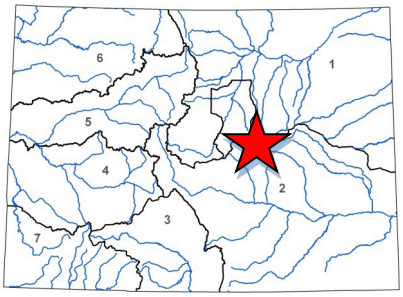
COLORADO
Colorado Water Conservation Board
Department of Natural Resources

University of Colorado Denver
Examining the Use of Recycled Water in Agricultural Production in Colorado

September 2022 Board Meeting

Water Plan Grant Application



LOCATION	
County/Counties:	Denver
Drainage Basin:	South Platte, Metro Basins

DETAILS	
Total Project Cost:	$200,058
Water Plan Grant Request:	$150,000
Recommended Amount:	$150,000
Other CWCB Funding:	$0
Other Funding Amount:	$
Applicant Match:	$50,058
Project Type(s): Study	
Project Category(Categories): Conservation and Land Use Planning	
Measurable Result: Demonstration of the potential for using reclaimed water in agricultural production in Colorado based on real-world growing conditions. If the study indicates that reclaimed water is a valid choice for irrigation, then they expect this to help drive demand and subsequently production of reclaimed water.	

Agricultural production in the intermountain West faces significant water resource challenges from climate change and decreasing the available water supply. Recycled water has the potential to provide affordable, consistently available water. Recycled water has also been shown to be safe in other climates and, since early 2020, has been legally available for food production in Colorado.

Expanding recycled water use for food production will help reduce pressures on irrigated agriculture. Agricultural producers need data generated in real-world growing conditions which are similar to their own. Parallel studies of soil health, crop yield, and food safety will be undertaken for potable and recycled water over the course of three growing seasons. The results of the studies will be widely disseminated through producer groups and at stakeholder events. The primary target audience for the resulting material will be agricultural producers, municipal water providers, and the general public.The aim is to explore the potential to increase the usage of reclaimed water for food crops which will have significant implications for conservation and land use planning and agricultural water usage while requiring both engagement and innovation.

RESEARCH OBJECTIVES:

1. Investigate recycled water irrigation compared to potable water irrigation for food production and determine relative effects on soil nutrients, soil sodicity and salinity, potential contamination, and crop yields.
2. Holistically compare economic costs and returns of using recycled water irrigation for food crops by conducting side-by-side comparisons with potable water irrigation using drip irrigation.

EDUCATION & OUTREACH OBJECTIVES:

1. Collaborate with the Colorado agricultural community across scales of operation to inform and assess recycled water irrigation opportunities for food production in Colorado.
2. Synthesize information, communicate key outcomes, and engage with a broad coalition of interested partners and stakeholders.
3. Provide resources for producers and the general public to understand and compare the relative natural resource benefits of using potable and recycled water for irrigation of food production in Colorado and other semi-arid climates; building trust and confidence in utilizing recycled water irrigation for food crops.

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Water Plan

Water Project Summary

Name of Applicant	University of Colorado Denver
Name of Water Project	Examining the use of recycled water in agricultural production in Colorado
Grant Request Amount	**$150,000.00**
Primary Category	$150,000.00
Conservation & Land Use Planning	
Total Applicant Match	**$50,058.00**
Applicant Cash Match	$25,000.00
Applicant In-Kind Match	$25,058.00
Total Other Sources of Funding	**$0.00**
Total Project Cost	**$200,058.00**

Applicant & Grantee Information

Name of Grantee: University of Colorado Denver
Mailing Address: 13001 E 17th Place, Room W1124, Anschutz Medical Campus, Fitzsimmons Bldg Aurora CO 80045
FEIN: 846,000,555

Organization Contact: Jody Beck
Position/Title: Associate Professor
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Grant Management Contact: Jody Beck
Position/Title: Associate Professor
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Grant Management Contact - Alternate: Garrett Steed
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Description of Grantee/Applicant

Public Institute of Higher Education
College of Architecture and Planning

Type of Eligible Entity

☐ Public (Government)

- [ ] Public (District)
- [ ] Public (Municipality)
- [ ] Ditch Company
- [ ] Private Incorporated
- [ ] Private Individual, Partnership, or Sole Proprietor
- [ ] Non-governmental Organization
- [ ] Covered Entity
- [x] Other

Category of Water Project

- [ ] Agricultural Projects
  Developing communications materials that specifically work with and educate the agricultural community on headwater restoration, identifying the state of the science of this type of work to assist agricultural users among others.
- [x] Conservation & Land Use Planning
  Activities and projects that implement long-term strategies for conservation, land use, and drought planning.
- [ ] Engagement & Innovation Activities
  Activities and projects that support water education, outreach, and innovation efforts. Please fill out the Supplemental Application on the website.
- [ ] Watershed Restoration & Recreation
  Projects that promote watershed health, environmental health, and recreation.
- [ ] Water Storage & Supply
  Projects that facilitate the development of additional storage, artificial aquifer recharge, and dredging existing reservoirs to restore the reservoirs' full decreed capacity and Multi-beneficial projects and those projects identified in basin implementation plans to address the water supply and demand gap.

Location of Water Project

Latitude	39.742043
Longitude	-104.991531
Lat Long Flag	Municipal centroid: Coordinates based on centroid of municipal boundary
Water Source	Denver municipal water: potable and reclaimed
Basins	Metro
Counties	Denver
Districts	1-South Platte: Greeley to Balzac; 2-South Platte: Denver Gage to Greeley; 8-South Platte Cheesman to Denver Gage; 9-Bear Creek

Water Project Overview

Major Water Use Type	Agricultural
Type of Water Project	Planning (e.g. watershed)
Scheduled Start Date - Design	9/1/2022
Scheduled Start Date - Construction	9/1/2022

Description

This study will compare potable and recycled water irrigation of food crops for the relative impacts on soil health and produce quality in order to examine the safety and benefits of using recycled water as a sustainable water resource for growing edible crops in Colorado.

Agricultural production in the intermountain West faces significant water resource challenges from climate

change, decreasing the available water supply. Recycled water has the potential to provide affordable, consistently available water. Recycled water has also been shown to be safe in other climates and, since early 2020, has been legally available for food production in Colorado. Expanding recycled water use for food production will help reduce pressures on irrigated agriculture. However, to feel confident in this water source, agricultural producers need data generated in real-world growing conditions which are closely their own. Parallel studies of soil health, crop yield, and food safety will be undertaken for potable and recycled water over the course of three growing seasons. The results of the studies will be widely disseminated through producer groups and at stakeholder events. The primary target audience for the resulting material will be agricultural producers, municipal water providers, and the general public.

Measurable Results

New Storage Created (acre-feet)
New Annual Water Supplies Developed or Conserved (acre-feet), Consumptive or Nonconsumptive
Existing Storage Preserved or Enhanced (acre-feet)
New Storage Created (acre-feet)
Length of Stream Restored or Protected (linear feet)
Efficiency Savings (dollars/year)
Efficiency Savings (acre-feet/year)
Area of Restored or Preserved Habitat (acres)
Quantity of Water Shared through Alternative Transfer Mechanisms or water sharing agreement (acre-feet)
Number of Coloradans Impacted by Incorporating Water-Saving Actions into Land Use Planning
Number of Coloradans Impacted by Engagement Activity

Other

Demonstration of the potential for using reclaimed water in agricultural production in Colorado based on real-world growing conditions. If the study indicates that reclaimed water is a valid choice for irrigation, then we expect this to help drive demand and subsequently production of reclaimed water which will impact most of the other results listed above. Without specific final infrastructure and land-use projects in hand to evaluate, we can not offer measurable results in the above categories. That will be contained in our follow up GIS study.

Water Project Justification

The Colorado Water Plan, which provides a policy roadmap for addressing state water resource challenges, highlights the Colorado Department of Public Health and Environment's (CDPHE) commitment to expand "safe and environmentally friendly water reuse" that protects stakeholders' health and the environment and, notably, shares the need for additional funding to research recycled water's use for food production. (pg. 6-76)

This study will compare potable and recycled water irrigation used in food crop production in controlled field conditions for their relative impacts on soil health and produce quality, as well as examine the safety and benefits of using recycled water as a sustainable water resource for growing edible crops in Colorado. The aim is to explore the potential to increase the usage of reclaimed water for food crops which will have significant implications for conservation and land use planning and agricultural water usage while requiring both engagement and innovation.

Related Studies

Review of water quality criteria for water reuse and risk-based implications for irrigated produce under the FDA Food Safety Modernization Act,
produce safety rule. Rock, et al. Environmental Research. 172 (2019) 515-629.

Reclaimed water: A safe irrigation water source?. Chen, et al. Environmental Development. 8 (2013) 74-83

Accumulation of Contaminants of Emerging Concern in Food Crops – Part q: Edible Strawberries and Lettuce Grown in Reclaimed Water. Hyland, et al. Environmental Toxicology and Chemistry. (2015) Vol. 34, No. 10. 2213-2221.

Perfluoroalkyl Acid Uptake in Lettuce (Lactuca sativa) and Strawberry(Fragaria ananassa) Irrigated with Reclaimed Water. Blaine, et al. Environmental Science and Technology. (2014) 48, pp. 14361-14368.

Taxpayer Bill of Rights

n/a

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Last Updated: May 2021

Colorado Water Conservation Board
Water Plan Grant – Statement of Work – Exhibit A

Statement Of Work	
Date:	
Name of Grantee:	
Name of Water Project:	Examining the use of recycled water in agricultural production in Colorado
Funding Source:	
Water Project Overview:	
Agricultural production in the intermountain West faces significant water resource challenges from decreasing available water supply. Water recycled after municipal use is a source of affordable, consistently available water. Recycled water has also been shown to be safe in other climates and since early 2020 has been legally available for food production in Colorado. Expanding recycled water use for food production will help reduce pressures on irrigated agriculture. However, to feel confident in this water source, agricultural producers need data generated which mimics their real-world production context showing that recycled water irrigation will not inhibit or hinder their operations. This study will evaluate the impacts – potentially positive or negative – of using recycled water for growing food in Colorado. Parallel studies of soil health, crop yield, and food safety will be undertaken for potable and recycled water over the course of three growing seasons. The results of the studies will be widely disseminated through producer groups and at stakeholder events. The primary target audience for the resulting material will be producers, and material will also be accessible and distributed to municipal water providers as well as to the general public.	
Project Objectives:	

Last Updated: May 2021

RESEARCH OBJECTIVES:

1. Investigate recycled water irrigation compared to potable water irrigation for food production and determine relative effects on soil nutrients, soil sodicity and salinity, potential contamination, and crop yields.
2. Holistically compare economic costs and returns of using recycled water irrigation for food crops by conducting side-by-side comparisons with potable water irrigation using drip irrigation.

EDUCATION & OUTREACH OBJECTIVES:

1. Collaborate with the Colorado agricultural community across scales of operation to inform and assess recycled water irrigation opportunities for food production in Colorado.
2. Synthesize information, communicate key outcomes, and engage with a broad coalition of interested partners and stakeholders.
3. Provide resources for producers and the general public to understand and compare the relative natural resource benefits of using potable and recycled water for irrigation of food production in Colorado and other semi-arid climates; building trust and confidence in utilizing recycled water irrigation for food crops.

Tasks
Task 1 – Growing Produce for Testing
Description of Task:

Last Updated: May 2021

The first task is to construct the agricultural beds to be used for production in year 1 and then grow produce to be used for analysis in years 1 through 3.
Method/Procedure:
Four raised beds of 4'0 x 10'0 will be built and filled with commercially available planters mix and amended with commercially available compost. The soil will be tested before and after each growing cycle. The water inputs will be tested periodically throughout each growing season. Three crops will be grown with seed commonly used in commercial production operations – one root vegetable, one leaf crop, and one fruit crop. All irrigation will be driven by moisture sensors. Two of the beds will be irrigated with potable water and two of the beds will be irrigated with recycled water. The water will also be tested periodically throughout the growing season. Produce will be harvested for testing at the appropriate mid-season for each crop and transported to the lab in a manner defined by the lab for delivering high-quality samples.
Deliverable:
Quality high-quality samples from ten replicates per crop for both potable and reclaimed water for each of three seasons.

Last Updated: May 2021

Tasks
Task 2 – Testing produce for relative impacts of potable and reclaimed water irrigation.
Description of Task:
Testing produce samples for variation between those grown with potable water and those grown with reclaimed water. Experiments will be conducted with three food crops: a root crop (eg. carrot), a leaf crop (eg. kale), and a fruit crop (eg. tomatoes) to represent varying edible portions of plants. When the food crops have reached peak maturity, plants will be harvested, thoroughly washed, dissected (separating roots, stalks, leaves, and fruit), homogenized, frozen, and freeze-dried prior to analysis.
Method/Procedure:
Targeted organic contaminants of emerging concern (CEC), including poly- and perfluoroalkyl substances (PFASs) and selected pharmaceuticals will be quantified in edible plant tissues by liquid chromatography/tandem mass spectrometry (LC-MS/MS). Inorganic constituents (eg., metals, nutrients) will be analyzed in plant tissues via inductively coupled plasma - optical emission spectrometry (ICP-OES).
Deliverable:
Annual reports of summarized data will be submitted and it is anticipated that research results will be submitted to a peer-reviewed journal upon completion of the study.

Last Updated: May 2021

Tasks
Task 3 – Analyze results and develop publications and other outreach to disseminate the outcome of the study.
Description of Task:
In the first year of the study, small peer and user groups will be identified and contacted in order to establish an internal review process for evaluating data and also for ensuring the effectiveness of communication strategies. The results will be analyzed beginning in year two once the first year's samples have been analyzed. Beginning in years two and three, longitudinal data will be analyzed as available. Relevant presentation venues will be identified and applications for presentation or publication slots will be made throughout the three year grant period. Also in year two, depending on the first evidence of the grant outcomes, funding for additional studies that build on this work will be applied for to study additional irrigation typologies as are indicated valuable for study based on year one results. If the study shows that there are no negative impacts on produce quality or farming operations, additional funding will be sought to fund a GIS study which will propose potential reach of reclaimed water for agricultural use in major metropolitan and urban areas in Colorado.
Method/Procedure:
The peer and user groups noted in the description of task 3 will be convened in person or remotely as is most convenient for the members. The results will be analyzed for their impact on real-world operations and communication strategies will be tested.
Deliverable:
Print publications where appropriate and electronic resources. Presentations at relevant conferences and in other forums where producers, water providers, and the general public will be present.

Budget and Schedule

Last Updated: May 2021

This Statement of Work shall be accompanied by a combined Budget and Schedule that reflects the Tasks identified in the Statement of Work and shall be submitted to CWCB in excel format.

Reporting Requirements

Progress Reports: The applicant shall provide the CWCB a progress report every 6 months, beginning from the date of issuance of a purchase order, or the execution of a contract. The progress report shall describe the status of the tasks identified in the statement of work, including a description of any major issues that have occurred and any corrective action taken to address these issues.

Final Report: At completion of the project, the applicant shall provide the CWCB a Final Report on the applicant's letterhead that:

- Summarizes the project and how the project was completed.
- Describes any obstacles encountered, and how these obstacles were overcome.
- Confirms that all matching commitments have been fulfilled.
- Includes photographs, summaries of meetings and engineering reports/designs.

The CWCB will pay out the last 10% of the budget when the Final Report is completed to the satisfaction of CWCB staff. Once the Final Report has been accepted, and final payment has been issued, the purchase order or grant will be closed without any further payment.

Payment

Payment will be made based on actual expenditures and must include invoices for all work completed. The request for payment must include a description of the work accomplished by task, an estimate of the percent completion for individual tasks and the entire Project in relation to the percentage of budget spent, identification of any major issues, and proposed or implemented corrective actions.

Costs incurred prior to the effective date of this contract are not reimbursable. The last 10% of the entire grant will be paid out when the final deliverable has been received. All products, data and information developed as a result of this contract must be provided to as part of the project documentation.

Performance Measures

Performance measures for this contract shall include the following:
(a) Performance standards and evaluation: Grantee will produce detailed deliverables for each task as specified. Grantee shall maintain receipts for all project expenses and documentation of the minimum in-kind contributions (if applicable) per the budget in Exhibit C. Per Grant Guidelines, the CWCB will pay out the last 10% of the budget when the Final Report is completed to the satisfaction of CWCB staff. Once the Final Report has been accepted, and final payment has been issued, the purchase order or grant will be closed without any further payment.
(b) Accountability: Per Grant Guidelines full documentation of project progress must be submitted with each invoice for reimbursement. Grantee must confirm that all grant conditions have been complied with on each invoice. In addition, per Grant Guidelines, Progress Reports must be submitted at least once every 6 months. A Final Report must be submitted and approved before final project payment.
(c) Monitoring Requirements: Grantee is responsible for ongoing monitoring of project progress per Exhibit A. Progress shall be detailed in each invoice and in each Progress Report, as detailed above. Additional inspections or field consultations will be arranged as may be necessary.

(d) Noncompliance Resolution: Payment will be withheld if grantee is not current on all grant conditions. Flagrant disregard for grant conditions will result in a stop work order and cancellation of the Grant Agreement.

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Last Updated: May 2021

ENGAGEMENT & INNOVATION GRANT FUND SUPPLEMENTAL APPLICATION

Introduction & Purpose

Colorado's Water Plan calls for an outreach, education, public engagement, and innovation grant fund in Chapter 9.5.

The overall goal of the Engagement & Innovation Grant Fund is to enhance Colorado's water communication, outreach, education, and public engagement efforts; advance Colorado's water supply planning process; and support a statewide water innovation ecosystem.

The grant fund aims to engage the public to promote well-informed community discourse regarding balanced water solutions statewide. The grant fund aims to support water innovation in Colorado. The grant fund prioritizes measuring and evaluating the success of programs, projects, and initiatives. The grant fund prioritizes efforts designed using research, data, and best practices. The grant fund prioritizes a commitment to collaboration and community engagement. The grant fund will support local and statewide efforts.

The grant fund is divided into two tracks: engagement and innovation. The Engagement Track supports education, outreach, communication, and public participation efforts related to water. The Innovation Track supports efforts that advance the water innovation ecosystem in Colorado.

Application Questions

*The grant fund request is referred to as "project" in this application.

Overview (answer for both tracks)
In a few sentences, what is the overall goal of this project? How does it achieve the stated purpose of this grant fund (above)?
This study will compare potable and recycled water irrigation of food crops for the relative impacts on soil health and produce quality in order to examine the safety and benefits of using recycled water as a sustainable water resource for growing edible crops in Colorado. Agricultural production in the intermountain West faces significant water resource challenges from climate change, decreasing the available water supply. Recycled water has the potential to provide affordable, consistently available water. Recycled water has also been shown to be safe in other climates and, since early 2020, has been legally available for food production in Colorado. Expanding recycled water use for food production will help reduce pressures on irrigated agriculture. However, to feel confident in this water source, agricultural producers need data generated in real-world growing conditions which are closely their own. Parallel studies of soil health, crop yield, and food safety will be undertaken for potable and

recycled water over the course of three growing seasons. The results of the studies will be widely disseminated through producer groups and at stakeholder events. The primary target audience for the resulting material will be agricultural producers, municipal water providers, and the general public.

Who is/are the target audience(s)? How will you reach them? How will you involve the community?

The primary target audience for the resulting material will be agricultural producers, water providers, and the general public. We will seek out focus groups through our respective professional networks in each of these areas to test language and communication strategies for the dissemination of the results.

Describe how the project is collaborative or engages a diverse group of stakeholders. Who are the partners in the project? Do you have other funding partners or sources?

The following stakeholders have been vocal in listing the study of expanding and diversification of uses for recycled water as an important research topic, particularly for agricultural applications in Colorado, and will be engaged throughout this project:

- Denver Water
- Denver Botanic Gardens
- Colorado Department of Natural Resources, Colorado Water Conservation Board (CWCB)
- Colorado Fruit and Vegetables Growers Association (CFVGA)
- Colorado Department of Public Health and Environment (CDPHE)
- Colorado State University
- WateReuse Association Colorado Chapter
- Colorado Food Systems Advisory Council (COFSAC)
- Colorado Department of Agriculture
- One World One Water Center (OWOW), Metro State University of Denver
- Colorado Water Quality Control Division (WQCD)

Last Updated: May 2021

Our partners are: the University of Colorado Denver, the Colorado School of Mines, Denver Water, and the One World One Water Center.
We do not have additional funding partners or sources other than in-kind matching funds from Denver Water and the University of Colorado Denver and cash matching funds from the University of Colorado Denver.

Describe how you plan to measure and evaluate the success and impact of the project?

The success of the project will be measured by the quality of the study completed and the dissemination of the results to relevant audiences including producers, water providers, and the general public.

What research, evidence, and data support your project?

Colorado is a drought- and fire-prone Western state where, according to the Colorado Water Conservation Board, agriculture accounts for 89% of the state's water consumption. Colorado producers often cite long-term access to water as a significant limiting factor to their ongoing success and note that their agricultural needs are often in direct competition to increasing municipal water demands. As climate change reduces supply, irrigated agriculture will face a severe shortage of access to water, one of agriculture's most precious and necessary resources. This shortage will have far-ranging impacts on Colorado's economy. However, recycled water resources increase in volume as population increases. Recycled water is a drought-resistant water resource with little diurnal and seasonal variation. Of additionally significant importance for agricultural producers, it often costs less than municipal water sources.
Additionally, recycled water has a lower embodied energy intensity than most other water sources, resulting in reduced atmospheric greenhouse gas emissions. It also boasts the ability to reduce pressure on environments and habitats by limiting withdrawal of water from surface and groundwater sources. (Water Research Foundation, 2019)
The term "recycled" (also "reclaimed") water refers to water produced as a result of treating municipal wastewater to a level that makes it fit for specific uses allowed by regulation. In 2013, Colorado expanded recycled water use under Regulation 84 – Reclaimed Water Control Regulation to include Agricultural Irrigation, yet excluded irrigation of food crops intended for direct human consumption. In a 2015 issue brief titled *Use of*

Reclaimed Water for Food Crops, the Colorado Food Systems Advisory Council (COFSAC) advised the removal of recycled water irrigation's use limitation to non-edible crops. Colorado's General Assembly passed HB18-1093 in 2019, which compelled the expansion of Regulation 84 to include edible crops as a new, allowed use for recycled water.

Despite authorization to utilize recycled water for edible crop irrigation, concerns remain that food safety would be compromised if recycled water came in contact with the edible portion of the crop. It is important to note that no adverse health effects have been associated with or caused by recycled water's use on edible crops in any of these places. (Colorado WaterWise, 2016) Yet, there remains an underlying question of public health and food safety that necessitates more comprehensive study of potential risks and impacts of recycled water as a use for edible food crops to help garner acceptance by producers and their consumers that is climate and production typology specific.

Previous studies, such as the comprehensive and long-term Monterey Wastewater Reclamation Study for Agriculture (MWSRA) (Sheikh et al., 1998), confirm that recycled water does not compromise public health when used to irrigate edible crops in full compliance with proper treatment techniques and water management practices. However, there has not yet been a similar comprehensive study conducted on the use of recycled water in Colorado.

While other states' experiences would allow Colorado to leverage outside expertise, Colorado's climate, soils, and rainfall are considerably different from areas where recycled water is currently in wide agricultural use. Local agricultural producers and consumers find greater confidence and assurance from studies conducted in familiar conditions similar to their own operational and climatic situations.

Producers who elect to use recycled water for irrigating edible crops could potentially realize important cost savings as well. For example, Denver Water "provides recycled water at approximately 25% of the price of potable water" and higher nutrient (N) levels of recycled water could possibly reduce fertilizer application amounts and associated labor/ energy costs.

"In aggregate and under idealized conditions, existing effluent could supply an average of about 17% of the irrigation water needed in the west and

more than 75% of demand in the eastern states . . . 80% of irrigated croplands in the United States (44.4 million ac, 18 million ha) are located within 10 miles (16 km) of" Publicly Owned Treatment Works (POTWs) that produce nearly 33,000 MGD of treated effluent, with "only a small fraction" going to beneficial use. (Water Research Foundation, 2019, pg 115)

The Colorado Water Plan, which provides a policy roadmap for addressing state water resource challenges, highlights the Colorado Department of Public Health and Environment's (CDPHE) commitment to expand "safe and environmentally friendly water reuse" that protects stakeholders' health and the environment and, notably, shares the need for additional funding to research recycled water's use for food production. (pg. 6-76) This study further supports the CDPHE's commitment by expanding recycled water's safety inquiry and, additionally, would inform future updates to the Colorado Water Plan alongside future efforts to scale the application of recycled water in the agriculture sector.

Describe potential short- and long-term challenges with this project.

There are no short or long term challenges to this study which are significant. The methodology for growing produce and testing it is well established. The project leadership has significant experience in producing materials for various audiences.

The short to medium term challenge for the larger question of using reclaimed water for agricultural production is one of acceptance and subsequently demand.

The long term challenge to this question is one of supply infrastructure and land use. This longer term challenge will be the focus of a follow-up study if this work indicates that using reclaimed water for crop irrigation in Colorado is viable.

Please fill out the applicable questions for either the Engagement Track or Innovation Track, unless your project contains elements in both tracks. If a question does not relate to your project, just leave it blank. Please answer each question that relates to your project. Please reference the relevant documents and use chapters and page numbers (Colorado's Water Plan, Basin Implementation Plan, PEPO Education Action Plan, etc.).

Last Updated: May 2021

Engagement Track
Describe how the project achieves the education, outreach, and public engagement measurable objective set forth in Colorado's Water Plan to "significantly improve the level of public awareness and engagement regarding water issues statewide by 2020, as determined by water awareness surveys."
This project is largely geared to a producer audience to demonstrate the benefits of using recycled water and address any producer concerns. Our secondary audience is water providers in the state of Colorado and our goal is to encourage them to increasingly consider this delivery mechanism. This could include feedback on current regulatory requirements, cost-incentives necessary to be developed for incentivizing recycled water use, and to understand needs associated to scale the use of recycled water more broadly. We expect that producers will adopt the use of recycled water as a cost-saving, safe, and reliable water source based on the results of this study. In addition, it is our hope that agricultural producers will begin to initiate conversations with other local water providers about the possibility of accessing recycled water. Our primary means of distribution will be through electronic formats and through presentations at stakeholder gatherings and conferences. In addition, we will prepare the results for publication in peer-reviewed journals. A critical component of all our presentations and electronically distributed materials will be a demystification of the existing regulations around the use of recycled water.
Describe how the project achieves the other measurable objectives and critical goals and actions laid out in Colorado's Water Plan around the supply and demand gap; conservation; land use; agriculture; storage; watershed health, environment, and recreation; funding; and additional.
The use of reclaimed water for agricultural production will help close the supply and demand gap by allowing water to be used for two beneficial uses within the same urban system mediated by water treatment infrastructure. This will reduce demand for water and allow for increased conservation, storage, watershed health, recreational opportunities, and generally improved environmental impacts. It will have significant implications for land use planning as it will have the most significant impact as agricultural production is drawn closer to urban areas.
Describe how the project achieves the education, outreach, and public engagement goals set forth in the applicable Basin Implementation Plan(s).
This project has direct implications for many of the goals in the South Platte Basin Implementation Plan; maintaining and promoting reuse and protecting irrigated agriculture. In order to achieve these, significant outreach and education about the viability of using reclaimed water for food production will have to be undertaken.
Describe how the project achieves the basin roundtable's PEPO Education Action Plans.

The second key element noted in the South Platte Basic Education Action Plan includes an emphasis on "leadership and advancement of conservation and reuse". This project directly supports this goal and communications outreach will be coordinated with the Metro Roundtable and the Education Committee.

Innovation Track
Describe how the project enhances water innovation efforts and supports a water innovation ecosystem in Colorado.

The relative impacts on soil health and produce quality related to irrigation with potable and recycled water will be examined in this study, as well as the potential benefits of using recycled water as a sustainable water resource for growing edible crops in Colorado. Colorado state Regulation 84 defines recycled water as, ". . . domestic wastewater that has received secondary treatment by a domestic wastewater treatment works (centralized system or a localized system) and such additional treatment as to enable the wastewater to meet the standards for approved uses." The terms reclaimed and recycled are synonymous and interchangeable.

Water availability in Colorado's semi-arid climate is a barrier to food production. Colorado producers often cite long-term access to water as a significant limiting factor to their ongoing success and note that agricultural needs are often in direct competition with increasing municipal water demands. Recycled water is a drought-resistant water resource with little diurnal and seasonal variation and is the only water resource that increases in volume as population increases, reducing water-based conflict between food production and urbanization. Furthermore, recycled water often comes at a lower cost. For instance, Denver Water charges 75% less for recycled water than it does for potable water – a significant savings for agriculturalists.

This project proposes a side-by-side model for a comparative study of recycled and potable water sources for edible crop irrigation with drip irrigation to model medium to large scale mixed vegetable production methodologies. Our proposed research will investigate effects on soil health,

produce quality, and crop yields. The project team will grow common Colorado crops at the Denver Water reclaimed water production site.

This study seeks to build on and amplify vigorous research programs happening throughout Colorado academic institutions investigating the impacts of recycled water irrigation. Overall, the findings from these studies have consistently shown safe use of recycled water. However, most studies are focused on landscape irrigation sites in parks and golf courses rather than in agricultural applications and thus avoid the question of public safety related to food production. Our hope is to extend these findings to the agricultural community and, in doing so, provide awareness around a more dependable and predictable source of water for edible crops in Colorado.

Water Research Foundation's 2019 report titled *Agricultural Use of Recycled Water,* notes substantial interest from growers and water utilities to use recycled water for irrigation of food crops, however, cites the inadequacy of available scientific evidence specific to Colorado and considers the long-term field experiences of other states as non-transferrable to Colorado's unique situation. Concurrently, the Colorado Water Plan highlights the imperative to meet Colorado's supply-demand gap induced by staggering population growth. (Colorado Water Plan, 2015)

As of December 2019, the use of recycled water for food production is an allowable use under Regulation 84. Yet, there remains an underlying question of public health and food safety that necessitates more comprehensive study on the risks and impacts of recycled water for edible food crops irrigation specific to real-world conditions parallel to those of Colorado growers in order to help garner producer and consumer acceptance.

Furthermore, higher nutrient content (N) of recycled water may allow growers to reduce the amount of fertilizer used on their crops, thus saving time, money, and labor. A typical Denver area farming operation applies 3 ft of water (3 acre feet/ acre) during an irrigation season, with an equivalent of 122 lb of N delivered per acre, representing half the nitrogen demand for crops (Denver Water, 2015). Knowing the soil nutrient makeup and chemical characteristics of irrigation water, as this study seeks to do, would provide growers with the knowledge and tools to adjust their practices.

Last Updated: May 2021

Describe how the project engages/leverages Colorado's innovation community to help solve our state's water challenges.
We will be working closely with Denver Water which is at the forefront of reclaimed water distribution. Results will be presented to the Colorado Water and Land Use Planning Alliance in particular for feedback on how to most effectively use the data to drive positive impact.
Describe how the project helps advance or develop a solution to a water need identified through TAP-IN and other water innovation challenges. What is the problem/need/challenge?
The problem is a dwindling availability of water as a resource. This study seeks to reinforce the capacity to reduce demand by increasing re-use.
Describe how this project impacts current or emerging trends; technologies; clusters, sectors, or groups in water innovation.
This project will provide data with which the use of reclaimed water for agricultural irrigation can be promoted.

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Colorado Water Conservation Board

Water Plan Grant - Exhibit C
Budget and Schedule

Prepared Date: 6/29/2002

Name of Applicant: Jody Beck

Name of Water Project: Examining the use of recycled water in agricultural production in Colorado

Project Start Date: 09/01/2022

Project End Date: 08/31/2025

Task No.	Task Description	Task Start Date	Task End Date	Grant Funding Request	Match Funding	Total
1	*Growing Produce for Testing*	09/01/2022	08/31/2025	$11,842	$45,279	$57,121
2	*Testing produce for relative impacts of potable and reclaimed water irrigation*	09/01/2022	08/31/2025	$121,038	$0	$121,038
3	*Outreach, dissemination of results*	09/01/2022	08/31/2025	$17,120	$4,779	$21,899
						$0
						$0
						$0
						$0
						$0
						$0
						$0
						$0
						$0
						$0
			Total	$150,000	$50,058	$200,058

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Colorado Water Conservation Board

Water Plan Grant - Detailed Budget Estimate
Fair and Reasonable Estimate

Prepared Date: 6/29/2022
Name of Applicant: Jody Beck
Name of Water Project: Testing produce for relative impacts of potable and reclaimed water irrigation

EXAMPLE B: Engineering

Task 1 — CU Denver

Growing Produce for Testing

	Principal Investigator	Students (PhD/ Grad)	Students (Undergrad)	Travel	Water Testing	Soil Testing	Garden Construction		
	$ 79	$ 26	$ 18	$ 672	$ 13,500	$ 2,700	$ 6,995	**Subtotal**	
	Estimated Hours								
Growing	169	585	104	3	1	1	1	**$**	**55,575**
Indirect Costs (15%)								**$**	**1,545**

Subcontracts (Colorado School of Mines)

Principal Investigator	Students (PhD/ Grad)	Other Direct Costs	Other Direct Costs		Project Total	CWCB Funds	Matching Funds
				Subtotal			
					$55,575	$ 10,297	$ 45,279
					$1,545	$ 1,545	

Task 2 — CU Denver

Testing produce for relative impacts of potable and reclaimed water irrigation

	Principal Investigator	co-PI	Students (Undergrad)	Other Direct Costs	Other Direct Costs	Other Direct Costs	Other Direct Costs		
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	**Subtotal**	
	Estimated Hours								
Testing								**$**	**-**
Indirect Costs (15% - calculated on the first $25,000 of subcontracts)								**$**	**3,750**

Subcontracts (Colorado School of Mines)

Principal Investigator	co-PI	Students (Undergrad)	Materials & Supplies	Lab Analysis		Project Total	CWCB Funds	Matching Funds
$ 129	$ 40	$ 22	$ 10,023	$ 13,927	**Subtotal**			
Estimated Hours								
8	1404	928	1	1	**$ 101,990**	$101,990	$ 101,990	
					$ 15,298	$19,048	$ 19,048	

Task 3 — CU Denver

Outreach, dissemination of results

	Principal Investigator	Students (PhD/ Grad)	Travel	Other Direct Costs	Other Direct Costs	Other Direct Costs	Other Direct Costs		
	$ 79	$ -	$ -	$ -	$ -	$ -	$ -	**Subtotal**	
	Estimated Hours								
Outreach	169							**$**	**13,381**
Indirect Costs (15%)								**$**	**1,290**

Subcontracts (Colorado School of Mines)

Principal Investigator	co-PI	Students (PhD/ Grad)	Other Direct Costs	Other Direct Costs		Project Total	CWCB Funds	Matching Funds
	$ 40				**Subtotal**			
Estimated Hours								
	156				**$ 6,285**	$19,666	14,887	4,779
					$ 943	$2,233	2,233	

TOTAL	**$200,058**	$ 150,000	$ 50,058

	Name	Vendor	Quantity	Unit Price	Line Total	Category Total	Proposed Total
Disposables	250 µL pipette tips	Rainin	4	$57.20	$228.80		
	1000 µL pipette tips	Rainin	2	$57.20	$114.40		
	2000 µL pipette tips	Rainin	2	$68.80	$137.60		
	50 mL centrifuge tubes	VWR	6	$183.09	$1,098.54		
	15 mL centrifuge tubes	VWR	6	$112.57	$675.42		
	2.0 mL micro-centrifuge tubes	VWR	4	$15.73	$62.92		
	HPLC autosampler vials	Agilent	8	$236.00	$1,888.00		
	HPLC PTFE autosampler vial caps	Agilent	4	$110.00	$440.00		
	HPLC starburst autosampler vial caps	Phenomenex	4	$320.00	$1,280.00		
						$5,925.68	
Columns/SPE	Gemini C18 analytical columns	Phenomenex	1	$639.00	$639.00		
	Gemini C18 guard cartridges	Phenomenex	1	$429.00	$429.00		
	Gemini guard cartridge holders	Phenomenex	2	$229.00	$458.00		
	WAX SPE	Phenomenex	2	$393.00	$786.00		
	Diols	Phenomenex	2	$100.00	$200.00		
						$2,512.00	
Solvents / Standards	Methanol, Water, Isopropanol, Acetonitrile, etc.	Fisher	40	$24.00	$960.00		
	PFOAs Standard	Absolute Standards	1	$125.00	$125.00		
	NIST SRM ????	Wellington	1	$500.00	$500.00		
	????	Wellington	1		$0.00		
						$1,585.00	
					TOTAL SUPPLIES COSTS	**$10,022.68**	

Details	No of samples	No of Days	Daily Rate	Per Sample Rate	Billing Amount	Proposed Total
Instrument Time - Method development		4	$ 400.00		$ 1,600.00	
Instrument Time - Analytical samples	180			$ 32.00	$ 5,760.00	
QC sample replicates	72			$ 32.00	$ 2,304.00	
QC checks	32			$ 32.00	$ 1,024.00	
				Instrument Costs	**$ 10,688.00**	

284

3029.24 +

Table 3. Proposed costs for the study

	Staff 1 Time (hrs)	Staff Level 1 Hourly Rate*	Staff 2 Time (hrs)	Staff Level 2 Hourly Rate*	PI Time (hrs)	PI Hourly Rate*	Total Personnel Costs	Instrument Charges^	Materials	Total
Task 1 (data pl	0	$22	0	$40	0	$100	$0	$ 1,600		$1,600
Task 2	928.8	$22	93	$40	0	$100	$24,149	$ 9,088	$10,022	$43,259
Task 3	0	$22	360	$40	0	$100	$14,400	$0		$14,400
Task 4	0	$22	40	$40	0	$100	$1,600			$1,600
Overhead (12%)										$7,303
										$68,162

*Hourly Rates including Fringe

^Instrument charges only include instrumental time, and do not include sample preparation or data analysis.

if we do 5 replicates (bare minimum)/3 crops = 65k

change for 180 samples

Per sample Cost $189

Task 1: Method Development and Validation
Task 2: Sample Prep and Analysis
Task 3: Data Processing
Task 4: Report

2080 hrs per year

	Annual Salary	With Fringe	Daily Rate	Hourly Rate ($/hr)	10% contigency
Level 1 State: UG/GRA				$20	$22.00
Level 2 Staff: Erin as tech	$57,500	$75,038		$36	$39.68
PI: Erin as PI			$987	$123	$135.71

Task 1 **Hours?**

80 hours (Erin)

Method development

360 samples
20 samples per batch
18 batches

Task 2

1 hr per batch	Inventory	18 hours	(Shannon or equivalent)
3 hr per batch	Prep	54 hours	(Shannon or equivalent)
3 hr per batch	QC	54 hours	(Shannon or equivalent)
	Total Prep Time	**126 hours**	**(Shannon or equivalent)**

Insrument time:

60 samples per cal curve
6 Cal curves (runs)
6 cal curve hrs per run
36 total hrs for cal curves
0.45 hrs per sample (and QC)
284 samples and QCs per run (see other sheet)
127.8 hours of samples and QCs per run
766.8 total sample hours per run (not including cal curves)

Total hours for Sample Acquisition	**802.8 hours**	**(Shannon or equivalent)**
Total Task 2 hours (Shannon or Equivalent)	**928.8 hours**	**(Shannon or equivalent)**
Contingency hours - Task 2 (Erin)	**92.88 hours**	**(Erin)**

Task 3

Data Processing

1 hour per sample

Total Hours Data Processing	**360 hours**	**(Erin)**

Task 4 - Reporting

40 hours (Erin)

Overall PI time (all tasks)

5 hours (Chris)

agvise			
initial and end: x 3	6	x3 reps	18
ICP plants		x3	
4 treatments x 3 crop	60	x3 years	180

Budget Justification
Colorado School of Mines (Mines)

All costs proposed in the budget are in accordance with any limitations, exclusions or special conditions set forth in the FOA, and all costs are reasonable, allocable, and allowable. Colorado School of Mines defines a year based on every 12-month period from the start date of this project.

Senior/Key Personnel
Senior Personnel: This research will be directed by Colorado School of Mines Professor Christopher Higgins as the PI and includes 1 day of summer salary in year 1 to carry out the proposed research activities. Co-PI Erin Sedlacko will support the research with 25% annual effort. Dr. Higgins will supervise the project and Dr. Sedlacko will perform the plant tissue analyses, and oversee soil analysis. Dr. Sedlacko will also provide overall project support with the aim of collecting and managing data and assisting with project deliverables. In addition, she will work closely with Dr. Beck and his team. Salaries are budgeted based on actuals with a 3% increase annually.

Fringe Benefits: The fringe benefits for Dr. Higgins are based on the current Colorado School of Mines academic PERA rate of 36.1%. Co-PI Sedlacko receives fringe benefits based on Mines research Converted rate of 41%. All rates receive an annual escalation of 0.5 per university policy.

Other Personnel

Undergraduate Support: $20,416 is requested to support an undergraduate researcher for 309 hours per year at the rate of $22.00 per hour. The role of this undergraduate will be to prepare analytical samples for liquid chromatography-mass spectrometry (LC-MS) instrumental analysis.

Other Direct Costs
Materials and Supplies: $10,023 is requested in laboratory supplies associated with liquid chromatography-mass spectrometry instrumental analysis.

Lab Usage Fees: $13,927is requested to cover the costs of Mines shared facility fees for use of large-scale shared equipment, including LC-MS at liquid chromatography-mass spectrometry instrumental analysis at $32.00/sample and a method development day rate of $400.00.

Indirect Costs
Mines' approved indirect cost rate is negotiated with our cognizant audit agency, the Office of Naval Research. The current approved rate is:

Fiscal Years 2022 - 2025: July 1 2021 – June 30 2025
On-Campus Organized Research Overhead rate: 51.5% MTDC

However, we are using the state required rate of 15% as directed by the sponsor.

The Modified Total Direct Cost (MTDC) base is calculated by excluding capital expenditures (buildings, individual items of equipment, alterations and renovations), the portion of each subaward in excess of $25,000, participant support costs, and graduate student tuition, fees, and insurance.

Statement of Work

Examining the use of recycled water in agricultural production in Colorado

Christopher P. Higgins, Ph.D
Erin M. Sedlacko, Ph.D.
Colorado School of Mines

Objective

The overall goal of this proposal is to compare potable and recycled water irrigation used in food crop production for their relative impacts on soil health and produce quality, as well as examine the safety and benefits of using recycled water as a sustainable water resource for growing edible crops in Colorado.

Agricultural production in the intermountain West faces significant water resource challenges from climate change, which is decreasing available water supply. Agricultural production also hinges on an affordable, consistently available, and safe source of water. Water recycled after municipal use is a source of affordable, consistently available water. Recycled water has also been shown to be safe in other climates and since early 2020 has been legally available for food production in Colorado. Often a source of new water supplies for growing urban communities, expanding recycled water use for food production will help reduce pressures on irrigated agriculture. However, to feel confident in this water source agricultural producers need data generated in their production context showing that recycled water does not inhibit or hinder their operations. This study will evaluate the impacts – potentially positive or negative – of using recycled water for growing food in Colorado. Parallel studies of soil health, crop yield, and food safety will be undertaken for potable and recycled water over the course of three growing seasons. The results of the studies will be widely disseminated through producer groups and at stakeholder events. The primary target audience for the resulting material will be producers, and material will also be accessible and distributed to municipal water providers as well as to the general public.

Research Approach

As described in the attached proposal, to attain the objectives of this study, Dr. Higgins and Dr. Sedlacko, along with hourly undergraduate assistance, will work with Dr. Jody Beck (UCD) and his team on all aspects of the proposal with a particular focus on LC-MS analysis of produce. Experiments will be conducted with three food crops: a root crop (eg. carrot), a leaf crop (eg. kale), and a fruit crop (eg. tomatoes) to represent varying edible portions of plants. When the food crops have reached peak maturity, plants will be harvested, thoroughly washed, dissected (separating roots, stalks, leaves, and fruit), homogenized, frozen, and freeze-dried prior to analysis. Targeted organic contaminants of emerging concern (CEC), including poly- and perfluoroalkyl substances (PFASs) and selected pharmaceuticals will be quantified in edible plant tissues by liquid chromatography/tandem mass spectrometry (LC-MS/MS). Inorganic constituents (eg., metals, nutrients) will be analyzed in plant tissues via inductively coupled plasma - optical emission spectrometry (ICP-OES).