confidential).

Mar. 15, 2020 Update: This task is complete, with final deliverables covered in the September 15, 2020 Progress Report. The second and last payment to participants under the contract was completed in November.

Task 2: Perform remote sensing measurement and estimation of consumptive use (CU) and conserved consumptive use (CCU) on research sites.

Deliverables: Chapter in final report addressing: (1) Estimating and verifying water conservation from multiple irrigation practices using in-field instrumentation and remote sensing. (2) Evaluate how variations in crop species, soil moisture, and depth to groundwater affect crop water use and potential water conservation.

An important contribution of this research is the estimation of consumptive use (CU) on "high elevation" fields in Colorado. We define "high-elevation" as being above 5,700 to 6,500 feet. While this designation is somewhat arbitrary, it has its basis in previous work[1] against which this research can be compared. The description "high elevation pastures" or "high elevation hay fields" is commonly used to describe these landscapes homogenously, despite biophysical and ecological differences between locations. In the Grand County area, fields at these

[1] URS. (2013). Assessing Agricultural Consumptive Use in the Colorado River Basin. 160 pp; Denver Board of Water Commissioners (1990). ET and Agronomic Responses in Formerly Irrigated Mountain Meadows.

elevations are used primarily for ranching and grazing, largely dominated by grass species brome (*Bromus biebersteinii* or *Bromus ramosus),* 'Garrison' creeping meadow foxtail (*Alopecurus arundinaceus* Poir.) and Timothy (*Phleum pratense*), along with assorted rushes and sedges in low-lying areas. Differences in underlying soil conditions, grassland ecology and local micro-climates present the need to evaluate the extent to which a scalable and translatable technique can be used to assess CU on large parcels that would be critical to any future voluntary and market-based water sharing arrangements. An annual report summarizing results of data gathered in the first year of the project (2020-2021 Project Summary Report) is being prepared and will be submitted with the next quarterly report in June 2021. There will be a chapter in this report that summarizes the results provided by several contemporary modeling tools that estimate CU by using remotely-sensed data from satellite imagery, multi-spectral measurements and energy fluxes, combined with local meteorological data. This chapter will provide: (1) Modeled estimations of CU on high-elevation pasture/hay fields using remote sensing data; (2) An evaluation of how variations in crop species, soil moisture, and depth to groundwater affect actual CU, and; (3) Estimations of potentially conserved CU (CCU) based on comparisons between actual CU measured on fully irrigated, partially irrigated and non-irrigated fields. The report will also provide the imagery of CU mapping for the fields in the research region.

Mar. 15, 2020 Update: The OpenET partners (Matthew Bromely, Justin Huntington) have applied several ET estimation models to select treatment and reference fields (GPR, RCR, RSR, SBR and SPR) in the study area. The models used are *Mapping Evapotranspiration at High Resolution with Internalized Calibration* (METRIC), *Priestly-Taylor Jet Propulsion Laboratory Model* (PT-JPL), *Satellite Irrigation Management Support* (SIMS), and *Operational Simplified Surface Energy Balance* (SSEBOP). These models have been applied to 2016-2019, and the data for the 2020 season is currently undergoing quality assurance and quality control checks. The approach to this process also provides an "ensemble result" of the averaged results from individual models. As mentioned in the previous progress report (December 15, 2020), the modeled CU estimates exhibit a low "coefficient of variation" (CV ranging from 0.1 to 0.2) for the ensemble results, indicating a low variability) between results, suggesting that the different models do not provide significantly different estimates. However, we hasten to note that these lesser CV values are for fully irrigated conditions in previous years, whereas the CU estimates under the condition of non-irrigation may significantly vary. Previous performance of the METRIC model in fully irrigated systems has shown that it captures the most intra-field CU variability, and it remains to be seen if this performance holds for non-irrigated conditions.

The complete evaluation for 2020 will entail comparisons of the ensemble and individual ET model estimates for all REF research fields against their respective TRT research fields at multiple scales (e.g. subfield, field, and regional). Prof. Alfonso Torres-Rua (Utah State University) is lending his expertise to the interpretation of these results and offer possible explanations for patterns pertaining to the unique landscape of high-elevation pastures/hay fields. The full Consumptive Use Research Team (CURT) will meet during the week of March 15, 2021 to collaborate on the next stage of interpreting the modeling estimates and offering explanations for detected patterns in CU rates.

CWCB/DWR Update: CWCB/DWR staff finalized updates to a new version of the Lease Fallow Tool (LFT) to include additional West Slope data and improve ET estimates for various grass crops. Initial Historical Consumptive Use (HCU) analyses were also completed for participating project lands using the updated LFT, Colorado's Decision Support Systems (CDSS) model assumptions, and estimated parameters. State staff will produce brief documentation of the HCU assumptions and results and will continue to refine the HCU analyses based on any

local information and feedback from the project team over the next months. In January, staff evaluated 2020 climate data using the state's ET system, which will facilitate evaluation of stream impact/crediting frameworks and methodologies using 2020 data.

Lotic Hydrological Update: Lotic completed the 2020 field data collection campaign in November. Data was collected on four field dates in the summer and fall of 2020: August 9, September 13, October 2, and November 3. Streamflow was measured during each campaign using an Acoustic Doppler Current Profiler on the Colorado River immediately upstream of the point of surface water diversion and downstream of the presumed point of surface and groundwater return flows for the T1 SBR 2020 and the T1 RSR 2020 parcels. Data was collected in a quasi-synoptic fashion. A large number of repeat discharge measurements (n >= 8) were required to reduce measurement error at locations on the Colorado River in the late fall due to interference from periphyton. Measurements were completed with a Marsh McBirney on Pass Creek, bracketing the westernmost participating parcel on T1 GPR 2020. Discharge measurement locations were mapped in a GIS and longitudinal plots of discharge were graphed for each stream system. Upstream-downstream changes in discharge in the vicinity of each parcel were characterized for the 2020 sampling period.

Additionally, the data collation task continued over the last quarter. This task included a search for data and special studies characterizing historical patterns of water use and surface water hydrology in the Kremmling area. 30 years of diversion data was retrieved from Hydrobase and local streamflow data was retrieved from U.S. Geological Survey (USGS) streamflow gauges. In the coming quarter, this task will be expanded to include a data retrieval and review of 2020 reservoir release records from the River District, Denver Water, and others. The Data Collation task is now approximately 50% complete.

In the first quarter of 2021, Lotic will complete a map set of data collection locations and participating parcels. Work will begin to develop a probabilistic characterization of water availability at each diversion location for the 2020 season. This will help inform future assessments of potential consumptive use on the participating parcels. Work will also begin in earnest on a water balance modeling code base that will permit a modeling sensitivity analysis and an analytical approximation of return flow deficits incurred by participation in the ATM project.

Task 3: Validate multiple remote sensing models for CU and CCU verification that is scientific based, replicable, scalable and can be used in conjunction with broader remote sensing platforms on high elevation pastures in Western Colorado.

Deliverables: Chapter in Final Report with estimates of CCU for each study site and a description of the factors influencing the range of potential conserved consumptive use.

Another contribution of this research is the estimation of CU at extremely low levels, having modeled the CU rates of grass pastures/hay fields under harsh non-irrigated conditions, and as coincidence would have it, during a season of abnormal drought. Previous work performed using remotely sensed data has not been able to capture these conditions, given that ranchers obviously apply irrigation water to their fields throughout the spring and summer months. Understanding field CU rates under non-irrigated or partially-irrigated conditions, and developing reasonable estimates of CU reductions, goes directly to the question of measuring and verifying how

much CU is actually conserved under any given water sharing arrangement. The 2020-2021 Project Summary Report will interpret the CU rates in the context of underlying biophysical and ecological factors.

Mar. 15, 2020 Update: A "pipeline" for data delivery and coordination has been developed, which will benefit the project in the coming years. So as to maximize the efficiency of data usage, the Open ET partners have agreed to serve in the role of the project's data nexus. This role will entail a procedure similar to that being currently used by Martin Schrader (USU) and Prof. Larry Hipps (USU) whereby the hourly and daily CU flux is supplied to Open ET after post-processing by Prof. Hipps. The data currently being supplied to Open ET is based on the unclosed and closed energy balance, the comparison of which is a somewhat contentious issue in micrometeorology. Some experts argue that forcing closure is unwarranted and in fact creates errors in the final values. Others consider the unclosed values as being final, since closure overestimates the sensible heat (H) and latent heat (LE) fluxes in order to account for underestimates in soil heat flux (G). These decision likely bias net radiation measurements (Rn) to "lush" vegetation patches. For these reasons, the measurements supplied for CU by the eddy covariance method are highly important to undergo thorough review, since the field conditions monitored in this study will likely exhibit elevated G values.

After several conversations among members of the research team, a critical distinction in terminology needed to be made. This project was originally proposed (as described in Task 3) as being focused on "validation" of existing remote-sensing models. The position of Open ET is that the models being applied to this study are already considered validated, having undergone extensive peer-review. The term "validation" will therefore be substituted going forward with the term "intercomparison," which more accurately applies to the work being performed in this study. Specifically, this intercomparison of the modeling results, eddy covariance data and the in-field soil water balance will contribute a necessary understanding of how accurately the remote sensing models are able estimate CU under the high and low levels of irrigated field conditions designed to be part of this study.

Estimation of ET using the eddy covariance system (installed on June 17, 2020) at the GPR_T1_H location has been conducted through November 3, 2020. Data collection will resume in the timeframe of May 2021. Collection of the eddy covariance data is performed by Martin Schrader and evaluated by Prof. Larry Hipps (USU). The post-processing phase subsequent to the collection of the eddy covariance data was expected to have been completed February 2021 but is still underway.

Dr. Perry Cabot has recorded soil moisture data 15-minute timesteps for the 2020 field season at depths 6, 18, 30 and 42 cm at the research equipment enclosures. This data includes volumetric water content (%), soil temperature (°C), soil permittivity, soil bulk electrical conductivity (µS/cm) and soil pore water conductivity (µS/cm). The sensors used were Acclima® TDR-315 models, which use time domain reflectometer (TDR) to derive soil permittivity and water content from the propagation time of an electromagnetic impulse conveyed along waveguide (metal prongs in contact with soil). The data from the sensors was stored and recorded by a solar powered Acclima® DataSnap data logger and uploaded to a shared drive several times a month. The soil moisture data has been checked for inaccuracies and gaps and includes approximately 3 months of measurements, for a total of 650 research days, which provides more than sufficient data for intercomparison with the remote sensing modeling estimates. The soil moisture data will be used to perform a soil water balance, based on the assumption made in similar studies that the change in soil water storage during unsaturated soil conditions can reflect the

departure of water from the root zone profile, and thus provide another means of estimating CU at specific in-field locations.

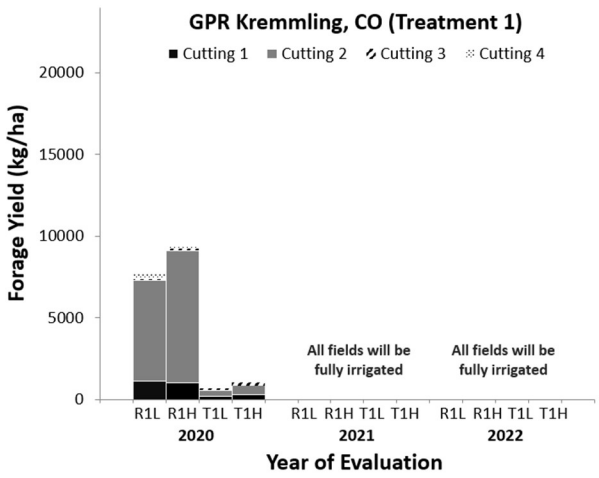
Task 4: Construct water production functions for different grass, forb and sedge forages under varying soil and groundwater conditions in order to understand yields as a function of CU rates.

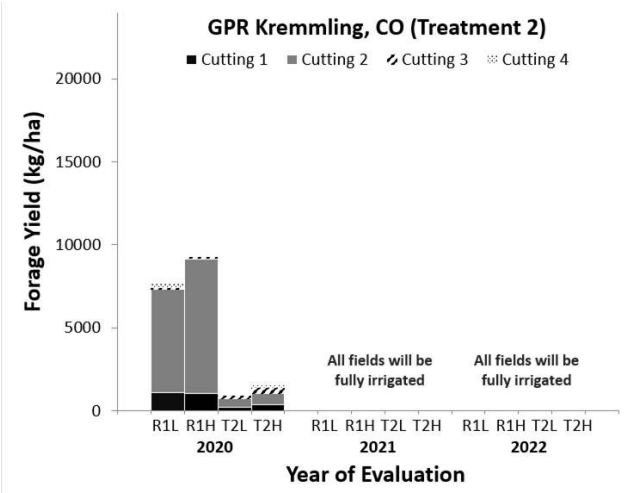
Deliverables: Chapter in final report addressing the factors that influence grass production and CU under reduced irrigation practices.

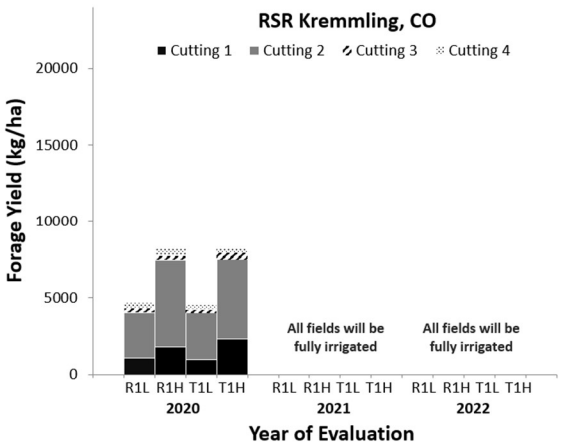
Mar. 15, 2020 Update: Forage data was collected at the high (H) and low (L) grass production research enclosures on the treatment and reference fields for the GPR, RSR, SBR, and SPR parcels. Samples were collected monthly near the end of June, July, August and September to compare the impacts of irrigation curtailment between the reference and treatment fields. Additional samples were also taken at the RCR parcel. Due to the tremendous efforts of the Field Technician Wendy Thompson, a collective 95, 83, 96, 78 and 80 samples were taken at the GPR, RCR, RSR, SBR and SPR locations, respectively. These samples consisted of a single sample taken within the research equipment enclosure itself, along with five (5) samples taken within a 50 ft radius of the enclosure. These data were obtained using a 0.25 m^2 grid square, and then weighed wet and dry after 24 hours at 104°C. Forage sample masses were converted to estimate yields (in kg/ha and T/ac) for the specific research fields. Ms. Thompson has also provided an estimated count of total hay bales from individual producers, providing additional data to estimate total yield.

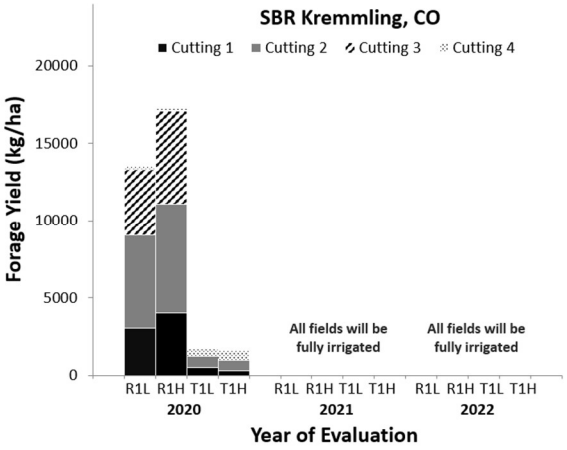
The patterns of yield under irrigated REF, partially-irrigated TRT (RSR, RCR) and non-irrigated TRT (GPR1, GPR2, SBR, SPR) are shown in the charts below. With the exception of the partially-irrigated comparison at RSR, the fields all experienced significant reductions in yield. When compared with the CU rates estimated by the soil water balance, this data will allow us to determine the yields as a function of water consumed. These water production functions provide another means of understanding CU and CCU using in-field conditions, based on yield values, which tend to be more relatable to producers than estimates of actual evapotranspiration.

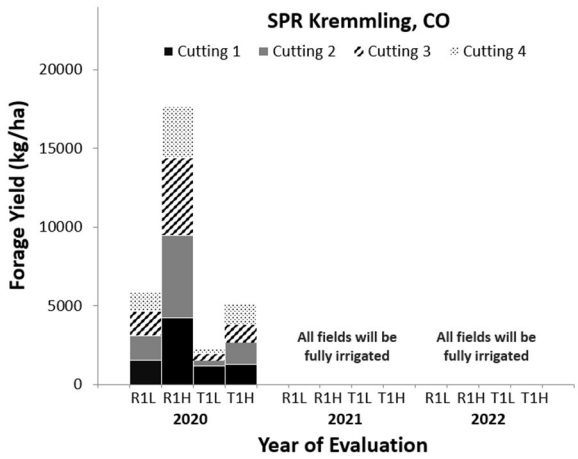
FIGURE 1: INITIAL FORAGE RESULTS

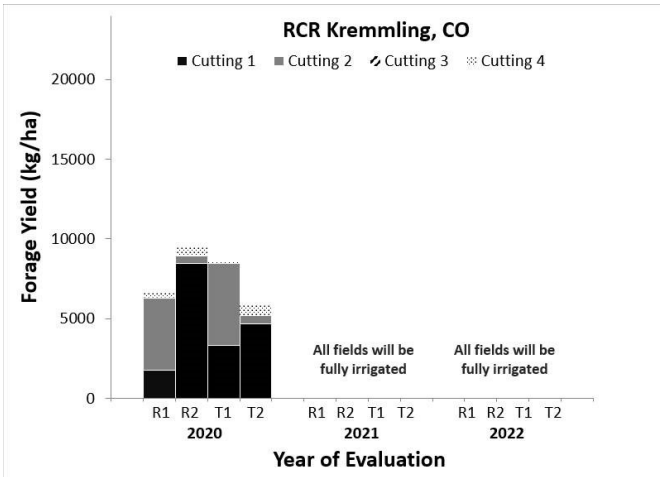












Task 5: Evaluate impacts and recovery for forages subjected to different levels of irrigation curtailment.

Deliverables: Chapter in the final report addressing the agronomic impacts of reduced irrigation on forage yield, quality, grass stand density, species composition and weed pressure.

Mar. 15, 2020 Update: Recovery from the two different treatment conditions (full curtailment and 6/15 shutoff) will be evaluated for this task by comparing yield and forage quality between the treatment and reference fields. Yield samples from all fields have been ground using a Wiley Mill and evaluated by Prof. Joe Brummer for the forage quality analysis. Prof. Brummer has provided the results of forage quality analysis as of March 12, 2021.

Grasses will be sampled in Spring 2021 to determine accumulation of carbohydrates in storage organs (stem bases, roots, rhizomes and/or stolons). A third-party lab is being identified that can analyze the sugar profiles of these samples. We can then can reasonably approximate the percent non-fibrous carbohydrates *(100 - CP - Fat - NDF - Ash),* an important measure of forage quality and patterns of recovery. In the case of grass forages, most non-fibrous carbohydrates are nonstructural and largely comprised of glucose (sugars and starches). Field Tech Wendy Thompson will also follow up with a local biologist (Jeff Grasser), who has volunteered to help further classify grass species in Spring 2021.

Task 6: Quality analysis and quality control (QA/QC).

Deliverables: None

Mar. 15, 2020 Update: Quality Analysis and Quality Control (QA/QC) has been ongoing throughout the project and includes monitoring the uploading of data (e.g. soil moisture, forage, atmometer) to a common, cloud-based shared drive, verifying the data format, and converging the data to master files. Subsequent follow up between Dr. Perry Cabot and Field Tech Wendy Thompson have clarified questions regarding data discrepancies. Student intern Cordelia Anderson has additionally checked data for anomalies. The teams at OpenET and USU are also underway with post-processing of data from the remote-sensing modeling and the eddy covariance measurements.

Task 7: Construct enterprise budgets to better understand economic considerations and to assist agricultural producers in comparing water leasing against baseline farming and ranching conditions.

Deliverables: Chapter in the final report detailing enterprise budgets for the fields, farms and region of the study.

Mar. 15, 2020 Update: Jenny Beiermann (CSU Agricultural Business Management Economist) and Project Field Leader Paul Bruchez met to identify the variables necessary to construct field-scale enterprise budgets. The team confirmed that the field scale is the best initial level at which to perform enterprise budgeting, which will subsequently allow farm and inter-farm enterprise budgeting. Subsequent to the first meeting, another meeting involving the project participants was held, during which Ms. Beiermann was put in contact with producers who manage the GPR, RCR, RSR, SBR and SPR fields. The next step in this process is for Jenny to meet with these other

producers and begin to fine-tune the detail of the enterprise budgets, which will compare economic outcomes of fields that are irrigated and non-irrigated.

Task 8: Outreach and engage with the Colorado Water Conservation Board and other stakeholders interested in alternative transfer methods in order to facilitate constructive dialogue on water sharing programs affecting the Colorado Basin and Western Slope overall.

Deliverables: Field tours, written materials, summary document of participant experiences with reduced irrigation practices.

Mar. 15, 2020 Update: Below is a summary of the outreach and engagement our team has completed for the project since our December 15th progress report. We have included links to relevant presentations and articles where relevant.

- Members of the Project Team presented to the Colorado Basin Roundtable Demand Management Workgroup at their January 13th meeting.
- The project was featured prominently in an article in the Arizona Central on January 8th, titled: *Climate change is hitting the Colorado River 'incredibly fast and incredibly hard.'*

Budget

Task	Description	Total CWCB Grant Funds	1st Quarter 2021 CWCB Expenditures	Total CWCB Expenditures to Date	Remaining CWCB Funds	Total Matching Contributions
1	Participant Contract / Research Locations	$356,283.00	$0	$356,283.00	$0.00	$298,765.44
2	CU/CCU Remote Sensing	$69,890.00	$3,909.11	$4,363.65	$65,526.35	$63,914.37
3	Validation	$38,303.00	$7,770.00	$7,770.00	$30,533.00	
4	Water Production Functions	$4,568.00				
5	Impact/Recovery Evaluation	$4,568.00				
6	QA/QC	$4,967.00				
7	Construct Enterprise Budgets	$2,284.00				
8	Outreach	$3,571.00				
9	Reporting (Includes Admin Costs)	$15,566.00	$0	$6,976.67	$8,589.33	$51,283.47
	TOTALS	**$500,000.00**	**$191,426.61**	**$371,484.19**	**$128,515.81**	**$396,042.91**

Schedule

The project schedule is on track.

Progress Report:
Evaluating Conserved Consumptive Use in the Upper Colorado

To:	Alex Funk, CWCB Agricultural Water Resources Specialist
From:	Upper Colorado Project Management Team
CC:	Jason Turner, Colorado Basin Roundtable
Date:	December 15, 2020
Re:	Dec.15 Progress Report for ATM Grant – CTGG1 2020-2976

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Deliverables: Final table of participating lands with acreages, associated conservation measure(s), and indication of signed contract with participant (identities will be kept confidential).

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Task 2: Perform remote sensing measurement and estimation of consumptive use (CU) and conserved consumptive use (CCU) on research sites.

Deliverables: Chapter in final report addressing: (1) Estimating and verifying water conservation from multiple irrigation practices using in-field instrumentation and remote sensing. (2) Evaluate how variations in crop species, soil moisture, and depth to groundwater affect crop water use and potential water conservation.

Dec. 15, 2020 Update: Prof. Alfonso Torres-Rua (Utah State University) and the OpenET partners have applied several ET estimation models to select treatment and reference fields (GPR, RCR, RSR, SBR and SPR) in the study area. The models used are *Mapping Evapotranspiration at High Resolution with Internalized Calibration* (METRIC), *Priestly-Taylor Jet Propulsion Laboratory Model* (PT-JPL), *Satellite Irrigation Management Support* (SIMS), and *Operational Simplified Surface Energy Balance* (SSEBOP). The team has also averaged models together to provide an "ensemble" of results for previous years 2016-2019.

Looking specifically at the ensemble of ET modeling results for the GPR parcel, we can make a few initial observations. First, the "coefficient of variation" (CV) of the ensemble results indicates a low variability (CV ranging from 0.1 to 0.2) between results, suggesting that the different models do not provide significantly different estimates. Secondly, estimates from SIMS were generally on the higher end versus SSEBOP on the lower end. Additionally, METRIC results appeared to capture the most intra-field variability in ET rates, perhaps capturing differences in soil types, soil moisture levels and forage production.

As the project progresses towards the complete evaluation for 2020, we will compare ensemble and individual ET estimates for all REF research fields with their respective TRT research fields at multiple scales (e.g. subfield, field, and regional).

CWCB/DWR Update:

CWCB/DWR staff finalized updates to a new version of the Lease Fallow Tool (LFT) to include additional West Slope data and improve ET estimates for various grass crops. Initial Historical Consumptive Use (HCU) analyses were also completed for participating project lands using the updated LFT, Colorado's Decision Support Systems (CDSS) model assumptions, and estimated parameters. State staff will produce brief documentation of the HCU assumptions and results and will continue to refine the HCU analyses based on any local information and feedback from the project team over the next months. In January, staff will evaluate 2020 climate data using the state's ET system, which will facilitate evaluation of stream impact/crediting frameworks and methodologies using 2020 data. The state is also working on improved documentation for the statewide ET datasets.

Lotic Hydrological Update:

Lotic completed the 2020 field data collection campaign in November. Data was collected on four field dates in the summer and fall of 2020: August 9, September 13, October 2, and November 3. Streamflow was measured during each campaign using an Acoustic Doppler Current Profiler on the Colorado River immediately upstream of the point of surface water diversion and downstream of the presumed point of surface and groundwater return flows for the T1 SBR 2020 and the T1 RSR 2020 parcels. Data was collected in a quasi-synoptic fashion. A large number of repeat discharge measurements (n >= 8) were required to reduce measurement error at locations on the Colorado River in the late fall due to interference from periphyton. Measurements were completed with a Marsh McBirney on Pass Creek, bracketing the westernmost participating parcel on T1 GPR 2020. Discharge measurement locations were mapped in a GIS and longitudinal plots of discharge were graphed for each stream system. Upstream-downstream changes in discharge in the vicinity of each parcel were characterized for the 2020 sampling period.

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2020 season. This will help inform future assessments of potential consumptive use on the participating parcels. Work will also begin in earnest on a water balance modeling code base that will permit a modeling sensitivity analysis and an analytical approximation of return flow deficits incurred by participation in the ATM project.

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Deliverables: Chapter in Final Report with estimates of CCU for each study site and a description of the factors influencing the range of potential conserved consumptive use.

Dec. 15, 2020 Update: Estimation of ET using the eddy covariance system (installed on June 17, 2020) at the GPR_T1_H location has been conducted through November 3, 2020. The eddy covariance system has been prepared for winter, with the expectation that it will resume data collection in Spring 2021. Evaluation of the eddy covariance data is overseen by Prof. Larry Hipps (USU) and is expected to be completed in February 2021.

Dr. Perry Cabot has recorded soil moisture data 15 minute timesteps for the 2020 field season. This data includes volumetric water content (%), soil temperature (°C), soil permittivity, soil bulk electrical conductivity (µS/cm) and soil pore water conductivity (µS/cm). The sensors used were Acclima® TDR-315 models, which use time domain reflectometer (TDR) to derive soil permittivity and water content from the propagation time of an electromagnetic impulse conveyed along waveguide (metal prongs in contact with soil). The data from the sensors was stored and recorded by a solar powered Acclima® DataSnap data logger and uploaded to a shared drive several times a month.

Due to timing issues, the soil moisture sensing equipment was unable to be purchased until 5/26, not shipped until 6/2, and not received until 6/5. Installation of sensors occurred between 6/17 and 6/28. The soil moisture data collection encountered a few issues that often occur at research locations where a significant amount of field instrumentation is installed. As a result of the installation timeline overlapping with the irrigation season, we were not able to install sensors at the GPR_R1_H research enclosure. Instrumentation at SBR_R1_H, SPR_R1_H and SPR_T1_H was installed on the same timeline, but data loggers encountered a firmware problem that was confirmed by the manufacturer. These data loggers were retrieved from the sites, returned to the manufacturer and reinstalled. As an aside, as a result of this project, the manufacturer was able to detect a firmware problem in their equipment and has since uploaded it to their website for all other clientele to use. Although the timeline of equipment installation and operation was truncated due to the above issues, it is important to understand that the purpose of the soil moisture sensors is to provide another layer of comparison with the remote sensing models. To date the soil moisture sensors have supplied a total of 650 research days, which provides more than sufficient data for model comparison and calibration.

Groundwater data was also recorded at 15 minute timestep which, along with barometric pressures, allows us to measure depth to groundwater and the presence of standing water under irrigation. Table 1 below summarizes the data collection time periods for both soil moisture and groundwater measurements

Table 1. 2020 soil moisture and groundwater data collection

Field Name	Soil moisture data collection (mo./day)	Groundwater data collection (mo./day)
GPR_R1_H	*unable to install	06/25 – 10/28
GPR_T1_H	06/17 – 09/29	06/25 – 10/28
GPR_T2_H	06/25 – 09/29	*need to retrieve logger
RSR_R1_H	07/15 – 09/29	06/25 – 10/27
RSR_T1_H	06/17 – 09/29	06/25 – 10/27
SBR_R1_H	07/15 – 08/18	06/25 – 11/02
SBR_T1_H	06/26 – 08/27	06/25 – 11/02
SPR_R1_H	06/28 – 09/30	06/25 – 11/02
SPR_T1_H	06/28 – 09/16	06/25 – 11/02

Note: T = Treatment Field, R = Reference Field, H = High forage productivity

Atmometer data was also obtained at the GPR (6/25-9/07), RCR (7/14-9/07) and RSR (6/17-9/07) parcels using the alfalfa (#54) canvas cover for estimating alfalfa-reference ET. Rain gage data was also measured at the GPR (6/17-9/18), RCR (6/17-9/17), RSR (6/17-9/17), SBR (6/17-9/18), and SPR (6/17-9/17) parcels.

Table 2. 2020 Atmometer and rain gage data

Field Name	Atmometer (in.)	Rain gage (in.)
GPR	20.79	1.28
RCR	11.69	0.71
RSR	19.21	1.01
SBR	--	0.66
SPR	--	1.50

Task 4: Construct water production functions for different grass, forb and sedge forages under varying soil and groundwater conditions in order to understand yields as a function of CU rates.

Deliverables: Chapter in final report addressing the factors that influence grass production and CU under reduced irrigation practices.

Dec. 15, 2020 Update: Forage data was collected at the high (H) and low (L) grass production research enclosures on the treatment and reference fields for the GPR, RSR, SBR, and SPR parcels. Samples were collected monthly near the end of June, July, August and September to compare the impacts of irrigation curtailment between the reference and treatment fields. Additional samples were also taken at the RCR parcel. Due to the tremendous efforts of the Field Technician Wendy Thompson, a collective 95, 83, 96, 78 and 80 samples were taken at the GPR, RCR, RSR, SBR and SPR locations, respectively. These data were obtained using a 0.25 m^2 grid square, and then weighed wet and dry after 24 hours at 104°C. Results will be converted to estimate yields (mg/ha and T/ac) for research fields. Ms. Thompson is also expected to provide an estimated count of total hay bales from individual producers, providing additional data to estimate total yield.

Task 5: Evaluate impacts and recovery for forages subjected to different levels of irrigation curtailment.

Deliverables: Chapter in the final report addressing the agronomic impacts of reduced irrigation.

Dec. 15, 2020 Update: Recovery from the two different treatment conditions (full curtailment and 6/15 shutoff) will be evaluated for this task by comparing yield and forage quality between the treatment and reference fields. Yield samples from all fields have been ground using a Wiley Mill and shipped to Prof. Joe Brummer for the forage quality analysis. Prof. Brummer expects the forage quality analysis to be completed in January 2021.

Grass stubble and root sampling will take place in Spring 2021 on the treatment and reference fields to examine the carryover of energy stores. A third party lab will analyze sugar profiles of these samples. We can then can reasonably approximate the percent non-fibrous carbohydrates *(100 - CP - Fat - NDF - Ash),* an important measure of forage quality. In the case of grass forages, most non-fibrous carbohydrates are nonstructural and largely comprised of glucose (sugars and starches). Field Tech Wendy Thompson will also follow up with a local biologist, who has volunteered to help further classify grass species in Spring 2021.

Task 6: Quality analysis and quality control (QA/QC).

Deliverables: None

Dec. 15, 2020 Update: Quality Analysis and Quality Control (QA/QC) has been ongoing throughout the project and includes monitoring the uploading of data (e.g. soil moisture, forage, atmometer) to a common, cloud-based shared drive, verifying the data format, and converging the data to master files. Subsequent follow up between Dr. Perry Cabot and Field Tech Wendy Thompson have clarified questions regarding data discrepancies. Student intern Cordelia Anderson has additionally checked data for anomalies.

Task 7: Construct enterprise budgets to better understand economic considerations and to assist agricultural producers in comparing water leasing against baseline farming and ranching conditions.

Deliverables: Chapter in the final report detailing enterprise budgets for the fields, farms and region of the study.

Dec. 15, 2020 Update: Jenny Beiermann (CSU Agricultural Business Management Economist) and Project Field Leader Paul Bruchez met to identify the variables necessary to construct field-scale enterprise budgets. The team confirmed that the field scale is the best initial level at which to perform enterprise budgeting, which will subsequently allow farm and inter-farm enterprise budgeting. The current draft version of the field-scale enterprise budget is available here.

Task 8: Outreach and engage with the Colorado Water Conservation Board and other stakeholders interested in alternative transfer methods in order to facilitate constructive dialogue on water sharing programs affecting the Colorado Basin and Western Slope overall.

Deliverables: Field tours, written materials, summary document of participant experiences with reduced irrigation practices.

Dec. 15, 2020 Update: Below is a summary of the outreach and engagement our team has completed for the project since our September 15th progress report. We have included links to relevant presentations and articles where relevant.

- We have provided updates to the Colorado Basin Roundtable at their September 28th and November 23rd meetings, which included this update from Dr. Perry Cabot (CSU). At the November meeting, we also received letters of support from the CBRT and the PEPO committee for a Colorado Water Plan grant application submitted December 1st to support outreach and engagement activities related to the research project.
- On October 22nd, we met with Division 5 staff from the Colorado Division of Water Resources to provide an overview of the project, including the different research components and the enrollment of participating water rights in the River District's Conservation Program.
- On November 5th, members of the project team presented on a panel at Colorado Mesa University's Upper Colorado River Forum on: *Three Stories of Agriculture Leadership on Colorado's Most Pressing Water Challenges.*
- On December 2nd, we hosted a webinar (passcode: V@rh*3.9) to provide an overview of the different research elements of the project and a focused discussion of the work to address how to efficiently and effectively estimate and verify water savings. The webinar covered our partnership with OpenET on remote sensing, the work with CSU on the soil water balance approach, and our work with the CO Division of Water Resources to apply the Lease Fallow Tool to the project.
- On December 3rd, we presented on the project as part of a demand management discussion at the Colorado Ag Water Alliance's *Western Colorado Agricultural Update on Water*.
- Two additional articles on the project were published:
    - Colorado Sun: These hay fields may know something we don't: How to save the Colorado River
    - Politico: The Rancher Trying to Solve the West's Water Crisis

Budget

Task	Description	Total CWCB Grant Funds	4th Quarter 2020 CWCB Expenditures	Total CWCB Expenditures to Date	Remaining CWCB Funds	Total Matching Contributions
1	Participant Contract / Research Locations	$356,283.00	$180,420.10	$356,283.00	$0.00	$298,765.44
2	CU/CCU Remote Sensing	$69,890.00		$454.52	$69,435.48	$45,994.00
3	Validation	$38,303.00	$7,770.00	$7,770.00	$30,533.00	
4	Water Production Functions	$4,568.00			$4,568.00	
5	Impact/Recovery Evaluation	$4,568.00			$4,568.00	
6	QA/QC	$4,967.00			$4,967.00	
7	Construct Enterprise Budgets	$2,284.00			$2,284.00	
8	Outreach	$3,571.00			$3,571.00	
9	Reporting	$15,566.00	$3,236.51	$6,976.67	$8,589.33	$51,283.47
	TOTALS	**$500,000.00**	**$191,426.61**	**$371,484.19**	**$128,515.81**	**$396,042.91**

Schedule

The project schedule is on track.

Evaluating Conserved Consumptive Use in the Upper Colorado River

ATM Grant – CTGG1 2020-2976

Upper Colorado Conservation Project

September 15, 2020 Progress Report

Photo: Upper Colorado River, Russ Schnitzer ©

Introduction

This report provides an update on progress implementing the *Evaluating Conserved Consumptive Use in the Upper Colorado River* research project. The report contains a short project summary, an overview of the project team, a description of the project tasks, and progress towards key deliverables. Future reports will build on this structure with an update on progress since the last report.

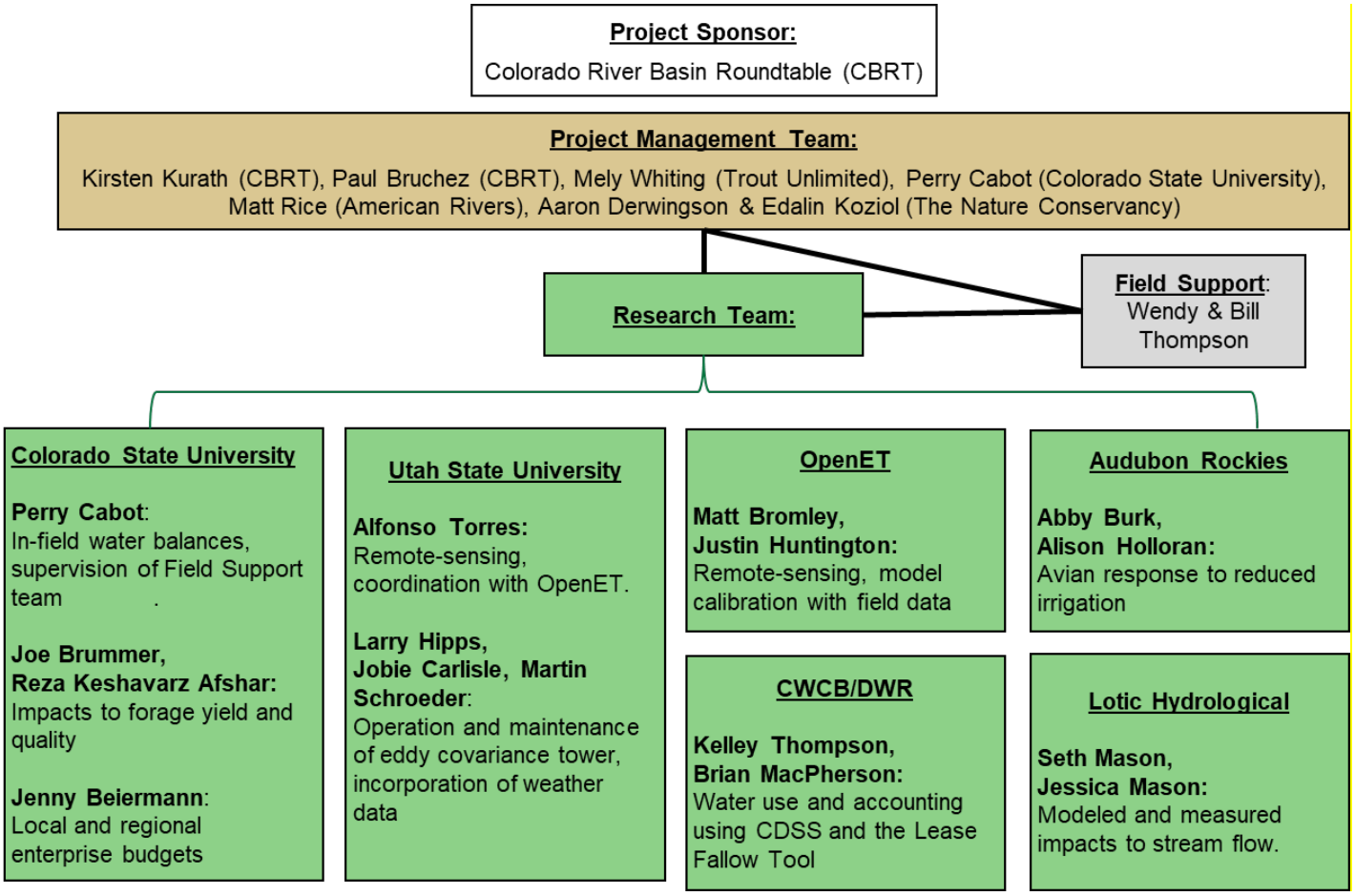
Project Summary

Under the leadership of the Colorado Basin Roundtable, the *Evaluating Conserved Consumptive Use in the Upper Colorado River* project brings together local water users, University researchers, non-profit conservation organizations, and other stakeholders to address priority questions related to voluntary, temporary, and compensated reductions in agricultural water use. Given the potential for these types of water conservation activities to address a number of regional water resource challenges, the goal of this project is to evaluate the viability of reducing irrigation on high elevation irrigated pasture to supply water that can be used for a number of potential purposes, including enhancing environmental flows and providing temporary municipal supplies in times of shortages. In addition, the project will also help address related questions on how to best implement, manage, monitor, and verify water conservation from reduced irrigation.

To accomplish this goal, the project team is integrating on the ground agricultural activities with robust research to address these main objectives:

- Use remote sensing technology to estimate consumptive use (CU) and conserved consumptive use (CCU) on large irrigated high-elevation pastures characterized by various grasses, forbs, and sedges under varying soil and groundwater conditions. Evaluate how CU rates change in relation to these different species in order to inform estimates of water conservation.
- Validate several remote sensing based evapotranspiration (ET) estimation models for CU and CCU verification that are replicable, scalable, and can be used in conjunction with broader remote sensing data platforms. Model verification will incorporate field instrumentation, including an eddy covariance tower, soil moisture sensors, and groundwater observation wells.
- Evaluate changes to streamflow that result from water conservation activities.
- Construct water production functions that compare the relationship between the marketable yield and the total amount of water used for different grass, forb, and sedge forages under varying soil and groundwater conditions to better understand the relationship between yields, forage quality, and CU rates.
- Evaluate impacts and recovery for forages subjected to different levels of irrigation curtailment. This will include documentation of weed pressure and other impacts to yield, forage protein, plant carbohydrates, root depth and nutrient carryover.
- Evaluate ranch enterprise budgets and understand basic economic impacts to assist agricultural producers in comparing compensations for water conservation against baseline farming and ranching profitability. This evaluation will be performed for individual participating ranches as well as regionally.
- Assess potential impacts to wildlife habitat from changes in irrigation practices.
- Outreach in order to facilitate constructive dialogue on water sharing programs affecting the Colorado Basin and Western Slope overall.

Project Team:



Task 1 - Contract with participants and selection of research locations

Description: The project management team will work with local producers in the Kremmling area to identify participating fields that have a variety of grass species and soil moisture profiles, records of previous irrigation and associated yields, and a reliable water supply. Since the proposed verification method uses Landsat 7 and 8 imagery, participating fields also need a minimum field width of approximately 1,000 feet for the statistical assessment of the study. The contract with the participants describes the field location, irrigation management, compensation terms, and expectations for project involvement.

Deliverables: Final table of participating lands with acreages, associated conservation measure(s), and indication of signed contract with participant (identities will be kept confidential).

Task Members: Paul Bruchez, Perry Cabot, Wendy Thompson, and Mely Whiting

Percent complete: 100%

September 15, 2020 Update: The project management team worked with the participating producers in March and April 2020 to address questions regarding the purpose and organization of the project and finalize contracts. Members of the management team and research team then visited participating fields in April and May to establish boundaries for reference (REF) and treatment (TRT) fields and install field equipment.

- Task members met in Kremmling to choose specific locations within the REF and TRT fields to install fixed research enclosures (REs) for water balance monitoring and forage sampling. These REs were georeferenced and are intended to be permanent locations for monitoring and sampling in sequential years. The task team developed and applied the concept of a "productivity gradient" for selecting these locations. Within large fields, different sub-field locations exhibit relatively higher and lower levels of productivity. The concept of selecting high and low areas of productivity was intended as a means of packaging several research variables into a single location, since productivity is largely influenced by grass species and underlying soil conditions. Ranchers were able to inform us of these sub-field locations, which helped us to choose the REs.
- An alpha-numeric coding system was created for each RE, based on sub-designations for the ranch name, research condition, RE site and productivity level. For example, GPR R1 H designates the 3-letter abbreviation for the ranch name, 1-letter designation for R or T (REF or TRT), 1 number for field name and 1 letter for H or L (high or low productivity).
- Both the high and low production REs were encircled with cow paneling approximately 10 feet in diameter, to protect against animal grazing or intrusion. Table 1 below describes the field instrumentation the research team installed in each RE. Only the high productivity locations contain the water balance instrumentation since we expect greater canopy cover at these locations and ET rates that are more consistent with measurements taken at other scales.

Figure 1: Members of the project team installing research enclosures

- Given the importance of understanding the relationship between water use and the associated effects of irrigation curtailment for this project, the team chose to install an eddy covariance measurement system at one field subjected to full-season cutoff. Eddy covariance uses micro-meteorological tools to directly observe the exchanges of gas, energy, and vapor between earth surfaces and the atmosphere. It is considered the most reliable method for determining the accuracy of remotely-sensed ET estimates. While eddy covariance data for grass pastures under irrigated conditions is available, high elevation pasture fields under curtailment have not been evaluated. This project offered a once-in-a-decade opportunity to obtain data under extremely dry conditions caused by voluntary curtailment.

Participant Contracts:
As indicated in Table 1, the Project Team through Trout Unlimited has a signed contract with each participant; A total of 10 participants signed contracts. The contract outlines the terms and requirements of the project as well as the details of each participating field, requirements for water conservation and irrigation water management, expectations for working with the research team, and the compensation terms. A template contract with associated attachments is attached to this report. Figure 2 below shows the field boundaries of the participating lands.

Enrollment of Participating Lands in Water Conservation Program.
To protect project participants' water rights, Trout Unlimited on behalf of the Project Team applied for inclusion of the participating lands and water rights in the Colorado River Water Conservation District's Water Conservation Program under SB 13-019. Inclusion in this program protects the participant's water rights from abandonment and reductions in historic consumptive use during their period of non-use as a part of this project. The River District approved Trout Unlimited's application on April 21, 2020 and approved additional participant lands and water rights on June 19, 2020.

Table 1: Participating Lands & Research Instrumentation

Field Name	Water Conservation Activity	Acres	Signed Contract?	Research Instrumentation*
T1 SPR 2020	Full Season	213.1	Yes	H/L Enclosure, SMS, GW, NP
T1 SBR 2020	Full Season	77.2	Yes	H/L Enclosure, SMS, GW, NP
T1 GPR 2020	Full Season	210.4	Yes	H/L Enclosure, SMS, GW, NP, EC
T2 GPR 2020	Full Season	337.8	Yes	H/L Enclosure, SMS, GW, NP
T1 BJM 2020	Full Season	31.7	Yes	None
T1 JLM 2020	Full Season	15.8	Yes	None
T1 SBT 2020	Full Season	9.12	Yes	None
T1 HSR 2020	Full Season	88.5	Yes	None
T1 RCR 2020	Split Season	34.5	Yes	H/L Enclosure, SMS
T1 RSR 2020	Split Season	124.2	Yes	H/L Enclosure, SMS, GW, NP
	Sub-Total	**1142.32**		
R1 SPR 2020	Reference		n/a	H/L Enclosure, SMS, GW, NP
R1 SBR 2020	Reference		n/a	H/L Enclosure, SMS, GW, NP
R1 GPR 2020	Reference		n/a	H/L Enclosure, SMS, GW, NP
R1 RSR 2020	Reference		n/a	H/L Enclosure, SMS, GW, NP
R1 RCR 2020	Reference		n/a	H/L Enclosure
	Sub-Total			

** H/L Enclosure = High/Low Forage Productivity Enclosure, SMS = Soil moisture sensors,*
GW = Groundwater observation well, NP = Neutron probe access, EC = Eddy covariance tower

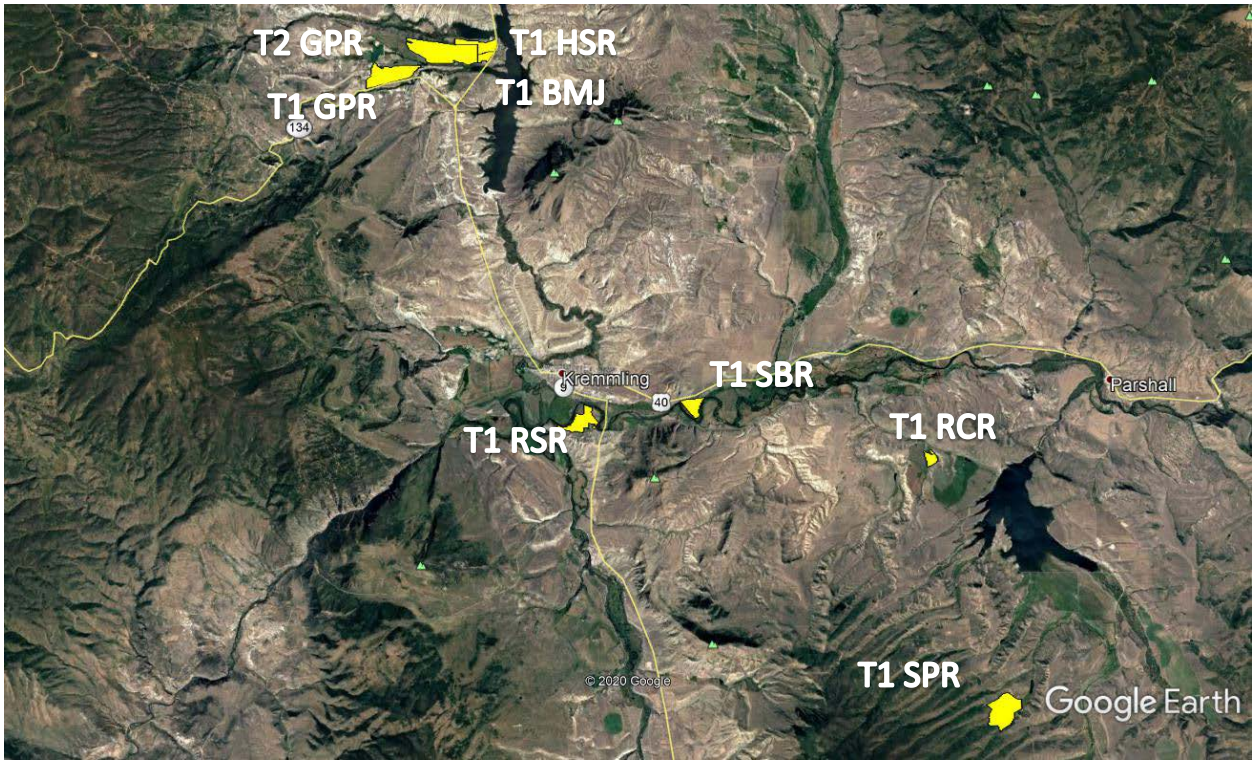


Figure 2: Map of Participating Lands

Task 2 - Perform remote sensing measurement and estimation of consumptive use (CU) and conserved consumptive use (CCU) on research sites.

Description: For each of the participating lands identified in Task 1, we will complete a due diligence assessment of water rights and historical consumptive use. This information will provide a baseline to better understand potential and actual water conservation. The working concept to defining actual CCU in this study is to subtract ET estimates from the treatment fields from ET estimates from companion reference fields, with the necessary adjustments for effective precipitation. The research team will derive the ET estimates through remote-sensing evaluations that use a spatially averaged ET rate over the areal coverage of the fields.

Given the ability to conduct spatially broad estimates with reasonable accuracy, the use of satellite remote-sensing to study ET has grown significantly over the past three decades. In brief, remote-sensing is a technique that employs proxy measurements, such as surface energy fluxes or spectral signatures, that are then correlated to ET using spatial algorithm and models. Because these models are based in GIS and require technical proficiency, they have largely been the purview of research institutions. More recently however, a collaborative effort to make these models available to the broader public was initiated by OpenET (www.etdata.org). This effort intends to provide "*reliable, trusted and widely available ET data at the field scale*" for the purposes of maximizing water use efficiency, reducing agricultural input costs, developing water budgets, and supporting "*trading programs that protect the financial viability of farms during droughts while ensuring that water is also available for other beneficial uses*."

For this project, OpenET will provide access to field- and pixel-scale reduced ET estimation at monthly and annual time-steps for the participating fields. In addition, OpenET will provide access to historical ET information for these fields to determine water use variability between dry, wet, and average years. This information will be validated with ground measurements from the local CoAgMet stations as well as eddy covariance instrumentation, soil moisture sensors, and groundwater observation wells installed for this project.

As part of this task, staff from the CWCB/DWR will complete work on two main tasks related to estimating and administering conserved consumptive use. This work follows two main tasks:

1. Evaluate the historical consumptive use (HCU) of project fields in a streamlined manner using state tools, existing state data and data collected by project.
2. Evaluate methods and framework for a streamlined and standardized accounting tool to estimate streamflow credits and return flow requirements on a monthly and/or daily basis incorporating data collected during project operation.

To further understand and verify the actual amount of water conserved under the project and its impact on stream conditions, estimates of CU and CCU from OpenET and the CWCB/DWR will be combined with a companion study evaluating hydrological changes resulting from the project's water conservation practices. Lotic Hydrological will complete this work by assessing hydrological changes along reaches of the Colorado River, Pass Creek, Red Dirt Creek, Williams Fork and Bull Run during the summer and early fall of 2020 and 2021 and compare them with historical data. This effort will provide an accounting of water conserved by the project between the participating parcels and the confluence of the Colorado River and Blue River. Data and information produced by this effort may be used to characterize potential effectiveness of water conservation projects at delivering water to the outlet of a drainage basin, evaluate environmental benefits or impacts, and for other purposes. This effort will also inform efforts to develop streamlined tools supportive of similar projects across the Colorado River basin.

Deliverables: Chapter in final report addressing primary research questions:

1. Estimating and verifying water conservation from multiple irrigation practices using in-field instrumentation and remote sensing.
2. Evaluate how variations in crop species, soil moisture, and depth to groundwater affect crop water use and potential water conservation.

Task Members: Perry Cabot, Alfonso Torres, Larry Hipps, Jobie Carlisle, Martin Schroeder, Matt Bromley, Justin Huntington, Kelley Thompson, Brian Macpherson, and Seth Mason.

Percent complete: 50%

September 15, 2020 Update: A key dynamic in using remote-sensing to estimate ET is that the method relies on the application of modeling approaches based on measured data that is known to correlate with actual ET. Model outputs are inherently an estimate, and while advancements in remote-sensing have informed more reliable estimates, certain environmental conditions relevant to irrigation curtailment have not been widely studied. In other words, ET estimates and model results using remotely-sensed data are based on *typical conditions*, which in the case of irrigated pastures means well-watered conditions during the irrigation season. This project represents a unique opportunity to perform these estimates on intentionally water-limited fields, while comparing these fields to fully-irrigated fields experiencing the same weather conditions.

To date, OpenET has provided estimates of ET for the study fields for 2016, 2017, 2018, 2019 and year-to-date 2020 from an ensemble of remote-sensing models through the beta version of their platform.

CWCB/DWR Update:
CWCB/DWR staff are finalizing an update of the Lease Fallow Tool (LFT) that will make it more accurate for the West Slope, including Division 5. CWCB/DWR will then use the updated LFT to estimate HCU for the participating project lands. Additionally, CWCB/DWR staff are currently working with the Project Team to review model assumptions and identify any locally available data. Prior to completing the HCU estimations, CWCB/DWR will refine these assumptions based on any local data and feedback from the project team. CWCB/DWR anticipates having initial results available by November 2020.

Lotic Hydrological Update:
Lotic began work on two tasks: Data Collation and 2020 Field Collection. The data collation task includes a search for data and special studies characterizing historical patterns of water use, groundwater return flows and surface water hydrology in the Kremmling area. Data sources include the Hydrobase database maintained by the Colorado Division of Water Resources (DWR); Colorado Water Conservation Board (CWCB) StateMod and StateCU simulation data sets for the Colorado River basin; U.S. Geological Survey (USGS) streamflow gauges, and reservoir release records from the Colorado River Water Conservation District (River District), Denver Water, and others. Data characterizing local water infrastructure, water rights, and water use provided by The Nature Conservancy will also be reviewed. The Data Collation task is approximately 25% complete.

The 2020 Field Collection task includes four field data collection campaigns in the summer and fall of 2020, two of which have been completed to date. Streamflow is measured during each campaign using an Acoustic Doppler Current Profiler on the Colorado River immediately upstream of the point of surface water diversion and downstream of the presumed point of surface and groundwater return flows for the T1 SBR 2020 and the T1 RSR 2020 parcel. Similar measurements are carried out on Pass Creek, bracketing the westernmost participating parcel on T1 GPR 2020. Data is collected in a quasi-synoptic fashion and each discharge measurement consists of a replicate sample (n >= 3).

Task 3 - Validate multiple remote sensing models for CU and CCU verification that is science-based, replicable, and scalable and can be used in conjunction with broader remote sensing platforms on high elevation pastures in Western Colorado.

Description: In implementing Task 3, the Project Team has worked to keep the bigger picture goals of the project in mind. Namely, what would a robust water conservation program need in terms of measuring and verifying conserved consumptive use for temporary transfers? Our Project Team has identified three general needs:

1. Parties to any water conservation agreement need estimates of CU and CCU for project development and due diligence and for negotiating the agreement and associated compensation.
2. Those same parties, as well as key stakeholders, need verification that the water conservation activity occurred as described in the agreement, and need an estimation of the actual volume of CCU created given water availability and other field conditions.

3. Finally, a successful water conservation program at scale needs a process to address what happens when the pre-project estimates differ from the post-project verification.

To address the main question and associated needs, we propose that results from this project can help inform a policy discussion around an approach that would balance the precision offered by available science against what is administratively feasible and practical for participants and stakeholders.

The first year of the project (2020) will involve field work to establish and instrument the research sites. As outlined in Table 1, reference and treatment fields have a research enclosure where the project team has installed soil moisture sensors to measure conditions in the root zone. Throughout the irrigation season, the Field Support team will make periodic site visits to collect data and verify that participating fields in the project are operated according to their contract and management plan.

Field instrumentation is designed to provide "real-time" measurements on energy fluxes, soil moisture conditions, soil electrical conductivity, and temperature that will be used to verify the remote sensing models. With these measurements, we can compare ground and satellite estimates of ET under the actual conditions of irrigation curtailment and reference conditions. These comparisons can be performed daily, weekly, monthly, and seasonally through various validation methodologies and statistical comparisons, ranging from simple linear regression to mean bias error (MBE) and root mean square errors (RMSE). Given the frequency of data collected these "ground-truth" estimates will allow us to check the accuracy of an ensemble of remote-sensing models for ET estimates and also interpolate estimates between satellite pass dates, which occur every 8 days.

Advantages that remote-sensing can offer to water sharing programs include the scalability and transferability of the method to other regions, such that intensive in-field monitoring is not required under every circumstance, as long as an ensemble of models for estimating ET is acceptable to the parties involved. An ensemble of model estimates contrasts with a single model estimate, which may not be advisable since different models provide different results, by grouping results to show a defined range within which the estimate is reasonably accurate. The goal of the ensemble approach is to inform a larger discussion on measurement and verification of ET to address questions on the importance of balancing model uniformity versus local variability, spatial coverage versus temporal accuracy, and administrative convenience versus scientific accuracy.

Estimating ET through existing State tools, remote-sensing models, eddy covariance, or a water balance approach will always provide a range of reasonably accurate, but nonetheless divergent, results. Therefore, the role of this science-based field project is to provide ET estimates from these different methods, along with their associated costs and considerations, as a basis for further discussion. Any water conservation program will need to determine an agreed upon approach for estimating CCU and work through how that approach impacts other programmatic elements, such as contracts and payments, as well as other policy issues, such as how to address return flow impacts or what to do when pre-project estimated CCU differs from post-project verified CCU. Each approach will also inform specific measurement requirements at different scales, from the field to the region.

Deliverables: Chapter in Final Report with estimates of CCU for each study site and a description of the factors influencing the range of potential conserved consumptive use.

Task Members: Perry Cabot, Paul Bruchez, Alfonso Torres, Larry Hipps, Jobie Carlisle, Martin Schroeder, Matt Bromley, Justin Huntington, Kelley Thompson, Brian Macpherson, Bill & Wendy Thompson, Mely Whiting, and Edalin Koziol.

Percent complete: 35%

September 15, 2020 Update:
As described above, this project utilizes field instrumentation that measures water fluxes and soil deficits in the field to improve the reliability of remote-sensing models to derive ET. The project team has installed Acclima TDR 315H soil moisture sensors with DataSnap Loggers at each RE at depths of 6, 18, 30 and 42 cm. These depths were selected based on evaluations of the root zones for the grasses at these locations. These sensors were chosen based on comparisons between various soil moisture measuring tools (Varble and Chavez, 20XX).

Figure 3: Installing Acclima soil moisture sensors

The data loggers are programmed to record measurements every 15 minutes, allowing us to carefully measure the changes in soil moisture as a technique for also estimating ET. Additionally, each RE is also equipped with a groundwater observation well and water level logger (Solinst Level Logger), neutron probe access tube (for CPN Instrotek probe), direct reading rain gage, and an atmometer (ET Gage, Loveland, CO). As described in Task 2, the project team also installed an eddy covariance tower on June 15. The USU team is actively maintaining the tower through regular visits and telemetric data collection.

Task 4 - Construct water production functions for different grass, forb, and sedge forages under varying soil and groundwater conditions in order to understand yields as a function of CU rates.

Description: The purpose of Task 4 is to better understand the relationship between consumptive use (CU) and agronomic variables including crop yield and forage quality. Dr. Cabot and Prof. Brummer are taking the lead on this task, with additional input from Dr. Keshavarz and Dr. Torres-Rua to develop the CU/CCU relationship with agronomic variables. The Project Team is collecting regular yield measurements and will evaluate yields against local CU rates.

A crop water production function is the relationship between the marketable yield and the total amount of water used by plant through evapotranspiration. Through this task, the research team will calculate these functional relationships for the grasses in this study, which represent species similar to many high elevation pastures of Colorado, such as Garrison foxtail (*Alopecurus pratensis*) and Timothy grass (*Phleum pratense*). Once calculated through this direct field experiment, these different mathematical expressions are transferrable to other water conservation projects and programs to predict yield knowing water use and vice-versa.

The benefit to the producer of a reliable crop water production function is that it provides a credible measurement of how much production was lost based on the water conservation activity, and how that correlates to CCU. From the perspective of the lessee, this is a tangible relationship between one of the major monetary losses incurred by the producer versus how much water could be expected to have been conserved. More simply, the crop water production function provides a relatable means of monetizing conserved consumptive use against lost yield. Therefore, the crop water production functions are developed in concert with the data collected in Task 2 and 3 and help inform the enterprise budget work in Task 7.

Deliverables: Chapter in final report addressing the factors that influence grass production and CU under reduced irrigation practices.

Task Members: Perry Cabot, Joe Brummer, Reza Keshavarz Afshar, and Alfonso Torres.

Percent complete: 20%

September 15, 2020 Update: The Field Support team has completed regular forage sampling at the reference and treatment field sites throughout the season. These samples consist of taking clipped grasses from a 0.25 m^2 grid square at each RE fixed location. Additionally, the Field Support team has also taken composite samples from the area surrounding the REs. All samples are then dried and weighed to determine dry matter forage, allowing comparison between reference and treatment conditions. To date, the team has taken forage samples from the high and low production enclosures in June, July, August and September. The initial data gives reasonably good confirmation that the project team properly selected high and low production locations.

Task 5 - Evaluate impacts and recovery for forages subjected to different levels of irrigation curtailment.

Description: This task will focus on the agronomic and biophysical impacts of reduced irrigation versus irrigation to maximize yield or irrigation to fully utilize water throughout the season (i.e., "typical" irrigation). Understanding how variations in crop species, soil moisture, and depth to groundwater impacts yield and forage quality under reduced irrigation and recovery with full irrigation is a priority research question for the Colorado Basin Roundtable, local water users, and other stakeholders evaluating potential water conservation programs. In 2020, this task will involve collecting data from both reference and treatment fields on yield, plant count and density, forage protein, plant carbohydrates, nutrient carryover, and weed pressure. This data will help establish a baseline that will allow the project team to assess the recovery period and pattern of vegetation on fields that have undergone a period of reduced irrigation in future years. *(Note: While this ATM grant only covers the first year of reduced irrigation, the applicants have obtained the participants' agreement to allow for continued study of recovery through April 30, 2024 and will seek additional funding for that purpose)*.

Results from this task will help stakeholders and decision makers better understand the potential long-term impacts and recovery issues associated with reduced irrigation on high elevation perennial grass fields. In combination with the results from Task 7, results from this task will provide information agricultural producers need to evaluate compensated water conservation activities and effectively negotiate compensation and terms for such activities. This information is also critical for any party looking to acquire CCU through a temporary,

voluntary, and compensated water conservation program as it directly informs program costs and other considerations for long term success.

A goal of this project is to provide additional explanation for observations made in previous studies, which showed a range of recovery timelines for irrigated pasture grasses that experienced voluntary water curtailments or drought. Important data collected in this current effort will include the change in soil organic matter levels and rooting zone depths. A promising thread of evaluation also involves the testing of total nonstructural carbohydrates. Previous research has reported that around 85 to 90% of sugars are stored in the stems. The less quantity of stem ”stubble” actually available for carbohydrate storage, the more likely that plant mortality will occur and it is expected that dry conditions would reduce stubble. However, there is evidence to suggest that grasses may also respond to water stress by storing higher levels of carbohydrates for later use. In the case of this project, later use of carbohydrates may occur in the spring when grasses are returned to full irrigation.

Figure 4: Active root zone

Deliverables: Chapter in the final report addressing the agronomic impacts of reduced irrigation.

Task Members: Perry Cabot, Joe Brummer, Reza Keshavarz Afshar, Wendy Thompson

Percent complete: 25%

September 15, 2020 Update: As described in Task 4, we have completed regular forage sampling to date on both the treatment and reference fields. This information will provide a baseline yield against which the project team will compare yields for 2021 when all fields will receive full irrigation.

Task 6 - Quality analysis and quality control (QA/QC).

Description: In order to maintain data quality and address problems as they are encountered, the Project Team has established a Quality Analysis and Quality Control (QA/QC) protocol. This involves regularly compiling data, formatting spreadsheets, and generating appropriate charts in order to determine any issues arising with the data collection system. Additionally, regular interactions with the project participants will allow any unplanned changes to the irrigation schedules to be understood and reflected in the data.

Deliverables: None

Task Members: Perry Cabot, Alfonso Torres

Percent complete: 25%

September 15, 2020 Update: The types of data collected and created for this project include spreadsheet-based files of quantitative and qualitative variables associated with remote sensing, irrigation, and soil water balances for the purpose of obtaining ensemble model estimates of ET. The project team will provide a separate file that summarizes various data forms with the final report. This file will describe a record of all data collected during the execution of the project. In order to maintain participant privacy, partner names will not be included in data reporting. The only analyzed data that will be presented will pertain to the analysis of results in concert with the objectives of the project. Data is being stored on an external hard-drive as well as a server associated with the fiscal agent. This data set will be available for access by project participants upon request. The data collected will be used for a final report and will be disseminated in articles to peer-reviewed journals.

Task 7 - Construct enterprise budgets to better understand economic considerations and to assist agricultural producers in comparing water leasing against baseline farming and ranching conditions.

Description: A better understanding of economic factors is needed for agricultural producers to evaluate how compensation for reduced water use may fit into their operational planning. This task involves an evaluation of crop enterprise budgets and regional economic factors for participating lands and the region. This information will incorporate the impact on yield and agricultural operations to inform the value of the water to the ranching enterprise. Results from Tasks 4 and 5 on the impact of reduced irrigation on CCU and future yield will help complete an economic assessment of impacts of water conservation programs.

A farm enterprise budget is a tallying of estimates for the full economic costs and returns projected to accrue to an agricultural activity, such as raising livestock, producing hay, or in the case of this project, receiving payment for implementing water conservation activities. Enterprise budgets use information about yearly management practices, labor costs, and inputs used in production. They can also be used to compare potential income and the resources needed to earn a specified return, or to compare the profitability of two or more systems of production, such as the reference and treatment conditions evaluated in this project. A good enterprise budget states what is generally expected from different farm management scenarios, listing the expected revenue and expenses incurred. It is designed to compare the profitability of the approaches, not just cash flow.

In this project, the enterprise budgets will be used to compare economics at the field, farm and regional scale between “water conservation activities” and baseline “business as usual” scenarios. Similar to the results from Task 5 on the impacts of reduced irrigation, the economic data from this task will inform two main aspects of voluntary water conservation activities. First, agricultural producers need a thorough understanding of both scenarios to evaluate whether and how to participate in any water conservation activity. Results from this task will help interested water users compare compensation with reduced yields and other potential impacts and benefits to an operation engaged in water conservation. Stakeholders and decision makers evaluating water conservation programs more broadly need an accurate understanding of the potential costs for compensation as well as any associated management costs required for temporary activities.

Deliverables: Chapter in the final report detailing enterprise budgets for the fields, farms and region of the study
Task Members: Jenny Beiermann, Perry Cabot, Paul Bruchez

Percent complete: 5%

September 15, 2020 Update: To date, the Task Members have developed a template enterprise budget spreadsheet. At the end of the irrigation season, the Task Members will meet virtually with each individual participant to input real costs and revenue, evaluate budgets, and prepare a report

Task 8 - Outreach to and engage with the Colorado Water Conservation Board and other stakeholders interested in alternative transfer methods in order to facilitate constructive dialogue on water sharing programs affecting the Colorado Basin and Western Slope overall.

Description: The project team will work with the CWCB to share information on the project and explore opportunities to leverage this field work to address additional questions. Furthermore, at the request of the CWCB, an extension and outreach program can be developed for the project, consisting perhaps of such approaches as field tours, video materials, and fact sheets.

Deliverables: Field tours, written materials, summary document of participant experiences with reduced irrigation practices.

Task Members: Matt Rice, Paul Bruchez, Aaron Derwingson, Kirsten Kurath, Perry Cabot, Mely Whiting

Percent complete: 25%

September 15, 2020 Update: While Project Team members have engaged in significant outreach and communication around the project since March, the challenges of the current COVID pandemic have made certain types of outreach challenging or not feasible.

To date, the Project Team has engaged with the CWCB's Demand Management workgroup process, describing the project to workgroup members and soliciting input and feedback on how the project could potentially help address questions coming from the feasibility investigation.

In July, the Project Team gave their first official project update to the Colorado River Basin Roundtable and a copy of that presentation is available here.

Finally, two articles were published that focused on the project:

- Aspen Journalism: How a high-elevation irrigation study in Kremmling could help Colorado avoid future water shortages
- Opinion: Farmers and ranchers lead the way on conserving the Colorado River

Budget:

Date: September 15, 2020 Update										
Water Activity Name: Evaluating Conserved Consumptive Use in the Upper Colorado River										
Grantee Name: Trout Unlimited										
Task No.	Description	Start Date	End Date	Matching Funds (cash & in-kind)	Matching Funds Spent	Remaining Matching Funds	ATM Grant Funds	ATM Grant Funds Spent	Remaining ATM Grant Funds	Total
1	Participant contract/Research locations	4/1/2020	5/1/2020	$290,283.00	$151,848.46	$138,434.54	$356,283.17	$175,862.90	$180,420.27	$646,566.17
2	CU/CCU remote sensing	4/15/2020	3/1/2021	$40,000.00	$25,347.58	$14,652.42	$69,890.38	$454.52	$69,435.86	$109,890.38
3	Validation	4/15/2020	3/1/2021	$40,000.00	$25,347.57	$14,652.43	$38,303.18	$0.00	$38,303.18	$78,303.18
4	Water production functions	5/1/2020	3/1/2021	$1,500.00	$0.00	$1,500.00	$4,567.57	$0.00	$4,567.57	$6,067.57
5	Impact/recovery evaluation	4/15/2020	3/1/2022	$1,500.00	$0.00	$1,500.00	$4,567.57	$0.00	$4,567.57	$6,067.57
6	QA/QC	4/15/2020	12/1/2021	$0.00	$0.00	$0.00	$4,966.79	$0.00	$4,966.79	$4,966.79
7	Construct enterprise budgets	4/15/2020	3/1/2021	$0.00	$0.00	$0.00	$2,283.79	$0.00	$2,283.79	$2,283.79
8	Outreach	4/1/2020	3/1/2021	$0.00	$0.00	$0.00	$3,571.48	$0.00	$3,571.48	$3,571.48
9	Reporting (includes Admin Costs)	7/1/2020	3/1/2021	$15,000.00	$10,000.00	$5,000.00	$15,565.75	$4,903.19	$10,662.56	$30,565.75
			Total	$388,283.00	$212,543.61	$175,739.39	$499,999.68	$181,220.61	$318,779.07	$888,282.68

Schedule:

The project schedule is on track.

Attachment A: Template Contract

AGREEMENT FOR PARTICIPATION IN THE UPPER COLORADO RIVER CONSERVED CONSUMPTIVE USE STUDY

This agreement (the "Agreement") is entered this _____ day of _____, 2020 ("Effective Date"), between _____ (the "Water User") and Trout Unlimited ("TU") (collectively, the "Parties") for the purpose of defining the Parties' responsibilities and commitments for the Water User's participation in the Upper Colorado River Conserved Consumptive Use Study (the "Study").

Recitals

A. TU is a non-profit, section 501(c)(3) corporation, the mission of which is to conserve, protect and restore North America's cold-water fisheries and their watersheds.

B. TU is working with the Colorado River Basin Roundtable on the Study to evaluate the benefits and impacts of voluntary, temporary, and compensated irrigation reductions on high altitude hay and grass in Grand County.

C. The Water User owns and/or leases the water rights (the "Water Rights") and the lands (the "Participating Lands") described in the Field Summary Sheet, which is attached as Attachment 1 and incorporated into this Agreement by this reference. The Water Rights allow for diversion of water from [name of stream], and the Water User has the right and intent to use these water rights to irrigate Participating Lands. Attachment 1 details the acreage, time period and duration of no irrigation or reduced irrigation, payment schedule, and study expectations for participation.

D. The Water User desires to participate in the Study and is willing to work with TU under the terms set forth in this Agreement.

E. The Colorado Water Conservation Board ("CWCB") and others have committed funding for the Study.

F. TU will work with the Water User to enroll the water rights in the water conservation program sponsored by the Colorado River Water Conservation District as described in C.R.S. § 37-92-103 and C.R.S. § 37-92-305(3)(c) in order to protect the water rights against abandonment or diminishment of historical consumptive use.

Therefore, in consideration of the mutual promises and commitments contained herein, the Parties agree as follows:

Agreement

1. The term of this Agreement will commence on the Effective Date and will end on April 30, 2024 to enable completion of Study activities. Conservation Measures described in the Agreement will be completed by December 31, 2020.

2. The Water User hereby enrolls the Water Rights and Participating Lands described in Attachment 1, and incorporated to the Agreement by this reference, in the Study. As a participant in the Study, the Water User will forgo or reduce diversions of the water rights as further specified in Attachment 1. The act of foregoing or reducing diversions as described in this paragraph will be considered implementation of "Conservation Measures." The Water User also agrees to comply with the terms of the Verification Plan, attached as Attachment 2 and incorporated into this Agreement by this reference, and with the Study Participation actions identified in Attachment 1.

3. TU will manage grant funds, payments to participants, and grant reporting requirements to the entities funding the Study. The Water User will provide information requested by TU to comply with reporting requirements.

4. TU will make payments to the Water User for implementation of Conservation Measures as provided in Attachment 1. In exchange for payment, the Water User will implement the Conservation Measures and the Study Participation actions identified in Attachment 1. No other payments will be made to the Water User under this Agreement.

5. If a downstream call is placed during the 2020 irrigation season, the Water User will continue to be compensated for implementation of the Conservation Measures identified in Attachment 1.

6. The Water User understands that compliance with the directions set forth in Attachment 1 is critical to the implementation of the Conservation Measures and to the success of the Study and agrees to comply with those directions.

7. The Water User hereby grants TU, its contractors, agents and partners, access to the Participating Lands and related water structures for purposes of data collection, verifying compliance with the Agreement, and other activities necessary for successful completion of the Study.

8. Neither Party may assign or delegate their respective rights, duties, and obligations hereunder absent the written consent of the other Party.

9. The Water User recognizes that participation in the Study, as set forth in this Agreement, may have impacts on the Participating Lands and/or potential short term and long term economic impacts to the Water User and waives any right to claim compensation for such impacts.

10. To the full extent allowed by applicable law, the parties shall hold each other harmless against any and all liability, loss, damages, penalties, costs or expenses for personal injury or damage to real or tangible personal property which the parties may sustain, incur or be required to pay, resulting from, arising out of, or in connection with the performance of this Agreement.

11. All provisions herein, including the benefits and burdens, shall extend to and be binding upon the Parties' respective heirs, legal representatives, successors, and assigns. This Agreement may be executed in multiple identical original counterparts constituting one Agreement.

12. Modifications of this Agreement shall not be effective unless agreed to by the Parties in a written, properly executed amendment hereto.

13. Enforcement of this Agreement and all rights and obligations hereunder are reserved solely to the Parties. Any services or benefits which third parties receive as a result of this Agreement are incidental to the Agreement and do not create any rights for such third parties.

14. The Parties agree that the terms and conditions of this Agreement are enforceable by specific performance and the Parties hereby waive any defenses to specific performance.

15. Jurisdiction and venue for any action relating to this Agreement or the interpretation, enforcement or determination of the rights and duties of the Parties hereto shall be in the District Court in Grand County, Colorado. By signing this Agreement, the Water User and TU submit to the personal jurisdiction of the District Court of Grand County, Colorado and waive any and all rights under the laws of any State to object to said jurisdiction or venue.

16. In the event of any arbitration or litigation arising out of this Agreement, the arbitrator or court shall award to the prevailing party all reasonable costs and expenses, including attorney fees.

17. Whenever notice is to be given pursuant to this Agreement, it shall be in writing and shall be delivered in person, by electronic mail to the address set forth below, or by U. S. Mail, first class postage prepaid, to the address set forth below.

Notice to TU shall be given to:

Mely Whiting
PO Box 1544
Pagosa Springs, CO 81147
mely.whiting@tu.org

Notice to the Water User shall be given to:

NAME
ADDRESS
EMAIL

Trout Unlimited

_____

Name of Water User:

_____

By (name of person signing):

Title:

Attachment 1
Field Summary Sheet

Table 1: Participating Lands where Conservation Measures will be Implemented

Field Name	Irrigation Source	WDID	Acres	Conservation Measure

Table 2: Participating Lands that will be used as Reference Field(s)

Field Name	Irrigation Source	WDID	Acres	Conservation Measure

Conservation Measure:

As part of the Upper Colorado River Conserved Consumptive Use Study, the Water User agrees to implement the Conservation Measure(s) identified in Tables 1 and 2 as follows:

Full Season – No Irrigation: For Conservation Measures requiring Full Season – No Irrigation, the Water User shall not apply any irrigation water from any source (other than natural rainfall) to the participating lands described in Table 1 from January 1, 2020 through December 31, 2020.

Split Season – No Irrigation after June 15: For Conservation Measures requiring Split Season – No Irrigation, the Water User shall not apply any irrigation water from any source (other than natural rainfall) to the Participating Lands described in Table 1 from June 15, 2020 through December 31, 2020.

Reference Field: Water user shall continue normal operation and irrigation of the reference field(s) described in Table 2.

The Water User agrees to apply the specific Conservation Measure identified to the specific Field(s) identified in Tables 1 and 2, continuously, for the duration of the required Conservation Measure implementation period. The Water User shall not shift Conservation Measures from one Field to another or to fields that are not identified in Tables 1 and 2.

Study Participation: In addition to implementing the Conservation Measures described above, for the duration of the Agreement, the Water User agrees to undertake the following actions necessary for implementation of the Study:

- Coordinate with TU, its agents, contractors, and partners to identify, establish, and maintain suitable research plot(s) on Participating Lands. These research plot(s) must remain in place and delineated for the duration of the Study.
- Coordinate with TU, its agents, contractors, and partners to enable installation and maintenance of field equipment and scientific measurement tools in the Participating Lands. The equipment and scientific measurement tools must remain in place for the duration of the Study.
- Implement reasonable measures to protect field equipment and scientific measurement tools from loss or damage.
- Provide access to TU, its agents, contractors, and partners to the Participating Lands for purposes of data collection, verifying compliance with the Agreement, and other activities necessary for successful completion of the Study.
- Communicate with TU, its agents, contractors, and partners regarding irrigation and agricultural operations.
- Return Participating Lands subject to Full Season and/or Split Season Conservation Measures to normal operations and historic irrigation practices for the remaining term of the Agreement, unless prevented from doing so by acts of God or other such conditions beyond the control of the Water User.
- Other reasonable actions needed for the successful implementation of the Study.

Payment and Schedule:

Subject to the verification provisions described in Attachment 2, Trout Unlimited shall make the following payments to Water Users for the implementation of conservation measures on Participating Lands:

1. For participating lands where "Full Season – No Irrigation" conservation measures are implemented, Trout Unlimited shall pay Water User a total of $621.00 per acre of participating lands for the 2020 calendar year. This amount shall be paid as follows:
    a. $ shall be paid by May 1, 2020.
    b. The remaining balance of $ shall be paid within thirty days after Trout Unlimited has verified that Water User has fully implemented the Conservation Measure(s) consistently with the terms of the Agreement.

2. For participating lands where "Split Season – No Irrigation after June 15" conservation measures are implemented, Trout Unlimited shall pay Water User a total of $281.00 per acre of participating lands for the 2020 calendar year. This amount shall be paid as follows:
    a. $ shall be paid by June 15, 2020.
    b. The remaining balance of $ shall be paid within thirty days after Trout Unlimited has verified that Water User has fully implemented the Conservation Measure(s) consistently with the terms of the Agreement.

3. There shall be no payment or compensation for reference field acres.

Figure 1: Map of Participating Lands with Associated Conservation Measures, Reference Field(s), and Irrigation Sources

Attachment 2
Verification Plan

Project Background:

The Water User has agreed to implement Conservation Measures identified in Attachment 1 of the Agreement for Participation in the Upper Colorado River Conserved Consumptive Use Study ("Agreement"). In accordance with Attachment 1, the NAME fields, all located on NAME Ranch, will not receive irrigation water from START DATE through END DATE. Typically, water is diverted from the SOURCE at the HEADEGATE, WDID ##, and delivered to the project field turnouts. Starting IRRIGATION START DATE, the project field turnouts will be closed through END DATE.

Implementation of Conservation Measures specified in Attachment 1 of the Agreement and described above, will be verified according to the Verification Plan described below.

Verification Plan:

A. **Coordination with Division Engineer's Office.** Trout Unlimited will coordinate with the Division 5 Engineer's Office to inform them of project participation. This is important so that the diversion records and comments adequately reflect that water was intentionally not diverted as part of an approved conservation plan. Water Commissioners can also help ensure diversions are not taken at the river headgates.

B. **Site Visits.** Site visits will consist of verifying that the headgate(s) and/or field turnout(s) are operated in accordance with the Agreement for the duration of the project, and no water is being applied to the Participating Lands that are subject to Conservation Measures during the periods specified in Attachment 1 of the Agreement. Site visits will be completed approximately every two weeks by Trout Unlimited staff and/or their agents or contractors. A site verification report, including at least one photo of each headgate and/or field turnout and photos covering the full extent of the participating field(s), will be submitted to the Colorado Water Conservation Board and other project funders to verify Implementation of Conservation Measures.

C. **Consumptive Use Analysis.** A consumptive use analysis will estimate the amount of water savings throughout the duration of the project. After the completion of the Conservation Measure, Trout Unlimited and their project partners will perform a consumptive use analysis using satellite imagery, climate data from a selected CoAgMet station located near the project area, and other field data collected for this project by Colorado State University. Note, the consumptive use analysis is for study purposes only. Compensation to the participant shall be provided as specified in the Agreement.