West Slope Basin Explorer Methods

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Prepared by The Freshwater Trust

PO Box 9205
Portland, OR 97207
www.thefreshwatertrust.org

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INTRODUCTION

This report summarizes the objectives, methods, and data used in the Colorado West Slope Basin Explorer Web Application (Web App). The goal of the Web App is to provide data and insights to a range of Colorado River Basin stakeholders on Colorado's Western Slope. These data and insights can help stakeholders secure funding for the implementation of conservation projects and programs, which make a difference for the production, economic, and environmental objectives of local communities. The Web App is a screening-level tool that illustrates various water delivery, ecosystem, and regional economic trends. The Web App allows stakeholders to visualize trends and baseline metrics throughout the Western Slope (the area of interest or AOI) and explore geospatial relationships between water delivery in dry, normal, and wet years; ecosystem health; water quality; agricultural production; and water infrastructure.

The Web App is not a decision support tool. It is a screening application that uses public data to help users identify potential conservation opportunities, so they can work with communities to better understand the situational context and more effectively build agricultural and ecological resilience in the face of climate change and drought. More information for understanding and navigating the Web App and its functions can be found in the accompanying User Guide[1].

The report is organized by the three themes – Production, Ecosystems, and Water Quality. Each theme focuses on specific subsets of data and are described in detail in the following sections.

PRODUCTION

The Production theme focuses on measured and estimated water volumes associated with irrigation diversions, and the resulting estimated economic impacts of agricultural production. The data sources used in the Production theme include The Freshwater Trust's (TFT) BasinScout® Analytics (BSA), as well as HydroBase[2], StateMod[3], and USDA Cropland Data Layer (CDL)[4]. A description of each data source is provided below.

BasinScout Analytics (BSA)

BSA is an integrative modeling and analytics framework for structured decision making developed by The Freshwater Trust (TFT). It compiles, analyzes, ranks, and visualizes information to quantitatively evaluate watershed management or conservation alternatives that employ cost-effective best management practices and/or natural infrastructure projects distributed across the landscape. BSA is used to identify site-level land and water management actions that can be implemented to achieve specific water resource objectives.

The **irrigation module** in BSA was used to estimate consumptive use, precipitation, and irrigation demand for each agricultural field within the AOI. The BSA irrigation module relies on Google Earth

[1] https://thefreshwatertrust.shinyapps.io/wsba/
[2] https://cdss.colorado.gov/software/hydrobase
[3] https://opencdss.state.co.us/statemod/latest/doc-user/
[4] https://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php

Engine[5] (GEE), which processes large satellite-based imagery and vector data using cloud computing. Monthly evapotranspiration and precipitation data are obtained from the OpenET[6] eeMetric and PRISM[7] models, respectively, which generate output datasets in GEE. Analysis of the monthly evapotranspiration and precipitation data is aggregated over the irrigation season (April – October) from 2016 – 2022.

Consumptive use is calculated at the field-level by subtracting precipitation from evapotranspiration. Irrigation demand is calculated at the field-level as consumptive use divided by the irrigation efficiency estimated for each field's irrigation-type.[8, 9, 10] Thus, irrigation demand is an estimate of the minimum water volume required to apply to fields based on crop demand and irrigation efficiency; it does not reflect an estimate of the actual amount of water applied to a field by irrigators.

The **economic module** in BSA was used to estimate direct, indirect, and induced economic and employment impacts. The BSA economic module relies on methods and data from IMPLAN[11]. IMPLAN is an input-output (I:O) model used to define direct, indirect, and induced impacts of an economic shock within a specific region. IMPLAN defines relationships within and between industries in a regional economy as ratios (multipliers) such that the spending and/or economic output in one industry can be characterized by its own impacts (direct); its impacts across supporting industries (indirect); and its impacts resulting from spending in unrelated industries that are a result of the shock (induced). Multipliers are similarly defined for employment impacts, which represent the number of full-time equivalent (FTE) jobs per million $ of direct output value.

The direct impacts of agricultural production are represented by gross revenue ($ per acre) and calculated as yield multiplied by price for each crop type. This gross revenue ($ per acre) is multiplied by the average annual acreage (CDL data for 2011–2021) of each crop type to get average annual total gross revenue ($). The average annual total gross revenues ($) for all crop types are converted into 2022 dollars using the Consumer Price Index (CPI)[12] to align with the dollar year associated with IMPLAN multipliers used in this analysis.

Yield and price data for alfalfa, non-alfalfa hay, and grains were obtained from Colorado State University (CSU) Crop Enterprise Budgets (2022)[13]. Yield and price data for orchards were obtained from USDA National Agricultural Statistics Service (NASS) because CSU Crop Budgets did not provide recent data[14].

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[5] https://earthengine.google.com/

[6] https://openetdata.org/

[7] https://www.prism.oregonstate.edu/

[8] Rogers, D. H., Lamm, F. R., Alam, M., Trooien, T. P., Clark, G. A., Barnes, P. L., & Mankin, K. (1997). *Efficiencies and Water Losses of Irrigation Systems*. https://www.bookstore.ksre.ksu.edu/pubs/MF2243.pdf

[9] Neibling, H. (1997). *Irrigation Systems for Idaho Agriculture* (pp. 1–8). University of Idaho, College of Agriculture.,; Howell, T. (2003). Irrigation Efficiency. *Encyclopedia of Soil Science, Second Edition*. https://doi.org/10.1201/noe0849338304.ch191

[10] Amosson, S. H., New, L., Almas, L., Bretz, F., & Marek, T. (2011). *Economics of Irrigation Systems*. http://hdl.handle.net/1969.1/87095

[11] https://implan.com/

[12] https://www.bls.gov/cpi/data.htm

[13] https://abm.extension.colostate.edu/enterprise-budgets-crop/

[14] https://quickstats.nass.usda.gov/

Alfalfa yield data were categorized into one, two, three, and four harvests (cuttings); corresponding yields are estimated as 1.1, 2.9, 3.5, and 5 tons/acre, respectively. Each county was assigned a yield based on the average number of alfalfa cuttings; these are informed by elevation, temperature, and precipitation conditions[15].

An assumption was made for pasture that both livestock grazing and hay harvest occur within each year. Gross revenue for pasture/hay ($/acre) was estimated as the average gross revenue of cattle/calve operations and hay production. Gross revenue for cattle/calve operations was calculated using cattle/calve sales divided by irrigated pastureland acreage, and then averaged across 22 counties in the AOI. Data on cattle/calve sales and pastureland acreage was obtained from USDA Ag Census reporting (2017)[16] and converted into 2022 dollars. Gross revenue for hay production was calculated using yield multiplied by price with data from CSU Crop Enterprise Budgets (2022).

HydroBase

HydroBase is the state of Colorado's database cataloging diversion volume, water use, streamflow, and legal water rights priority. HydroBase data is estimated at the diversion-level and each diversion structure is assigned a unique identifier referred to as a WDID. Fields associated with a diversion structure are assigned WDIDs. The GIS data associated with fields is updated every 5 years, and the latest available data from 2020 is used to establish baseline crop mix and irrigated acreage of diversions. Analysis of diversion volume is restricted to the irrigation season (April – October) and spans 1983 – 2022.

StateMod

StateMod is the State of Colorado's water allocation and accounting model designed for comparative analyses and assessment of various historical and future water management conditions in a river basin. There are five regional StateMod models that cover the AOI: the Gunnison River, Upper Colorado River, Yampa River, White River, and San Juan River models. These models are used to assess the availability of water to users based on hydrology, water rights, and operating rules and practices. The models provide baseline simulations extending from 1909 to 2013, and simulate demands, infrastructure, project impacts, and the administrative environment as though they had been in place throughout the modeled period. For this assessment, analysis is restricted to the irrigation season (April – October) and spans 1973 – 2013.

The models were developed as tools to test the impacts of proposed diversions, reservoirs, water rights, and/or changes in operations and management strategies. The baseline simulations serve as the starting point, demonstrating conditions of the system absent the proposed change but including all current conditions. Only data from the baseline simulations are included in the Web App.

StateMod divides the river system into a series of structures (e.g., diversion structures, gauging stations, and reservoirs) and nodes (e.g., river confluences). Accounting is performed on a water right basis while reporting is performed by structure and river node. For each structure, StateMod calculates a water use and structure mass balance. The water delivery mass balance estimates

[15] Communication with CSU Crop Budget Expert Dr. Jenny Beiermann in March 2024.
[16] https://www.nass.usda.gov/Publications/AgCensus/2017/index.php

diversion volume, consumptive use, return flow, soil moisture storage, and incidental loss. The structure mass balance estimates inflow, depletions, outflow, and available flow. Available flow is the volume of water available to a potential user who is most junior to the basin.

Most of the structures in StateMod are directly associated with a WDID in HydroBase, while smaller diversions are aggregated within the model. For the aggregated diversions the StateMod quantities are scaled by percentages of area associated with diversion WDIDs. Once apportioned to a WDID, the StateMod data are scaled by the area scaling factors used for the HydroBase data so that the data are representative of the West Slope.

CDL

CDL data on crop types and associated acreage were collected from 2011 to 2021 and then averaged across all years in which a marketable crop was observed. The average annual acreage for each crop type was used to calculate direct, indirect, and induced economic impacts (output and employment).

The production metrics focus on water delivery and regional economic impacts and are summarized in the following sections.

Water Delivery

Water delivery metrics are reported at the diversion-level; these are defined in Table 1. For the periods when the BSA and HydroBase time series overlap (2016–2022), the consumptive use, irrigation demand, and diversion volume estimates are combined to assess water delivery metrics associated with each diversion.

Analysis has been conducted to understand the ranges of water delivery within the AOI. Representative water year conditions are considered in the context of precipitation, stream flow, and diversion volume. These data are validated against each other and against the Historical Palmer Drought Indices[17] to determine correlations and trends amongst these indicators. Table 2 shows the representative dry and wet water years selected based on this analysis. The dry and wet years are compared with average year conditions that are calculated as the mean from 2016 – 2022 and the dry year data is used to assess variability.

[17] https://www.ncei.noaa.gov/access/monitoring/historical-palmers/overview

Table 1. Water delivery metrics.

METRIC	DESCRIPTION
Application Efficiency (E_a)	The percentage of irrigation demand that is consumptively used.
Available Flow	The volume of water available to a potential user who is the most junior in the basin.
Consumptive Use (CU)	The irrigation water applied to agricultural fields that is beneficially consumed via evapotranspiration by crops, not including water supplied from effective precipitation.
Consumptive Use Shortage	The difference between simulated crop consumptive demand and consumptive use.
Diversion Efficiency (E_d)	The percentage of diversion volume that is consumptively used.
Diverted Flow	The volume of water diverted.
Diversion Volume (DV)	Total volume of water delivered to a diversion.
Inflow	Flow entering a diversion from the upstream reach.
Irrigated Acreage	The land area associated with a diversion that can receive irrigation water.
Irrigation Demand (ID)	The volume of irrigation water demand to meet crop consumptive use, including water not consumptively used due to irrigation-type efficiency.
Irrigation Demand Efficiency (E_{id})	The percentage of diversion volume that is required to meet irrigation-type demand.
Outflow	Flow leaving a diversion into the downstream reach.
Return Flow	The amount of diversion volume that is not consumptively used, stored in soil moisture, or lost, and returns to the stream and or aquifer.
Total Shortage	The difference between total demand and diversion volume.
Variability	The relative change between the dry year and average water volume or efficiency metric, where negative variability indicates adverse impacts during dry conditions. Variability provides a measure how reliable water delivery is for a given diversion; small values indicate the water delivery metric is reliable.

Table 2. Representative dry and wet water years for each dataset.

	BSA/HydroBase	StateMod
Dry	2021	2012
Wet	2019	2011

Economics

Regional economies are defined at three geospatial levels: 1) the entire West Slope AOI, 2) counties, and 3) Colorado water divisions. Multipliers for each of these levels were defined and exported from IMPLAN. Employment and output multipliers are multiplied by the average annual total gross revenues from agricultural production within each regional economy to calculate average annual direct, indirect, and induced impacts. Since the multiplier for direct impacts are always one, the average annual direct impact of output is identical to the average annual total gross revenue from crop production within the regional economy. Table 3 describes the regional economic metrics used in the analysis.

Table 3. Regional economic impact metrics

METRIC	DESCRIPTION
Direct Economic Impacts	The dollar amount or full-time equivalent (FTE) number of jobs generated from production in a specific industry within a region (e.g., total gross revenues from agricultural crop production).
Indirect Economic Impacts	The dollar amount or FTE jobs generated from forward-or backwards-linked industries (e.g., food processors, seed companies, equipment suppliers, fertilizer suppliers, etc.) that supply or interact within a region.
Induced Economic Impacts	The dollar amount or FTE jobs generated from businesses/industries that provide household goods and services to directly and indirectly affected workers and their households within a region (e.g., food, retails, hair salons, etc.).
Total Economic Impacts	The sum of direct, indirect, and induced economic impacts of output value ($) or full-time equivalent (FTE) jobs.

ECOSYSTEMS

The Ecosystems theme focuses on agricultural irrigation ecosystem services, conservation potential of endangered species, and identification of ecologically valuable habitats in relation to water delivery. The Ecosystems theme is a compilation of publicly available geo-spatial data associated with specific regions or stream reaches within the AOI. The data sets have been organized into three categories: habitat, streams, and shade. The associated data sources and metrics are described in the following sections.

Habitat

The habitat data sets relate to geographical regions focused on biodiverse wetlands, flood-irrigated wetlands, protected lands, and critical sage grouse and are summarized in the following.

Biodiverse wetlands were compiled from multiple data sources. Colorado Natural Heritage Program (CNHP) wetland inventory and riparian inventory data[18] were merged into a single feature layer after filtering out any riverine types redundant to NHD streamlines (flowing water), intersections with NHD high resolution canals and ditches, and fens or playas typically not associated with irrigated production areas on the West Slope. CNHP Potential Conservation Areas (PCA), filtered to wetlands[19], were intersected with the wetland habitat units. This represents biodiversity significance ranks B1-B5

[18] https://cnhp.colostate.edu/cwic/tools/mapper/
[19] https://cnhp.colostate.edu/ourdata/pca-reports/

(globally outstanding to locally significant) based on rare species, natural plant communities and other ecological conditions. Areas with no biodiversity significance or missing information may be significant for other non-target or upland habitat types but were omitted from the Web App to reduce latency.

Flood-irrigated wetlands map the proportion of wetland resources (i.e., flooded grasslands) supported by grass-hay production in the Intermountain West[20]. In other words, these are wetlands that benefit from the inefficiencies of flood-irrigation and would be impacted by upgrading to more efficient irrigation systems. Often, historic wetlands that were connected to the floodplain and charged by seasonal flood cycles are today, with altered hydrological regimes, solely charged by flood irrigation.

Protected lands geospatial data is subset of public and private protected lands data managed by the Colorado Natural Heritage Program (CNHP) and Colorado State University[21]. Land conservation efforts in Colorado target ecologically important areas and provide a significant economic stimulus to the State's economy and benefits to residents. These benefits are expected to continue to accrue into the future and increase on a per-acre basis due to Colorado's increasing population and wealth and decreasing supply of open lands[22].

Critical sage grouse habitat maps the geographical regions of sagebrush habitat upon which the sage grouse relies[23]. Sage grouse are an important indicator of the sagebrush ecosystem. Colorado Parks and Wildlife (CPW) has established a sagebrush and sage species conservation strategy that[24]

- Estimates the extent of historic sagebrush habitat lost in Colorado.
- Assesses the status of sagebrush habitat in Colorado and quantifies widespread threats to its continued existence.
- Identifies declining or potentially declining sagebrush-dependent wildlife species not addressed by other regional conservation planning efforts.
- Establishes conservation goals, objectives, and strategies to avert further decline of species of concern, and outlines monitoring steps to assess conservation accomplishments.

[20] J. Patrick Donnelly, Kelsey Jensco, John S. Kimball, Johnnie N. Moore, David Ketchum, Daniel P. Collins, David E. Naugle, Beneficial 'inefficiencies' of western ranching: Flood-irrigated hay production sustains wetland systems by mimicking historic hydrologic processes, Agriculture, Ecosystems & Environment, Volume 370, 2024, 109051, ISSN 0167-8809, https://doi.org/10.1016/j.agee.2024.109051.

[21] https://comap.cnhp.colostate.edu/about-comap/

[22] Seidl, A., Anderson, D., Bennett, D., Greenwell, A., and M. Menefee. 2017. Colorado's return on investments in conservation easements: Conservation Easement Tax Credit program and Great Outdoors Colorado. Colorado State University, Fort Collins, Colorado. (pdf)

[23] https://geodata.colorado.gov/maps/Wilderness::cpw-speciesactivitymapping/about

[24] https://cpw.state.co.us/learn/Pages/SagebrushSpeciesConservationStrategy.aspx

Streams

The streams data are characterized by stream reaches and focuses on depletions, instream flow status, endangered fish, recreation use, and temperature. These data are summarized in the following section.

Depletions are the relative difference between natural and actual flow estimates where actual and natural flow refer to estimates with and without diversions, respectively. Depletions are calculated using the National Hydrography Dataset (NHD) summarized by mean annual, mean monthly, and maximum monthly flow for stream reaches within the AOI spanning 1971 – 2000[25].

Instream Flow (ISF) status refers to the reaches with decreed water rights that require a minimum flow to remain instream[26]. In 1973, the General Assembly authorized the Colorado Water Conservation Board (CWCB) to appropriate water rights for ISF requirements to preserve the natural environment to a reasonable degree. After receiving detailed recommendations for ISF water rights from state and federal agencies, conservation groups and members of the public, the CWCB reviews and processes the recommendations in accordance with the Board's ISF Rules. The CWCB performs detailed hydrological analyses to ensure that all recommendations meet the statutory requirements for an ISF appropriation. The CWCB notifies and involves the public throughout the ISF appropriation process. Since 1973, CWCB has appropriated ISF water rights on nearly 1,700 stream segments covering more than 9,700 miles of stream. The CWCB has also completed more than 35 voluntary water acquisition transactions[27].

Endangered fish habitat refers to specific reaches that contain features essential for the conservation of a threatened or endangered species and that may require special management and protections. When a species is proposed for listing as endangered or threatened under the Endangered Species Act, the U.S. Fish and Wildlife Service considers whether there are areas of habitat believed to be essential for the species' conservation. Those areas may be proposed for designation as critical habitat; a term defined and used in the Act. Critical habitat may include an area that is not currently occupied by the species but that will be needed for its recovery. The final boundaries of the critical habitat are published in the Federal Register. Federal agencies are required to consult with the U.S. Fish and Wildlife Service on actions they carry out, fund, or authorize to ensure that their actions will not destroy or adversely modify critical habitat. These areas provide notice to the public and land managers of the importance of these areas to the conservation of a listed species. Special protections and/or restrictions are possible in areas where Federal funding, permits, licenses, authorizations, or actions occur or are required[28].

Recreation use data includes stream reaches identified as gold medal waters or designated as fully supporting boating and swimming uses. The gold medal waters data include stream reaches designated by CPW that are greater than 2 miles long and demonstrate that the fishery consistently produces a trout standing stock of at least 60 pounds per acre and produces an average of at least 12

[25] https://pubs.usgs.gov/of/2019/1096/ofr20191096.pdf
[26] https://cdss.colorado.gov/gis-data/gis-data-by-category
[27] https://cwcb.colorado.gov/focus-areas/ecosystem-health/instream-flow-program
[28] https://gis-fws.opendata.arcgis.com/maps/794de45b9d774d21aed3bf9b5313ee24/about

"quality trout" (14+ inches) per acre. This designation can only be applied to waters that are accessible for fishing by the general angling public[29]. Colorado Department of Public Health and Environment (CDPHE) designates stream reaches as fully supporting boating and swimming activities, meaning there is a low level of risk to humans due to toxicity or pollutants such as E. Coli or nutrients[30].

Historic temperature data represents the mean August temperature averaged from 1993 to 2011. The data was obtained from the U.S Forest Services (USFS) NorWest stream temperature program[31, 32].

Shade

The shade dataset is comprised of a TFT analysis designed to quantify uplift due to increased riparian shade along a stream reach. Uplift is the calculated difference between the current and future canopy conditions and is measured in kilocalories/day on August 15th. Shade-a-lator, a module of the Heat Source[33] model, is used to calculate thermal load reductions and visualize potential riparian revegetation shade along a section of the Uncompahgre River. Planting areas along streambanks that produce significant new shade 20 years after planting are ranked accordingly using summer uplift values.

WATER QUALITY

The Water Quality theme focuses on watershed health insights that could affect the quality of ecosystems and fish habitat due to stream impairments. This theme includes compilation of publicly available data on impaired waterways, along with preliminary water quality modeling of baseline loading by diversion. A description of the data sources and modeled metrics follows.

Stream Impairments

Stream impairment information is sourced from the CDPHE Segmentation Data[34], which compiles information under the federal Clean Water Act 303(d), TMDL, and Monitoring & Evaluation Lists[35]. These data are used to assess impairments for common agricultural runoff pollutants such as sediment, nitrogen, phosphorus, mercury, sulfate and selenium. The presence of these pollutants, also known as "analytes" (or their various chemical constituents), generally indicate lowered water quality.

Temperature impaired reaches were also used to assess potential aquatic life impacts and potential lethal exposure due to adverse warming or cooling of water from both point and nonpoint sources.

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[29] https://coloradogoldmedalwater.tu.org/

[30] https://cdphe.colorado.gov/clean-water-gis-maps

[31] Isaak, D., S. Wenger, E. Peterson, J. Ver Hoef, D. Nagel, C. Luce, S. Hostetler, J. Dunham, B. Roper, S. Wollrab, G. Chandler, D. Horan, S. Parkes-Payne. 2017. The NorWeST summer stream temperature model and scenarios for the western U.S.: A crowd-sourced database and new geospatial tools foster a user community and predict broad climate warming of rivers and streams. Water Resources Research, 53: 9181-9205. https://doi.org/10.1002/2017WR020969.

[32] https://www.fs.usda.gov/rm/boise/AWAE/projects/NorWeST.html

[33] Boyd & Kasper, Analytical Methods for Dynamic Open Channel Heat and Mass Transfer: Methodology for the Heat Source Model Version 7.0 (2003). http://www.deq.state.or.us/wq/TMDLs/tools.htm.

[34] https://cdphe.colorado.gov/clean-water-gis-maps

[35] https://www.epa.gov/tmdl/overview-identifying-and-restoring-impaired-waters-under-section-303d-cwa

Impairment data were used as a contextual piece for spatial overlap when assessing runoff results from irrigated fields at a diversion scale.

Environmental Load

The Nutrient Tracking Tool (NTT)[36] is used via BSA's **runoff module** to estimate existing field-level sediment and nutrient loads based on existing crop and irrigation types. Model results provide edge-of-field load estimates that are aggregated to the diversion-level to estimate runoff. Model inputs are configured to represent production within the AOI. Soil data from USDA's SSURGO database[37] are also included in the model inputs. The output results in an estimated quantity of on-farm sediment and nutrient edge of field loading. These environmental loads are reported in pounds/acre (nitrogen and phosphorus) or ton/acre (sediment).

Salinity

Salinity data includes areas where irrigation modernization projects have been implemented as part of the Colorado Salinity Control Program[38] and estimated loads from Nauman et al., 2019.[39] The estimated salinity loads integrate data from previous coarse scale models with updated salinity gauge measurements and 30-meter resolution soil, erosion risk factor, bare ground exposure, and topography data.

Selenium

Selenium data includes modeling results from Williams et al., 2023[40]. This work developed maps of selenium yield using multiple linear regression models for the lower Gunnison River Basin. Concentrations of selenium and discharge measurements were used to compute subbasin loads, which were adjusted for canal loads. Load regression equations were developed from explanatory basin characteristics that include physical properties, precipitation, land use and cover, surficial deposits (soil and unconsolidated geologic materials), and bedrock geology.

CONCLUSIONS AND NEXT STEPS

TFT created the Colorado West Slope Basin Explorer to examine water delivery metrics in normal, wet and dry years for diversions in the Colorado River basin within the state of Colorado. These metrics are displayed in context with other agricultural and ecological datasets. This was completed by aggregating, normalizing, and visualizing data from scientifically vetted tools and models across three analytic themes: Production, Ecosystems, and Water Quality. The resulting Web App allows users to explore relevant geospatial data and obtain insights regarding (and inform opportunities to strengthen, restore, and build resilience in) agricultural and ecological systems. Web App data structures and insights, when verified or improved with input from local experts, can also support the

[36] https://ntt.tiaer.tarleton.edu/NTT_technical_documentation_21-9.pdf
[37] https://www.nrcs.usda.gov/resources/guides-and-instructions/soil-survey-manual
[38] https://coloradoriversalinity.org/documents.php
[39] https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2018WR024054
[40] Williams, Cory A., Rachel G. Gidley, and Michael R. Stevens. *Salinity and selenium yield maps derived from geostatistical modeling in the lower Gunnison River Basin, western Colorado, 1992–2013*. No. 2023-5013. US Geological Survey, 2023. https://pubs.usgs.gov/sir/2023/5013/sir20235013.pdf

subsequent development of decision support tools that solve for specific problems—providing prescriptive approaches to, for example, reduce temperature impairments in streams, build drought-resilience in irrigation systems, or preserve and enhance wetland habitats.