Keyline Design for Restoration of Headwater Slope Wetlands in the Holman Creek Wetlands Complex Assistance Agreement CD# 01F109-01-0C

Log Split, Log Mat and Log Reinforced Contour Berm spreads water across a previous wetland surface, West Drainage, Holman Creek Watershed Complex. September 13, 2018. Photo by Emile Sawyer

New Mexico Environment
Department Surface Water Quality
Bureau Wetlands Program

Final Report
December
2021

Problem Statement

Headwater slope wetland ecosystems are generally situated at the tops of watersheds and are critical to the functioning of entire river systems due to influences on downslope rivers and floodplains. Headwater slope wetlands are characterized by soils high in organic matter important to the capture of water and storage of baseflow, unidirectional dispersed (rather than concentrated) flow from snowmelt and runoff spreading across the wetland surface, a groundwater component (fen) that safeguards wetland stability during drought, and thick palustrine emergent (marsh/wet meadow) vegetation. Headwater slope wetlands act as sponges that absorb snowfall in winter and monsoon rains in summer, tempering the intensity of storms, and cooling and slowly releasing the subsurface water downstream throughout the year. Baseflow from headwater slope wetlands often maintains constant streamflow and cold-water temperatures necessary for cold water aquatic life downstream.

However, many of the New Mexico's high country headwater slope wetlands are dissected, channelized and drained due to stressors such as roads and vehicle tracks, historic mining impacts, livestock and wildlife grazing and trailing. These impacts reducing their size and quality. Due to their position at the top of the watershed, continued drying, lowering of the local water table, channelization and loss of headwater slope wetlands results in diminished watershed health overall. Loss of headwater slope wetlands has cascading negative downstream effects of increased head cutting and erosion, sedimentation, fragmented wildlife habitat, loss of riverine wetlands/riparian vegetation, encroachment of upland vegetation, reduced based flows, and warmer stream temperatures. Conversely, restoring headwater slope wetlands has significant positive downstream effects of increasing the quality and quantity of downstream riverine wetlands, reducing stream sediment and temperature, supporting wildlife habitat, and regulating and increasing stream base flows.

Project Goals and Objectives

The New Mexico Environment Department Surface Water Quality Bureau (SWQB) Wetlands Program conducted a demonstration project to apply Keyline Design* principles to restore a minimum of 40 acres of headwater slope wetlands in the Holman Creek Wetlands Complex. The main objective of the project was to utilize Keyline Design principals to increase the quality and quantity of headwater slope wetlands by spreading out runoff and increasing infiltration. A Technical Guide was produced to share results of the project so that the method can be used in other headwater slope wetland settings.

Water flow patterns are determined by gravity and landscape conditions, which cause water to take the shortest route down a hillside. Landscape conditions can be modified to alter flow patterns that spread the flow and lengthen water routes to increase water resource benefits. These are the primary goals of Keyline Design concepts.

*("Keyline" is a registered trademark. "Keyline Designs" is a registered business name of Ken B. Yeomans.)

Project tasks included the assembly of a design charrette to prepare for the conducting, planning and field reconnaissance to support the design and installation of restoration structures in accordance with Keyline Design principles. The project team included restoration contractors, US Forest Service and Wetlands Program staff. The Wetlands Program Project Officer developed a QAPP for pre- and post-project monitoring which was approved by EPA. State and Federal Clearances were obtained after the contractor and design charrette created a preliminary design using Keyline Design concepts. Restoration was achieved by qualified contractors and through volunteer work weekends installing the project using machinery and volunteer labor. Each work weekend included outdoor instruction to learn about headwater wetlands and restoration theory and train the workers in how to perform the restoration work safely and effectively. A technical guide describing the methods used for the Keyline Design approach for restoring headwater slope wetlands was presented in a half-day workshop in conjunction with the annual Quivira Coalition Conference where over 100 attendees learned about applying keyline design to wetlands nationwide.

Project Location

The project is located along the north-central boundary of Colorado and New Mexico within the within the Carson National Forest – Valle Vidal Unit in New Mexico. Project work was performed in the Holman Creek Sub-watershed, focused on the Holman Creek Wetlands Complex (HCWC). This high elevation drainage sits along the southwestern end of the ridgeline leading south from Little Costilla Peak (Elevation: 12584 ft/3836 m). And is situated in the northeastern portion of the USGS HUC8 - Upper Rio Grande - 13020101 and within USGS HUC12 - Comanche Creek - 130201010102 (Figure 1).

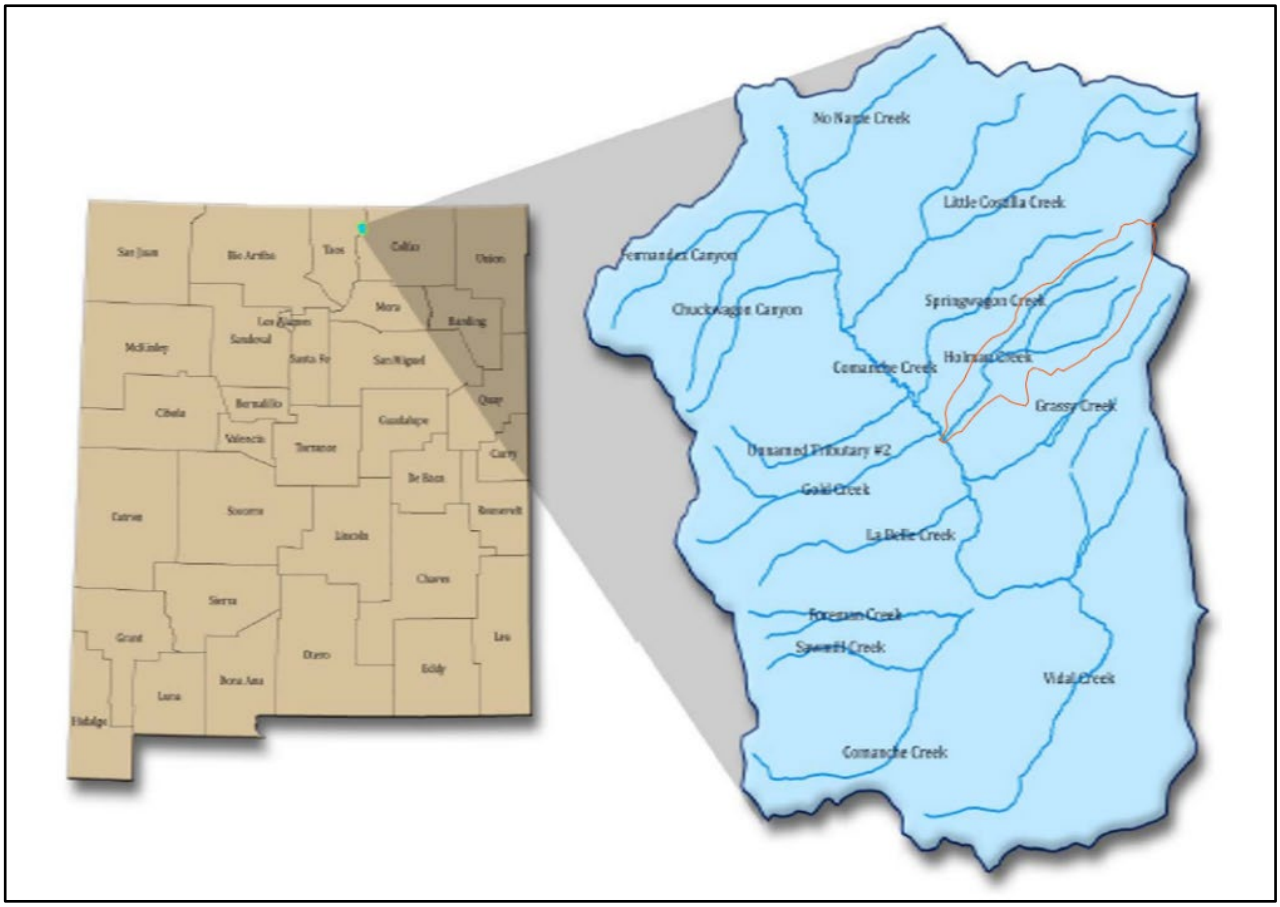

Figure 1. USGS HUC12 Comanche Creek – 130201010102 enlarged with relative location in New Mexico and stream names shown. Holman Creek Sub-watershed orange outline at top right.

Project Outputs

Through this project seven major objectives were accomplished:

1) The restoration of approximately 40 acres of headwaters slope wetlands in a manner that increases resiliency to climate change.

2) The technical guide that describes the use and effectiveness of Keyline Design for headwater slope wetlands.

3) Two work weekends that assisted the installation of restoration structures according to the project design, and educated volunteers.

4) A half-day workshop at the Annual Quivira Coalition conference about Keyline Design restoration.

5) Dissemination of the technical guide to potential users.

6) Installation of 10 piezometers to monitor ground water in the project area and continue research of Headwater Slope Wetlands in New Mexico.

7) This final report on the project including project results and interpretation of baseline and post-installation data.

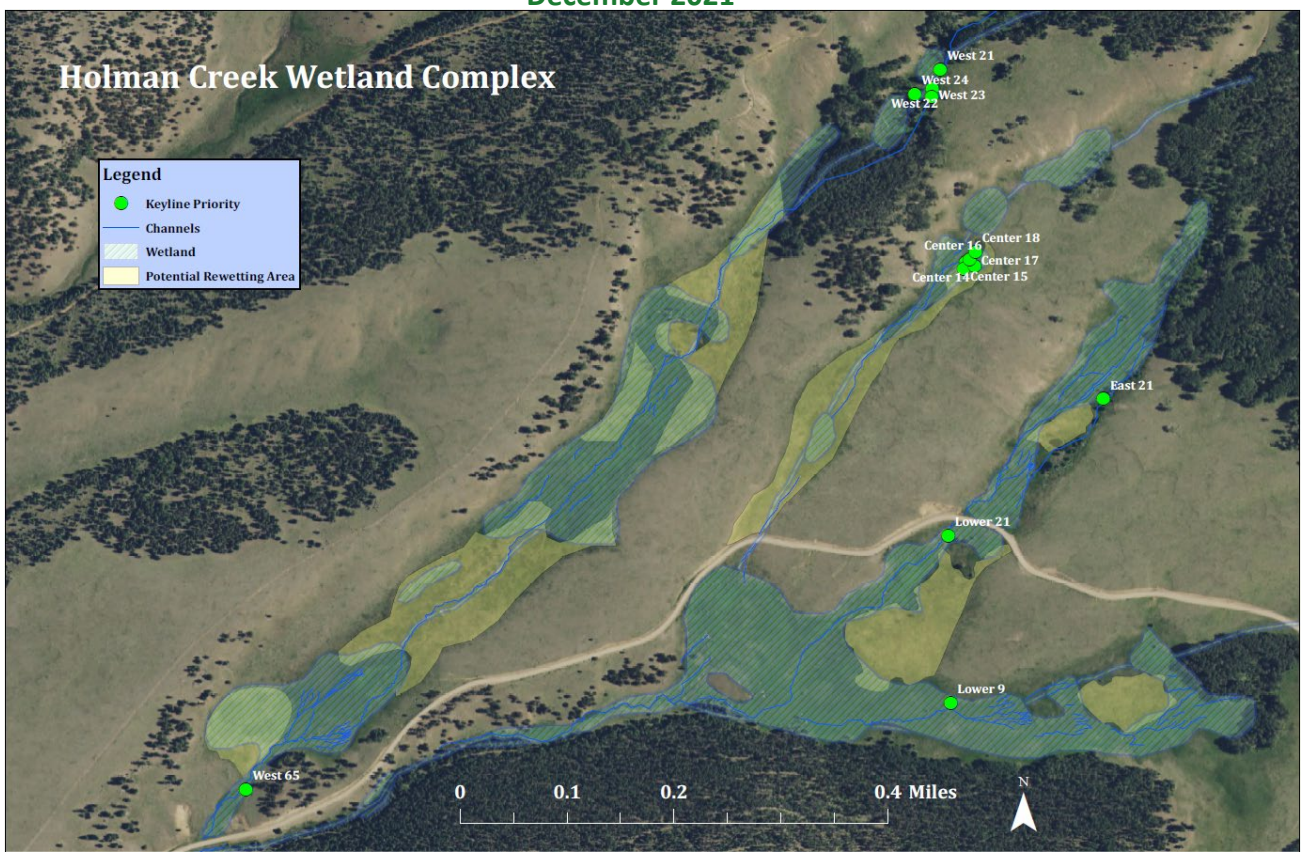

Figure 2. Keyline Design Priority Locations identified early in the design process for Holman Creek Wetlands Complex water spreading structures are marked as bright green dots. Channelization is indicated by blue lines. Mapped wetlands are shown as green with gray hash-lined polygons. Potential re-wetting areas are shown as yellow polygons that are adjacent to or connected by mapped wetlands.

Project Outcomes

The project outcomes include:

- A final technical guide "Applying Keyline Design Principals to Slope Wetland Restoration in a Headwater Ecosystem" for keyline design application to headwater slope wetlands was completed and published in hard copy by the NM Department of Health Printshop and online at: Water Cloud (nm.gov). Nearly 200 copies of the guide were distributed to potential users at the annual Quivira Coalition Conference and at Wetlands Roundtables increasing understanding of restoration tools and techniques by end users.
- A half-day wetlands workshop on Keyline Design was conducted by project partners, and a booth about Keyline Design and Headwater Slope Wetlands was staffed by the SWQB Wetlands Program at the annual Quivira Coalition Conference in November 2019, which targeted practitioners nationwide and was attended by over 100 attendees.
- Two wetlands restoration volunteer weekends were conducted in 2018 and 2019 to assist with restoration treatment construction and educate volunteers about the demonstration project.
- Partners including the US Forest Service, volunteer organizations, restoration contractors and others have additional tools for the management of thousands of acres of public lands and

the restoration of headwaters in the lands they manage and protect.

- The installation of 10 piezometers in the project area provide important data about groundwater in the project area, restoration effectiveness, and inform future efforts including the development of a rapid assessment method for headwater slope wetlands by the Wetlands Program.
- Restoration benefits include increase of functioning wetlands in headwater positions, filtration of pollutants and sediment through headwater wetlands, improvement of downstream aquatic environments that sustain fish, wildlife and other biota, and the enhancement of economic, recreational and subsistence activities in the watershed.
- This final report describing project results, effectiveness, and lessons learned is available on the NMED Wetlands Program website Wetlands Projects (nm.gov) for access by practitioners and the general public.

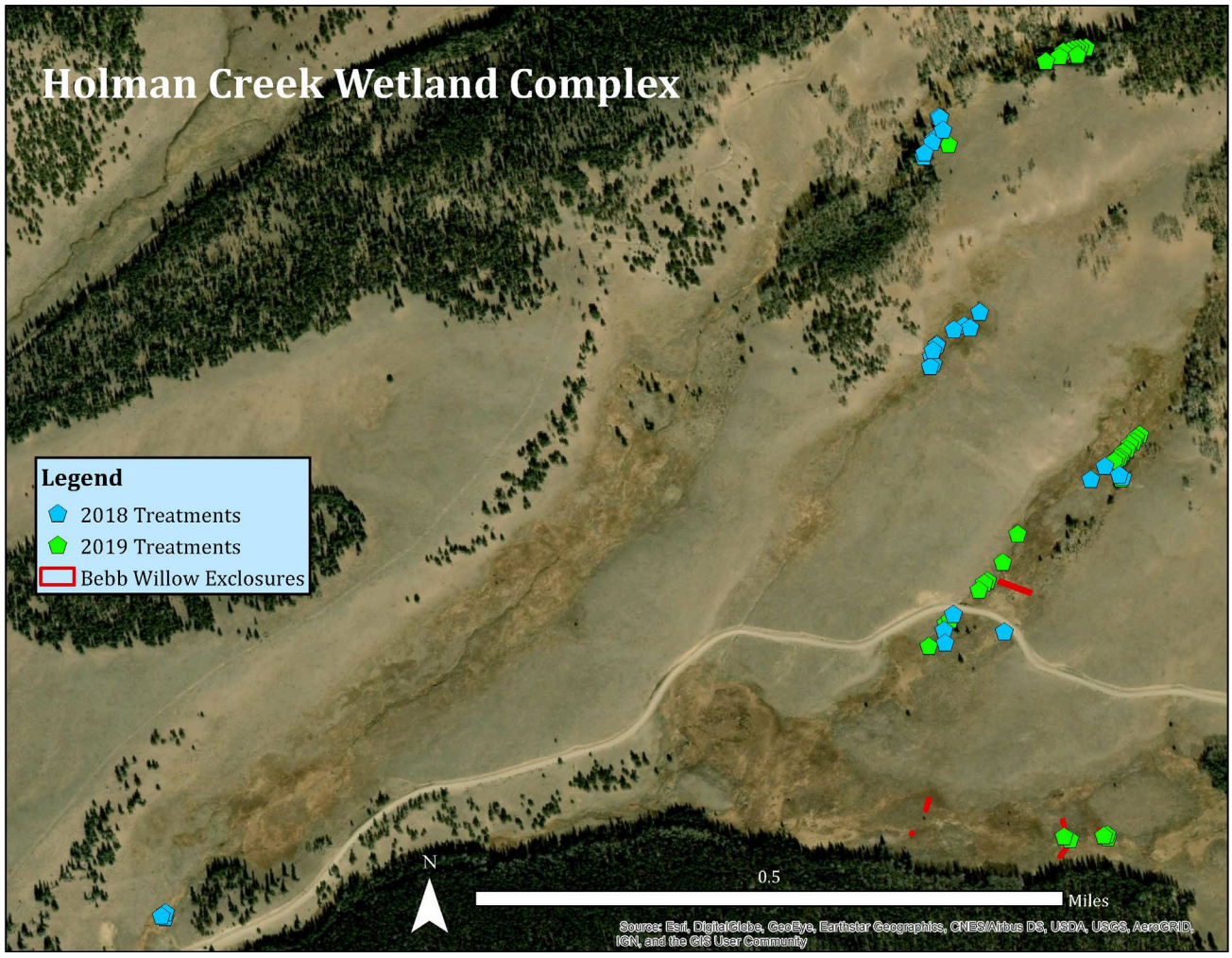

Figure 3. Keyline Design As-built map with 2018 treatments, Holman Creek Wetlands Complex water spreading structures are shown as blue pentagons. 2019 treatments are green pentagons. Bebb Willow Exclosures are red polygons. Map by Mollie Walton.

Construction and Restoration Workshops

Restoration subcontractors Reineke Construction and Terrasophia used their professional

expertise to adapt traditional Keyline Design principles to restoration of headwater slope wetlands. In 2018, structures were built with the aid of heavy machinery as well as manual labor (Fig. 4). Over the course of the project, 29 structures were installed in 2018 (blue pentagons), 37 structures were installed in 2019 (green pentagons) and five (5) Bebb Willow (*Salix Bebbiana*) exclosures (red polygons) were constructed during the two (2) workshops. See Figure 3 above.

Figure 4. The mini-excavator is used to dig and place anchor rocks, while manual labor, shown here by Margie Tatro, is used to set and chink log berm structure. Photo by Mollie Walton.

In 2018 at the volunteer work weekend, volunteers added structures for adaptive maintenance and to increase impact of existing design features (Figures 5 & 6 below). Figure 5 shows a volunteer digging a footer trench for a media luna while volunteers in the background install a series of sod plugs in an incised channel. The completed structure is shown a week later capturing and spreading water, Figure 6.

Figure 5.

Figure 6. Photos by Mollie Walton.

Field Workshop Participants (August 2018 & 2019)

Volunteers

Name	***From***
Clay Walton	Austin, TX
Kai Jensen	Denver
Laurie Applebee	Denver
Stephen Monroe	Tucson
Rachel Ryzewicz	Taos
Kim Peters	Taos
Sylvette Vidal	Los Angeles
Owen Hablutzel	Los Angeles
Stephanie Brock	Roy, NM
Brandon Wade	Norman, OK
Jamie Head	Albuquerque
Mike Kelly	Albuquerque
Dorothy Williams	Unknown
Vick Williams	Unknown
Jill Walton	Austin, TX
E. Walton	Austin, TX
Peter Obrien	Gardener, CO
Mori Hensley	Santa Fe, NM
Amber Harchrik	Santa Fe, NM
Christian Meuli	Edgewood, NM
Julia Stafford	Cimarron, NM
Art Vollman	Santa Fe, NM
Toney Hofner	Santa Fe, NM
Reba Epler	Hillsdale, WY
Rick Smith	Vermejo Park, NM
Heather Scott	Montrose, CO
Valerie McCarn	Cimarron, NM
Josh Gaslin	Cimarron, NM
Chance Sloan	Cimarron, NM
Linda Doherty	Santa Fe, NM
Sharon Miles	Santa Fe, NM
Rich Schrader	Santa Fe, NM
Mark Torres	Costilla, NM
Karen Turnorire	Costilla, NM
Andi Rutherford	Denver
Haley Leslie-Bole	Santa Fe, NM
Jennifer Gathis	Taos, NM

Original Timeframe

The Award for this grant CD #01F10901, includes five projects that originated in October 2015. The Notice of Award for this project (Cooperative Agreement CD #01F10901-C) was issued on May 10, 2016. On January 5, 2018, EPA approved a no-cost grant extension for the Award to September 30, 2020. In September 2019, a no-cost grant extension was requested specifically to accommodate two other projects in the Award but affected the end date for all projects in the Award and the new end date of April 30, 2021, was approved on October 4, 2019. In October 2020 the Wetlands Program requested a no cost extension to September 30, 2021 because NMED was experiencing project delays due to COVID-19, staff changes, and for this project to also complete piezometer installation.

Partners Involved

Quivira Coalition was the principal contractor that oversaw tasks in partnership with sub-contractor Ecotone Landscape Planning and SWQB Wetlands Program Project Officer Emile Sawyer, in performing the many tasks and sub-tasks needed to complete this project including design development, performance of pre-and post-construction monitoring, scheduling volunteer workshops, and subcontractors; assistance with technology transfer by helping to create the technical guide and host a half-day workshop on keyline design at their annual conference.

Vegetation monitoring and piezometer installation partners included volunteers, contractors, NMED staff and USDA Carson National Forest and USDA Natural Resources Conservation Service staff.

SWQB Wetlands Program was involved in every aspect of project, participating in the Keyline Design Charette, Quivira Coalition volunteer workshop days, Quivira Coalition Annual Conference, in office, online and in the field, planning meetings; review of construction design and implementation in the field oversight, work products and reports, and setting up groundwater monitoring program.

The Project involved a design team whose members are as follows:

Keyline Design for Restoration of Headwater Slope Wetlands in the Holman Creek Wetlands Complex Charette Participants

Name	**Organization**
Emile Sawyer	NMED-SWQB Wetlands Program
Chris Cudia	NMED-SWQB Watershed Protection Section, now retired.
Mollie Walton	Quivira Coalition
Jan-Willem Jansens	Ecotone Landscape Planning
Sarah Wentzel-Fisher	Quivira Coalition
Bill Zeedyk	Zeedyk Consulting
Jeff Adams	Terra Sophia
Mark Reineke	Reineke Construction
Margie Tatro	Reineke Construction
Michael Gatlin	USFS-Carson National Forest

Greg Miller USFS-Carson National Forest
Reid Wittlesey volunteer, now with Rio Grande Return

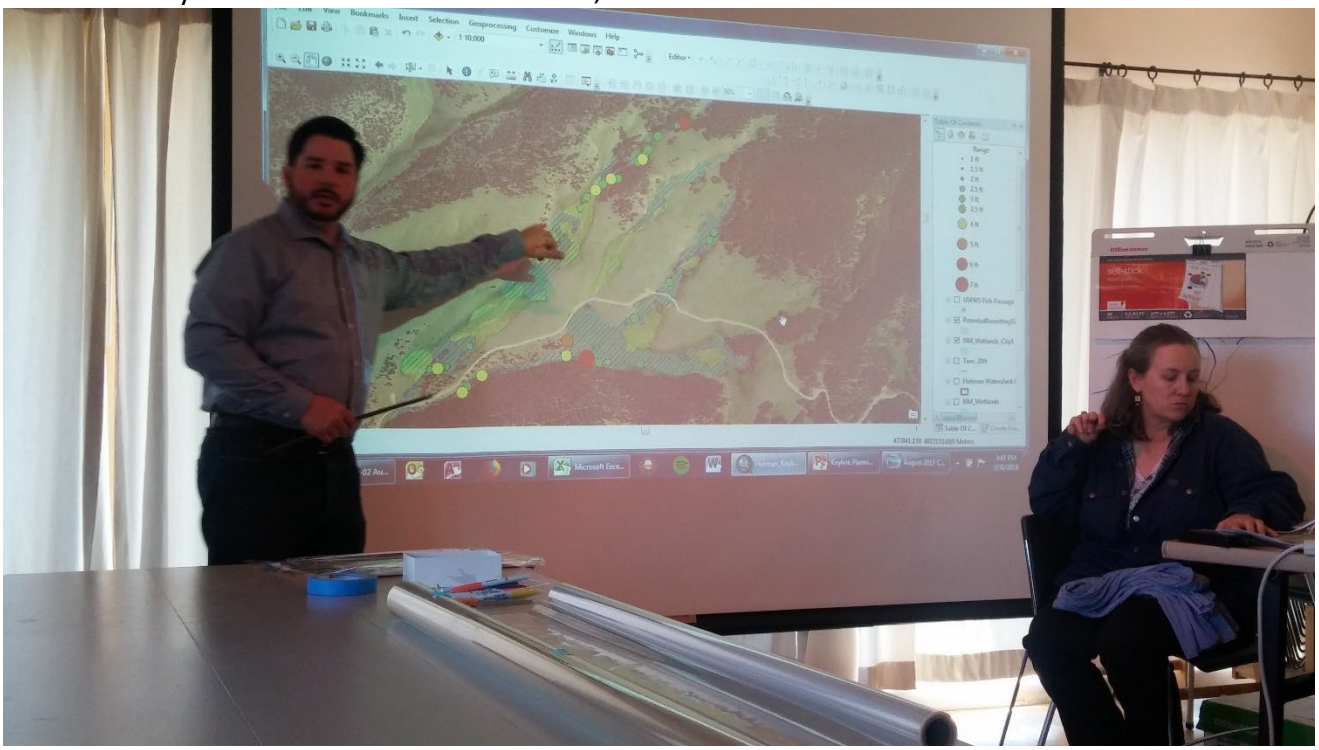

Figure 7. Michael Gatlin, Fisheries Biologist with Carson National Forest discusses headcuts and restoration structures already built in the Holman Creek Wetlands Complex, while Mollie Walton, Quivira Coalition, runs the slide projector during the Keyline Design Charette on December 30, 2018.

Figure 8. Bill Zeedyk, Chris Cudia, Margie Tatro and Mark Reineke listen to a presentation about Keyline Design and how it could be applied with wetlands restoration during the Keyline Design Charette on December 30, 2018. Photo Emile Sawyer.

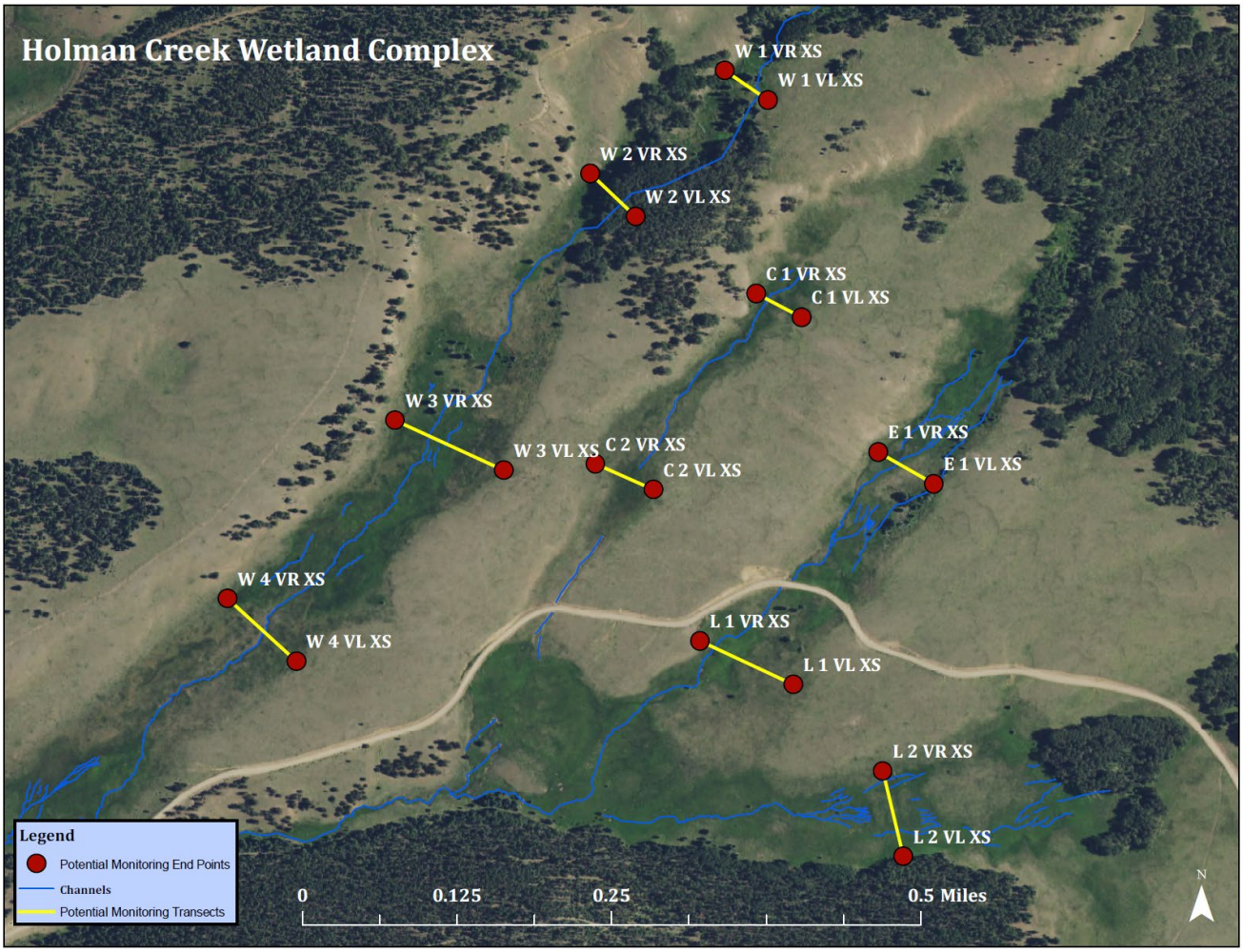

Figure 9. Potential vegetation monitoring cross-sections map submitted by Quivira Coalition's Mollie Walton. Red dots are estimated end point locations. Yellow lines are potential transect locations. Blue lines are channels mapped with a GPS device by Mollie Walton in 2017.

Vegetation Monitoring Team

Mollie Walton	Quivira Coalition
Karen Menetrey	NMED/SWQB Wetlands Program
Rachel Jankowitz	NMED/SWQB TMDL Program
Mori Hensley	volunteer, now ED, Santa Fe Watershed Association
Chris Michael	volunteer, owner CM Arborcare

The Vegetation Monitoring Team was composed of volunteers, contractors and NMED staff that measured cross-section and long profiles of the area before and after construction in order compare data and use a modified version of Greenline Survey (citation? 2000) to evaluate field observations for changes in vegetation. A pre-construction survey was conducted in 2018. A post-construction survey was conducted in 2020. Unfortunately, overall, no major vegetation changes were observed within the short term of two years between surveys.

Figure 10. Volunteers - Chris Micheal reads an elevation rod, while Mori Hensley writes down elevation and vegetation information along the W2LVXS (See Figure 8 map above) vegetation monitoring cross-section in the upper west drainage of the Holman Creek Subwatershed – August 23, 2018. Photo by Emile Sawyer.

Figure 11. Rachel Jankowitz observes vegetation along the W2LVXS (See Figure 8 map above) vegetation monitoring cross-section in the upper west drainage of the Holman Creek sub-watershed – September 1, 2020. Photo by Emile Sawyer.

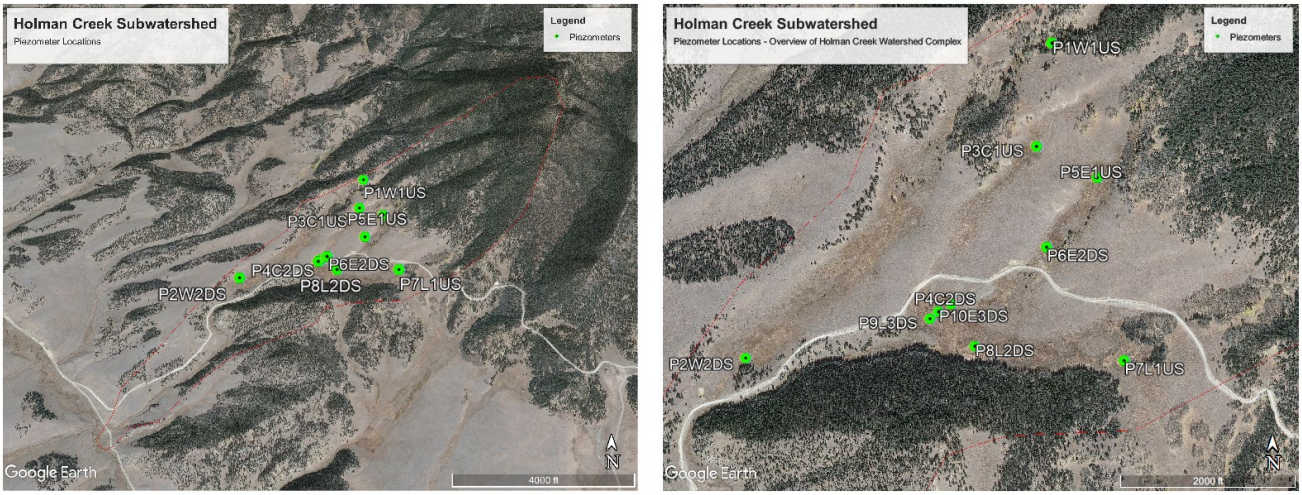

Figure 12. Left square above shows overview of Holman Creek Subwatershed with piezometer locations (green circles with black dots) and locations. Right square shows a closer view of piezometer locations with FS 1910 crossing the center of the image.

Piezometer Installation Team

Emile Sawyer	NMED/SWQB Wetlands Program
Aaron Miller	USDA Natural Resources Conservation Service
Logan Peterson	USDA Natural Resources Conservation Service
Hamish Tomson	Albuquerque Wildlife Federation
J.T. Jones	NMED/SWQB Wetlands Program,
Gunnar Johnson	NMED/SWQB TMDL Program, now EPA region 8
Jonathan Beyeler	NMED/GWQB Mining Environmental Compliance Program
Jennifer Muss	NMED/GWQB Brownfields Program
Dan Guevara	NMED/SWQB Effectiveness Monitoring Program

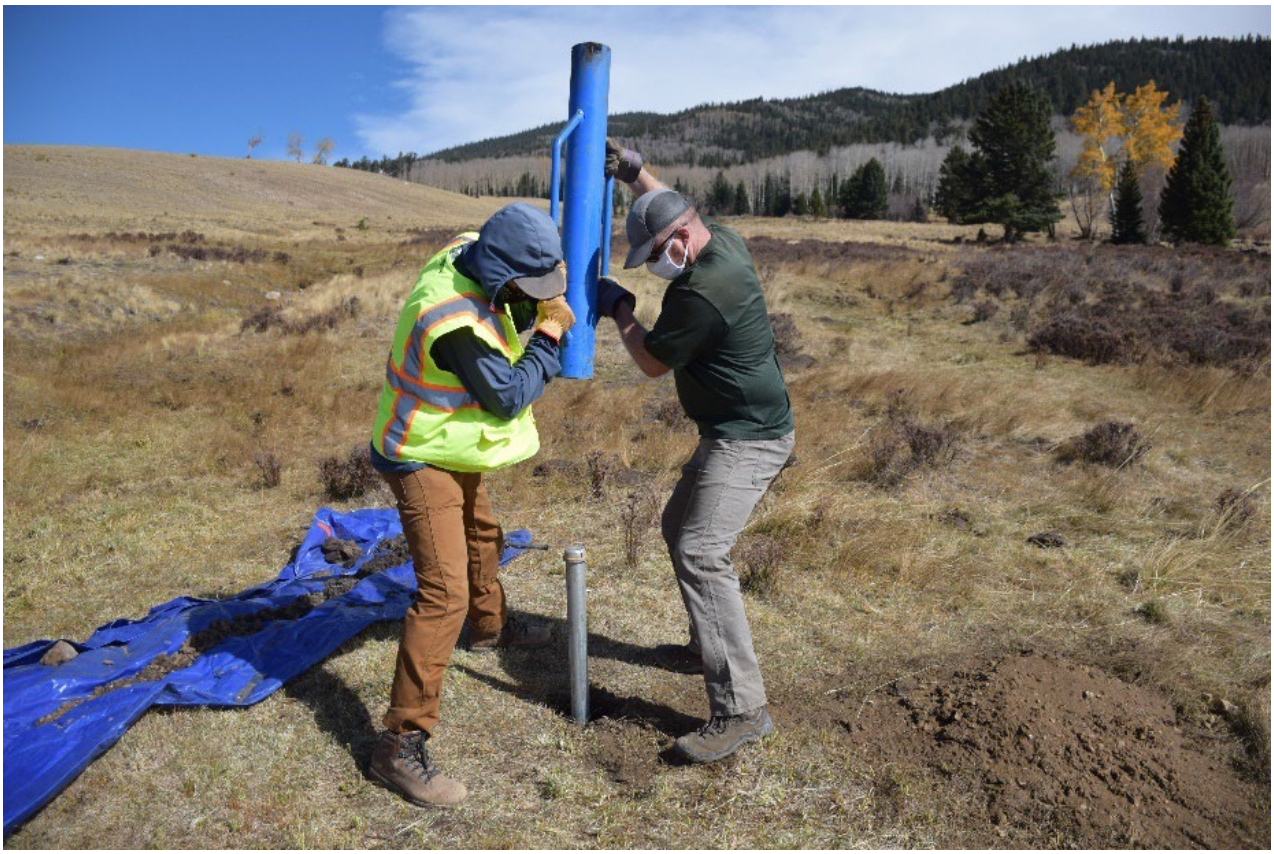

Figure 13. Jonathan Beyeler and Gunner Johnson, NMED, pound 2 inch steel casing of P6E2D2 piezometer into place with specialty well pounder. Photo Emile Sawyer.

NMED Project Participants

Maryann McGraw	NMED/SWQB Wetlands Program Coordinator
Karen Menetrey	NMED/SWQB Wetlands Program, now with GWQB Brownfields
Emile Sawyer	NMED/SWQB Wetlands Program
Rachel Jankowitz	NMED/SWQB TMDL Program
Alan Klatt	NMED/SWQB Restoration Team
J.T. Jones	NMED/SWQB Wetlands Program
Gunnar Johnson	NMED/SWQB TMDL Program, now EPA Region 8
Jonathan Beyeler	NMED/GWQB Mining Environmental Compliance Program
Jennifer Muss	NMED/GWQB Brownfields Program
Dan Guevara	NMED/SWQB Effectiveness Monitoring Program

Figure 14. Gunner Johnson fills borehole with bentonite mixture to complete P6E2DS piezometer.

Figure 15. Completed piezometer P6E2DS in the East Drainage just up hill of FS 1910. Photo Emile Sawyer.

Holman Creek Wetlands Complex waters were collected for isotope measurement from piezometers and one spring in the project area by filling 25 mL amber glass bottles, rinsing a bottle and cap three (3) times with the subject water prior to collection. No air bubbles were visible in bottles after filling to confirm their validity. They can be stored at room temperature and are relatively cheap to process, approximately $10 per sample. Samples were processed and analyzed at the New Mexico Institute of Mining and Technology, Department of Earth and Environmental Sciences, Stable Isotope Laboratory on a Picarro Cavity Ringdown Spectrometer (L1102-I Isotopic Water Liquid Sampler) in cooperation with the New Mexico Bureau of Geology and Mineral Resources Associate Director Stacy Timmons, Hydrogeology Programs.

Figure 17 shows a graph of deuterium (δD (‰)) versus Oxygen-18 (δ18O (‰)) results for October 2020 and August 2021 sampling events along the Global Mean Water Line (GMWL) (Craig, 1961). While the data is limited in timeframe, and additional data will need to be acquired for definitive answers, the data appears to show little evaporation, where data is far from the GMWL, as the given the samples all fall close to the GMWL. This confirms that the samples are from groundwater. It is likely that lighter samples (the samples with larger negative numbers -120 dD) may be from Pacific events, whereas heavier samples (less negative numbers -90 dD) could be from Atlantic storms during the monsoon season. Additional data will provide more evidence for seasonality and may help understand fens and other headwater slope wetlands in New Mexico and the region.

Figure 16. Contractors installing log structures in the HCWC East Drainage in 2018. Photo by Emile Sawyer.

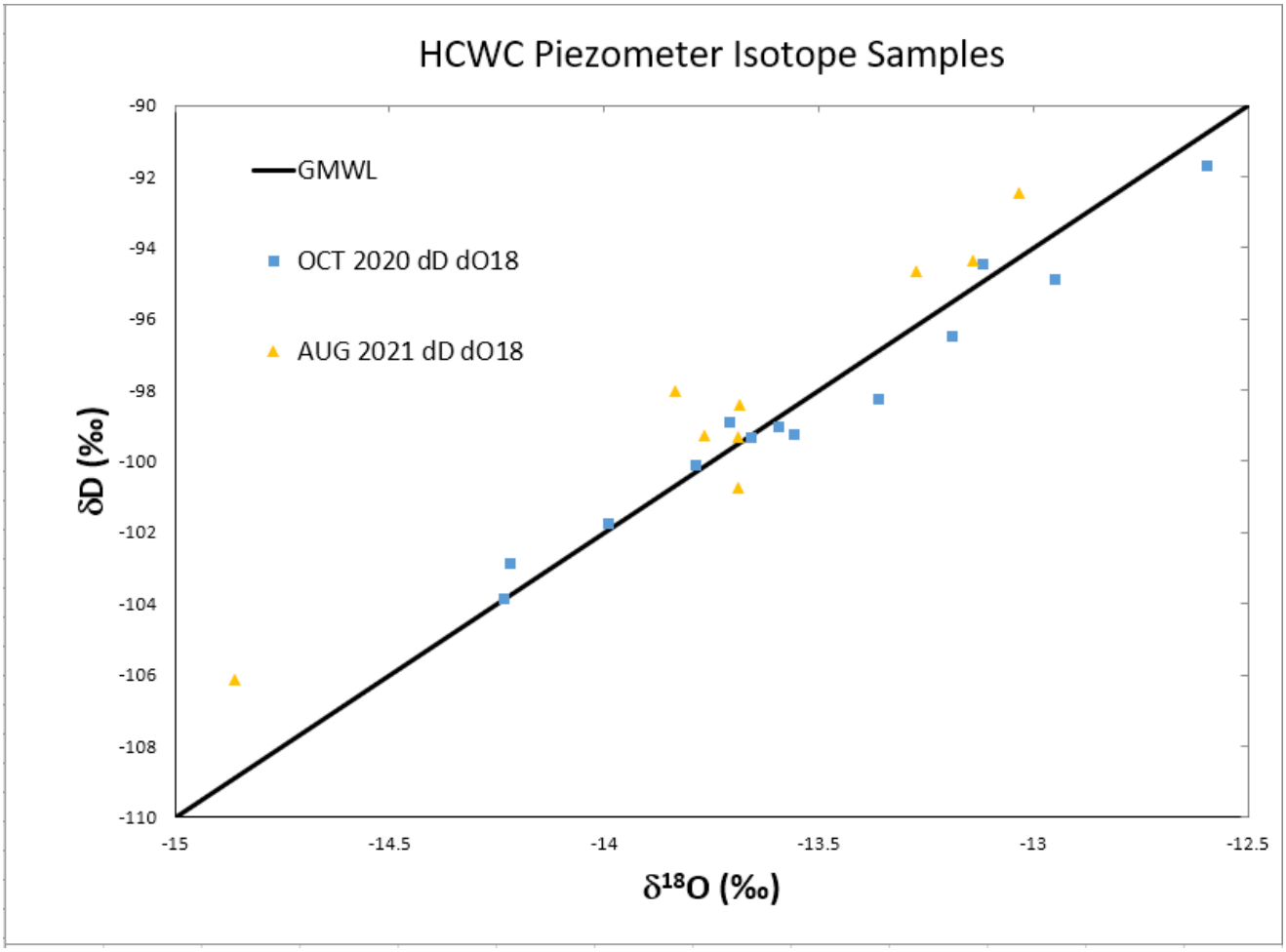

Figure 17. HCWC isotope measurement data from piezometers and springs in the project area. The graph displays deuterium (δD (‰)) versus Oxygen-18 ($\delta^{18}O$ (‰)) data for October 2020 (blue squares) and August 2021 (yellow triangles) sampling events along the Global Mean Water Line (GMWL) (Craig, 1961). While the data is limited in timeframe, there appears to be little evaporation given the samples all fall close to the GMWL – confirming that the samples are from groundwater. Lighter samples with larger negative numbers may be from Pacific events, whereas heavier samples, less negative numbers suggest possible Atlantic origins.

Funding

The original Federal amount budgeted for this project was **$310,899.00** and **$108,855.00** match. The **final federal amount** spent was **$279,901.43** and **the final match amount** was **$164,047.17. This project as was overmatched by *$55,192.17***. See semi-annual reports for details.

Additional Funds

The Quivira Coalition staff, restoration contractors, volunteers, and workshop attendees provided substantial match to this project. Quivira donated the 10% de minimus overhead amount of the project for a match of $18,799.33. Contractors donated $10,876.14 in match over the life of the project from reduced billing and reimbursement rates. The required contractor match for the project was $80,824.64. The Quivira Coalition and non-federal project partners, including volunteers and

Quivira Conference workshop attendees, contributed a total match of $153,696.89. The required contractor match was exceeded by $72,872.25.

Lessons Learned

The collaborative approach to innovative restoration is expensive and takes more time than if fewer parties are involved. It was challenging to use the collaborative model and still keep costs within budget. Different chapters for the technical guide were assigned to individual team members. However, it might have worked better to assign one person to prepare a first draft and then have team members review the draft document.

Major Project Highlights and Chronology

- SWQB Wetlands Program was awarded federal assistance for this project on the Cooperative Agreement between NMED and EPA were completed on September 17, 2015.
- Emile Sawyer, Wetlands Program Project Officer (WPO), was chosen to be the Project Officer for this project.
- The WPO began attending Comanche Creek Working Group meetings on October 6, 2015.
- The WPO attended the Quivira Coalitions Annual Conference in Albuquerque, NM November 11 through 13, 2015. Several lectures were attended including one on Keyline Design.
- WPO began an effort on December 11, 2015 to create a sole source contract for a preferred contractor and then discovered that many contractors were interested in performing the contract work and thus began a process to develop a Request for Proposals (RFP) which continues to date.
- The WPO conducted two hours of field reconnaissance for the project on March 16, 2016.
- The Request for Proposals (RFP) effort for Keyline Design contractor continues to date.
- The Request for Proposals (RFP) for Keyline Design contractor is still under review by several Financial Bureaus at NMED.
- The WPO attended the Comanche Creek Working Group Meeting by phone on February 16, 2017.
- The Request for Proposals (RFP) for Keyline Design project contractor was finalized and posted on line via NM GSD, State Purchasing Division on April 7, 2017 and NMED website on April 10, 2017.
- NMED RFP Evaluation Committee met June 5 and 6, 2017 to determine a project contractor. The committee chose Quivira Coalition.
- The WPO contacted USGS and NMED staff to develop a monitoring plan for Keyline Design. The information is being used for the development of a project QAPP.
- WPO attended Comanche Creek Working Group Restoration Workshop weekend August 4 and 5, 2017.
- An implementation contract was signed with the Quivira Coalition on November 30, 2017.
- A No-Additional-Cost time extension request was approved on January 9, 2018.
- A project kick-off meeting was held on January 12, 2018 with NMED staff and contractors.
- A draft QAPP was provided to Acting QA Officer Jennifer Fullam on February 16, 2018.
- Our new QA Officer Miguel Montoya began work on February 26, 2018.
- A day-long keyline design charette was held on March 30, 2018.
- The Keyline Design QAPP was approved by EPA on June 12, 2018 and will expire on June 13, 2021.

- A draft outline for the Keyline Design technical guide was received on June 13, 2018.
- Project design and planning with the Quivira Coalition was finalized and approved by the WPO on July 23, 2018.
- Pre-construction monitoring was completed on September 13, 2018.
- Initial project construction was completed on September 15, 2018.
- WPO participated in the Comanche Creek Working Group Restoration Workshop, which took place during the weekend of August 4 & 5, 2018.
- Administrative activities related to data transfer, planning, budget and accounting completed.
- The Nationwide Permit Verification was signed on August 3, 2018 and provided to Jack Lewis, Carson National Forest, Questa Ranger District as Action No. SPA-2018-00168-ABQ.
- The project NEPA is covered under a February, 26, 2013 Categorical Exclusion as part of the Supplemental Information Report Comanche Creek Native Trout Habitat Restoration Project.
- Comanche Creek Working Group meetings took place April 2nd and September 16th, 2019.
- Draft Keyline Design Technical Guide was delivered to the WPO and WPC on July 30, 2019.
- Comanche Creek Working Group Restoration Workshop took place during the weekend of August 3 and 4, 2019.
- Michael Gatlin, Carson National Forest, Comanche Creek Working Group partner and USFS contact for this project leaves Carson National Forest at end of September, 2019.
- Emile Sawyer (WPO), Karen Menetrey (WPO) and Maryann McGraw (WPC) staff a conference display table, provide handouts and attend the Quivira Coalition Regenerate Conference in November 2019.
- A Keyline Design half-day workshop was conducted on November 22, 2019, during Quivira Coalition Regenerate Conference with 99 participants in attendance.
- A Final Draft Keyline Design Technical Guide was submitted to the Wetlands Program for review and printing, and about 100 copies were distributed at the Quivira Coalition Regenerate Conference.
- Emile Sawyer (WPO) attended the Land and Water Summit in Albuquerque in February 2020. Emile Sawyer attended the Association of State Wetland Managers Federal , State, Tribal Coordination virtual meeting April 7-9, 2020.
- Coordination with the USFS and Office of the State Engineer on Groundwater Monitoring (GWM) for Headwater Slope Wetlands began on May 14, 2020.
- Contract work by the Quivira Coalition was completed on June 30, 2020.
- A revised Keyline Design Project QAPP was submitted to EPA on June 23, 2020 and approved on July 9, 2020. QTRAK #20-311.
- Vegetation Monitoring was completed by SWQB staff September 1 through 4, 2020
- Piezometer installation for the GWM project began September 15, 2020.
- Piezometer installation for the GWM project field work continued from October 1 – 17, 2020.
- NRCS Soil Scientists evaluated soils during piezometer installation at Holman Creek Watershed Complex in October 2020.
- The Keyline Design project was presented to the SWQB Bureau on February 5, 2021.
- Emile Sawyer continued to complete administrative tasks to finalize project.
- Piezometer installation for the GWM project field work completed.

Unexpected Benefits of the Project

The project provided an opportunity for the team to think creatively about how to apply Keyline Design principal concepts to the headwater slope wetland restoration toolbox. The team added to the toolbox by re-imagining structures which, ultimately, became more effective in spreading water over dried wetland surfaces than previous treatments. It offered the opportunity to look at past projects with new eyes and identify places where the keyline techniques could have been placed higher in the watershed and had a greater effect for rewetting drier wetlands away from the incised stream channels. People who attended the workshops and the conference provided feedback that they could identify places on their own properties or in their projects where the techniques might work well to improve the health of their landscapes.

The piezometer installation effort provided additional opportunities for collaboration with partner agencies and volunteers alike. The groundwater information obtained will be used in future projects that support the continued development of restoration techniques, rapid assessment method metrics and critical scientific understanding of headwater slope wetlands in New Mexico and intermountain western North America.

Restoration Design, Permitting and Clearances

The restoration design was based on the collaborative efforts of Ecotone Landscape Planning, the Quivira Coalition, Reineke Construction, and Terrasophia. Emile Sawyer approved the design for the NMED Wetlands Program. The Carson National Forest aided in obtaining the archaeological clearance and Quivira submitted the New Mexico 401 certification and the United States Army Corps of Engineers 404 permit. The New Mexico Office of the State Engineer provided significant assistance in permitting the piezometers and the New Mexico Bureau of Geology and Mineral Resources provided assistance in geochemistry sampling, processing of samples and data review.

EPA Feedback Loop

What would you suggest that EPA do differently to improve the process in regard to this project?

EPA was very supportive in all aspects of this project during the project period, especially allowing grant period extensions to complete high quality and meaningful work.

Future Activity Recommendations

The concepts of Keyline Design should continue to be explored as a way of conceptualizing and thinking about wetland restoration. This project provided important insights to restoration planning, systematically designing and sequencing treatments that balance the goals of overall recovery of the headwater slope wetland complex, implementation in priority areas based on a variety of criteria, and optimizing the use of existing infrastructure such as old stock ponds, etc., which can be used as keypoints for redistributing water.

Figure 18. Mollie Walton leads Quivira Coalition workshop on wetlands restoration in East Drainage of Holman Creek Wetlands Complex – August 2, 2019. Photo Sarah Wentzel-Fisher.