PROYECTO EMBUDO DE AGUA SAGRADA
An Updated Watershed-Based Plan for the Lower Rio Embudo Watershed, New Mexico

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Prepared for:
Embudo Valley Regional Acequia Association
and
New Mexico Environment Department - Surface Water Quality Bureau

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Prepared in Response to:
State of New Mexico, Environment Department, Surface Water Quality Bureau
Request for Quotes of 8/15/2018 and Professional Services Contract # 19-667-2060-0002

Prepared in Response for:
The Embudo Valley Regional Acequia Association (EVRAA), Dixon, New Mexico

Dedicated to:
The late **Juan Estévan Arellano**, Historian, Author, Acequiero, Mayordomo, Farmer, and past President of the Embudo Valley Acequia Association

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The Ecotone project team wants to acknowledge the following people who have participated in and contributed to the development of this Watershed-Based Plan for the Lower Embudo watershed. The project team has greatly appreciated the contributions made by each of them. Many other people have contributed to the plan as well, although not mentioned here, and the project team also thanks them for their support.

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DEDICATION TO JUAN ESTÉVAN ARELLANO

This **Watershed-Based Plan for the Lower Rio Embudo Watershed – *Proyecto Embudo de Agua Sagrada*** – is dedicated to the late Juan Estévan Arellano, of Embudo, New Mexico. Estévan Arellano was the initiator, teacher, and leader of many activities concerning the protection and improvement of water and land conditions. He also offered local support for this updated watershed plan. Estévan passed away in early October 2014 during the plan's research phase.

Estévan Arellano was widely respected for his deep passion for and knowledge of *acequias* and their history, contemporary use and management, and the role of *acequias* in agricultural communities, such as Embudo and Dixon. He is also remembered as a respected scholar of Southwestern Hispano history and culture, a prolific writer, an expert activist of the preservation of local food, culture, and community, and above all as a teacher, *a maestro,* in all things about water management and conservation for *acequia*-based irrigated agriculture.

A humble but passionate instructor, Estévan loved telling stories and entering into intricate and vibrant debates about the importance of the foundational historical components of *acequia* community life, agricultural practices, original Spanish language, and historic Spanish law. According to the Winter issue of *Noticias de las Acequias* "his life and voice served as a bridge to *ancianos*, or elders who were his teachers, and his spirited engagement in current political issues."

Estévan was also forward looking and understood the changes of his time and what the future might have in store for his community and the land. He was very concerned about the availability of water for the continuation of *acequia* agriculture and about the need to keep the knowledge about *acequia* organization and technical management alive among landowners and land managers. He served for many years as the President of the Embudo Valley Acequia Association (EVAA) and as a member of the *Concilio* of the New Mexico Acequia Association. His local and regional leadership experience carried weight when he advocated for the restoration of watersheds that feed *acequia* flows. As a result, he secured many resources for the improvement and repairs of *acequias*, hosted numerous workshops and seminars, including the annual *Celebrando las Acequias* event in Dixon, and gave presentations at many conferences nationally and internationally.

With this background, he initiated and coordinated local support for the launching of a series of programs for landscape restoration, community education, and watershed planning for the improvement of water quality and supplies in the Embudo Valley. His leadership and inspiring voice are foundational to this Watershed-Based Plan Update. It was his hope that the plan would carry the title *Proyecto Embudo de Agua Sagrada.* [By Jan-Willem Jansens]

ABBREVIATIONS

Abbreviation	Description
ALI	Arid Lands Institute
ARID1, ARID2	Names of stationary automated sampling stations along the Rio Embudo
AU	Assessment Unit
BIA	US Bureau of Indian Affairs
BLM	US Bureau of Land Management
CCC	Chimayo Conservation Corps
CFRP	Collaborative Forest Restoration Program
cfs	Cubic feet per second
CNF	Carson National Forest
CWA	Clean Water Act (of 1972, as amended)
CWPP	Community Wildfire Protection Plan
DI	Depth-integrated, manually collected
EA	Environmental Assessment
EPA	US Environmental Protection Agency
EVAA	Embudo Valley Acequia Association (precursor of EVRAA)
EVRAA	Embudo Valley Regional Acequia Association
EWI	Earth Works Institute
FONSI	Finding Of No Significant Impact
FSG	Forest Stewards Guild
ft2	Square feet
FWS	US Fish & Wildlife Service
GIS	Geographic Information System(s)
HUC	Hydrologic Unit Code
ISCO	Trade name of auto-pumping sampler, manufactured by Teledyne ISCO
Lbs/d	Pounds per day
Lbs/ac/d	Pounds per acre per day
NMAA	New Mexico Acequia Association
NMDOT	New Mexico Department of Transportation
NMED	New Mexico Environment Department
NMFWRI	New Mexico Forest and Watershed Restoration Institute
NMDGF	New Mexico Department of Game and Fish
NMSU	New Mexico State University
NPS	Non-point source
pQAPP	Project Quality Assurance Project Plan
RAC	Rio Arriba County
RERI	River Ecosystem Restoration Initiative
RUSLE	Revised Universal Soil Loss Equation
SGCN	Species of Greatest Conservation Need
SIDMA	Social Indicators Data Management and Analysis
SIPES	Social Indicators Planning and Evaluation System
SLO	New Mexico State Land Office
SSC	Suspended sediment concentration, mg / L (or ppm)

SSL	Suspended sediment loading
STEPL	Spreadsheet Tool for Eliminating Pollutant Load(s)
SWQB	Surface Water Quality Bureau, of the New Mexico Environment Department
TC	Taos County
T&E	Threatened and Endangered (species)
TMDL	Total Maximum Daily Load (also TMDL report)
TNC	The Nature Conservancy
TTS	Turbidity Threshold Sampling
USFS	USDA Forest Service
USPED	Unit Stream Power-based Erosion and Deposition (equation or model)
WBP	Watershed-based Plan
WMP	Watershed Management Plan
WRAS	Watershed Restoration Action Strategy

EXECUTIVE SUMMARY

The 2019 Watershed-Based Plan (WBP) Update addresses water quality problems identified by the State of New Mexico in the three most western 12-digit hydrologic units of the Rio Embudo – Rio Pueblo watershed. Water quality for the designated use as a cold-water fishery in the Lower Rio Embudo (Rio Grande to Cañada de Ojo Sarco) is impaired. The probable causes for the water quality impairment are turbidity, sedimentation/siltation, and temperature.

The 2019 WBP Update addresses the "9 Elements" of a WBP as outlined by the EPA and combines the New Mexico Environment Department Surface Water Quality Bureau's (NMED-SWQB) goals for a data driven plan to address the State of New Mexico's load reduction goals and the community's goals for soil stabilization and cleaner water in streams and *acequias*. The 2019 WBP Update provides a plan with strategically phased and selected implementation activities to meet the goals.

The WBP study area is located between the eastern watershed boundary of the Rio de las Trampas, just west of the boundary of the Picuris Pueblo grant and the confluence of the Rio Embudo and the Rio Grande. The total project area covers approximately 60,362 acres (94.31 mi^2 or 244.28 km^2). The Lower Embudo watershed is the most western part of the Rio Embudo-Rio Pueblo watershed, which encompasses approximately 195,199 acres (305 mi^2 or 790 km^2). This watershed is one of the contributing headwaters of the Upper Rio Grande watershed, which encompasses approximately 4,838,400 acres (7,560 mi^2 or 19,580 km^2) above the confluence with the Rio Embudo. While only encompassing 4% of the Upper Rio Grande watershed, the Rio Embudo-Rio Pueblo watershed contributes between 7% and 78% of the Rio Grande's suspended sediment below the confluence.

Empirical research on turbidity and suspended sediment loads (SSL) in the Rio Embudo between 2013 and early 2015 have confirmed a pattern of high variability and periodic extremes in sediment loads originating either from the Lower Rio Embudo's lowest hydrologic unit, called Cañada Aqua (Arroyo la Mina/Embudo Creek), or from any upstream part of the watershed. SSL varies from season to season and from year to year. Following a dry spell in 2012-2013, highly concentrated monsoonal cloud bursts in 2014 over the northwestern lower part of the watershed led to large amounts of soil loss and sediment transport from this area. The estimated amount of SSL based on field samples in 2014 was 18,991 tons per year (t/y) (104,062 lbs/day) at the lower end of the watershed above the confluence with the Rio Grande, and only 5,233 t/y (28,674 lbs/day) just below the confluence of the Cañada de Ojo Sarco sub-watershed with the Rio Embudo, approx. 6.2 miles upstream. This results in a net sediment discharge contribution of 13,758 t/y (75,387 lbs/day) for the Lower Rio Embudo (Rio Grande to Cañada de Ojo Sarco) sub-watershed, which is also known as the Cañada Aqua (Arroyo la Mina/Embudo Creek). Most of the SSL originating from the Cañada de Ojo Sarco sub-watershed, the Rio Trampas sub-watershed, and the upper watershed beyond Picuris was concentrated in September through November 2014.

Geo-spatial modeling confirms that the landscape in the Lower Rio Embudo (Rio Grande to Cañada de Ojo Sarco) is highly erosive. The area consists of more than 110 small sub-watersheds across nearly 19,000 acres. Many drainages in this landscape have the geomorphological structure of badlands and consist of steep, barren sandstone rock outcrops, unstable, colluvial slopes, broad alluvial fans, and a network of gullies that transport large amounts of sediment to the river. The terrain is sparsely vegetated with bunch grasses and piñon-juniper open woodland and shrubland. Most of these lands are managed by the BLM and NM State Land Office. In the lower elevations of the Ojo Sarco drainage similar badlands occur, which are mostly under BLM and US Forest Service management.

The large amount of soil loss and sediment discharge in the Rio Embudo mostly has natural causes, which include occasional, highly localized, high-intensity rain storms, exposed soils, poor soil structure, and sparse vegetation. Other causes include legacy land uses, including grazing, mining, logging, and construction, as well as stream channel modifications and riparian habitat degradation. Specific source areas for these causes are woodlands and rangelands, degraded wildlands, disturbed riparian habitat, unimproved roads and dirt tracks, areas with off-road vehicle use, cleared areas, poorly managed grasslands, and arroyos and streambanks.

The WBP research phase compared SSL findings from geo-spatial and spreadsheet modeling, empirical field sampling, State (TMDL) monitoring data, USGS data, and Forest Service data, and found a considerable spread in the magnitude of SSL volumes. Sediment transport modeling generated an estimated sediment amount of 4,719 t/y (25,856 lbs/day). This number is in the same order of magnitude of SSL volumes calculated by the USFS for the Ojo Sarco and Trampas drainages, and also similar to the SLL volume measured in 2014 for the upstream watershed portion starting at the Cañada de Ojo Sarco. State targets, however, are based on sampling data from 2001 described in a “TMDL (Total Maximum Daily Load) report” of 2005 that suggests a load reduction of 9,143 t/y (50,098 lbs/day). While the modeled SSL amounts may represent a mean SSL amount for the last 30 years, the TMDL findings may represent longer term averages that include SSL amounts in years with stream flow rates and sediment discharges of twice the TMDL amounts, such as measured in 2014 (which was 18,991 t/y or 104,062 lbs/day) and according to historical USGS data online. The range of soil loss and sediment transport modeling numbers generated estimates for priority areas for treatment and target goals for sediment reduction measures.

The spread in the range of magnitude between these sediment discharge volumes underscores a need to develop a strategy that addresses the variability in sediment transport incidences. The strategy needs to focus on at least three scenarios of sediment discharge volumes: (1) years with extreme precipitation events and flow regimes and excessive sediment transport loads, (2) years with sediment transport around the long-term mean, possibly represented by the TMDL data, and (3) years with little precipitation, low stream flows, and low sediment transport volumes.

The first scenario would include incidents with catastrophic floods caused by large-scale wildfire in the upstream parts of the watershed. The Lower Embudo watershed includes a large area of forest land at higher elevations managed by public agencies, such as the US Forest Service and BLM. Large parts of this forest landscape are considered at high risk of wildfire. The US Forest Service and BLM both have developed strategies to reduce catastrophic wildfire risks. These include forest thinning and prescribed fire treatments at select locations. Catastrophic wildfire followed by even mild precipitation events could lead to flash floods and debris flows that impact water quality and stream morphology downstream.

The public land management agencies have considerable capacity to address the forest health conditions and to improve watershed health. However, the nature of the rugged terrain, the scale of the areas that are not meeting reference conditions, and the perceived urgency due to the high risk of catastrophic forest degradation and sediment and debris flows are asking for a response capacity beyond what is available. Private landowners, *acequia* associations, and Rio Arriba and Taos Counties also have a great need for capacity building to be able to address the water quality problems addressed in the WBP. Capacity building would need to include effective information dissemination, joint fact finding, partnership development, fund raising, and mobilization of technical assistance.

Capacity building would need to focus particularly in local leadership development in the key organizations with a stake in water and land health in the watershed. Key partners may be EVRAA, the Rio Embudo Watershed Coalition, Rio Arriba and Taos Counties, the Eastern Rio Arriba and Taos Soil and Water Conservation Districts, and perhaps one or more regional conservation organizations. Because the large scope of the issues to be addressed and the multiple partners and jurisdictions that need to be included, it will be essential to build a culture of collaboration and distribute or rotate responsibility for the implementation of the various parts of this WBP.

Considering the scale and scope of the needed actions, an overall strategy for the sediment discharge reduction in the Lower Embudo watershed requires a tiered approach consisting of (a) large-scale, regional strategies, (b) large, watershed-wide initiatives, (c) smaller-scale, local projects, and (d) ongoing capacity building and educational outreach activities. The first category of strategies would require legislative policy proposals and statewide collaboration between government agencies, counties, the Rio Grande Water Fund, the NM Acequia Association and other parties. The second tier of strategies would include collaboration with the newly forming Rio Embudo Watershed Coalition, water users and livestock associations, local business, and any of the institutions listed above. The third tier of smaller-scale, local projects would require initiative by local actors, such as *acequias*, landowners, and local organizations, in collaboration with public land management agencies, regional service organizations, and Soil & Water Conservation Districts. Capacity building would ideally be part of each of the three other tiers and would also include specific initiatives, such as training on managing unpaved roads, education on specific management measures, on-the job training in monitoring, and youth involvement.

Appropriate management measures to reduce SSL volumes in each of the three scenarios vary between landscape type and landownership. Experience across northern New Mexico and within the Rio Embudo watershed has indicated that a broad spectrum of management measures is appropriate and the application of many small treatments would likely be effective and feasible. In the forested areas and woodlands, the most appropriate management measures include thinning treatments combined where possible with prescribed fire. Specific soil protection treatments would include lop and scatter of slash, seeding, and other activities that cultivate an herbaceous understory. In grasslands and rangelands, appropriate management measures include managed grazing, water source construction or removal, fence management, and riparian buffer establishment. In degraded stream corridors, appropriate management measures include the restoration of the channel, streambanks, and riparian areas, in such ways that natural stream functions are restored across the floodplain. Across the watershed, improvements to drainage of unpaved roads and driveways will play an essential role in retaining sediment during high flow events. On private lands, a suite of management measures could be employed to retain sediment, such as growing cover crops, terracing, establishing contour buffer strips, building soil conservation structures, mulching and composting, and applying restorative, rotational grazing practices. Additionally, the work farmers and *acequias* do to clean ditches and head gate areas is in itself a management measure that prevents sediment from entering the streams. This activity could perhaps be supported over time as an ecosystem service to downstream beneficiaries as part of a regional payment for ecosystem services scheme. Collaboration at a regional level would be necessary to realize this management measure.

Priority locations to apply management measures are those areas that are (1) accessible and feasible for the development of management measures and/or (2) comprise areas of great risk and are of vital importance to be managed. The first category of priority areas for treatment include the lower alluvial and colluvial slopes in sub-watersheds, slopes and terraces above arroyos, grassy alluvial swales and slopes, and flatter bottomlands and alluvial plains. Areas of great risk include forested areas with significant fire hazard, dirt roads, arroyos, streambanks, steep slopes with ORV use, and any area with significant infrastructure or property of value that is at risk of being undermined or damaged by flooding, erosion, or fire (e.g., roads, *acequias*, homes, and utilities). This second category of priority areas tends to contribute large amounts of sediment during extreme flow events, especially after fire or recent soil disturbance.

These priority locations include the selected forest treatment areas on the Carson National Forest as part of the Rio de las Trampas treatment project (approved in 2017) and the BLM and SLO treatment areas proposed in these agencies' planning processes in late 2019. The priority areas also include all unpaved roads and driveways, county roads and driveways in the Arroyo la Mina, Arroyo Pino, Arroyo Lorenzo, and several other arroyos, and critical stream banks, such as the ones along Rio Arriba County Road 240 and those near *acequia* head gates. The WBP also lists a series of drainage areas around Dixon that have been treated in the past and that could serve as demonstration areas and be improved to retain more sediment in the first two phases of WBP implementation. The total costs of the priority treatments is estimated between $10,000,000 and $20,000,000. Public land management agencies and project coordination entities will conduct educational outreach and public meetings to ensure optimal stakeholder support and ongoing justification for financial investments.

The proposed management measures and priority treatment areas will most likely not contribute to more than 21% of sediment retention toward the TMDL's load reduction goals. However, the WBP identifies additional priority areas that can be targeted for future planning and design of management measures in successive phases of the project once capacity is built and experience is gained with the first set of priority measures. Furthermore, it is likely that over time the entirety of proposed management measures would realize a certain amount of cumulative effects across the landscape that is greater than the sum of the anticipated sediment retention capability of each individual treatment or management measure.

Phasing and prioritization of actions is critical to spread the burden of work over time and to allow for appropriate monitoring and evaluation of individual steps in the sequence of actions, leading to learning opportunities and adaptive management. The WBP envisions five four-year phases. The first phase would be a start-up phase, followed by four implementation phases. Each phase would also focus increasingly on monitoring and evaluation. The start and completion of each phase would constitute significant milestones to measure implementation accomplishments. Each occurrence of a year with large flow events would constitute a significant milestone year to measure and analyze SSL volumes. Benchmarks for success measurements are the completion of planned activities and a target percentage for the reduction of SSL volumes in each phase.

The WBP proposes to monitor accomplishments by tracking and tallying the completion of planned activities and realization of each project of management measures ("implementation monitoring"), and to monitor reductions in SSL volumes by conducting simple field measurements and taking turbidity readings from the existing stationary gaging stations ARID1 and ARID2. The plan also recommends installing a third stationary gage (ARID3), which would need to include a turbidity sensor, above the confluence of the Rio de las Trampas with the Rio Embudo. In combination with ARID2, this ARID3 gage would offer the opportunity to obtain more detailed information about the sediment source area contributions from the Rio de las Trampas and Cañada de Ojo Sarco in comparison with any sediment originating from the upper watershed above the Trampas confluence. Recommendations for simple field monitoring include measurements (transects or plots) of soil cover and slope factors to update RUSLE equations and run STEPL modeling updates and arroyo cross-sectional information to analyze arroyo dimensions and their associated flows and sediment transport volumes. Additionally, *acequias* could track sediment removed each year from each individual *acequia*, which in combination with precipitation data from ARID1 and ARID2 and flow estimates from arroyos should over time give an indication of the trend of sediment transport in relation to precipitation and arroyo stream flows.

Annually, any useful monitoring information would help indicate whether additional action is warranted, such as any maintenance or technical adjustments. In some cases, management measures would need to be modified and adapted to new insights and terrain conditions, also known as "adaptive management". Monitoring findings would also be useful to direct new educational outreach and capacity building among landowners and partners in the watershed.

At the beginning of each new project phase after phase 1, the steering group or management team of the leading watershed coalition (e.g., EVRAA) would evaluate the findings from implementation monitoring and effectiveness monitoring completed throughout and at the end of the previous phase. Numerical results of the realization of target load reductions would need to be documented and reported to the NMED Surface Water Quality Bureau (SWQB). Ideally, at the end of the each phase, monitoring results should show the targeted percentages of load reductions, as expressed in measured sediment loads (by turbidity sensors and data analysis), land cover increase, and arroyo dimension improvements.

Lessons learned from the evaluation of each phase would need to be analyzed to discern the need for maintenance of and modifications to management measures that were implemented previously and for changes in the application of management measures in the future. After the completion of the five phases, or earlier when the evaluation of monitoring results demands it, the WBP should be entirely revised and renewed with new considerations for targets, timeline, strategies, and management measures.

TABLE OF CONTENTS

1. INTRODUCTION

1.1. Main Actors and Approach

This 2019 Watershed-Based Plan (WBP) Update has been developed by Ecotone Landscape Planning, LLC in collaboration with the Forest Stewards Guild, Embudo Valley Regional Acequia Association (EVRAA), many Lower Embudo watershed residents, and New Mexico Environment Department Surface Water Quality Bureau (NMED-SWQB) staff. The development of this WBP Update spanned two phases. The first phase was a data collection phase between 2013 and 2015, led by the Arid Lands Institute (ALI) and Ecotone. The second phase was a plan development phase between 2018 and 2019, led by Ecotone.

During the first phase (phase 1), ALI and Ecotone conducted the initial research and data gathering work in collaboration with a team of local water sampling technicians who were trained and hired by ALI. Other phase-1 team members included Jack Veenhuis who served as a hydrology expert for Quality Assurance and Quality Control (QA/QC) purposes, and the late Juan Estevan Arellano of the Embudo Valley Acequia Association (EVAA), who served as the local outreach liaison. A stakeholders group of the Lower Embudo watershed served as advisors.

The Ecotone planning team used the insights and analysis of data collected during phase 1 along with information from public land management agencies, local organizations and individuals during the plan compilation. During the second phase (phase 2), the Ecotone team worked with the Embudo Valley Regional Acequia Association (EVRAA) as its main local partner and stakeholder group. EVRAA stepped forward as the beneficiary of the WBP and will take the responsibility of carrying it toward implementation in future years. The Ecotone team also reached out to obtain feedback from representatives of Rio Arriba County, BLM, New Mexico State Land Office (SLO), and the USDA Forest Service (USFS) Carson National Forest (CNF).

1.2. Purpose and Goal of the 2019 WBP

This 2019 WBP Update addresses water quality problems identified by the State of New Mexico in the three most western 12-digit hydrologic units of the Rio Embudo – Rio Pueblo watershed. Water quality within the Lower Embudo watershed is impaired. The USEPA-approved 2018-2020 State of New Mexico Clean Water Act (CWA) §303(d)/§305(b) Integrated Report, Appendix A[1] (NMED 2018), identifies the Lower Embudo watershed as the "Embudo Creek (Rio Grande to Cañada de Ojo Sarco)", referenced as Assessment Unit (AU ID) NM-2111-41. The Integrated Report states that the probable causes for non-attainment of the designated use of water (i.e., water quality impairment) in the Embudo Creek (Rio Grande to Cañada de Ojo Sarco) are turbidity, sedimentation/siltation, and temperature. The turbidity and sedimentation/siltation impairments were first listed in 1998. The temperature impairment was first assessed and listed in 2012. The Integrated Report indicates that the state's reports designating Total Maximum Daily Loads (TMDL) for turbidity and for sedimentation/siltation were completed on June 2,

[1] The IR was approved by the New Mexico Water Quality Control Commission (WQCC) on August 14, 2018 and EPA Region 6 on November 1, 2018.

2005. A “TMDL” (short for TMDL report) for temperature is scheduled to be issued in 2020 (NMED 2005, NMED 2018). This WBP responds to the need for a plan to address the load reduction goals of the TMDL for turbidity and implicitly addresses those for sedimentation/siltation.

<u>Goals and Objectives for the WBP</u>

The 2019 WBP Update follows the EPA guidance for WBPs that specifies inclusion of the “9 Elements of WBPs” (USEPA 2008). The goals and specific objectives of the 2019 Update of the WBP includes the following and reference each of the 9 Elements and indicates what chapters of the plan address them:

- Identify and characterize surface water impairments and their specific causes and sources or groups of sources (Element A) – Chapter 3.
    - Provide quantitative information on the specific pollutant loading in the impaired reach of the Rio Embudo (Embudo Creek – Rio Grande to Cañada de Ojo Sarco).
    - Identify and quantify potential sources of nonpoint source (NPS) pollution of surface water resources through high-resolution soil runoff and deposition geospatial modeling.
    - Implement modeling methods and community surveys, aimed at supplemental identification of pollutant source areas, selecting suitable and priority areas for future action.
- Develop prioritization methods for action and estimate associated load reductions for management measures (Element B) – Chapter 4.
- Identify the specific management measures aimed at reducing or eliminating the flow of identified pollutants into the stream systems at selected priority locations or areas (Element C) – Chapter 4.
    - Select and formulate specific non-point source (NPS) management measures for the various jurisdictions and/or terrain units in the project area and implement a feasibility assessment of alternative management measures and priority areas – Chapter 5.
- Estimate the amounts of technical and financial assistance needed to implement the plan (Element D) – Chapter 5.
- Identify, mobilize, engage, and educate community groups and other watershed stakeholders, including collaboration with local acequia associations, local residents and landowners, to self-organize and take initiative to develop activities that reduce pollutant discharges into the streams (Element E) – Chapters 2 and 5.
    - Obtain stakeholder feedback from community members, acequia associations, EPA, NMED, and other jurisdictional management entities of with this WBP.
    - Advance the understanding of how land cover management affects soil loss and deposition within the project study area using hi-resolution remotely sensed geospatial information
- Identify a time schedule for plan implementation (Element F) – Chapter 5.
- Describe interim, measurable milestones for determining whether the management measures and other actions are being implemented (Element G) – Chapter 6.

- Identify a set of criteria to determine achievement of pollutant loading reductions over time and progress toward attaining water quality standards, and, if not, the criteria for determining whether the WBP and / or TMDL need to be revised (Element H) – Chapter 6.
- Develop a monitoring plan to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under Element H (Element I) – Chapter 6.

Stakeholder Needs

The 2019 Update of the WBP is a direct response to ongoing efforts in the Embudo Valley community to form a long-term, collaborative program for ecological restoration and stabilization of soils on exposed sites and in arroyos, *acequias*[2], and streams in the valley, as has been documented in the Watershed Restoration Action Strategy (WRAS) of 2007 (Environmental Health Consultants and NMED 2010). Community meetings after 2007 confirmed that residents feel an urgent need to improve the ecological and hydrological dynamics in the watershed to protect their ditches, fields, orchards, roads, homes, and wetlands. Rio Arriba County has identified these needs countywide and formulated specific goals, strategies and priorities in its 2009 Amended and Approved Comprehensive Plan (Rio Arriba County 2009).

This WBP Update combines the New Mexico Environment Department Surface Water Quality Bureau's (NMED-SWQB) goals for a data driven plan to address load reduction goals of the TMDL and the community's goals for soil stabilization and cleaner water in streams and *acequias*. The WBP Update provides a plan with strategically phased and selected implementation activities to meet the goals.

The 2019 WBP Update consists of three versions. This full plan document aims to reach land and water management professionals and satisfy the WBP approval process by NMED-SWQB and EPA. A brief, illustrated summary aims to reach local landowners and decision makers. A third version encompasses the full and expansive body of detailed research reports and data analysis documentation in digital form and could be made available by NMED-SWQB upon request.

1.3. Area Definition

The WBP study area is located in the Lower Rio Embudo watershed[3], which drains into the Upper Rio Grande in northern New Mexico (Figure 1.1). The WBP study area is located between the eastern watershed boundary of the Rio de las Trampas, just west of the boundary of the Picuris Pueblo grant and the confluence of the Rio Embudo and the Rio Grande. The total project area covers approximately 60,362 acres (94.31 mi^2 or 244.28 km^2).

The Lower Embudo watershed is the most western part of the Rio Embudo-Rio Pueblo watershed, which encompasses approximately 195,199 acres (305 mi^2 or 790 km^2) (Figure 1.2). This watershed is one of the contributing headwaters of the Upper Rio Grande watershed. The Upper Rio Grande watershed encompasses approximately 4,838,400 acres (7,560 mi^2 or 19,580 km^2) above the confluence with the

[2] Traditional Hispanic irrigation ditches.
[3] In this WBP document the Lower Rio Embudo watershed is also referred to as the Lower Embudo watershed and the watershed.

Rio Embudo (USGS 2019). Stream elevations range from approximately 5,873 ft at the USGS gage 08279000 on the Rio Embudo (near the Highway 68 and 75 intersection) to 6,260 ft at the confluence with the Cañada de Ojo Sarco, to 11,660 ft at the headwater lakes of the Rio de las Trampas and 12,686 ft at the summit of Jicarilla Peak.

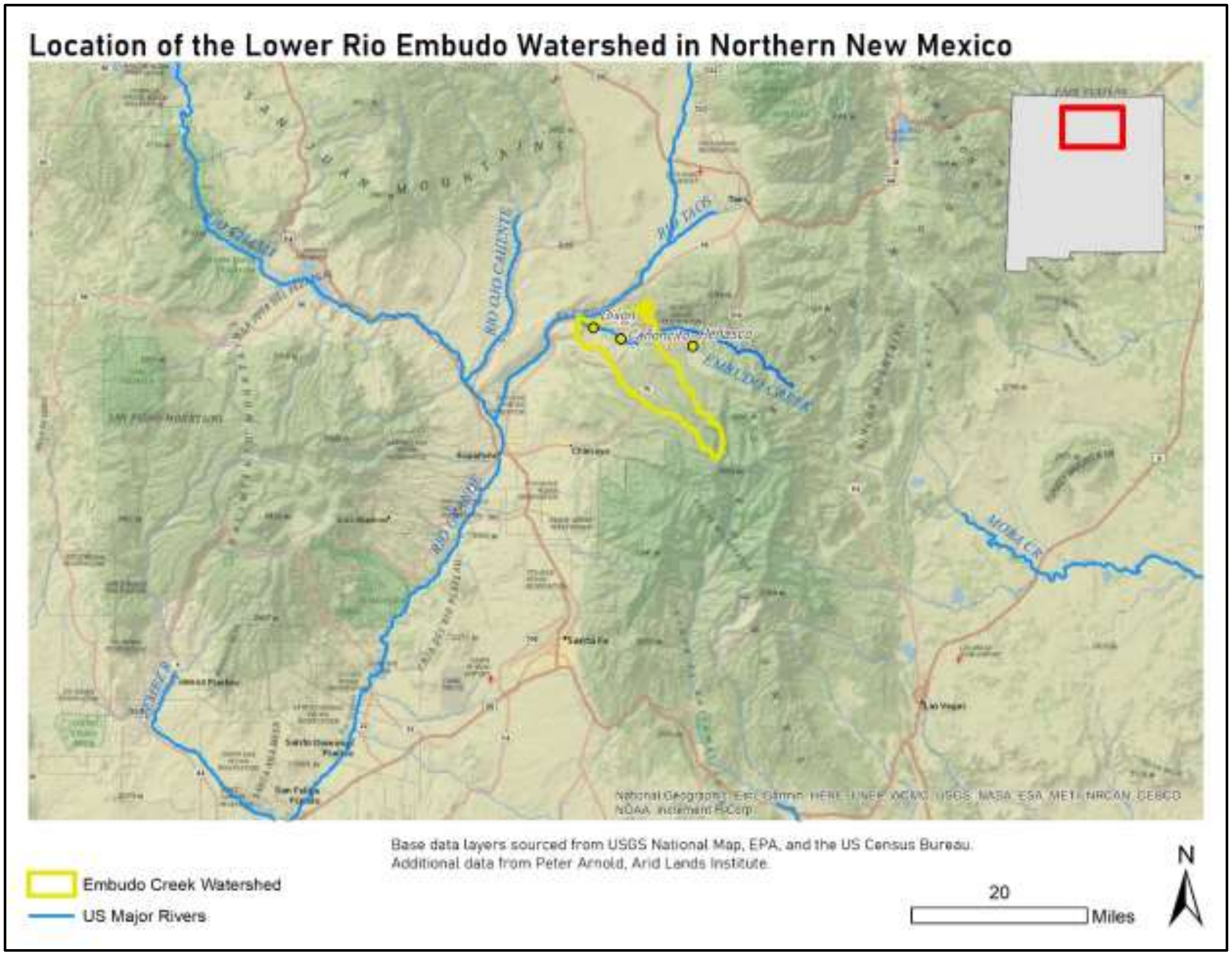

Figure 1.1. Overview location map of the Lower Rio Embudo watershed in relation to the Rio Grande basin and surrounding topography.

Although the entire Rio Embudo-Rio Pueblo watershed constitutes less than 4% of the Rio Grande basin at the confluence of both rivers, the Rio Embudo is an important tributary to the Rio Grande with a view to water quality concerns. USGS gage (08279500) data from the period between October 1997 and October 2002 show a cumulative average of measured suspended sediment discharge of the Upper Rio Grande and Rio Embudo of 65,240 tons per year (t/y) or 357,479 pounds per day (lbs/d). USGS gage (08279000) data between May 1981 and June 1995 show a cumulative average of measured suspended sediment discharge from the Rio Embudo into the Rio Grande of 50,842 t/y (278,586 lbs/d). It should be noted that this period was characterized by relatively deeper precipitation and greater flows than other periods in the last century. The WBP data gathered in 2014, a year of significant sediment flows, show an annual discharge of 18,991 t/y (104,061 lbs/d) of suspended sediment from the Rio Embudo into the Rio Grande, while estimates for average low-flow sediment discharge from the Rio Embudo into the Rio Grande are at least 4,700 t/y (25,753 lbs/d). While the USGS data are not smoothed to exclude years with extreme discharges, comparison of the sediment loads in both rivers gives a contextual suggestion of the Rio Embudo's significant proportional contribution (varying between 7% and 78%) of suspended sediment to the Rio Grande.

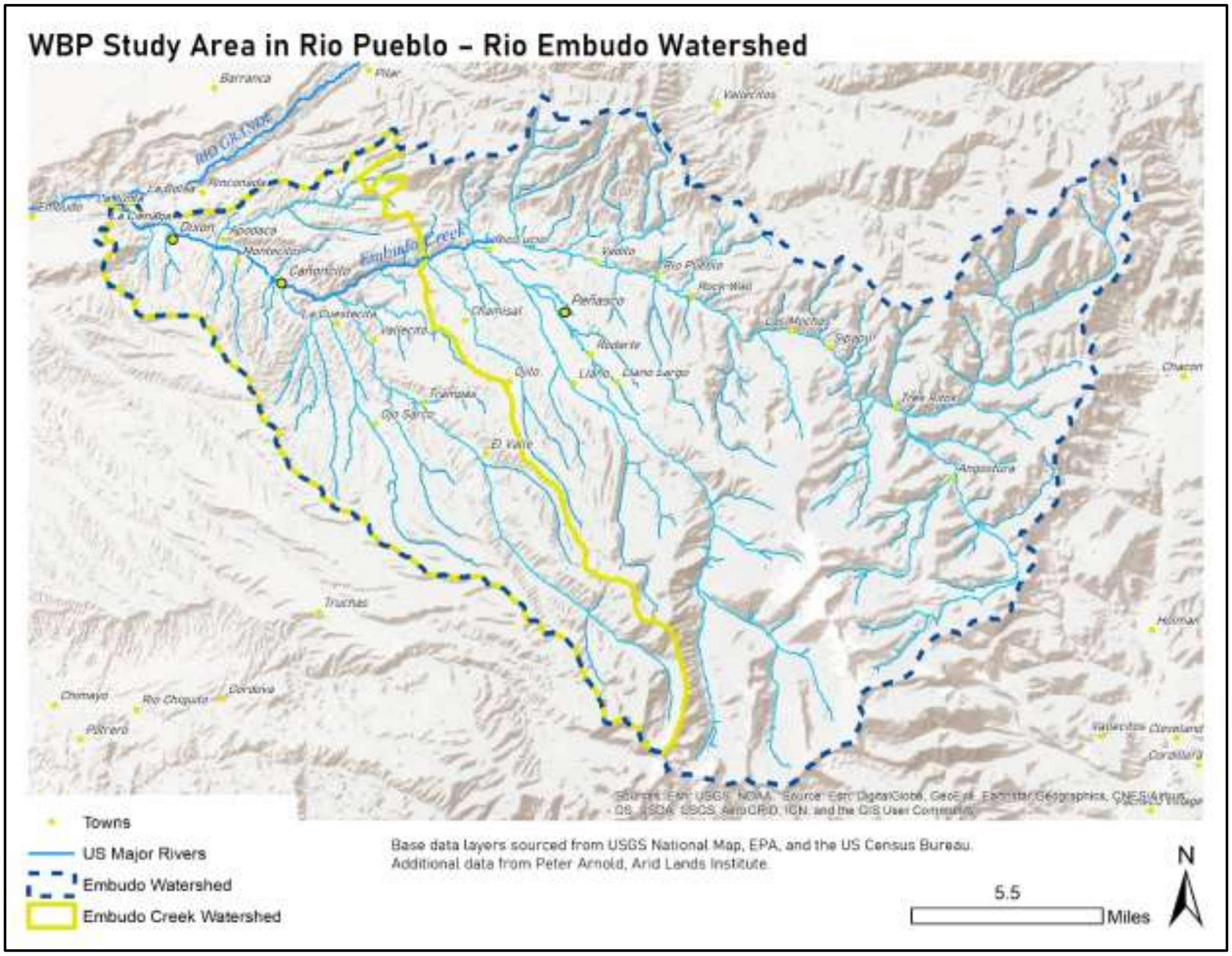

Figure 1.2. Overview map of the WBP study area in relation to the entire Rio Pueblo – Rio Embudo watershed.

1.4. Hydrologic Units and Impaired Stream Reaches

The project area comprises three Hydrologic Unit Code (HUC)-12 level administrative areas (i.e., sub-watersheds) (Table 1.1). The impaired reach is administratively known as AU ID NM-2111_41, Embudo Creek (Rio Grande to Cañada de Ojo Sarco) (Figure 1.3).

Table 1.1. HUC-12 Administrative areas within the WBP study area.

Sub-watershed Name	HUC: 12-digit Hydrologic Unit Code	HUC Size (Acres)	Assessment Unit / Impairment Notes
Cañada de Ojo Sarco	130201010907	Total size of HUC-12 watershed: 13,842 acres; [100% coverage included in WBP study area]	The impaired stream reach of the Cañada de Ojo Sarco from the confluence with the Rio Embudo to the Ojo Sarco Headwaters Link to EPA report
Cañada de Ojo Sarco / Embudo Creek	130201010908	Total size of HUC-12 watershed: 38,261 acres; [76.7% coverage included in project study area (~29,379 acres)]	NM-2111_40 The Embudo Creek from the confluence with the Ojo Sarco to the head waters of the Rio de las Trampas. (excluding the Chamisal Creek) Link to EPA report
Cañada Aqua (Arroyo la Mina / Embudo Creek)	130201010909	Total size HUC-12 watershed: 18,851 acres; [90.9% coverage included in project study area (~17,141 acres)]	NM-2111_41 and/or NM-98.A_003 The impaired stream reach of the Rio Embudo from the confluence with the Rio Grande to the confluence with the Ojo Sarco (excluding certain first order streams originating on Picuris Pueblo in the far northeastern corner of this HUC-12 watershed). Link to EPA report

The impaired reach of the Rio Embudo (from below the confluence with Cañada de Ojo Sarco to the Rio Grande) has a river length of approximately 6.2 miles (approx. 10.0 km) and drains 29.5 square miles (18,851 acres). However, only 17,141 acres of land within this HUC area is included in the WBP study area, because a few first-order drainages originating on Picuris Pueblo have been left outside the study area. This WBP Update focuses in particular on this sub-watershed, because watershed assessment research since 2013 revealed that this is the predominant source area for the impaired reach during unusually high runoff years.

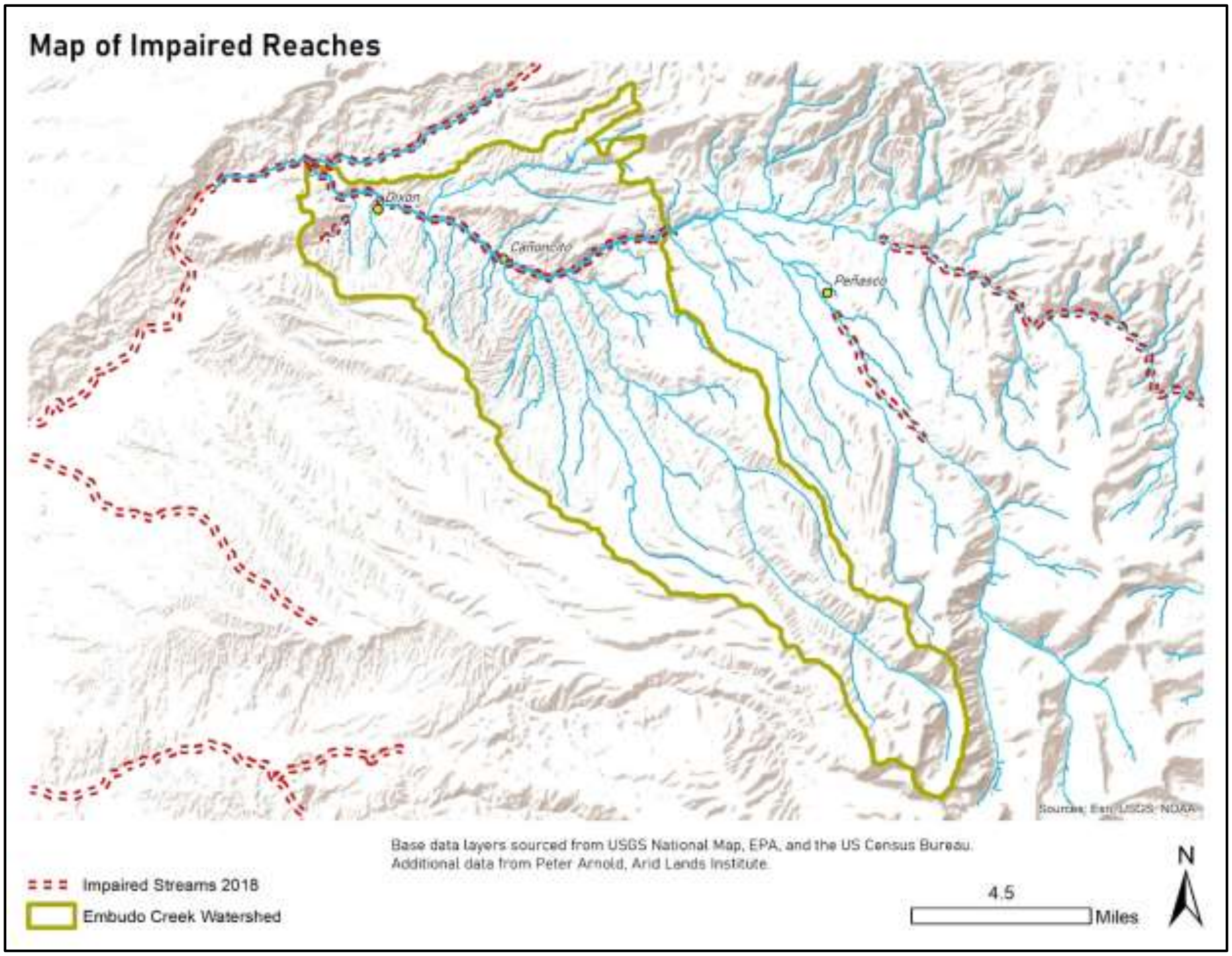

Figure 1.3. Map of the impaired reaches in and around the Lower Embudo watershed.

NMED-SWQB has noted two sections of special concern within the impaired stream reach:

(1) Embudo Creek (AU ID NM 2111_41, between Rio Grande and Cañada de Ojo Sarco). The Embudo Creek reach, 6.2 miles (10.0 km) in length, is listed as impaired for the designated uses of Marginal Coldwater Aquatic Life and Warmwater Aquatic Life. Probable causes for impairment include sedimentation/siltation, water temperature, and turbidity (EPA 2016-a and NMED 2018)

(2) Cañada Aqua (AU ID NM-98.A_003, Arroyo La Mina to headwaters). The Cañada Aqua/Arroyo La Mina reach, 1.15 miles (1.85 km) in length, is listed as impaired for the designated use of Marginal Warmwater Aquatic Life and a probable cause for impairment may be due to the presence of PCBs (USEPA 20126-b and NMED 2018).

As of March 2016, the upstream sub-watersheds of the Cañada de Ojo Sarco and Cañada de Ojo Sarco-Embudo Creek (a.k.a. Rio de las Trampas sub-watershed) are no longer listed as impaired, but they are included in this planning effort because they constitute sources of sediment that affect the lower Rio

Embudo. Simultaneously to this WBP-update initiative, through 2017, the US Forest Service and Forest Stewards Guild have been conducting a forest planning initiative to improve forest health and reduce wildfire risks for the same three hydrological units. It is expected that implementation of this forest restoration plan will help reduce sediment inflow from these upstream sub-watersheds and contribute to the goals of this WBP.

1.5. Surface Ownership

Surface ownership in the WBP study area is largely public land spread among multiple jurisdictions. Private lands constitute only 16.3% of the area and are mostly located in valley bottoms immediately along the Rio Embudo and in upstream river valleys (Figure 1.4 and Table 1.2).   The uplands are predominantly public land (nearly 84%) managed by federal and state agencies.

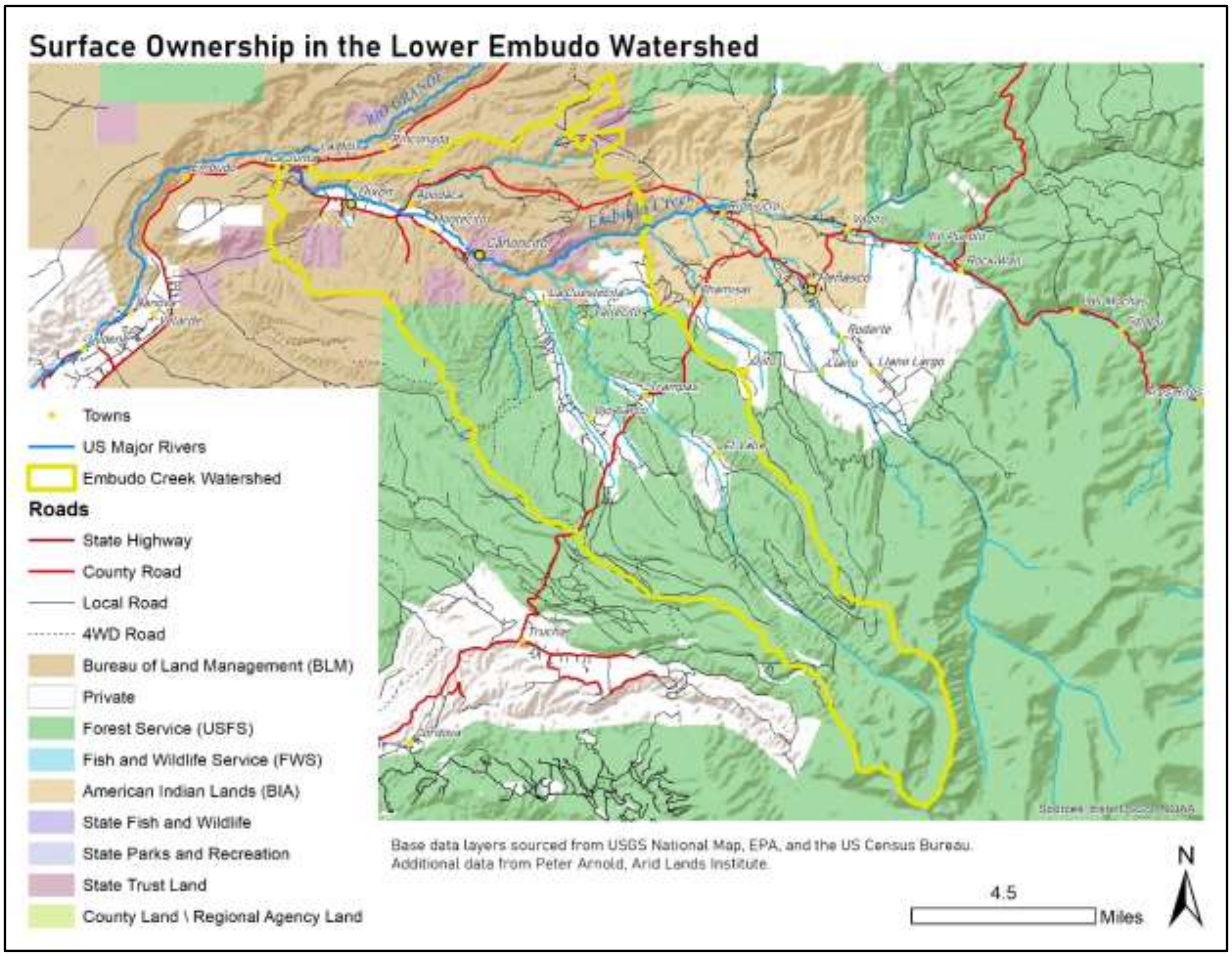

Figure 1.4. Map of surface ownership in the Lower Embudo watershed. Note the white areas on the map that indicate private lands and land grant areas.

Table 1.2. Approximate surface area size for each landownership in the WBP study area[4].

Units	Total	USFS	BLM	SLO	Private
km^2	244.28	129.00	65.00	10.47	39.80
mi^2	94.31	49.81	25.10	4.04	15.37
Acres	60,362	31,877	16,062	2,588	9,835
%	100%	52.8%	26.6%	4.3%	16.3%

1.6. Problem Statement and Previous Work

According to local, anecdotal information, the Rio Embudo historically supported a trout fishery that provided sustenance to the local population. Local residents explained that the fish population dwindled after the 1970s. The reduction of the fish population is possibly a result of sediment and heat pollution in the stream as well as other forms of water pollution and a trend toward increasing frequency and length of periods of low flows. However, despite these trends, there still is a viable trout fishery in the upper Rio Embudo and upper Rio Santa Barbara, in the upstream part of the Rio Pueblo-Rio Embudo watershed (Ecological Health Consultants and NMED 2010).

Soil loss due to erosion of natural surface roads and trails, exposed rocky outcrops, alluvial sediment deposits, and other bare areas caused by a combination of natural processes and past and ongoing land use contribute to periodic, high-volume sediment deposits in *acequias*, and on paved roads, in fields, and in streams. These processes have been identified, described, and sometimes quantified in a number of documents by land management agencies, NMED-SWQB, and private entities (USFS 2017-a, Environmental Health Consultants and NMED 2010, Rio Arriba County 2009). After the impaired reach of the Rio Embudo was first listed in 1998 (NMED 2018), the 2001 SWQB intensive water quality survey in the Upper Rio Grande Watershed (Part 2) documented impairment of the aquatic community due to excessive sedimentation/siltation (stream bottom deposits) at Rio Embudo (Rio Grande to Cañada de Ojo Sarco) (SWQB Stations 4 and 5) (NMED 2005).

Sediment flowing from the Rio Embudo into the Rio Grande amounts to more than 7% of the annual sediment loads of the Rio Grande measured at Embudo Station and can exceed 40% in exceptional years (USGS 2019). These sediment loads constitute considerable water quality limitations and purification costs for water users and water management agencies downstream. Additionally, watershed residents and the Ecotone team have observed that sediment removal from *acequias*, fields, roads, and culverts annually comes at high costs to the community, Rio Arriba County, and State of New Mexico, with total cost amounts likely exceeding $100,000 a year for all entities combined.

Climate change is expected to lead to an increasing occurrence of extreme weather events (see also chapter 3). Dry and hot weather conditions are known to increase the risk of catastrophic wildfire. The Environmental Assessment for the Trampas watershed states that climate change impacts leading to catastrophic wildfire could lead to 99% tree mortality and highly increased runoff and erosion that would affect water quality in the Rio Embudo (USFS 2017-a). Additionally, climate change and wildfire

[4] Adjusted and verified by GIS analysis of the project area.

impacts are also expected to lead to an increased incidence of catastrophic flooding events downstream (Rio Arriba County 2009). Such catastrophic events are expected to have sudden and long-lasting economic and social effects on the local communities in the area, in Rio Arriba County, and for downstream beneficiaries.

After a series of community discussions on the care and sustenance of the Embudo Valley in Dixon, NM, planning for the entire Rio Embudo Watershed began in 2005 with the formation of the Embudo Valley Watershed Group (EVWG) (Environmental Health Consultants and NMED 2010). The group began meeting monthly to examine issues within the watershed and invited the appropriate land management agencies to participate with a vision to improve watershed health through support, education, and collaboration with stakeholders.

In 2007, the EVWG, along with the La Jicarita Watershed and Wastewater Study Committee, the Embudo Valley Environmental Monitoring Group, the Northern New Mexico Watershed Institute, and various land management agencies and individuals developed a Watershed Management Plan (WMP) for the area identified as the Upper Rio Grande: La Jicarita through Embudo Valley (Environmental Health Consultants and NMED 2010). The WMP addressed seven watershed issues (forest health, arroyos/drainages, wetlands and riparian areas, illegal dumping, education/outreach, agriculture and *acequias*, and wastewater management) and identified management objectives for each, potential challenges, and recommended best management practices to reach the objectives.

In 2009, the Embudo Valley Acequia Association (EVAA) reached out to Earth Works Institute (EWI) about issues of erosion and sedimentation that were affecting *acequias* in the Lower Embudo watershed. In 2010, EWI secured a state River Ecosystem Restoration Initiative (RERI) grant to address some of these issues in a stream restoration pilot project around Dixon. After assessing the area, EWI identified four areas to focus erosion control and restoration efforts. Included was a complex of 3 small arroyos on BLM land on the west side of the Lower Embudo watershed, 2 small wetlands and a braided dry streambed on BLM and State Trust Land near Cañoncito east of Dixon, and an in-stream water diversion project in the Rio Embudo just above the bridge of State Road 75 in Apodaca for the Acequia de la Plaza. In 2012, after EWI closed its doors, the RERI grant was transferred to the Santa Fe Watershed Association. EWI and BLM completed an Environmental Assessment for the project and BLM issued a Finding of No Significant Impact (FONSI) and Decision Notice on March of 2013. Baseline and post-construction monitoring were completed in April and May of 2013, with a reduced timeframe due to the termination of the grant in June of 2013. At the same time, the Chimayo Conservation Corps (CCC), with funds from the EPA, completed the cleanup of about 11 acres of BLM land in Cañoncito, collecting nearly 100 tons of mixed waste material. CCC also coordinated thinning of 3 acres of riparian forest land along the river and supported a local education initiative on erosion control, wildfire prevention, and woodland thinning.

In 2007, the Forest Guild was awarded a Collaborative Forest Restoration Program (CFRP) grant for the *Santa Cruz and Embudo Creek Watershed Multi-jurisdictional Restoration and Protection Project,* supporting the restoration of 504 acres of forest land in preparation for a prescribed fire in stands across BLM, Forest Service, and Truchas Land Grant jurisdictions. The project included a soil conservation pilot project in combination with forest the restoration objectives.

In 2010, the Forest Stewards Guild (previously called Forest Guild) received another CFRP grant to develop a forest and watershed management plan for 10,000 acres of forest and woodland on land managed by the USFS, BLM, SLO, and Picuris Pueblo in the Lower Embudo watershed. The SLO accepted the forest plan for State Trust Lands in 2013, upon which the Guild and SLO received a CFRP implementation grant for forest restoration on nearly 450 acres on State Trust lands east of Dixon. This project combined soil conservation measures with forest health improvements toward forest resilience in the context of the reintroduction of fire.

The USFS completed the forest plan effort in 2017 with a FONSI for treatment of 5,718 acres of forest and woodland across an analysis area of 38,893 acres on the Carson National Forest in the Lower Embudo watershed. The USFS assessments supporting this decision included a watershed and soil loss analysis and a series of treatments that take into consideration the reduction of soil loss in the watershed (USFS 2017-a and USFS 2017-b). Also in 2017, Rio Arriba County (RAC) completed an updated Community Wildfire Protection Plan (CWPP) across the county. The CWPP classified the Lower Embudo watershed as a low hazard for wildfire. However, the CWPP assessment area in the Lower Embudo watershed predominantly consists of piñon-juniper woodland ecosystems which are typically at a moderate to low risk of wildfire (NMFWRI 2019).

In 2012, the Arid Lands Institute (ALI) at Woodbury University in Burbank, CA, in collaboration with EVAA and Ecotone of Santa Fe, entered into a cooperative agreement with NMED-SWQB based on CWA Section-319 funds to produce an Updated Watershed-Based Plan (WBP) for the Lower Embudo watershed. The project aimed to develop the WBP in order to quantify the levels and sources of sediment pollution causing the state listed impairments and to develop a plan of specific management actions aimed at reducing sediment pollution at priority locations. ALI collected field data between October 2013 and February 2015.

This 2019 WBP Update is based on the analyzed data and findings of ALI's assessment work, combined with the findings and conclusions of the forest planning and restoration initiatives in the watershed conducted by the Forest Stewards Guild, Ecotone, SLO, BLM, and USFS. The WBP also includes the feedback and input from the EVAA (renamed as Embudo Valley Regional Acequia Association, EVRAA in 2018), local residents, and agency professionals who reviewed and commented on drafts of the WBP.

As this WBP Update is being compiled, a new watershed planning initiative has been established in the Peñasco area under the name of the Rio Embudo Watershed Coalition. Sponsored by The Nature Conservancy, the coalition includes non-profit groups, public land management agencies, and local residents and landowners. In the process of the WBP Update, Ecotone shared information with the coalition in order to seek a future forum for WBP implementation.

1.7. Vision and Goals for the Lower Embudo Watershed

The <u>overarching watershed restoration goal</u> for the Lower Embudo watershed area as described in this 2019 WBP Update is ***to reduce soil loss and sedimentation to levels where the Rio Embudo meets the Target Loads and Load Reduction Goals described in the 2005 TMDL (NMED 2005), and as modified in this WBP.***

The process toward this goal will help meet other goals, such as improving the ecology and hydrology of the watershed to improve conditions for local residents and acequia users who currently suffer from the impacts of sedimentation and erosion, especially following large precipitation events, and for downstream beneficiaries along the Rio Grande.

In working toward these goals, it is important to keep the vision of local stakeholders in mind. In a series of community meetings, including the annual *Celebrando las Acequias* events held until 2013, residents of the Lower Embudo watershed have expressed a number of wishes and hopes for their landscape and community that has tentatively been compiled in one vision statement. The vision statement described below was informally approved by the EVRAA and watershed residents at a public meeting about this WBP on September 17, 2019. The vision statement will serve as a working statement until more feedback from a broader group of people in the community has been collected. The vision statement, combined with outcomes of a community survey (see Attachment 01), is sufficiently comprehensive to serve as a starting point. A side bar in this section states detailed components of the vision statement, as expressed by community members.

Key components of the community vision:

- *Acequias* are seen as human based, land-based democracies.
- There is community solidarity, collaboration, respect.
- Many community members are able to continue using the *acequias* and produce local food and forage products.
- Many community members support equitable forms of water distribution in times of drought, under a more efficient, reduced rate of land use under irrigation.
- There is maximum collaboration and participation between the various social groups, and broad interest in land and active stewardship among all groups.
- Community members include youth in all aspects of the community, such as farming, *acequias*, and environmental stewardship (and not only in the annual *acequia limpia*).
- There is a system of community education and orientation to environmental stewardship and acequia management.
- Traditional knowledge is broadly valued and used and there is transfer of knowledge between generations and social groups.
- There is a new-found balance in the use of modern technology next to old technology.
- Community members work on pollution management: trash and sediment.
- Acequia maintenance is essential and is organized to maintain head gates, acequia berms, and removal of invasive plant species.
- Acequia banks are reconstituted as trails (trail easements) for maintenance and recreational foot travel.
- The community has an adopt-an-acequia system for optimal care and maintenance.
- The community does brush removal, soil development, improvements of upland recharge capacity, and mulching to increase recharge.
- There is an increased number of projects and community members participate in soil conservation projects to improve water quality flowing into *acequias*.
- Wildlife management through terrain management keeps more wildlife away from the community.
- Winter cover crops on fields is encouraged.
- The community has more gardens planted to improve biodiversity.

The vision statement reads:

> *Communities in the Lower Embudo watershed live in a landscape that sustains the historic, local, agricultural lifestyle based on acequia irrigation, which is a form of integrated land use and agricultural technology as well as an expression of land-based democracy. In turn, this form of local and collaborative agriculture – both in its traditional subsistence and contemporary commercial forms – involves the community's collaborative stewardship of the land and its water resources in ways that sustain the community's way of life and the local economy.*

In order to realize the vision statement, community gatherings through 2013 and 2014 resulted in expressions of a need to be assisted in developing an implementation strategy. Such a strategy would include one or more implementation approaches and a timeline for implementation. This 2019 WBP Update intends to respond to these needs by recommending a variety of approaches which are outlined in Chapter 5.

The community meetings also expressed that the vision and the strategy towards its implementation should be summarized in a series of guiding principles that define the outcomes of the initiatives toward reaching the goals for the WBP. Principles to consider include:

- **Building local capacity:** Local leadership and local knowledge of management measures and land use practices must be further developed; planning must allow for local learning, trial and error, evaluation, and doing it again.
- **Encouraging local control:** Local residents influence and preferably lead planning and decision making for land restoration and water quality improvements).
- **Building agency capacity and regional multi-stakeholder collaboration:** Institutional capacity and collaboration should support agencies in achieving land restoration and pollutant reduction goals.
- **Stimulating local community collaboration and broad stakeholder participation**: Local collaboration and broad participation is essential for private and public land restoration efforts.
- **Growing soil:** The basis for reaching Target Load Reductions is to improve soil conditions in critical or target areas to such levels that soil loss and downslope delivery in surface waters is reduced to target levels; this all comes down to growing and modifying the soil in order to beneficially alter the land-cover and soil erodibility relationships that effect soil loss and erosion.
- **Growing vegetation cover and diversity**: A diversity of plant species, ages, and spatial structure offers resilience to the vegetation after severe weather events and a high percentage of vegetation cover protects the soil from erosion and stimulates sediment retention.

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2. WATERSHED STEWARDSHIP

2.1. Key Stakeholders: Actors and Partners

The Lower Embudo Watershed comprises approximately 60,362 acres, nearly 84% of which is under management of federal and state agencies (see also Chapter 1, Table 1.2). The US Forest Service (USFS) Carson National Forest (CNF) controls approximately 31,877 acres or nearly 53% of the watershed area, while the federal Bureau of Land Management (BLM) controls 16,062 or nearly 27% of the area. There are grazing permittees on the Trampas Allotment on the CNF, but no permittees on the BLM lands. Watershed residents have free access to these federal lands and do not have any stewardship responsibilities, unless the federal government hires them under an ecosystem stewardship, forest restoration, or wood harvesting contract.

Private land ownership comprises approximately 9,835 acres, or more than 16% of the watershed area. Five State Trust Land parcels are scattered throughout the private and public land area and comprise approximately 2,588 acres (4% of the area). Besides stewardship work by the State Land Office (SLO), these lands are under stewardship of grazing permittees. However, the permittees do not often use their grazing rights because of a lack of water infrastructure, fencing, and very sparse grass cover on the parcels. The Copper Hill Allotment of the SLO in the northeastern corner of the WBP study area has an exemption from grazing.

The local population and its private landownership in the Lower Embudo Watershed is spread in a narrow strip along the lower reach of the Rio Embudo around Dixon, between Embudo at the confluence with the Rio Grande, and upstream to the villages of Apodaca, Montecito and Cañoncito. Several other private enclaves exist higher up in the watershed, including the communities of Las Trampas, Ojo Sarco, El Valle, and Diamante (Figure 2.1).

No exact data exist about the population numbers for the study area. An estimate based on a study of 2010 Census data by Zip Code areas in the WBP planning area has led to a best guess of 1,182 individuals in 550 households. The target population of the estimate consists of residents of the study area (the Lower Embudo Valley), which includes an estimate of 15% of the population in the Zip Code area of Chamisal/Ojo Sarco (87521) and an estimate of 25% of the population in the Zip Code area of Rinconada/Embudo (87531), and the entire population of the Zip Code areas of Las Trampas (87576) and Dixon (87527). Table 2.1 provides a detailed number estimates for population categories.

The 2010 Census reveals that there are significant demographic differences across the watershed. The population in the higher elevations (Ojo Sarco and Las Trampas) is proportionally more numerous, relatively younger, of lower income, with larger families, relatively more females, and a greater percentage owning their homes than the populations downstream in Dixon and Embudo. The population in Embudo and Rinconada is proportionally the smallest in number, relatively the oldest, of the highest income, with the smallest families, relatively more males, and the lowest percentage of people owning their homes. Income levels vary greatly across the population, and many families live at or below the mean national income level. Income levels in the higher elevation communities and for young families and households across the watershed is hovering around the poverty level.

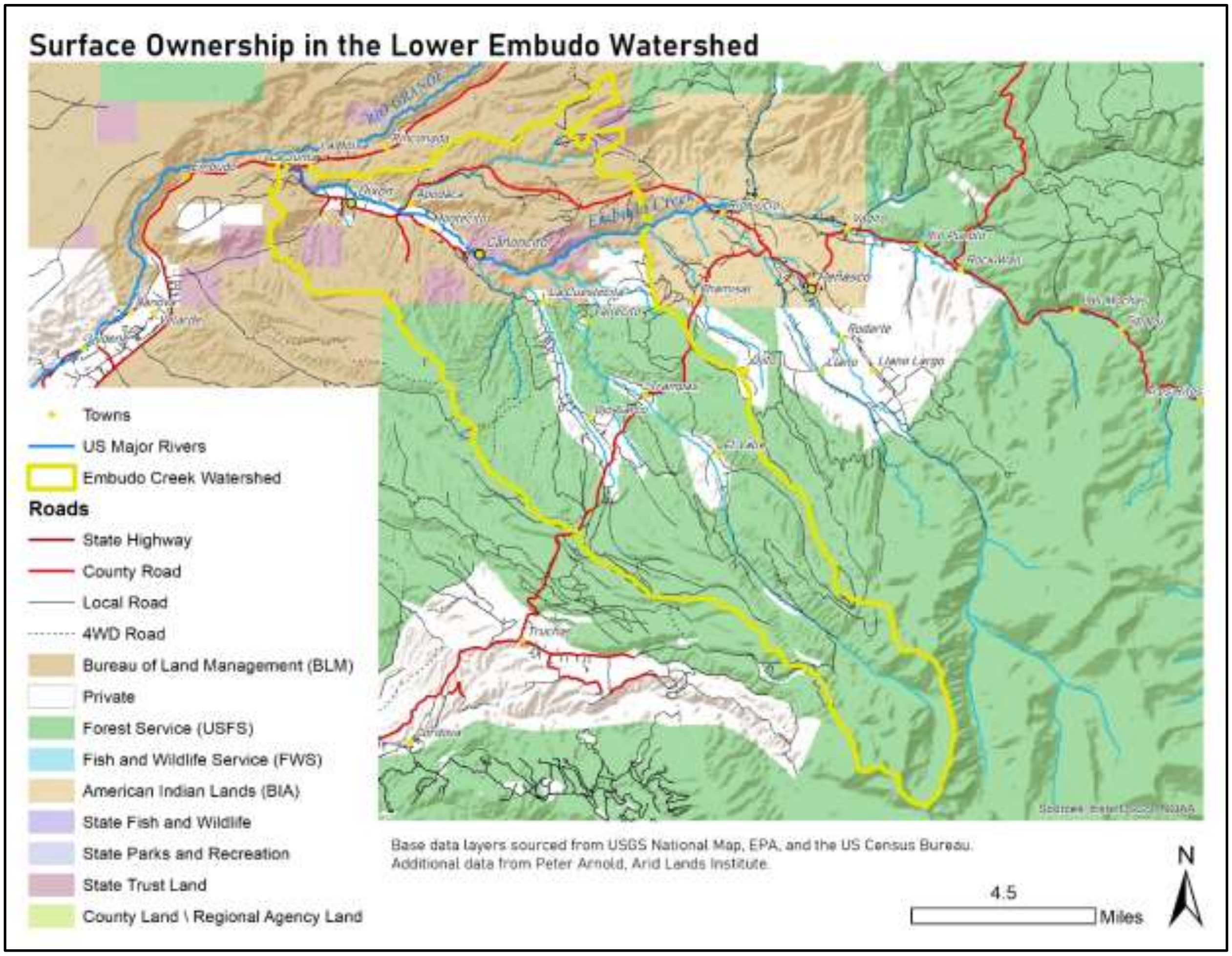

Figure 2.1. Map of private lands (white) and villages among other ownership jurisdictions.

Parciantes and administrators of the various local *acequia*s, many of which are organized in the Embudo Valley Regional Acequia Association (EVRAA), are concerned about the federal land management conditions regarding water supply and water quality. Such concerns are most acutely felt in times of drought (such as in 2013 and 2017) or after catastrophic events upstream that impact downstream water users. The EVRAA comprises twelve *acequia* associations in the Lower Embudo Valley, which irrigate approximately 880 acres of private lands along the Rio Embudo and approximately 225 acres along the Rio Grande[1]. Estevan Arellano estimated around 2014 that about half of these irrigated acres were being used for active cultivation.

[1] Estevan Arellano, personal communication, August 25, 2014.

Table 2.1. Target Population for the Study Area (US Census 2010).

Population Characteristics (Demographics per by Code)	Study Area Profile	Respondent Profile	Comparison
87521: Chamisal/Ojo Sarco: Population: 1003; Households: 422; Families: 264; Non-family: 158	Population: 150; Households: 64; Families: 40; Non-family: 24	1 = 1.6% of households	Chamisal and Ojito are outside the study area, with an estimated population of 85% of the Zip Code area.
87527: Dixon Population: 880; Households: 413; Families: 236; Non-family: 177	Population: 880; Households: 413; Families: 236; Non-family: 177	11 = 2.7% of households	
87531: Embudo/Rinconada Population: 368; Households: 195; Families: 92; Non-family: 103	Population: 92; Households: 49; Families: 23; Non-family: 26	5 = 5.4% of households	Rinconada, el Rincon, la Bolsa, Cienaga, and Embudo Station are outside the study area, with an estimated population of 75% of the Zip Code area.
87576: Las Trampas/El Valle Population: 60; Households: N/A; Families: N/A; Non-family: N/A	Population: 60; Households: N/A; Families: N/A; Non-family: N/A	0	
Total Area Population: 2311 Households: 1030 (-1055) Families: 592 (-608) Non-family: 348 (-357)	**Population: 1182 Households: 526 (-551) Families: 299 (-315) Non-family: 227 (-236)**	**17 (+ 1 no answer) = 18 = 1.7% of house-holds**	

Note: According to the definitions of the 2010 Census "Family households" consist of a householder and one or more other people related to the householder by birth, marriage, or adoption. They do not include same-sex married couples even if the marriage was performed in a state issuing marriage certificates for same-sex couples. Same-sex couple households are included in the family households category if there is at least one additional person related to the householder by birth or adoption. Same-sex couple households with no relatives of the householder present are tabulated in nonfamily households. "Nonfamily households" consist of people living alone and households which do not have any members related to the householder.

Other important stakeholders of the Embudo Watershed include Rio Arriba County (RAC), Taos County (TC), and the New Mexico Department of Transportation (NMDOT) with regard to their concern with roads and road drainage. In relation to watershed conditions, the RAC and TC governments are also concerned with managing various forms of development, fire and rescue, flood control, waste management, and public safety.

The Picuris Pueblo community and Picuris Pueblo as a sovereign native nation, and by extension the federal Bureau of Indian Affairs (BIA), also comprise an important stakeholder group, although the pueblo lands are located to the northeast, just outside the Lower Embudo watershed planning area. Many other Native American communities throughout the Southwest claim heritage rights and concerns with the watershed, and will need to be informed of any planned on-the-ground restoration activities.

Finally, stakeholders also include an undefined group of people and institutions who have professional or personal connections to the Lower Embudo Valley but live outside the area. It is unclear how large this group is, but in the context of a social survey for the 2013-2015 (phase-1) research for the WBP, the population size of this group was estimated in the order of 100,000 people. Because of the unique history of the area, its scenic beauty, agricultural role, tourism, recreation, and local business networks, the importance of outside stakeholders in water quality and land health conditions of the Lower Embudo watershed should not be underestimated. Table 2.2 provides a summary overview of stakeholder relationships in the Lower Embudo watershed.

Table 2.2. Summary overview of stakeholder entities in the Lower Embudo Watershed.

Lower Embudo Watershed Stakeholders and their Interests and Concerns						
Interests	**CNF**	**BLM**	**SLO**	**Private**	**Native American**	**Other**
Land Area (acres)	31,877	16,062	2,588	9,835	*(entire area as heritage lands)*	Negligible
Steward-ship Concerns	Forest land, wilderness, roads, and wildfire management	Forest, range, and wildfire management	Forest, range, and wildfire management	Farms, orchards, fields, homes, businesses, *acequia*s	Heritage lands and trails	Roads, drainage, fire, etc.
Other Interests	Multiple use services to all Americans	Special user services to specific user groups	Financial revenues for schools across NM	A home, historical connections, land/scenic appreciation	Spiritual and historical values	Many special interest values
Potential Role in Watershed Restora-tion	Key role on national forest land	Key role on BLM land	Key role on State Trust Land parcels	Key role on private lands and supportive role on federal land	Consultation; potential labor (crew) role	Support roles in planning, design, labor, and public input

Each of the key stakeholders and landowner categories in the Lower Embudo Watershed has limited capabilities to initiate and complete watershed restoration initiatives on their own. Collaboration with each other and with entities outside the watershed area that offer knowledge, technical, or financial assistance to watershed restoration projects will be critical for effective realization of restoration and stewardship goals. In the last ten years, such partners have included the NM Acequia Association (NMAA), the New Mexico State University (NMSU) Alcalde Field Station, Forest Stewards Guild, Ecotone Landscape Planning, and Arid Lands Institute (ALI).

Until recently, key stakeholder categories in the watershed have been operating mostly independently of each other. Besides collaborative initiatives, such as the USFS Collaborative Forest Restoration Program (CFRP) and watershed restoration projects, stakeholder entities are rarely encouraged in a tangible way to work together. However, some entities collaborate when a third party brings together a collaborative land restoration initiative. Between 2010 and 2017, several collaborative forest and watershed restoration projects took place in the watershed, which brought together the CNF, BLM, SLO, EVRAA, watershed residents, and several regional conservation groups, consultants, and contractors.

This 2019 WBP Update will assist in aligning goals between different stakeholders and in coordinating their collaboration. Chapter 5 of this WBP outlines suggested educational outreach strategies and activities that aim to encourage stakeholder groups to relate to each other, share information, and collaborate in order to achieve WBP goals.

2.2. Issues of Concern

Although issues of concern vary between stakeholders, there are several commonly shared concerns. These include the impacts of (a) drought and associated risks of water shortages, withering vegetation, bare soils, and catastrophic wildfire, (b) severe storms and high stream flows, and associated risks of flooding, erosion, debris flows, sediment build-up, and damage to farms, structures, and infrastructure, and (c) uncontrolled waste dumping and littering on public lands and in arroyos.

Survey results of 2014 indicated that watershed residents were most concerned about periodic water shortages, stream pollution due to trash and sediment, and the loss of fish habitat. Other concerns at that time included the lack of recreational boating on the river, the low water quality for recreational fishing and eating local fish, and problems of flooding and public safety caused by sediment clogged streams. Residents have also been concerned with the decline of the *acequia* culture, the lack of labor, and loss of local knowledge. Taken together, these concerns seriously threaten to undermine the vision for the watershed stated in Chapter 1.

The public agencies have been concerned about catastrophic wildfire in the forests, drying out of wetlands and streams, soil loss, and invasive plant species proliferation. In specific locations, land degradation due to off-road vehicle use is also seen as a serious problem in relation to land health, management, and water quality impairment.

2.3. Goals, Mandates, and Authorities of Various Stakeholders

<u>Carson National Forest</u>

In October 2017, the Carson National Forest (CNF) issued a decision based on a Finding of No Significant Impact (FONSI) which created the agency's authority to undertake forest restoration activities (USFS 2017-b). The purpose statement of the FONSI describes:

> *The purpose of this project is to approach desired environmental conditions that are more resilient to uncharacteristic disturbance, while providing access to traditional-use forest products to residents of local communities. Recent landscape assessments such as the New Mexico Statewide Natural Resource Assessment & Strategy and Response Plans (EMNRD 2010) and the North-Central New Mexico Landscape Assessment (Sisk 2007) have identified areas of the Embudo Creek 5th-code watershed (including Rio Trampas) as in need of active management.*

The approved activities focus on a range of silvicultural improvements, mainly through manual and mechanical vegetation treatments aimed at stand density reductions. The treatments span 5,718 acres across 18 treatment units and will take place between 2018 and 2025. The treatments are targeted largely on ponderosa pine stands (41% of the treatment area), and to a lesser extent on mixed conifer (30%) and piñon-juniper woodlands (27%), and marginally on spruce fir and aspen stands (together less than 2%). Thinning treatments will generally take place on slopes below 40% (USFS 2017-a, 2017-b) (Figure 2.2).

The activities also include treatments to protect and improve riparian areas and roads, among other aspects, and have a combined goal of habitat and stream health improvement. Planned activities include construction of small, instream structures, headcut repairs, and barriers to exclude motorized vehicles. Road treatments would include heavy maintenance on a few heavily degrading roads and general repairs and drainage improvements (USFS 2017-b).

The final Environmental Assessment (EA) states that there are 10,042 acres of "unsatisfactory" soils on the national forest lands in the watershed area. By the EA definition of an unsatisfactory soil rating, "loss or degradation of vital soil functions have occurred resulting in the inability to maintain resource values, sustain outputs, and recover from impacts." "Soils rated in this category are candidates for improved management or active restoration designed to recover soil functions." (USFS 2017-a).

This means that nearly a third of the national forest lands in the watershed have fragile and poor quality soil with a likelihood of soil loss. "Within the treatment units, there are 1,147 acres" … "of unsatisfactory soils within the Cañada de Ojo Sarco sub-watershed area proposed for treatment. This equates to 10.2 percent of the total sub-watershed area. There are also 1,338 acres" … "of unsatisfactory soils within the Cañada de Ojo Sarco-Embudo sub-watershed area proposed for treatment. This equates to 5.1 percent of the total sub-watershed area. Total acres treated in both sub-watershed areas (Cañada de Ojo Sarco and Cañada de Ojo Sarco-Embudo) is 2,485 acres" or 6.4 percent of the total treatment area. Consequently, the planned and approved treatments on the national forest would cover only about 20% of the areas with fragile soils (USFS 2017-a). Chapter 3 will provide more details on the fragile soil conditions in the watershed. Although not explicitly mentioned in the FONSI, the program's final EA states that the planned and approved practices are expected to contribute to significantly reduced soil loss and sediment flows (USFS 2017-a).

Areas in the portion of unsatisfactory soils that are not included in treatment units may or may not contribute to soil loss and /or sedimentation in the future. It is possible that soil loss from areas with unsatisfactory soils will be adequately buffered by the surrounding landscape. Additionally, it is possible that over time the areas with unsatisfactory soils develop vegetation cover and other mitigating conditions that significantly reduce their contribution to water pollution in the Rio Embudo. Given a structural lack of personnel, it is unlikely that the CNF will systematically monitor soil conditions in these areas. However, such monitoring may be undertaken by other stakeholders, and monitoring results and the CNF's internal observations may over time encourage the CNF to formulate proposed actions. This is a data gap, however, that could be filled by future actions flowing from this WBP Update and contribute to additional USFS actions on the national forest that contribute to sediment load reductions. Chapter 5 will further describe these opportunities for future sediment transport reductions on the national forest.

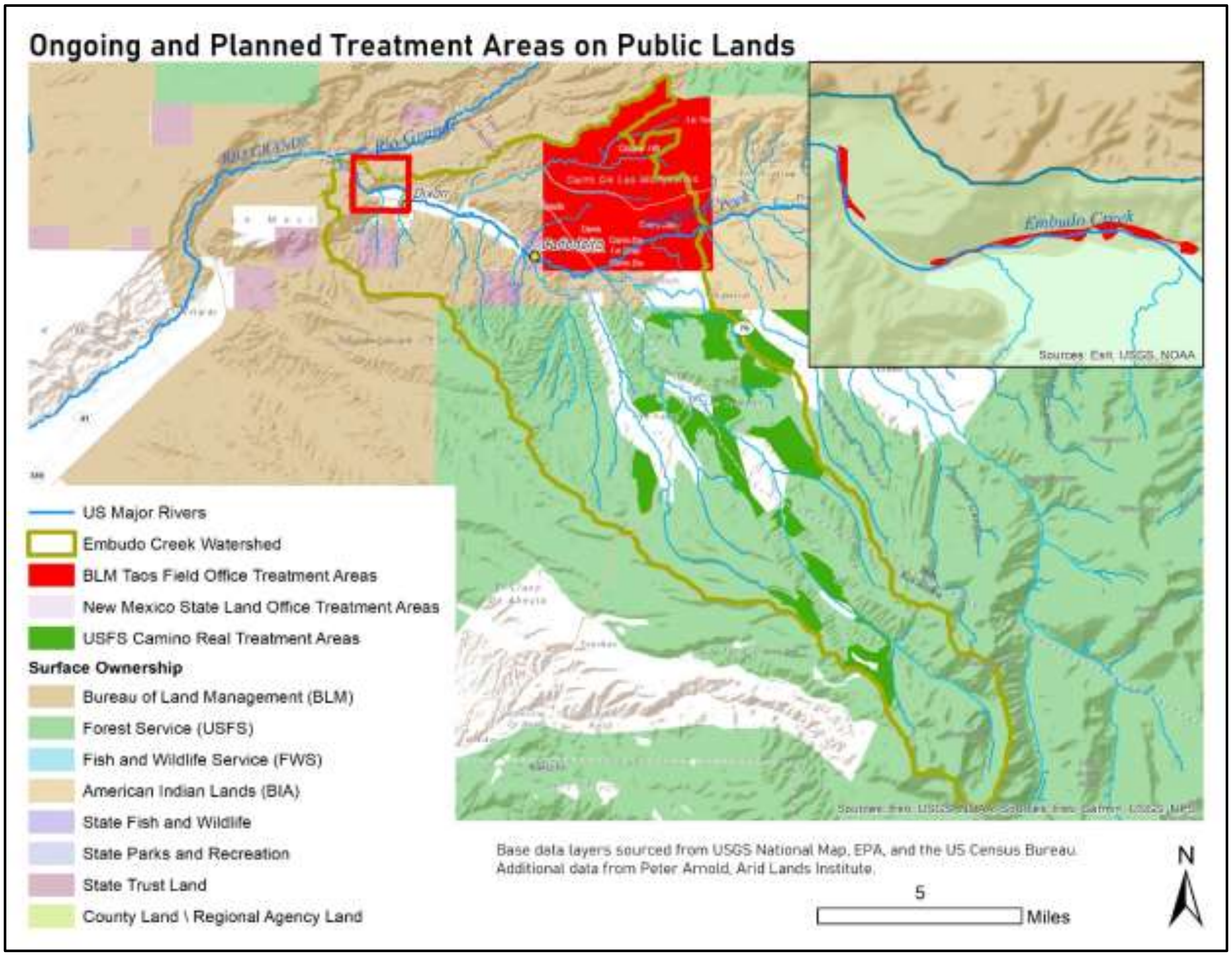

Figure 2.2. Map of ongoing and planned treatment areas of the USFS, BLM and NM SLO in the Lower Embudo watershed in 2019.

BLM

The BLM is in the process of preparing plans for continued treatment on lands under their management across 26,389 acres, most of which is in the northern part of the Lower Embudo watershed between Picuris and Embudo (Figure 2.2). The proposed purpose is to reduce hazardous fuels, enhance ecological diversity of the area, and reintroduce a regime of low- to mixed-severity ground fires which might be considered natural to the ecosystem. A large portion of the proposed treatments are in piñon-juniper savannah, shrubland, and woodland ecosystems, a smaller portion comprises ponderosa pine, and a 340-acre treatment area is planned along the Rio Embudo for the removal of invasive riverine trees. Additionally, the BLM has been considering to apply a chemical treatment across approximately 250 acres of sagebrush to create a vegetation mosaic that contains a greater percentage of herbaceous cover (BLM Taos Field Office staff, personal communication, May 1, 2019).

Treatments include managed wildfire (a.k.a. "wildland fire for resource benefit"), which entails that, under specifically described circumstances, the agency plans to use unplanned, natural wildfire starts and allow such fires to burn in order to meet hazardous fuel reduction goals and thus treat target areas. If no unplanned ignitions occur, the BLM may gradually treat the entire area with prescribed fire. The objective is to increase soil cover by herbaceous plants in order to stimulate natural wildfire regimes carried by grass.

The BLM also plans to gradually thin 4,050 acres to densities of 60-120 stems per acre and 1,350 acres to densities of 40-80 stems per acre in the eastern part of this project area, southwest of Picuris Pueblo. The thinning treatment may be accompanied with lop and scatter and soil conservation measures to meet soil conservation goals, including reduction of soil loss and sediment transport. The agency expects that approvals for these actions will become available by 2020.

State Land Office

The State Land Office manages 5 parcels of approximately a topographic map section each (measuring approximately one square mile) with a total area of approximately 2,588 acres across the Lower Embudo watershed. Most of the State Trust Land parcels have piñon-juniper savannah, open woodland and/or shrubland ecosystems and are seriously degraded and eroding. The most western parcel, comprising a full section, is located at the center of the Arroyo la Mina and Arroyo Pino drainage area, one mile south of the village of Dixon, and is subject to severe erosion. A second parcel spans approximately 520 acres in the Arroyo de los Pinos Reales and Cañada del Montecito drainages, and is also extremely eroded. A third parcel spans the Rio Embudo at Cañoncito, just to the northeast of the previous parcel, and includes the confluence of the Cañada del Ojo Sarco with the Rio Embudo at the mouth of the box canyon of the Rio Embudo, which extends upstream to Picuris Pueblo. Conditions at this parcel are mixed and include steep, rocky slopes subject to mass wasting of large boulders from eroded cliffs, and sandy and rocky alluvial and colluvial bottomlands. Vegetation on this parcel is very sparse. A fourth parcel is located two sections to the east from the last one and spans the Rio Embudo box canyon. This parcel has very steep, rocky slopes with cliffs and rocky ridges on both sides. The cliffs are subject to mass wasting of large boulders. The ridges bear witness to historic mining operations in the area. The vegetation comprises a piñon-juniper shrubland and is very sparse. The fifth parcel comprises a full section on the west side of Copper Hill, northwest of Picuris Pueblo. This section includes a westward descending ridgeline with piñon-juniper shrubland on south- and west-facing slopes and ponderosa pine on the north-facing slopes.

The agency has been implementing a series of woodland thinning projects with a soil conservation component across various parcels. The purpose of the treatments is fuels management and habitat management. The agency has been actively collaborating with non-profit partners, such as Forest Stewards Guild as well as with the BLM, to implement the projects with additional funding and technical support through the CFRP and Rocky Mountain Youth Corps. Treatments include mechanical thinning, prescribed fire, and erosion management treatments. The agency has also been considering a riparian restoration project at the confluence of the Ojo Sarco and the Rio Embudo.

Private Landowners

Private initiatives include activities by the *acequia* associations and by individual landowners and farmers. While the goals, mandates and authorities of each landowner are purely personal, collective goal setting and actions occur through participation by landowners who are *parciantes* of one or several of the *acequia*s in the area. Each *acequia* association has statutory authority as a local government. Many *acequia*s develop annual plans and have procedures for decision making on repairs and improvements to their system, supported by contributions from *parciantes* and grant funding through federal, state, county, and charitable grants and contracts. The *acequia*s and landowners also draw on support from EVRAA, NMAA, extension services from NMSU, and other sources.

Rio Arriba County and Taos County

Rio Arriba County (RAC), and to a lesser extent Taos County (TC), are concerned with regulating development, water use, stormwater management and flood control, and county road management. Most of the developed land in the Lower Embudo watershed falls under the regional authority of RAC. The land around Copper Hill and the Cerro Colorado, and the small settlements of Vallecito, Las Trampas, and El Valle are located within TC.

The RAC and TC governments have authorities through their land use plans and their stormwater and flood management ordinances to influence, and in some cases enforce, the reduction of bare ground, construction in appropriate locations, and stormwater management practices. However, in reality, their influence on water quality of the Rio Embudo is limited.

RAC and TC can potentially leverage significant positive influence on water quality improvement by improving and controlling county road management. Many miles of unimproved (dirt) roads are under management by either county. For at least ten years, RAC has participated in conversations and workshops in the field about road management in collaboration with BLM and various watershed restoration groups.

The location of many county roads in or next to arroyos across BLM land which also serve as major stormwater conduits in and around Dixon constitutes a serious management conundrum for county officials, BLM resource managers, and private landowners with property along these roads. Developing creative, collaborative solutions to these problems are an important aspect of this 2019 WBP Update.

NM Department of Transportation

The New Mexico Department of Transportation (NMDOT) manages State Road 68 through Embudo, State Road 75 through Dixon and toward Picuris Pueblo, State Road 580 from Dixon toward Ojo Sarco, and State Road 76 through Ojo Sarco and Las Trampas. NMDOT is responsible for road safety conditions and is faced with periodic flooding of road segments and with sediment deposited on roads. Periodic sediment deposits that clogged bridges and culverts has caused flooding of roads and undermining of roadsides, impairing the functionality and safety of the roads. In the last decade at least one fatality occurred in the Lower Embudo watershed as a result of these problems.

Annually, NMDOT is faced with the need to remove sediment buildup in bar ditches and at several notorious stream crossings, such as the Arroyo la Mina crossing in Dixon, and maintain protective structures at undermined road sides. NMDOT uses a road side storage area on BLM land along State Road 75 northeast of Dixon to pile accumulated sand and gravel debris from the Lower Embudo watershed.

2.4. Public and Stakeholder Outreach

Outreach activities in relation to this WBP to specific stakeholders and to the public at large date back several decades. Although supported by various initiatives and organizations, there has been a multitude of educational outreach and public involvement activities regarding watershed and forest restoration in the WBP planning area which support public awareness, capacity, and a vision for this 2019 WBP Update (see also Chapter 1).

Around 2006, local consultants compiled information for a Watershed Restoration Action Strategy (WRAS) with funding from NMED-SWQB and EPA. With local information from many community meetings and local landowner input the consultants completed the WRAS in 2007. NMED-SWQB updated the WRAS with a section on the Santa Barbara watershed in 2010 (Environmental Health Consultants and NMED 2010).

EVRAA and an informal watershed action group continued periodic meetings after 2007. Around 2009, these entities reached out to the Arid Lands Institute (ALI) at Woodbury University in Burbank, CA, and to Earth Works Institute (EWI) of Santa Fe. ALI started an annual summer program for architecture students in the Lower Embudo Watershed and assisted local *acequia*s with mapping their infrastructure and solving certain drainage problems. Around 2011, ALI and EVRAA established and annual gathering of *acequia* aficionados, known as *Celebrando las Acequias*, to educate local residents and the public at large about the cultural importance of *acequia*s. As of 2010, EWI held several community meetings and worked with *acequia*s, local residents, and regional support organizations on the formulation of proposals for a WBP and for several hands-on community-driven restoration and waste cleanup projects.

Starting in 2011, several proposed projects received funding and led to a series of community meetings, cleanup days, outreach events, and land and stream restoration activities, mostly under the guidance of EWI, in collaboration with EVRAA and other local entities. As of 2012, the Forest Stewards Guild (FSG) of Santa Fe and Carson National Forest (CNF) held a series of community meetings in relation to a comprehensive forest restoration planning initiative in the Lower Embudo Watershed, in collaboration with BLM, State Land Office, and Ecotone.

In 2012, ALI and Ecotone received EPA funding through the NMED-SWQB for the compilation of a WBP in the Lower Embudo watershed. The project partners closely coordinated this initiative with the CFRP project of the FSG and CNF. Starting in 2013 and running through early 2015, the WBP initiative included another series of community outreach meetings as well as the inclusion of local residents in water sampling in the Rio Embudo.

When from 2014 to 2016, the FSG and Ecotone built on the collaborative forest planning work to launch a forest restoration program on two State Trust Land parcels in the Lower Embudo watershed (one on Copper Hill and one across the middle reach of the Arroyo de los Pinos Reales), this program organized several community outreach meetings and several erosion control workshops for local residents, including crew members from Picuris Pueblo. The program implemented forest thinning and erosion control work with contractors from the Española Valley who hired several local residents from the Lower Embudo watershed.

After 2016, the EVRAA reorganized and reinvigorated itself with new leadership. EVRAA established regular meetings and organized a number of local outreach and education initiatives, such as recordings of stories told by local *ancianos*, which were included in the local KDLK radio broadcasts and video recordings posted online. EVRAA also worked closely with NMAA and other support organizations for the local *acequia* culture.

Between 2016 and 2017, the CNF completed an EA for the final decision on the forest planning work on national forest land. This work also included some public outreach and public involvement in the final decision process.

The 2019 initiative of NMED-SWQB and Ecotone to complete the 2019 WBP Update compilation also included a number of stakeholder and public outreach activities, including field trips with residents and EVRAA members, a brief presentation at EVRAA annual meeting in June, a presentation to EVRAA members and community residents on September 17, and a community meeting in Peñasco on October 24. It is expected that stakeholder outreach and public educational outreach will continue after 2019 with the presentation and distribution of the final WBP and with the planning of watershed restoration projects aimed at the implementation of the WBP.

In 2019, an independent watershed restoration initiative, the Rio Embudo Watershed Coalition, sponsored by The Nature Conservancy (TNC), started in the Peñasco area. This watershed group along with EVRAA will be well positioned to become lead entities in the Lower Embudo watershed to lead the outreach work, possibly with support from NMAA, TNC, and other partners and consultants from the wider region. BLM and CNF will likely hold public outreach meetings associated with any proposed actions on their respective federal lands.

2.5. Current Stewardship Activities

As of late 2019, local activities in the Lower Embudo watershed that contribute to water quality improvements include regular meetings of the 12 local *acequia* associations and of EVRAA, which focus on maintaining functional *acequia* irrigation systems throughout the valley. This work includes preparations for short-term improvements as well as long-term strategic activities for future land and water management. The Embudo Valley Library and EVRAA also collaborate on meetings to improve local climate change and emergency response preparedness. Additionally, local residents have expressed grave concern about the planned expansion of the Sipapu ski area. They expect that water diversion, rapid snow melt, terrain modification leading to increased runoff, and the release of toxic chemicals in the river water will impair water quality downstream in the Lower Embudo watershed. A coalition of residents is actively involved in researching and tracking ski area expansion plans and sharing concerns with the US Forest Service and the Sipapu ski resort.

Ongoing *acequia* maintenance and ongoing farming and orchard management practices, dirt road maintenance, and forest health treatments have many direct, indirect, and potential effects on impairment reductions through local education, collaboration, and terrain management. Community organization, knowledge system building, and practices on the land build a basis for the capacity needed to implement the strategies recommended in this 2019 WBP Update.

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3. WATERSHED DESCRIPTION

3.1. General Watershed Characterization

This sub-section on general watershed characteristics provides relevant contextual information about landscape and land use in the Lower Rio Embudo watershed. This information offers an overview of the sources of pollutants, the reasons for the accumulation of pollutant loads in the river, and the criteria to be considered for actions to reduce pollutant discharges.

<u>Ecoregions</u>

The planning area for the 2019 WBP Update is located on the western slopes of the Sangre de Cristo Mountains at a transition area between two Level III ecoregions (the Southern Rockies to the east and the Arizona/New Mexico Plateau to the west) (Figure 3.1), including eight Level IV ecoregions.

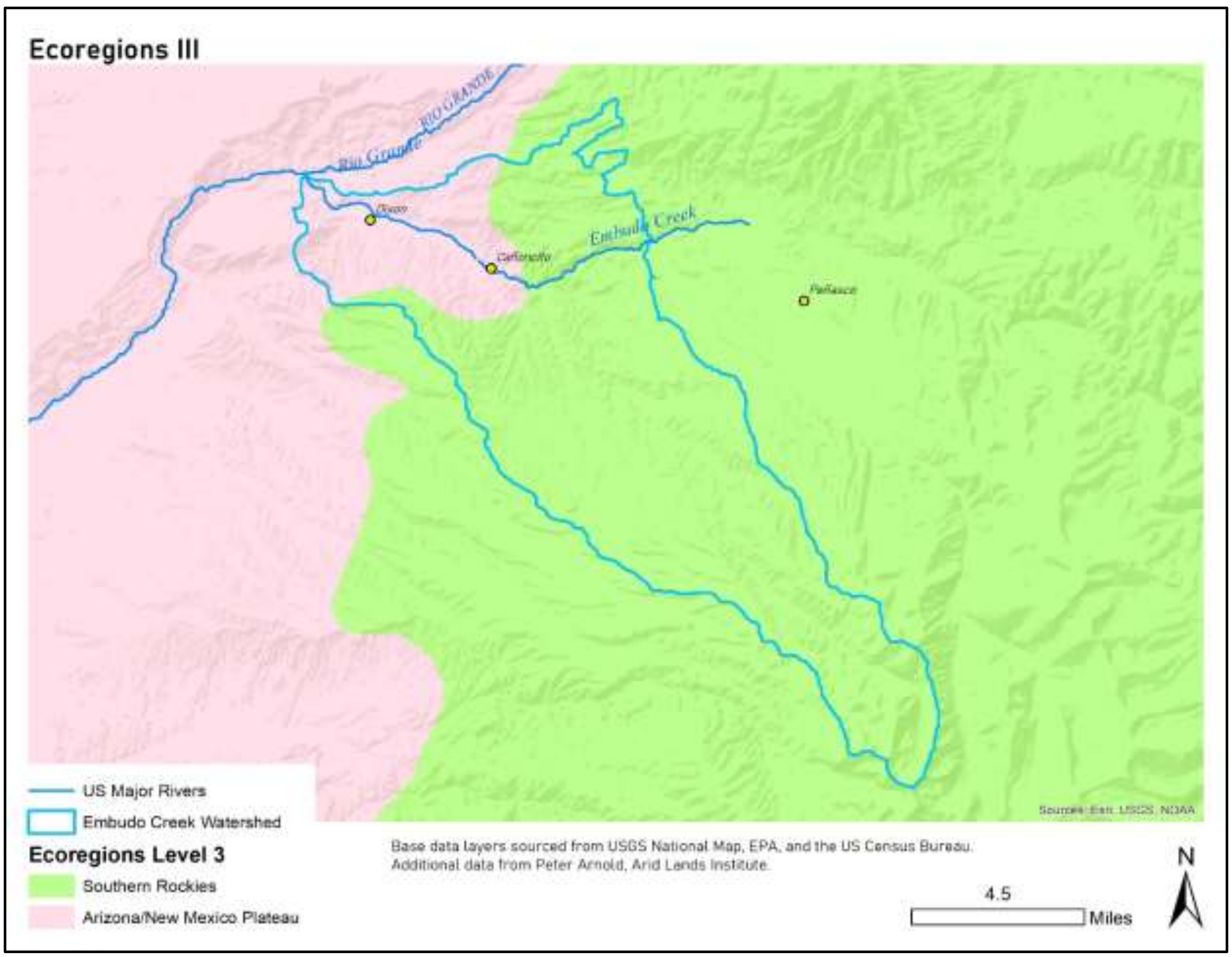

Figure 3.1. Map of level III ecoregions in the WBP study area (as per ecoregion map of New Mexico).

The Level IV ecoregions include the Crystalline Subalpine Forest, Mid-Elevation Forests, Sedimentary Subalpine Forests, Mid-Elevation Forests, Foothill Woodlands and Shrublands, the North-Central New Mexico Valleys and Mesas, the Taos Plateau, and the Rio Grande Floodplain (Figure 3.2). As a result, the area is highly diverse and complex, and includes many sequences of ecosystems with different soil types and plant communities (Griffith et al 2006).

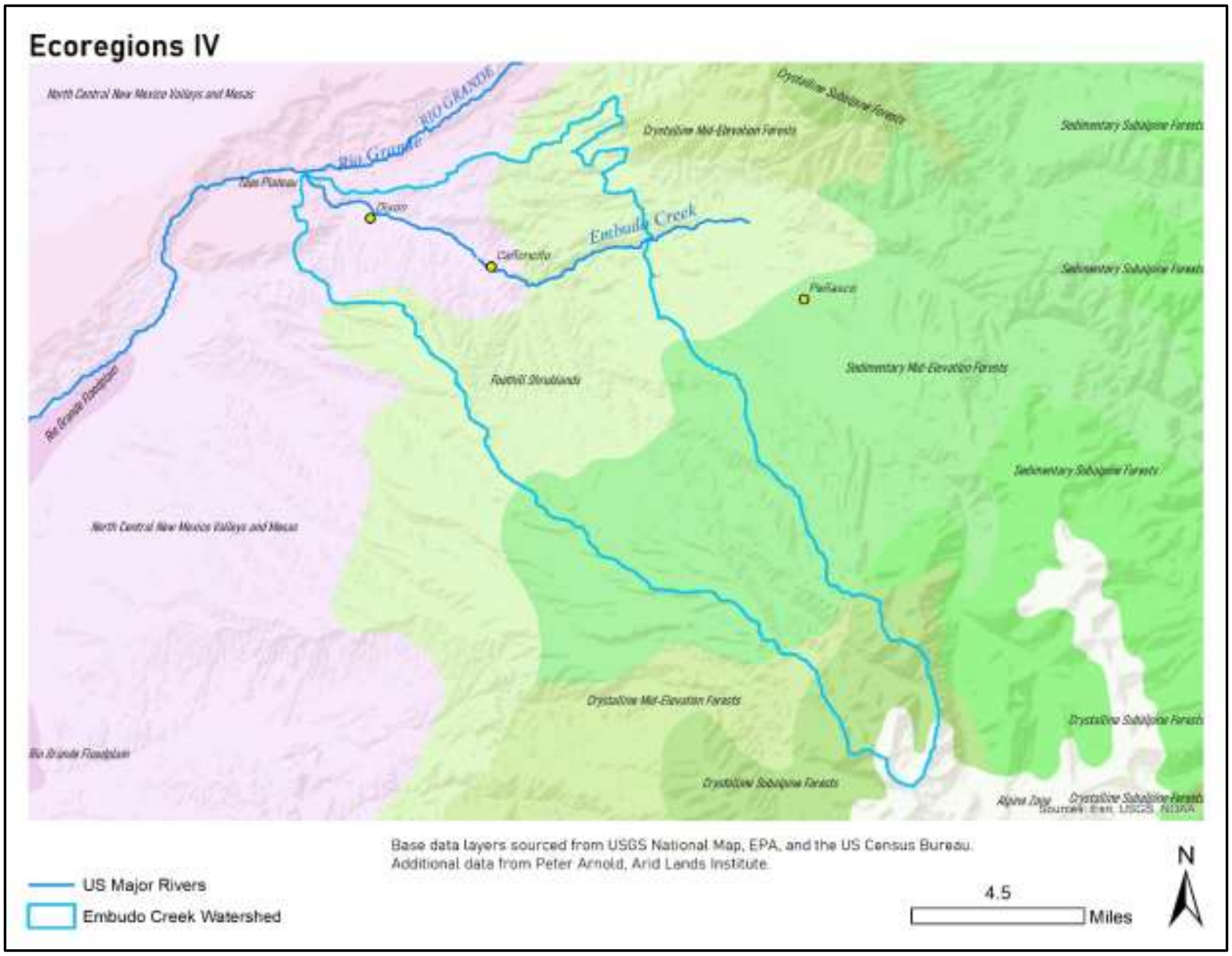

Figure 3.2. Map of level IV ecoregions in the WBP study area (as per ecoregion map of New Mexico).

<u>Wildlife</u>

Because of its transitional character between various ecoregions, the WBP study area is highly diverse and complex, and includes many sequences of ecosystems with different soil types and plant communities. Sixty-three species of greatest conservation need (SGCN) occur in the Southern Rocky Mountains ecoregion; over half are birds (NMDGF 2016). The Arizona/New Mexico Plateau contains the second largest number (102) of SGCN in New Mexico, 49% of which are birds (NMDGF 2016).

The US Fish and Wildlife Service (FWS) lists threatened and endangered (T&E) species by county[1]. In reports ran for Rio Arriba and Taos counties, these include one endangered amphibian (Jemez Mountains salamander, *Plethodon neomexicanus*), two threatened birds (Yellow-billed Cuckoo, *Coccyzus americanus* and Mexican spotted owl, *Strix occidentalis lucida*), two endangered birds (Least tern, *Sterna antillarum* and Southwestern willow flycatcher, *Empidonax traillii extimus*), one threatened mammal (Cañada Lynx, *Lynx canadensis*), two endangered mammals (New Mexico meadow jumping mouse, *Zapus hudsonius luteus* and Black-footed ferret, *Mustela nigripes*), one proposed threatened mammal (North American wolverine, *Gulo gulo luscus*), and one fish that is under review (Peppered chub, *Macrhybopsis tetranema*) (FWS 2015).

The community of Dixon has taken part in the annual Audubon Christmas Bird Count for 22 years (1997-2018), counting 2,151 individual birds of 67 species in 2018 alone. None of the federally listed birds have been counted during these surveys. However, one individual "Unidentified Empidonax Flycatcher" was counted in 2003. Additionally, 12 bird species identified in the 2016 *State Wildlife Action Plan for New Mexico* as SGCN for the Southern Rocky Mountains and Arizona-New Mexico Mountains have been counted in Dixon bird counts (NMDGF 2016 and Rio Embudo Birds 2019).

Riparian Areas

Most of the drainages leading into the Rio Embudo within the project boundary are ephemeral: they area only seasonally active with relatively short flow periods. Despite this, EPA has acknowledged that especially in the arid and semi-arid Southwest where ephemeral streams make up a larger portion of all streams (~81% compared to 59% nationally), ephemeral streams play a vital role in contributing to the hydrological, biogeochemical, and ecological health of a watershed (Levick et al. 2008).

In the 2007 *Rio Embudo Watershed Management Plan* (Environmental Health Consultants and NMED 2010), wetland and riparian areas were identified as valued features within the watershed, because they have direct impacts on water quality, quantity, and the overall wellbeing of communities within the watershed. Degradation of wetland and riparian vegetation was identified as a concern for the communities and as a possible cause of non-point source (NPS) pollution. Riparian areas serve many important ecological functions within the watershed, such as streambank stabilization, flood control, aquifer recharge, wildlife habitat, and filtering of sediment and pollution. Human interference has drastically altered conditions of wetland and riparian areas by activities such as river channelization, development in floodplains, loss of native vegetation, introduction of invasive plant species, and inappropriate livestock management. The combined results from these practices have resulted in stream bank erosion and collapse, changes to natural vegetative structures, increased fire hazard, and changes to overall natural functioning of the landscape (Environmental Health Consultants and NMED 2010).

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[1] Rio Arriba County: https://ecos.fws.gov/ecp0/reports/species-by-current-range-county?fips=35039 , Taos County: https://ecos.fws.gov/ecp0/reports/species-by-current-range-county?fips=35055, based on a referenced report of 2/13/2015 online data report by the US Fish & Wildlife Service, https://ecos.fws.gov/ecp0/reports/species-listed-by-state-report?state=NM&status=listed

Some of the challenges for restoring and protecting riparian and wetland areas in the Embudo watershed addressed in the 2007 WRAS included dealing with alteration of the river channel, urban development, and invasive plant species. Within the Embudo watershed alteration of the original river channel has resulted in degradation of streambanks, unhealthy distribution of the river's energy flow, and loss of riparian vegetation. Many homes, businesses, and farms have been developed on the original river floodplains, limiting the feasibility of floodplain restoration. Additionally, many invasive plant species, such as Russian olives, tamarisk, and Siberian elms, have been introduced to the riparian areas, often as a form of erosion control (Environmental Health Consultants and NMED 2010). This has resulted in degradation of riparian functions due to changes to soil properties, increased risk of wildfire, decline of native plants, and degradation of wildlife habitat. The great difficulty and cost involved with the complete removal of many of the non-native plant species leads to additional challenges for restoration.

<u>Land Use</u>

Forms of land use are closely related to landownership in the Lower Embudo watershed (Table 3.1. and Figure 3.3). In the absence of an accurate source of land use, landownership has been used as a proxy in the land use map for the watershed. Table 3.1. includes the proportional land use cover for the watershed planning area, identified in the 2007 *Upper Rio Grande Watershed Management Plan*, as updated in 2010 (Environmental Health Consultants and NMED 2010). Most land has uses that are marginally related to water, but that do cause significant sediment loading. Although water sources and wetlands constitute a very small portion of the land area (<1% each respectively) they are critical for both the population's economic basis and for the transportation and stabilization of sediment pollutants.

The 2017 WRAS (Environmental Health Consultants and NMED 2010) documents that most of the WBP study area is forest land and woodland (89% of the watershed area). With the exception of several high elevation areas in the far upper reaches of the Rio de las Trampas within the Pecos Wilderness, all forest and woodland areas are in principle available for multiple uses, including wood products harvesting, recreational uses, and varying forms of vehicular access. However, specific management designations and restrictions regulate land use forms and intensities across the forest lands. Approximately 6 mi^2 of national forest land in the Lower Embudo watershed is located in the Pecos Wilderness and consists largely of alpine tundra (2% of the watershed area). This area also includes a few high mountain trails.

The Lower Embudo watershed contains over a dozen communities located in the valley bottoms, including Ojo Sarco, Cañoncito, Apodaca, Dixon, and Embudo (Embudo Valley Library 2019). The valley bottoms are mostly privately owned and dedicated to various forms of agriculture (4% of the watershed area), including pasture and hay fields, orchards, vineyards, and irrigated produce farms. Traditional *acequia* irrigation is of high importance to a considerable number of farms, and *acequia* associations still actively maintain *acequia* infrastructure around Ojo Sarco, Las Trampas, and in the valley bottoms of Cañoncito, Apodaca, Dixon and Embudo. Additionally, a small portion of the valley bottom area is developed (approx. 1% of the watershed area), and consists of roads, residential and farm buildings, and a small number of commercial and service structures. Development is mostly scattered and interwoven with orchards, vineyards, fields and pastures. Many people cultivate small farms and kitchen gardens, although agriculture has for many not been economically viable for some time. Figure 3.4 provides an overview of the ten acequias and the associated irrigated land in Dixon and Embudo.

Table 3.1. Proportional land use cover in the assessment area (Environmental Health Consultants and NMED 2010).

Forest, Woodland, and Wildland	Agriculture	Alpine Tundra	Pasture and Rangeland	Developed Land	Water	Wetlands
89%	4%	2%	2%	1%	<1%	<1%

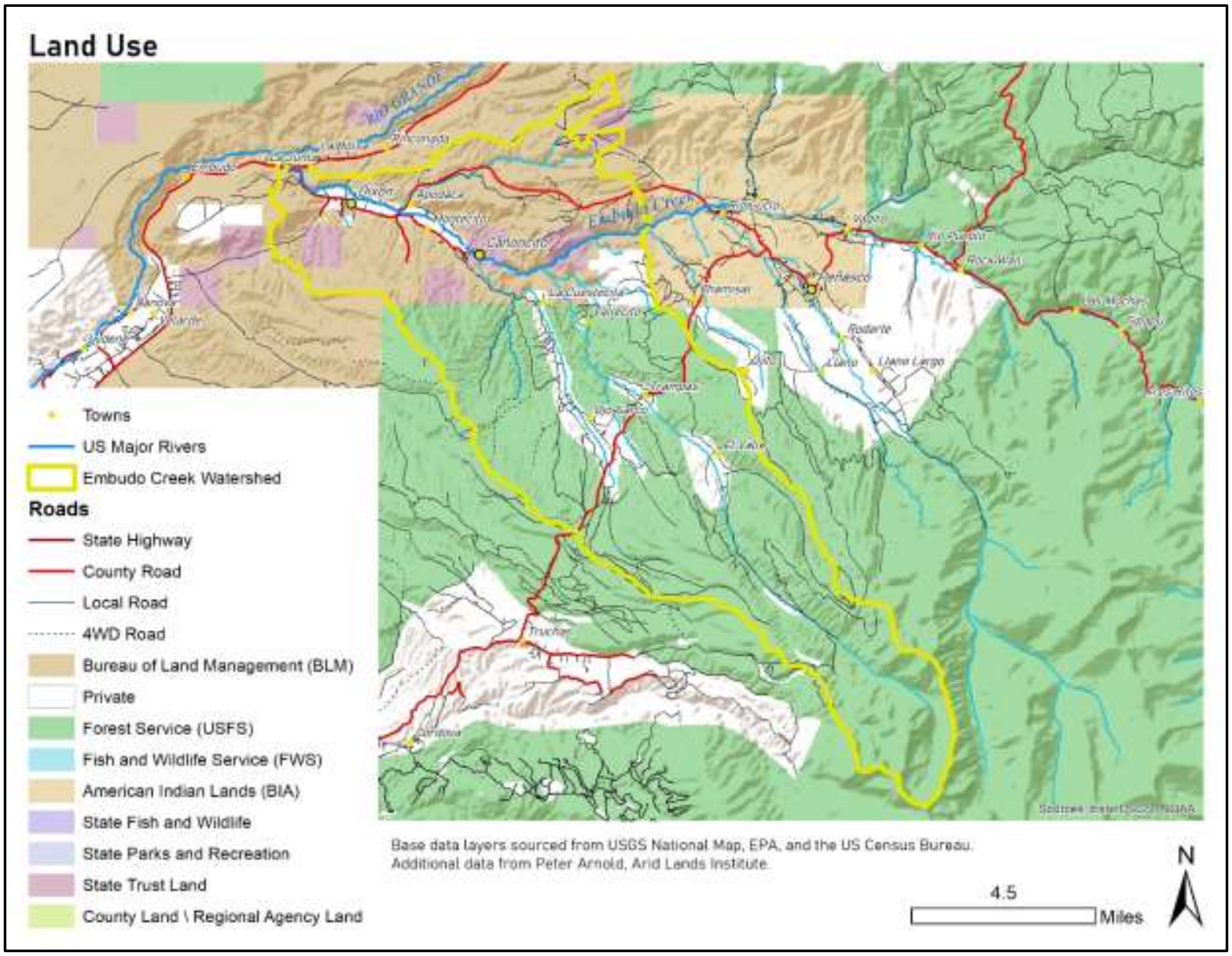

Figure 3.3. Land use map based on ownership for the Lower Embudo watershed. BLM and SLO parcels are woodlands used as de facto wilderness with specific areas used as grazing allotments and firewood areas; US Forest Service lands are used as multiple-use forest lands and wilderness; private lands (white) are used for transportation, residential, commercial and agricultural uses.

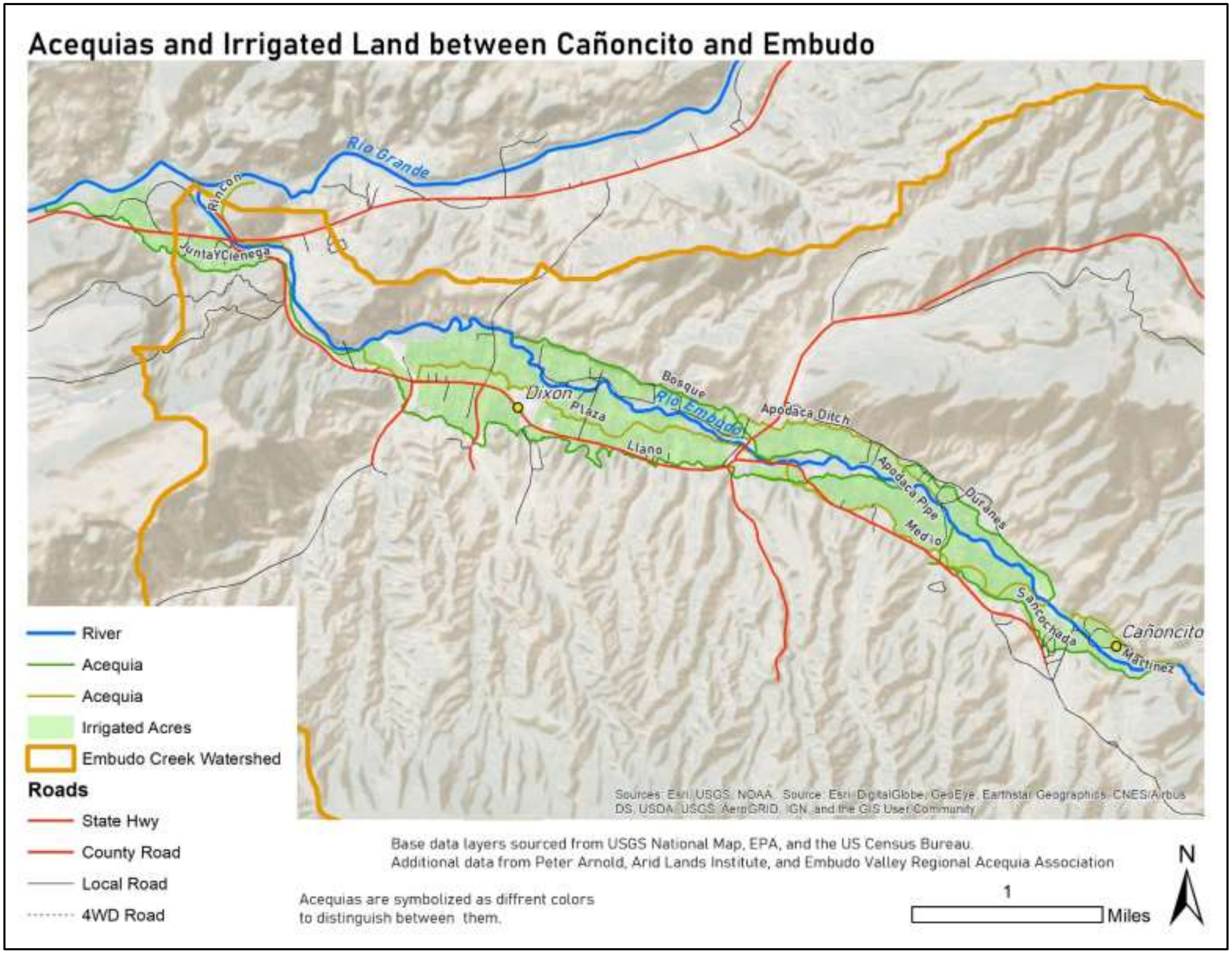

Figure 3.4. Map of acequias and irrigated land in the Embudo, Dixon, and Cañoncito area.

Livestock production on private, USFS, and BLM lands is an important land use in the watershed. The 2017 WRAS lists rangelands as a land use form (covering 2% of the watershed area). However, in practice, a considerable acreage of forest and woodland controlled by the USFS, BLM, and SLO is periodically used as rangeland by grazing permittees.

In the last decade, tourism and recreation comprise a growing sector of the local economy and associated land use. Additionally, a considerable part of the watershed's income sources are derived from employment income and retirement funds from outside the County and even outside New Mexico (US Census 2000).

Agricultural History

The Embudo Land Grant was first settled in 1725 by a group of three men, believed to be led by Francisco Martín (Environmental Health Consultants and NMED 2010). The settlers were in search of a place with land and water for agriculture, and portions of this land are believed to have been previously cultivated by the Picurís and San Juan (Ohkay Owingeh) people before the land grant came into existence (Arellano 2007). The first item on the agenda when a new area was settled was to establish an *acequia*. The first in the land grant's history was Acequia de la Plaza, beginning where Arroyo Lorenzo and Arroyo de Apodaca meet the Rio Embudo and draining at the Arroyo la Mina (Arellano 2007). The 1700's and 1800's were periods of great turmoil in these lands, but construction of new *acequias* and expanding opportunities for cultivation continued, with the majority of people living off the land until the early 20th century (Arellano 2007) (Figures 3.5 and 3.6). In 1881, the Chile Line, a railroad named after the chili it hauled north to Colorado, arrived in what is now Embudo Station and operated until its closure in 1941 (Environmental Health Consultants and NMED 2010).

The Lower Rio Embudo valley encompasses several villages including Cañoncito, Montecito, Apodaca, Bosque, la Plaza (Dixon), la Junta, Ciénaga, Rincón and la Nasa. Farmers in each of these villages irrigate using the water from the Río Embudo. Additionally, the villages of Rinconada, la Bolsa and La Otra Banda, which socially are part of the Lower Embudo valley but are outside the Embudo watershed, irrigate with water from the Río Grande. Historically, this area grew wheat, corn, and chili, and a variety of garden vegetables, with fruit being grown largely in the Rinconada area (Arellano 2007). Some households also had domestic animals for home consumption. While the majority of agriculture in the lower valley was for subsistence, some households would sell or barter chili and fruit in nearby communities such as Taos, Peñasco, and Mora valley, and as far north as Questa, Costilla and the San Luis valley in southern Colorado (Arellano 2007).

After World War II, Los Alamos National Laboratory became the prime employer for Dixon residents (Crawford 2019). This transition led in the 1950's to the conversion of many of the small subsistence farms and livestock operations into orchards that required much less time to manage. Education, health care, and state and federal government jobs also became significant sources of employment during this period. The area also began to attract a growing number of artists and craftsmen. Newcomers gained acceptance from the community through volunteering in *acequia* commissions, schools and fire departments. According to local, anecdotal information about Dixon's history, a cold spell in January

1971 killed most of the orchards in the area. Many orchards were cut for firewood and the few remaining fruit trees were largely for home use or sales at local farmer's markets.

Local community members estimate that approximately 80% of inhabited or managed lands in the watershed are used for some type of agriculture, although this has shifted away from the chili, corn, and grains of the past (Environmental Health Consultants and NMED 2010). There are still fruit orchards in the Embudo valley, but they are much less abundant than in the past with only three big orchards left as of 2007, ranging from ten to twenty acres in size. Commercial grape cultivation has gained popularity in recent history with three wineries currently in operation.

Figure 3.5 (left). Contemporary head gate inlet of the Acequia de la Plaza, one of the first acequias of Dixon. **Figure 3.6 (right).** Close up view of water flowing from head gate into the acequia system.

3.2. Pollutant Accumulation and Discharge: Pollution Sources and Causes

<u>Summary and Introduction</u>

The research phase for this WBP (2013-2017) confirmed that the cause of water quality impairment concerning turbidity levels in the impaired reach of the Rio Embudo is sediment-laden runoff. In 2014, the planning team measured the total annual stream discharge and loading of suspended sediments flowing from the WBP study area and identified the likely source areas where land cover and terrain features encourage the generation of soil loss and sediment transport that significantly contribute to the water quality impairment within the Lower Embudo watershed. The WBP planning team analyzed the collected environmental data and the possible factors, biases or conditions that may influence the results. The following findings describe the outcomes of the data analysis process and what the findings mean for watershed-based planning.

The WBP research process used two methods for identifying the likely sediment and erosional sources and for quantifying their impact within the WBP study area:

METHOD 1: Geospatial Modeling – Analytical assessment of sediment and erosional sources and sediment transport, using remote sensing technology and spreadsheet modeling

METHOD 2: Field Sampling – Empirical data gathering based on direct, automated field sampling and indirect estimation methods

This combined approach has been shown to strengthen the understanding of key sediment transport processes, including their linkages beyond the channel reach, and address land and resource management factors, such as land cover and land use considerations (Gao 2008). The approach is clarified in Figure 3.7. More detailed methodological background information is included in Appendix 05.

Findings of Pollutant Sources, Source Areas and Causes

The 2014 Geospatial modeling and field research revealed that the water quality impairment of the Rio Embudo is driven by short, intensive, seasonal precipitation events that generate runoff principally originating from sparsely vegetated, steep hillslopes and collected by a network of ephemeral stream channels discharging into the Rio Embudo.

Remote Sensing and GIS-based terrain studies helped identify areas of highest erosion and sediment transport (Figure 3.27). Terrain observations and a STEPL modeling study further helped identify current and past land use practices that are most likely associated with the erosion and sediment transport features identified.

Modeling findings indicate that the greatest soil loss and sediment transportation occurs in the Foothill Woodlands and Shrublands and the North-Central New Mexico Valleys and Mesas ecosystems (Griffith et al. 2006), which constitute the woodlands and rangelands under management by BLM and the State Land Office in the Arroyo La Mina-Embudo Creek sub-watershed (HUC 130201010909). Additionally, the GIS analysis identified considerable potential soil loss and sediment transport for the northern portions of the Cañada de Ojo Sarco sub-watershed (HUC 130201010907) and the Cañada de Ojo Sarco-Embudo Creek sub-watershed (HUC 130201010908). The GIS modeling supports findings from the empirical measurements that demonstrated greater sediment production at the lower site (ARID1) when compared to the upstream site (ARID2). However, STEPL modeling results show the greatest sediment transport in the Cañada de Ojo Sarco sub-watershed.

The results from these assessments led to the following grouping of pollutant sources.

Primary (Major) Pollutant Sources:

- ***Woodland/rangeland management:*** This source includes many other sources listed below, such as natural sources, unpaved roads, off-road vehicle use, rangeland grazing, and arroyo erosion, and is by far the most important source area for sediment transport and pollutant loading in the Rio Embudo, accounting for more than 82% of the pollutant loading calculated through STEPL modeling (Table 3.4). This source is largely occurring on BLM lands and State Trust lands and some of the national forest lands west of Ojo Sarco and Las Trampas.

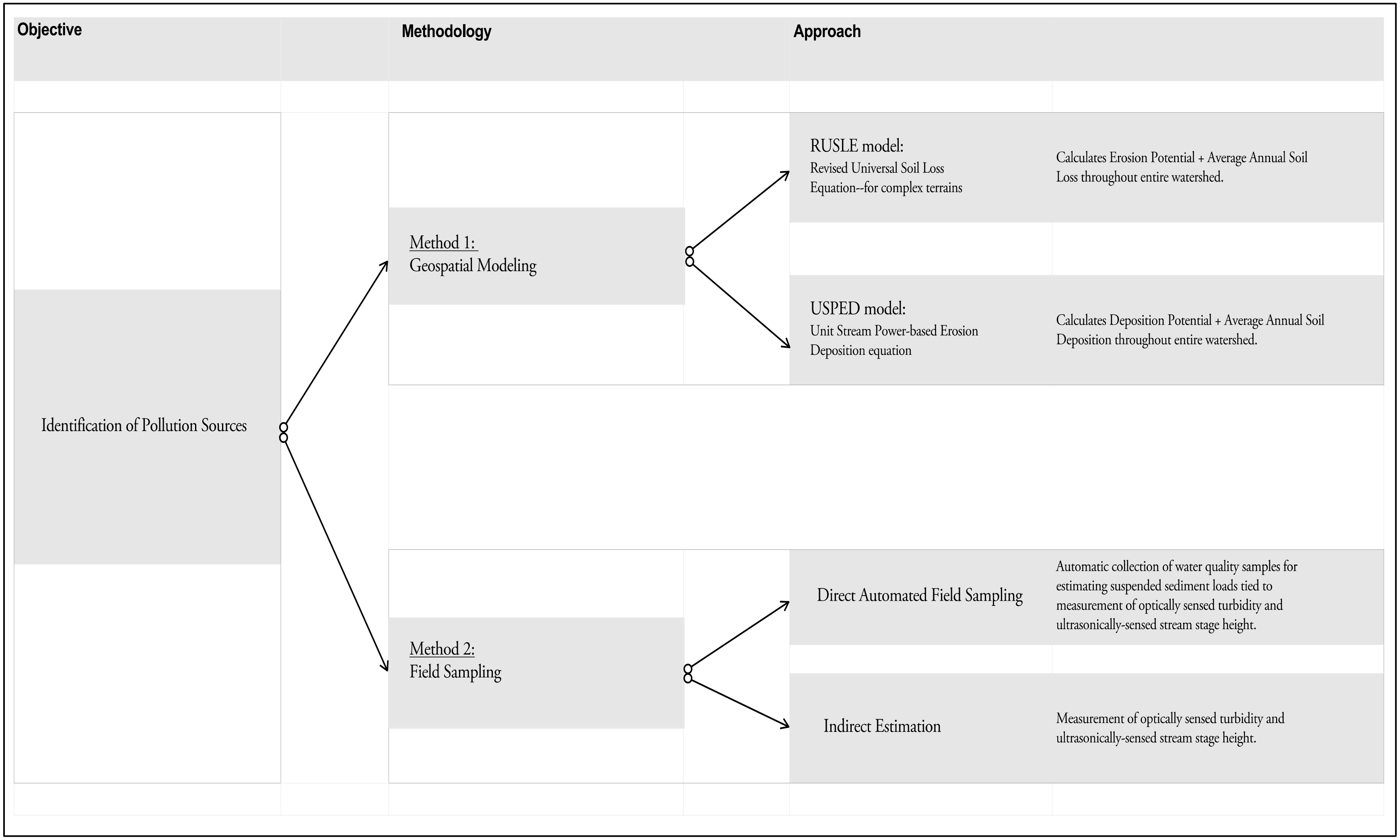

Figure 3.7. Diagram of Sediment Identification Methods

- ***Natural sources:*** As part of the woodland/rangeland source area, soil loss and sediment transport resulting from direct exposure of erodible soils to the energy of rain and gravity, combined with steep and long slopes, under conditions of poor vegetation cover constitutes one of the most important sources of sediment transport and sediment loadings. Natural sources include the cumulative effects of past land use and geophysical and ecological processes, such as drought, wildfire, browse, and mass wasting. WebSoil Survey review of the watershed area also indicates that many exposed ridges and plateaus with loamy soil components are very susceptible to soil loss due to wind erosion; wind erosion levels can reach up to 150 t/a/y on certain soil types in the area. Aeolian deposits are subsequently further transported downslope by surface runoff and adding to the turbidity load in the Rio Embudo (Environmental Health Consultants and NMED 2010).
- ***Historical land clearing and soil disturbance:*** Various cumulative anthropogenic causes, such as grazing, mining, and deliberate conversion of woodland to grassland occur mostly in woodland and rangeland source areas. They constitute a relatively small, but important pollutant source area.
- ***Loss of riparian habitat:*** Removal of natural riparian vegetation due to construction, vegetation removal, dumping of construction debris and other waste, off-road vehicle activity, wildfire, and natural causes constitute also a relatively small, but important pollutant source area.
- ***Site clearance:*** This is a sub-set of the previous two source, particularly in association with land development and redevelopment, waste dumping, preparation of fields, and removal of undesirable vegetation.
- ***Unpaved roads:*** Unimproved (dirt) roads constitute a rather unknown, but possible important source of sediment transport. Very little research data exist on this topic for this area. This source pertains especially to forests, woodlands, and rangelands, and in arroyos and other locations that lead to concentrated stormwater runoff on or along unpaved roads (Figures 3. 8 and 3.9).

Figures 3.8 (left) and 3.9 (right). Examples of the use of arroyo bottoms as dirt roads and driveways, which constitutes a serious cause and source of erosion and sediment transport.

- ***Two-track (rural) roads/off-road vehicle use:*** Included in various sources listed above, this is a small but important pollutant source, and includes the inadvertent creation of tracks, hollow roads, and associated highly erodible bare strips across sensitive rangeland soils (Figures 3.10 and 3.11).

Figures 3.10 (left) and 3.11 (right). Signs of the impacts of Off-Road Vehicles (ORVs) as a cause of land degradation, soil loss, and eventual sediment transport.

Secondary (Minor) Pollutant Sources:

- ***Rangeland grazing:*** This minor source specifically pertains to poorly managed grazing – mostly from historical grazing activities – across large acreages of rangeland on BLM, State Trust Lands, and national forest lands. Approximately 50% of the WBP study area is open to some form of permitted grazing. While the number of head of cattle per acre is relatively low, the lack of managed grazing involves the risk of foraging patterns that deplete the diversity of grass species, reduce the cover percentage of grasses and forbs, and expose more soil to erosive forces (Environmental Health Consultants and NMED 2010). Yet, the specific impact of rangeland grazing is difficult to establish among the various other stressors and pollutant sources.
- ***Streambank modification/destabilization:*** Streambanks have been modified throughout the watershed in association with the construction and maintenance of bridges, roads, irrigation systems, vegetation removal, dumping of waste materials, and stream meander patterns that have been altered due to sediment plumes from tributaries, woody debris piles, rock debris piles, tree planting or removal, and localized bank protection measures.
- ***Channelization:*** Parts of the Rio Embudo seem to have channelized in the past in relation to bridge and erosion infrastructure and flood control measures. Yet, the specific impact of channelization is difficult to establish among the various other stream modification processes that have taken place.

- ***Farming practices:*** Clearing of fields, tilling practices, poor maintenance of terracing and irrigation structures, and removal of boundary vegetation and water courses locally lead to soil loss, sediment transport and deposition, and renewed erosion in older sediment deposits on fields, orchards and pastures.
- ***Forest and woodland management practices:*** Lack of fire has led to the development of dense stands of woody biomass with impoverished ground cover vegetation. Because groundcover is more effective in retaining soil than canopy cover, the gradual decrease of vegetative ground cover exposes the soil to erosive forces across many thousands of acres of land across the watershed. STEPL modeling indicates that forest management alone (excluding woodlands) cumulatively accounts for 16% of the identified impairment (Table 3.4).
- ***Unknown sources:*** It is likely that there are several unknown sources of soil loss and sediment transport in the watershed associated with land use practices or a combination of land use and natural processes. It will require more field research to determine what other pollution sources occur in the watershed.

Indirect Pollutant Sources:

- ***Arroyo and streambank erosion:*** In association with the sources of soil loss listed above, rapid runoff and concentrated flows of stormwater and sediment have created many rills, gullies (arroyos) and steep, undermined, or otherwise eroding streambanks. The establishment of roads and tracks in arroyo bottoms has aggravated these conditions and led to accumulation of large amounts of loose and highly erodible soil debris along arroyos, roads, and streambanks. Arroyo and streambank erosion occurs mostly during high flows, and is, therefore, a sudden and flashy occurrence (Figures 3.12 through 3.15). STEPL modeling includes options for arroyo and streambank erosion estimates, but a lack of data on arroyo and streambank length and the frequency of erosive events leads to unsatisfactory STEPL modeling outcomes for arroyo and streambank erosion. This source of erosion is potentially much higher than estimated in the STEPL modeling, particularly for the Canada Aqua (Arroyo la Mina/Embudo Creek) sub-watershed, and especially during years with concentrated, high intensity precipitation events and high stream flow events.

<u>Data Gaps</u>

Despite detailed data collection in the phase-1 research activities for this WBP, several data gaps remain that have not been further addressed in phase-2 for WBP development. The Ecotone planning team believes that these data gaps are of such significance that they would skew the outcomes of this WBP Update or impede plan implementation. The description of the strategic planning and phasing aspect of this WBP Update in Chapters 4 and 5 indicate how data gaps could be addressed in future implementation phases once experience has been gathered with plan implementation.

The data gaps concern the following topics:

1. ***Weather data from other years than 2014 with associated runoff data for sub-watersheds*** that would provide more details about runoff incidences across the watershed and the frequency of runoff events in all arroyos
2. ***Specific turbidity data and calibrations for sediment loads originating from the Cañada de Ojo Sarco and Ojo Rio Trampas sub-watersheds***
3. ***Specific runoff and sediment load data from the Cañada de Ojo Sarco and Ojo Rio Trampas sub-watersheds*** that would allow for identification of the relative stream flow and sediment contributions from the upper watershed (above the WBP study area) to the stream reach in the WBP area
4. ***Specific, current land health conditions and suspended sediment loads from the Cañada de Ojo Sarco and Ojo Rio Trampas sub-watersheds*** to evaluate possible future project ideas for these areas.
5. ***Data on potential strategic treatment areas*** (***in the Cañada de Ojo Sarco and Ojo Rio Trampas sub-watersheds*** (e.g., areas with poor soil conditions, erosion sites, and potential areas where sediment retention would be feasible, esp. on the USFS Carson National Forest), in order to assess potential future treatment areas
6. ***Identification of appropriate management measures and the associated load reduction potential from these areas***, including prioritization of newly targeted areas by the CNF and cleared under NEPA regulations.
7. ***Detailed data on the total length of arroyos and their first order tributaries***, along with detailed data on arroyo bankfull dimension that help estimate flow characteristics and STEPL modeling
8. ***Detailed data on streambank length***, especially data on the length of unstable and eroding streambanks in order to estimate more precisely the ongoing streambank erosion levels for STEPL modeling
9. ***Quantitative RUSLE data*** for the GIS-based RUSLE and USPED modeling output
10. ***Research of the potential and anticipated amount of cumulative effects of sediment retention*** resulting from the combination of multiple management measures in treatment areas and over time across the WBP area.

It should be noted that much of the target areas associated with the data gaps are on USFS Carson National Forest (CNF) land. During the development of the WBP, the CNF was in the process of a Forest Plan Revision and CNF officials were largely unavailable to offer WBP feedback and address potential treatment planning aspects. The timeline for planning projects on CNF land would take 2 to 3 years, and the proposed work on data gaps for future activities on CNF land would be more effectively undertaken after completion of the Forest Plan Revision and at the start of the implementation of the WBP when funding becomes available.


Figures 3.12 (left) and 3.13 (right). Examples of the extent of erosion and sediment transport in arroyos, as shown here above and at the confluence of the Arroyo Lorenzo (arroyo #116) with the Rio Embudo.


Figures 3.14 (left) and 3.15 (right). Examples of stream bank erosion, undermining roads, driveways, riparian vegetation and power lines.

3.3. Geospatial Modeling

The description of geospatial modeling highlights the key factors leading to the accumulation of sediment and their transportation and discharge into the Rio Embudo and Rio Grande. The theory about sediment accumulation is built upon the Revised Universal Soil Loss Equation (RUSLE) and the theory of sediment transportation and discharge is built upon the Unit Stream Power-based Erosion Deposition equation (USPED). The geospatial modeling based on the RUSLE model and USPED model used a select set of geospatial factors that will be described below, followed by a description of the hydro-geological environment of the watershed in which these factors take shape.

The RUSLE model is typically expressed as:

$$Q = R * SL * K * C * P \qquad (1)$$

with the following factors:

R = rainfall intensity factor; described in the sub-sections about weather and climate trends

SL = slope length and steepness factor; described in the sub-section about geomorphology, soils and plant communities

C = vegetation cover factor; described in the subsection about geomorphology, soils and plant communities

K = soil erodibility factor; described also in the subsection about geomorphology, soils and plant communities

P = field practices factor; is considered 1 (constant) under non-improved terrain conditions. However, this factor comes into play when soil conservation measures are applied to the terrain. The P-factor will be explained and used in Chapter 4 in the discussion of management measures.

The WBP planning team largely used remotely sensed Geographic Information System (GIS) data analysis and mapping methods to conduct the geospatial modeling. Additionally, the team used the ***Spreadsheet Tool for Eliminating Pollutant Load(s) (STEPL)*** as a complementary alternate modeling approach. The combination of GIS and STEPL theoretically allows for a calibration of GIS output data with the soil loss volume and sediment transport estimates generated through the STEPL method.

In 2019, Ecotone reviewed an initial 2014 STEPL modeling exercise and adjusted it by using modified input data derived from updated research findings from the work in 2014-2015. The 2014 STEPL used default data that deviated considerably from the terrain specific data found in the WBP team's research at the time, leading to greatly inflated results.

Each STEPL model comprises one HUC area. The entire Lower Embudo WBP was modeled with STEPL for each of the three HUC areas. The updated 2019 STEPL model included the Cañada Aqua (Arroyo la Mina/Embudo Creek; HUC 130201010909) where the 2014-2015 geospatial modeling and empirical data results show the greatest soil loss results. Input data for the 2019 STEPL modeling were based on a modified rainfall intensity (R) factor that combines the default number for Taos County and Rio Arriba County, with a mean of 31.888. NOAA rainfall data found for the research period 2014-2015 were used to modify mean annual rainfall, using the identified 30-year mean for the ARID1 permanent monitoring station. Similarly, to match the STEPL data input formula, the 24-hour rainfall event frequency and the correction factor for the total annual mean rainfall were corrected, while the correction factor for the percentage of rain that generates runoff was kept at the default for New Mexico of 0.424.

The default RUSLE factors also were corrected based on data collected from 90 sampling points across 9 transects at two woodland restoration sites in the watershed between 2015 and 2017. The findings were averaged and generated a K-factor of 0.453 (up from 0.28) applied to woodlands and wildlands, while the default of 0.28 was maintained for pasture and cropland, and a modified Kf of 0.2 was chosen for forest land. K-factor variability in this landscape is described in detail in the section about soils below. Additionally, the averaged findings generated an LS-factor of 2.08 (up from 0.93) and a C-factor of 0.026 (down from 0.14). The latter is appropriate for the stoniness and the amount of duff on the ground in many places.

The ***USPED (Unit Stream Power-based Erosion Deposition)*** is "a simple model which predicts the spatial distribution of erosion and deposition rates for a steady state overland flow with uniform rainfall excess conditions for transport capacity limited case of erosion process" (Mitasova et al. 2016, Mitas and Mitasova 1998). The USPED model has been refined to be applied in particular for GIS-based sediment transport modeling. The essence of the model highlights the interplay between the magnitude of water flow change and both terrain curvatures to determine whether erosion or deposition will occur. The model typically assumes that sediment flow rate is at the sediment transport capacity. No experimental work has been performed to develop parameters needed for USPED (Mitasova et al. 2016, Mitas and Mitasova 1998). Therefore, scientists typically use RUSLE parameters to incorporate the impact of soil and cover and obtain at least a relative estimate of net erosion and deposition.

It is assumed that we can estimate sediment flow at sediment transport capacity (T) as:

$$T = R\ K\ C\ P\ A^m\ (\sin b)^n \qquad (2)$$

The variables R, K, C, and P are the same as in the RUSLE equation. Note that the RUSLE variable LS is expressed in USPED as $A^m (\sin b)^n$. Additionally, we define:

T = sediment transport capacity

A = upslope contributing area; described in the section about Geology and Surface-hydrology, which describes the sizes of all contributing sub-watersheds in the Lower Embudo watershed

m = constant (typically m=1.6, for prevailing rill erosion, or m=1, for prevailing sheet erosion)

n = constant (typically n=1.3 for prevailing rill erosion, or n=1, for prevailing sheet erosion)

The WBP team produced two different GIS map outputs with different standard deviation stretches which illustrate how a change in emphasis in the application of different erosion factors in the RUSLE / USPED models identifies different erosion locations in the drainage systems (Figure 3.27).

Geology and Surface Hydrology

The Lower Rio Embudo watershed stretches over a valley length of 18 miles between its highest elevation of 13,100 feet at the North Truchas Peak to the Rio Embudo's confluence with the Rio Grande at 6,000 feet (Figure 3.14). The Lower Rio Embudo watershed is the most western, lower part of the Rio Embudo-Rio Pueblo watershed which encompasses approximately 195,199 acres, having its source farther east into the Sangre de Cristo Mountains. The Lower Embudo watershed includes three 12-digit sub-watersheds: Cañada de Ojo Sarco (HUC 130201010907), much of the Cañada de Ojo Sarco/Embudo

Creek (HUC 130201010908), and most of Cañada Aqua (Arroyo la Mina/Embudo Creek (HUC 130201010909). Table 3.2 lists the 13 largest sub-watersheds and their drainage areas.

The valleys of the Lower Embudo watershed are cut into rocks formed from both volcanic and sedimentary deposits dating back approximately 1.8 billion and 3 million years ago (Environmental Health Consultants and NMED 2010). Over time, ancestral versions of the watershed's streams and rivers carved the valleys and other landforms that are present today (Embudo Valley Library 2019) (Figures 3.24 through 3.26). In the Dixon valley, these rocks belong to the Santa Fe group, comprised of basalts, ash, and sediment from the late Miocene to early Pliocene (Environmental Health Consultants and NMED 2010). The top strata near the headwaters of the watershed are sedimentary beds of shales, sandstones and limestones that were deposited by east-flowing rivers some 300 million years ago (Environmental Health Consultants and NMED 2010). Near the confluence of the Rio Embudo and Rio Grande a badlands landscape is the prominent topographic feature, characterized by claylike material with low permeability, little or no vegetation, and deeply incised drainage systems (Environmental Health Consultants and NMED 2010). Along the last few miles of the Rio Embudo upstream of the confluence with the Rio Grande, the river passes through a narrow box canyon. This narrowed outflow pattern to the confluence constricts the drainage basin like a funnel, which led to the stream's name: *"embudo"* is funnel in Spanish.

Table 3.2. Summary of the largest 13 sub-watersheds in comparison with all other sub-watersheds.

ORDER by Area (km2)	**KEY** (Hydro_ID)	**NAME:** Sub-watershed / Arroyo	**AREA**: Subwatershed (km2)	**AREA**: Subwatershed (acres)
1	119	Rio de las Trampas	104.5	25,822.5
2	118	Cañada del Oso	55.9	13,813.2
3	33	Arroyo del Plomo	29.4	7,264.9
4	113	Arroyo la Mina	7.0	1,729.7
5	75	Arroyo 75	5.6	1,383.8
6	116	Cañada de Lorenzo	5.0	1,235.5
7	112	Arroyo Pino	4.2	1,037.8
8	111	Arroyo 111	3.2	790.7
9	117	Cañada del Montecito	3.0	741.3
10	115	Arroyo 115	2.7	667.2
11	114	Cañada de los Pinos Reales	2.2	543.6
12	70	Arroyo 70	1.2	296.5
13	102	Arroyo 102	1.2	296.5
14 - 118	-	Sub-watersheds < 1 km²	19.5	4,818.6
		All sub-watersheds	244.1	60,441.8*

* The total watershed area is 60,362 acres, but conversion and rounding generated a slightly higher total sum.

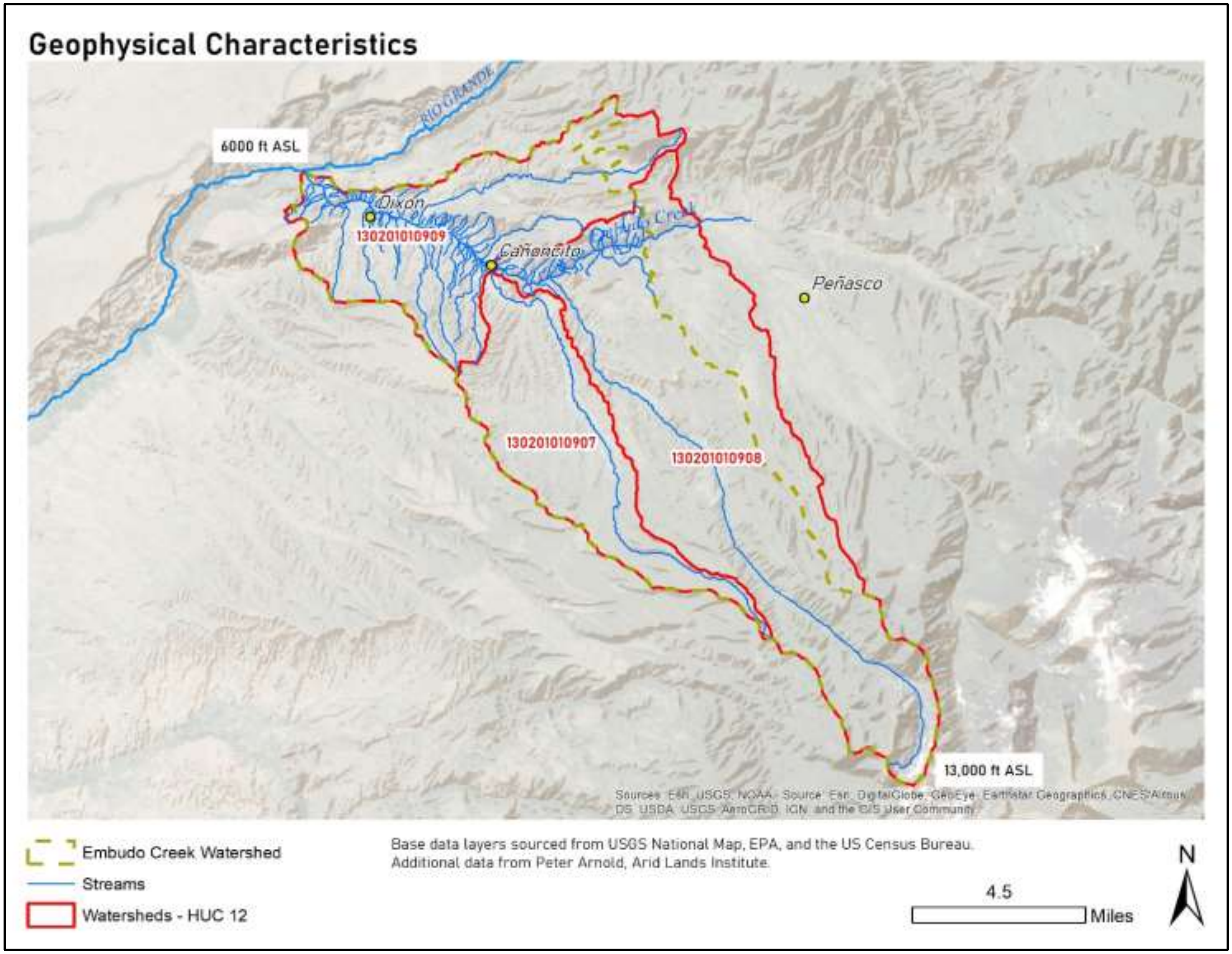

Figure 3.14. Map of geophysical characteristics, including the stream network and sub-watersheds, of the Lower Embudo watershed.

Drainage Networks and Sub-watershed Delineation

A GIS-based delineation of stream networks and sub-watersheds within the HUC-12 boundaries aided the identification of 118 sub-watersheds with first and second order drainages within the WBP study area (Figures 3.14 – 3.20). This approach helped identify the stream channel network and resulting drainage pattern of all ephemeral and perennial stream channels discharging into the Rio Embudo. Deriving the stream network required the use of the classical Horton stream ordering method (1945) with revisions by Strahler (1952). Nearly all of the stream channels draining into the Rio Embudo (within the WBP study area) and identified by this method are ephemeral in nature – seasonally active with relatively short flow periods. The 118 sub-watershed delineations define the foundational planning boundaries in the watershed which direct many of the WBP analyses and recommendations.

The range between the smallest sub-watershed drainage area (0.027 km^2 or 6.67 acres) and the largest (104.5 km^2 or 25,822.51 acres) is nearly four orders of magnitude in difference. Table 3.2 and Figures 3.16-3.19 show that only 13 sub-watersheds out of 118 have drainage areas larger than 1.0 km^2 (247.1 acres) and account for nearly 92% of the entire project study area's total drainage area. The remaining 105 sub-watersheds are less than 1.0 km^2 and provide only 8% of the WBP study area's drainage area (see Appendix 02: Stream Networks) for a comprehensive suite of stream network metrics. Many of these small (<1.0 km^2) sub-watersheds are likely to exhibit "flashy" hydrologic responses during precipitation events – runoff volumes increasing rapidly within a short duration of time – and are located within the steep walls of the Embudo Canyon as well as the hillslope areas within Montecito, Dixon, and Embudo.

Weather Impacts

The recording station at Alcalde, NM, represents the nearest, geographically similar, federally registered, long-term weather monitoring station located downstream along the Rio Grande. At this site, NOAA's 30-year observed precipitation normals have been compiled from 1980-2010, recording normal annual precipitation of 11.68 inches.

Observed precipitation was measured throughout 2014 at each of the two permanent stream monitoring sites for the project – ARID1 and ARID2 (Figure 3.15). The 2014 annual precipitation measured at ARID1 was 11.63 inches, and at ARID2 it was 10.77 inches. For a closer comparison of both sites, 30-year observed NOAA Precipitation Normals and 30-year modeled PRISM[2] Precipitation Normals data were used to estimate the 30-year (1980-2010) and long-term (1895-2015) precipitation at these locations. At ARID1, the 30-year PRISM Precipitation Normal was 12.72 inches annually, and long-term was 12.58 inches annually. At ARID2, 30-year PRISM Precipitation Normal was 13.78 and the long-term normal was 13.38 annual inches of rainfall. We will use the 30-year PRISM data in this WBP.

[2] PRISM datasets are publically available and could be used by GIS analyst to further describe precipitation trends (i.e. historical seasonal trends in precip and variability) and other climate trends.

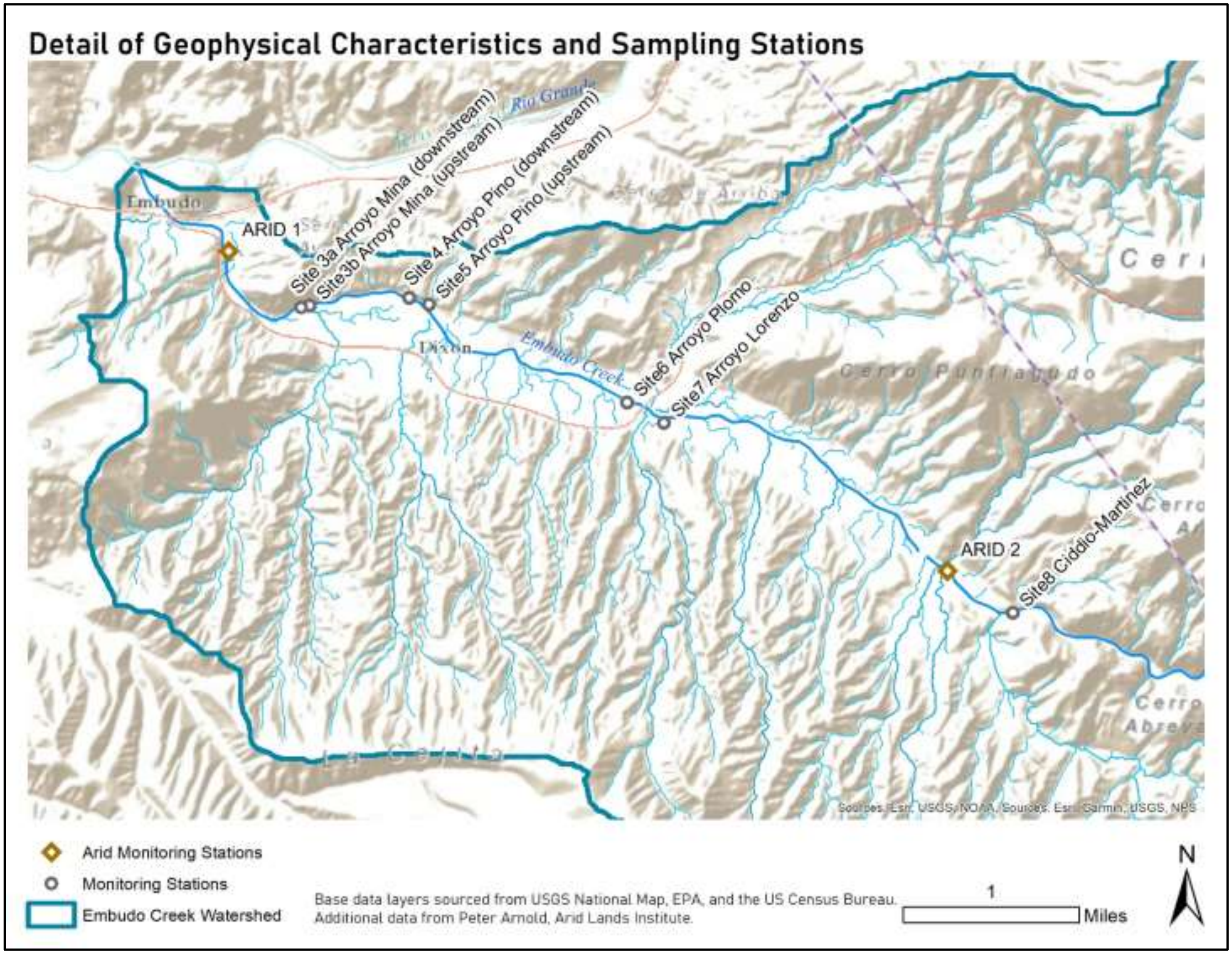

Figure 3.15. Detail of the northwestern part of the Lower Embudo watershed with the tributaries and locations of sampling stations along the Rio Embudo.

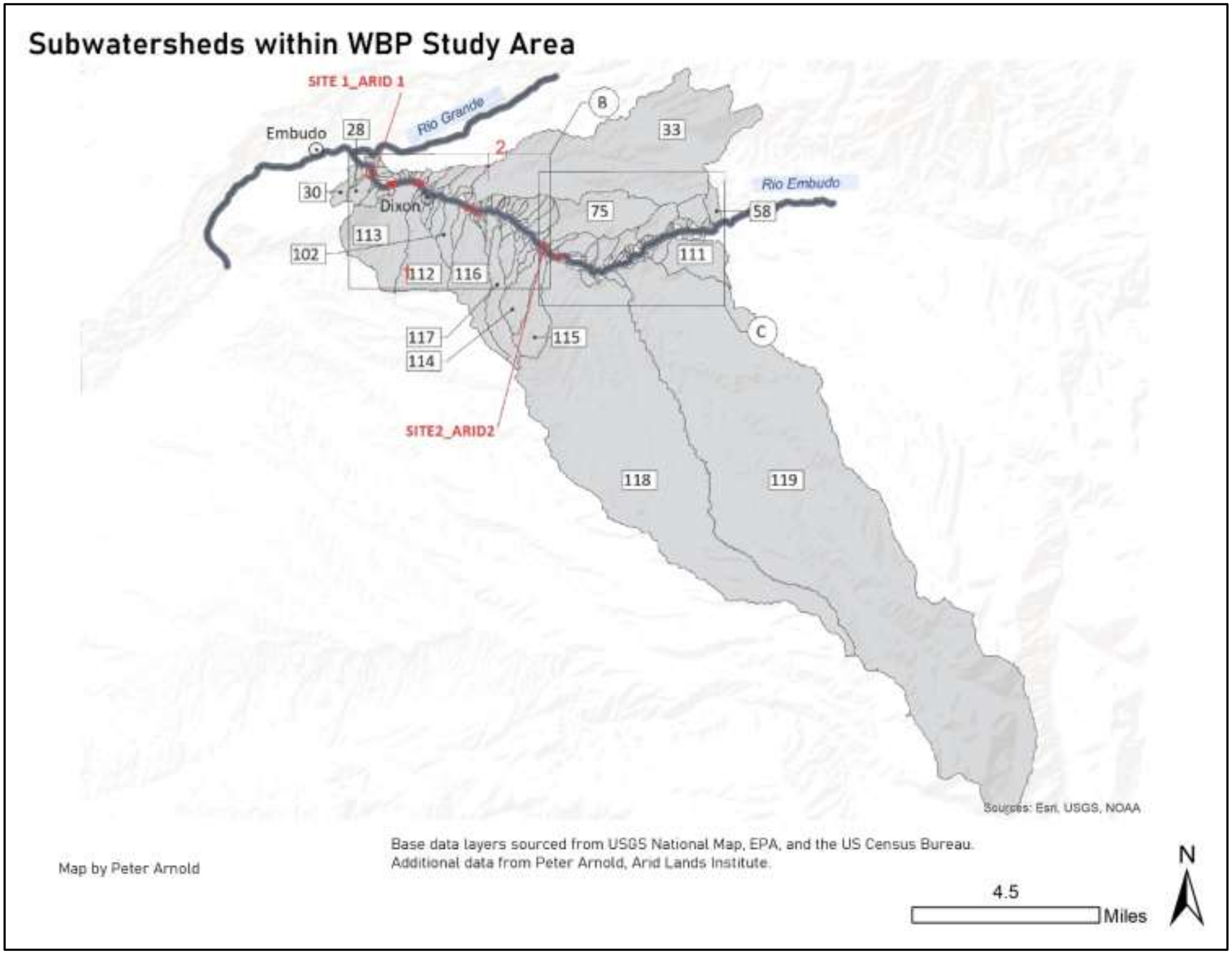

Figure 3.16. Map of sub-watersheds within the WBP study area. Numbers refer to the key for sub-watersheds.

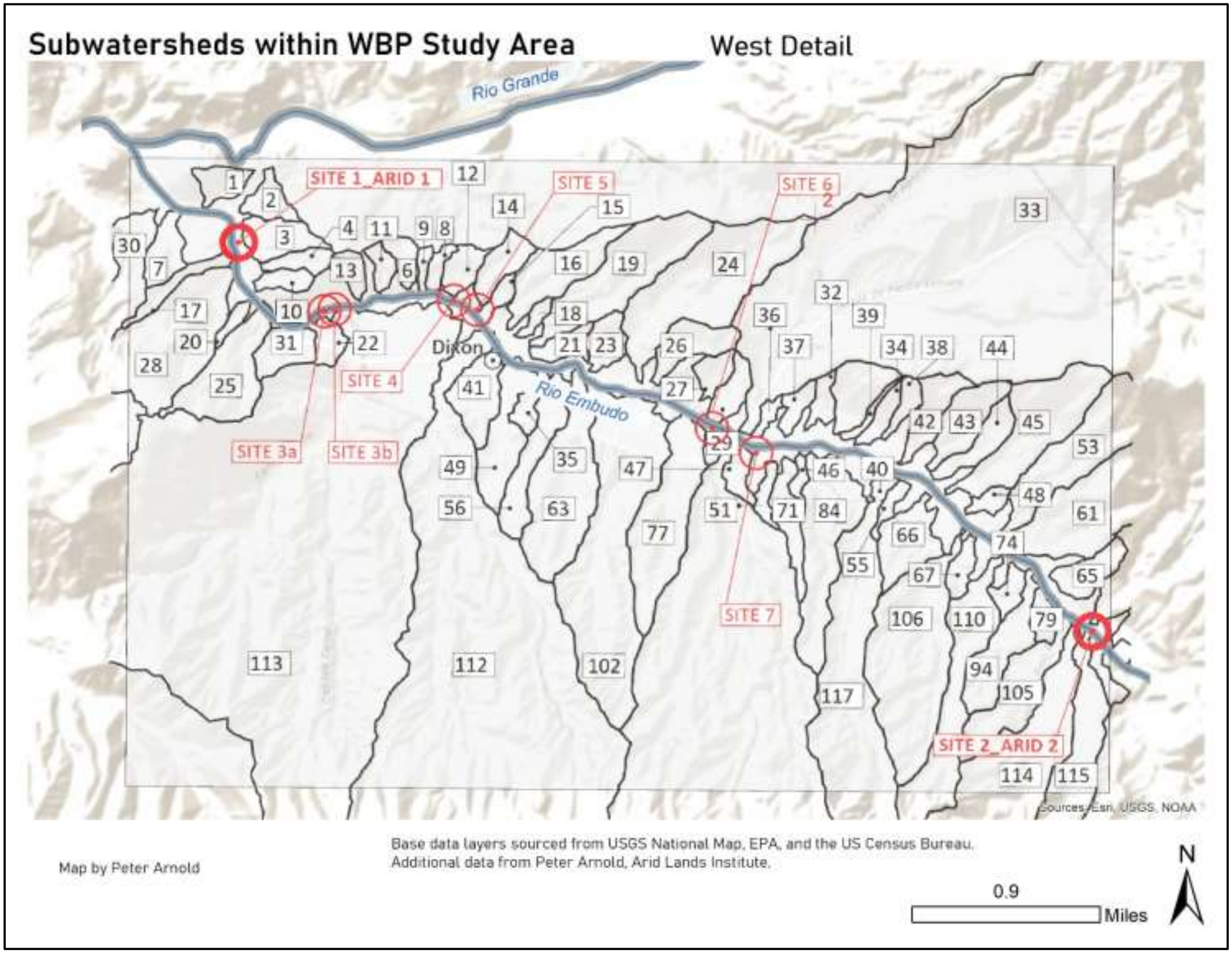

Figure 3.17. Map diagram of small sub-watersheds within the WBP study area (Area B in Figure 3.16).

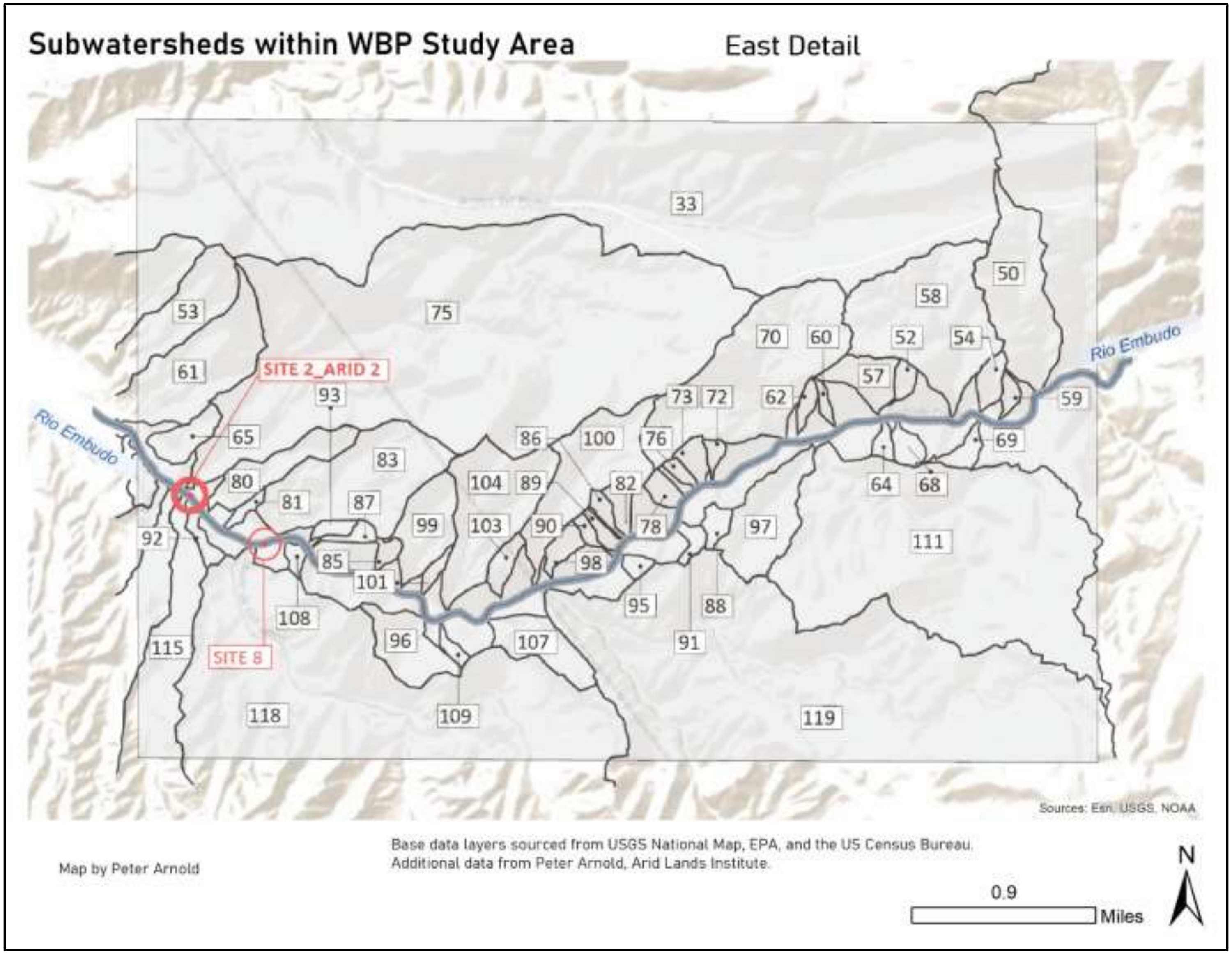

Figure 3.18. Map diagram of small sub-watersheds within the WBP study area (Area C in Figure 3.16).

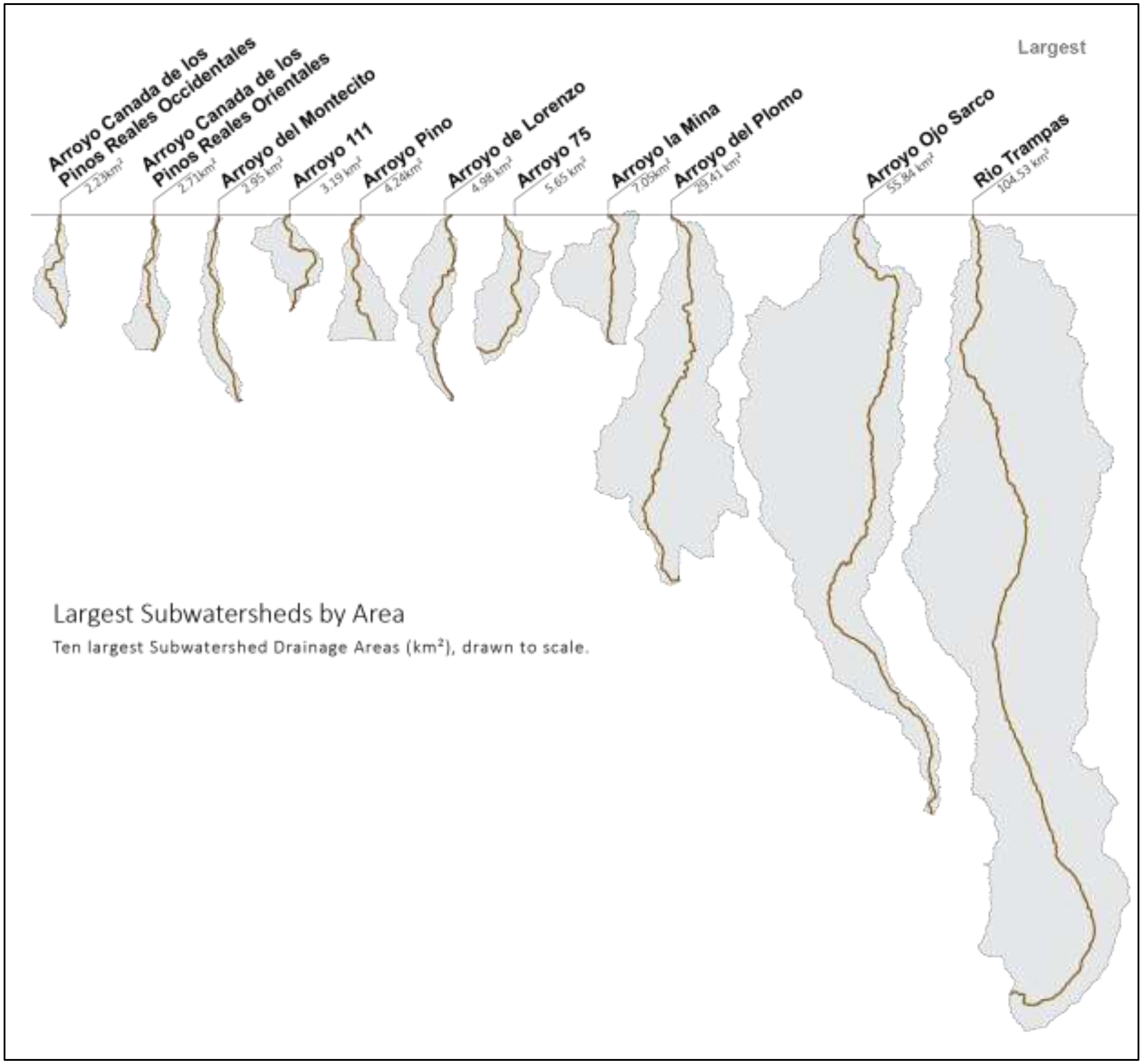

Figure 3.19. Diagram of the eleven largest sub-watersheds by area (km²) within the WBP study area.

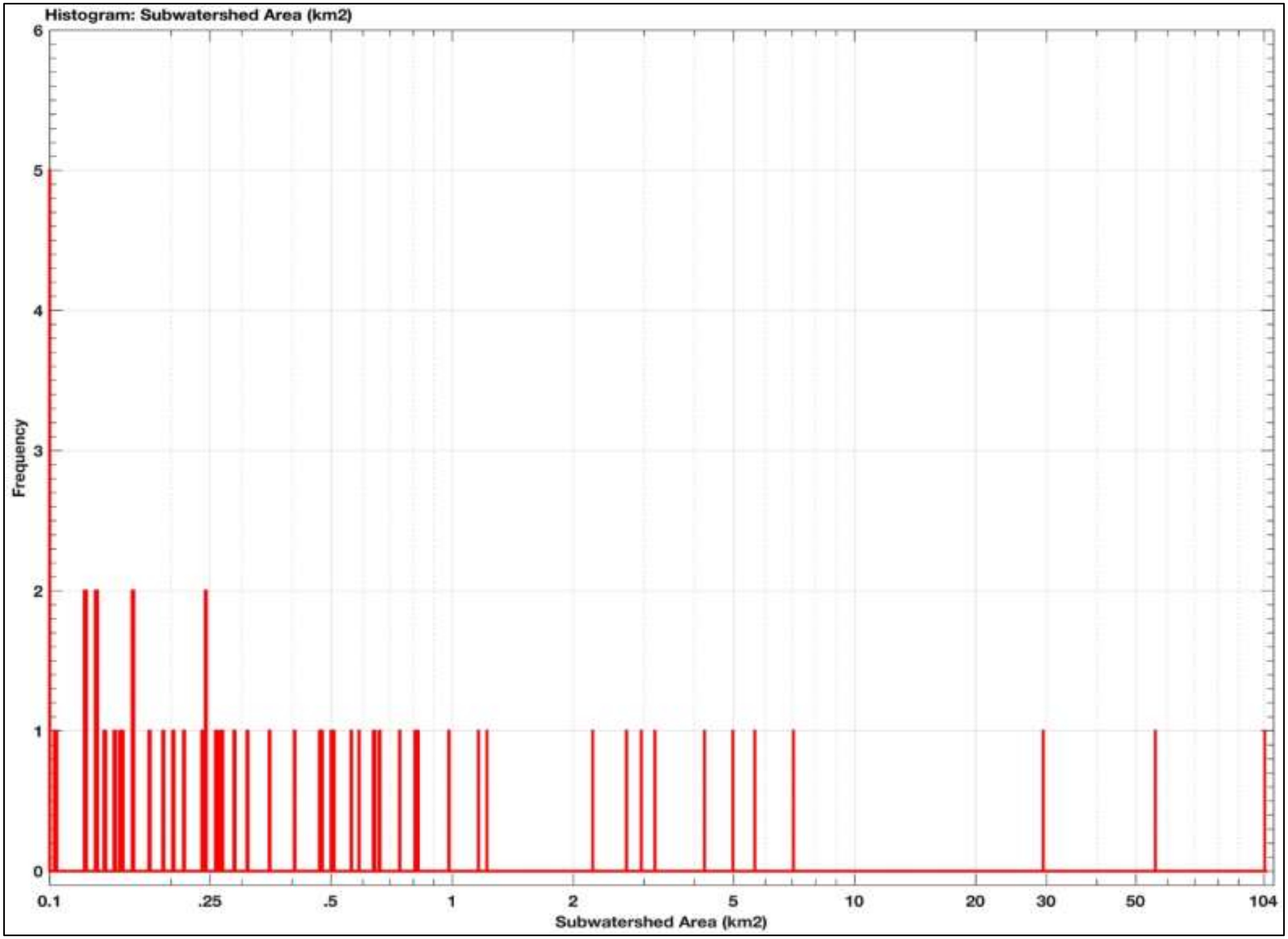

Figure 3.20. Histogram of the frequency in number of sub-watersheds by area (km²) within the WBP study area.

Comparison of the measured rainfall with the averaged modeling results for long-term precipitation shows that the 2014 measured precipitation at both ARID1 and ARID2 remained below the annual long-term averages, at 90% of averaged normals at ARID1 and 79% of averaged normals at ARID2. Precipitation was disproportionally larger than normal at ARID1 than at ARID2. This difference was also observed in significantly higher runoff and measured suspended sediment loads at ARID1 than at ARID2. For both monitoring sites, July was the month of highest accumulated precipitation. However, the monthly percentage of July's annual contribution was not consistent between both stations. At ARID1, July's precipitation accounted for 36% of the yearly total, while at ARID2 precipitation for the same time period accounted only for 20% of yearly total.

Seasonally, the summer monsoon period (July – September) delivered the majority of observed precipitation at both stations, but the impact of the summer monsoon's seasonal percentage differed substantially between stations. At ARID1 the summer monsoon period accounted for 55% of total yearly precipitation, while at ARID2 it accounted for only 39% of total annual accumulation (Figure 3.21).

Monthly precipitation levels at both sites, when analyzed against long-term 30-year normals, displayed similar patterns of extreme variability: either excessive or deep declines from long-term normals. For example, both sites within the winter season saw extreme variation: significantly higher observed precipitation levels for December 2014 (171% of normal @ ARID1 and 195% of normal @ ARID2), while January and February 2014 recorded substantial decreases in observed precipitation from long-term normals (0.01% of normal at both stations for January, 23% of normal for ARID1 in February, and 17% of normal for ARID2 in February) (Figure 3.22). Additionally, the precipitation values for the Summer Monsoon season were also in wide variation to long-term patterns: July saw dramatic increases at both sites (254% of normal at ARID1, 120% of normal at ARID2), and decreases for both August and September's normal values with greater variation occurring at ARID2. In summary, both sites exhibited wide variations in monthly precipitation as compared to anticipated precipitation values from long-term and 30-year trends.

Furthermore, the data indicate that in 2014 there were more storm events of higher rainfall intensity at ARID1 than at ARID2. However, when both sites received coincident rainfall greater than 0.25 inch/24-hours, they received nearly the same rainfall intensity, with the obvious exception of the major storm event of 08/01/2014. This is significant because generalized rainfall models (WMO 2009) predict the impact of higher elevation as one of the critical drivers of precipitation: one would expect to see (*i*) the site ARID2 with higher total annual rainfall accumulation and (*ii*) more rainfall intensity per storm event occurring at ARID2 than ARID1. However, during 2014 that was not observed. This precipitation pattern impacted the observed stream stage, discharge, and in-stream turbidity values particularly in the monsoon-driven precipitation season, producing more measured sediment flux at the lower monitoring station, ARID1, than observed from ARID2.

It is important to note that a period of high-intensity storm events during the period of July 11th – 15th as well as on August 1st, 2014 highlight a principle vulnerability of the Lower Embudo watershed: concentrated rainfall occurring directly over areas where soil erosion is predicted to be particularly acute will produce significant erosional runoff and high suspended sediment loads within the lower reaches of the Rio Embudo. NOAA Multi-Resolution/Multi-Sensor Radar imagery illustrate this for the August 1st, 2014 event (Figure 3.23).

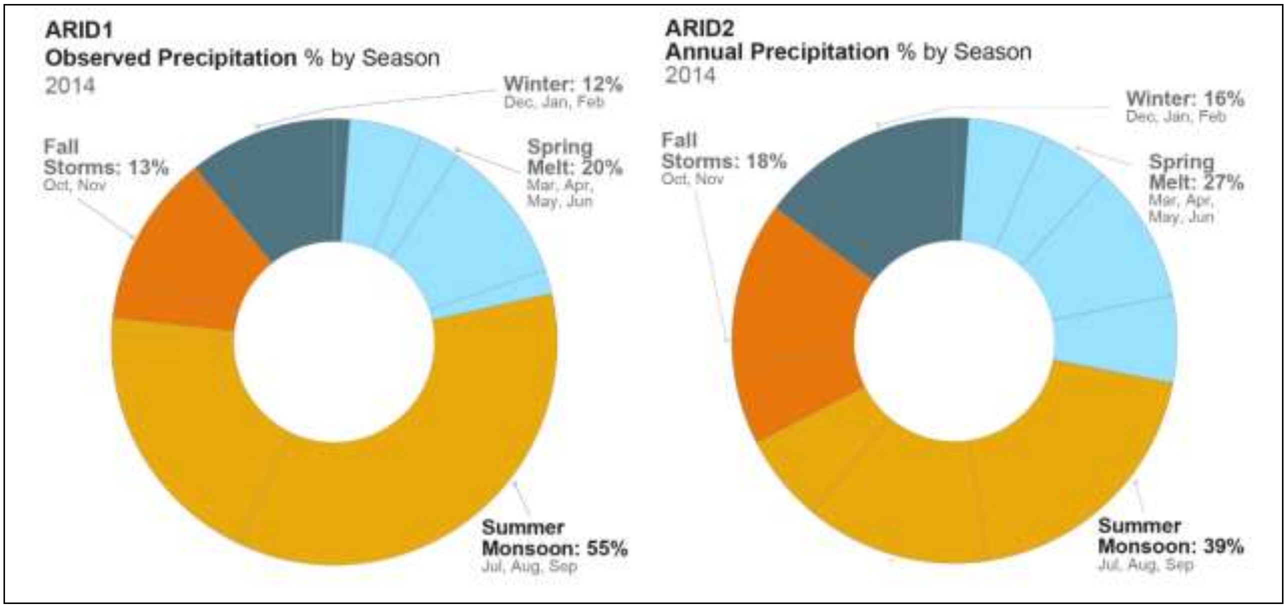

Figure 3.21. 2014 Observed Precipitation by Percentage by Season ARID1 and ARID2.

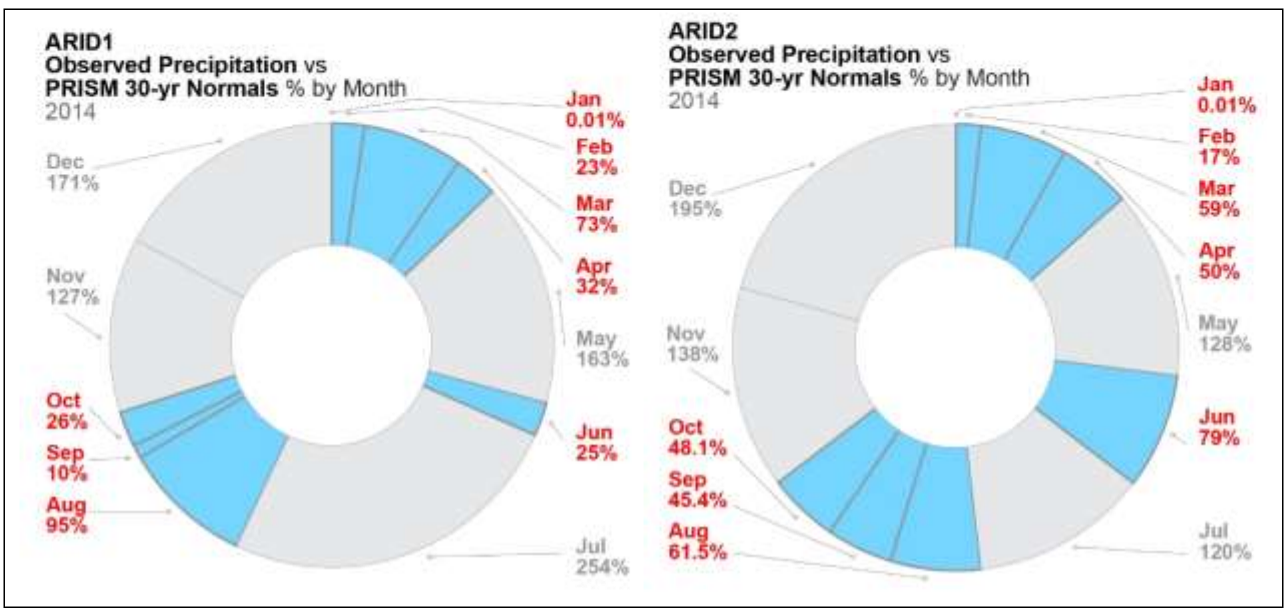

Figure 3.22. Observed Precipitation vs Long-term Normals, Percentage Difference [deficit in red] by Month at ARID1 and ARID2.

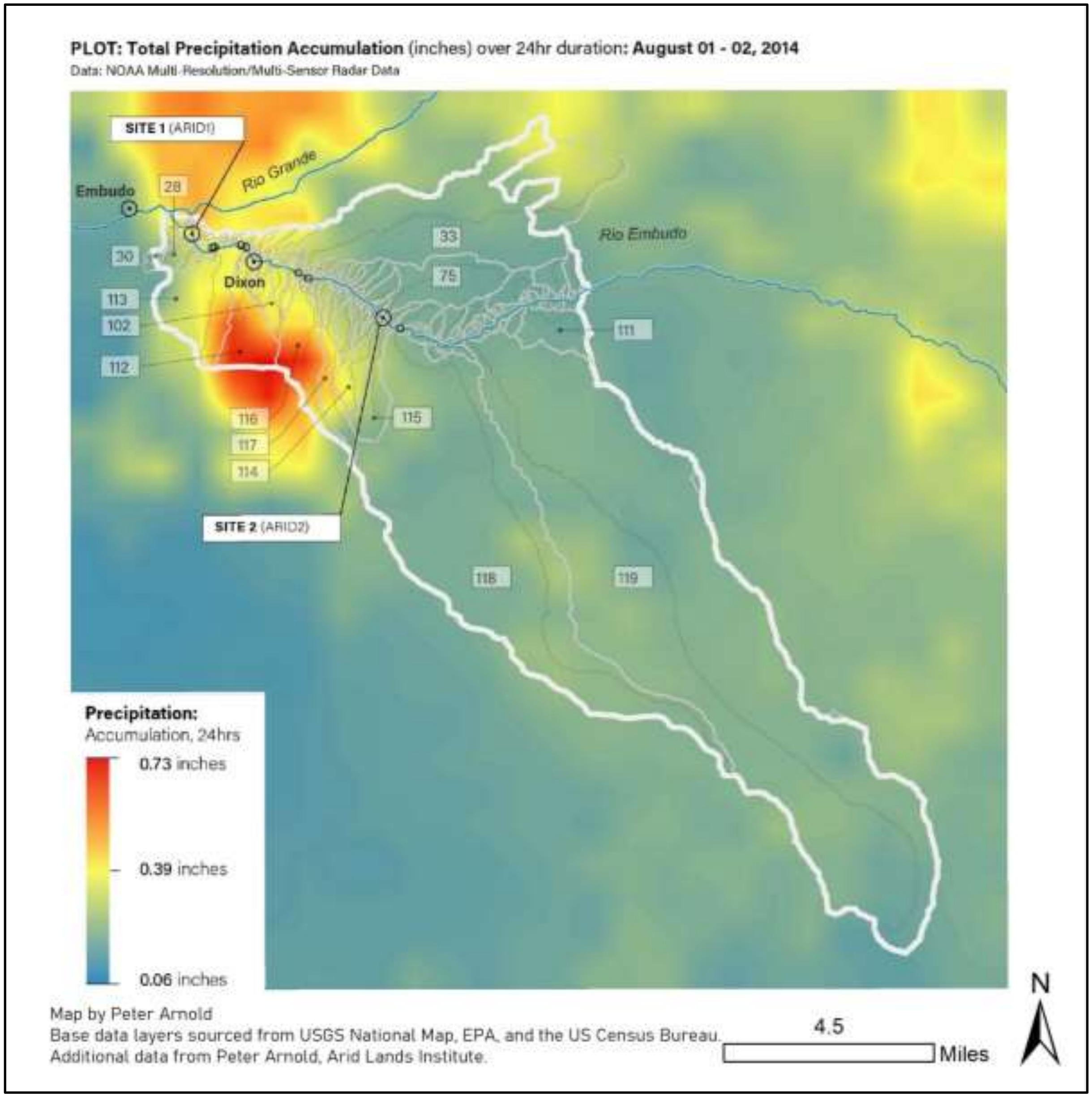

Figure 3.23. Map of watershed area with indication of the location of a high intensity storm event on August 1, 2014 over the northwestern part of the watershed (Arroyo la Mina and Arroyo Pino area). ARID1 recorded 1.09 inches of rainfall in a 1-hour increment of time and a resulting stage height in the stream of 4.97 feet. ARID2 measured only 0.56 inches of rainfall and a stage height of 2.95 feet.

To place the observed precipitation levels in context, we cite the probable maximum precipitation (PMP) generated from both a localized storm event as well as from larger regional-scale events. These theoretical limits describe, based on historical maximum rainfall intensities, the greatest depth of precipitation of a given duration that is physically possible over a given size storm area at a particular location at a certain time of the year (NOAA 2011). It is important to note that values for probable maximum precipitation well exceed the 1000-year storm frequency estimates. The PMP values cited are highly regionally specific and were developed and derived in response to the unique orographic and complex topological relationships of landforms between the Continental Divide and the 103rd Meridian.

Climate Impacts and Trends

After 2000, an increasing number of studies indicate that temperatures have been rising steadily across the Southwest (Melillo et al. 2014, Robles and Enquist 2010, Williams et al. 2010). By 2006, temperature increases after 1950 ranged between 1.4° and 1.6° F (Robles and Enquist 2010), and are likely to increase 2.4° to 2.6° F by 2039 (NASA 2019). According to a 2014 report (Melillo et al. 2014), increased heat, drought, and insect outbreaks, all linked to climate change, have increased wildfires across the Southwest. Impacts to people include declining water supplies and increased risks of flooding, wildfire, and public health impacts.

The impacts of a changing climate have led to ecological changes in 40% of Southwestern habitats, including changes in the timing of species events, increases in wildfire activity, widespread insect infestations and forest tree mortality (Robles and Enquist 2010). Winter warming due to climate change has exacerbated bark beetle outbreaks and an increase of burnt forest lands caused by wildfire throughout the region (Robles and Enquist 2010, Melillo et al. 2014, Williams et al. 2010).

While total precipitation changes are uncertain and may not change dramatically, the available water for plants is predicted to decline due to increased evapotranspiration losses and more concentrated stormwater runoff events. A TNC study reviewing climate change in the Southwest between 1951 and 2006 shows that these climate trends all apply to the subalpine forests and piñon-juniper (PJ) woodlands of the Lower Embudo watershed (Robles and Enquist 2010).

A USDA Forest Service study clarifies how ecological changes in ponderosa pine and mixed-conifer forest in the Southwest have caused shifts in forest composition (Reynolds et al. 2013). The forest has gradually changed toward a greater homogeneity in age and size classes. Forest structure has shifted toward greater densities with tree encroachment in meadows and beneath large trees. Additionally, many forests have also changed in disturbance regimes toward less frequent but much more intense wildfires and more frequent and much larger scale insect outbreaks (Reynolds et al. 2013).

As a result of drought stress, increased wildfire incidence, and more wide-spread bark beetle outbreaks caused by the gradual warming and drying climate, Williams et al. (2010) predict higher mortality of piñon pine, ponderosa pine, and Douglas-fir trees across the Southwest. The publication states that for all three tree species, "vulnerability to high mortality rates due to fire or drought-induced die-off is likely greatest in ecotones and dense stands where fuel build-up is high" (Williams et al. 2010). They caution, however, against taking these observations as a general impetus to start thinning out forest stands.

Instead, they advise to follow an approach of site-specific assessments and a learning-oriented, gradual treatment implementation with careful monitoring and evaluation of results.

Reynolds et al. (2013) caution that climate change may lead to a change that would increase the area covered by ponderosa pine and shrub forest and separately piñon-juniper savannah, which represent warmer and drier forest types. As climate change progresses the ponderosa pine with PJ understory type would then increasingly be found only at the higher elevations and north facing slopes (Reynolds et al 2013). Floyd, Hanna, and Romme (2004) observed that the ecological shifts in forest and woodland ecosystems that have been observed in the last few decades are generally not due to fire suppression or other direct human intervention. They concluded that the changes result from natural ecological responses to climatic variability.

Floyd and Romme (2012) point out that it is important to distinguish different PJ ecologies with different fire frequencies and levels of fire severity. Their research also clarifies that fire frequencies in PJ ecologies are different from those commonly identified in ponderosa pine forests. Fire frequencies in dense, persistent PJ woodlands without a grass component tend to be in periods of 400 years or more (Floyd and Romme 2012, Baker and Shinneman 2004). "Nearly all observed fires since EuroAmerican settlement in these woodlands were high-severity fires" (Baker and Shinneman 2004). Fire frequencies in PJ savannahs appear to have shorter fire frequencies. However, Baker and Shinneman (2004) and NMFWRI (2007) conclude that there are no reliable estimates of mean fire intervals for low-severity surface fires in these woodlands because of methodological problems and lack of reliable data. Their research also indicates that spreading, low-severity surface fires in PJ ecologies are likely not common (Baker and Shinneman 2004). They also point out that "fires can kill small trees in true savannas and grasslands, helping to maintain a low tree density, but that in most PJ woodlands low-severity surface fires do not consistently lower tree density and may become high-severity fires" (Baker and Shinneman 2004).

Scientific research as well as anecdotal observations from forestry operators indicate that treatments in PJ woodland and savannah ecosystems leading to reduced stem densities could lead to increased die back and reduced vitality in remaining trees. A study by Morillas et al (2017) found that counter to the expected result, induced tree mortality led to a decrease in both soil volumetric water content and sap flow rates in the remaining trees in comparison with an untreated site. Drought stress seems to exacerbate this result for the remaining trees, suggesting that piñon mortality may trigger feedback mechanisms that leave treated PJ woodlands drier relative to undisturbed sites and potentially more vulnerable to drought (Morillas et al 2017). Recent research in forest soil microbiology concerning relationships between mycorrhizal and microbial life and tree clumps seems to suggest that impacts of individual tree removal lead to die off of parts of the mycorrhizal networks between trees, leaving the remaining trees with reduced underground capabilities of exchanging water and essential aminoacids for alleviating stresses on individual tree, which is of special importance in times of drought and insect attacks (Phillips 2017, Hart et al. 2018).

If the climate scenarios for the Southwest play out, it is to be expected that in the course of the 21st century biodiversity of the Lower Embudo watershed's ecosystems will decline sharply. Additionally, increased incidents of wildfire and bark beetle outbreaks may further degrade the watershed ecology while natural regeneration opportunities from the outside decline. Other trends will likely include changes in the timing of species events, such as nesting and pollination (Robles and Enquist 2010). Downward trends in surface water shortages and plant species dependent on animal pollinators would eventually have dramatic impacts for insects in the area, cascading in the further collapse of the plant communities, and contributing to further desertification of great parts of the lower elevation watershed.

As a case in point, mortality in PJ stands in central New Mexico and the Southwest after 2000 have already led to a sharp, landscape-wide decline in the number of piñon pine trees and in the diversity and number of bird species that depend on this tree species (Faira et al. 2018, Coop and Magee 2016). The studies suggest that ongoing effects of climate, as well as proposed thinning operations in PJ stands, may further reduce bird species abundance and richness in these ecosystems

Die-off due to drought stress, fire and beetle impacts may lead to more homogeneous species, age, and genetic structure of forests and woodlands. This in turn will increase risks of sudden and large-scale beetle outbreaks (Raffa et al. 2008). Therefore, maintaining forest heterogeneity and reducing stressors in the forest is critical toward forest resilience in response to climate change impacts (Raffa et al. 2008). Dense, stressed stands in the lower elevation, transitional forests (ecotones) – for example in PJ woodlands and ponderosa pine stands – are potentially effective targets for management as they may buffer fire impacts on the upslope forests (Conver at al. 2018, Williams et al. 2010). Treatments at these lower elevations will thus help maintain forest resilience to wildfire for the entire landscape (Conver at al. 2018) and reduce mortality during climate induced species composition conversions as suggested by Reynolds et al. (2013).

There seems to be growing consensus among forest scientists and biologists that thinning in PJ ecologies is only advisable in select situations and must be conducted with great caution and with careful consideration of the impacts on the desired ecosystem (NMFWRI 2007). Most authors suggest that site-specific research and monitoring is needed to arrive at effective treatment prescriptions.

Floyd, Hanna, and Romme (2004) caution that their findings did not provide any ecological justification for aggressive management activities such as mechanical fuel reduction or prescribed burning, except in the immediate vicinity of vulnerable cultural resources. In 2012, Floyd and Romme, specified their advice for when thinning or mastication treatments would be advisable in PJ ecologies, depending on forest management goals and specific risk factors. Beyond maintenance thinning or mastication, such as for wildfire risk reduction and for cultural resource protection, they do not recommend any actions toward ecosystem restoration, except when PJ ecologies have been severely burnt or when noxious weeds, such as cheat grass, have encroached in these stands.

The trend toward ecosystem degradation and collapse, combined with increased unpredictability and intensity of rainstorms, increases the probability of years with increased erosion rates and greater sediment flux in the lower elevation areas of the watershed. The findings of the WBP study period in 2014 are a useful indicator for the magnitude of sediment emissions possible as a result of currently predicted climate trends.

Geomorphology, Soils, & Plant Communities

In 2019, as part of additional background research for geo-spatial modeling the project team produced a summary WebSoil Survey compilation for five selected portions of the Lower Embudo watershed. Detailed findings and custom WebSoil Survey reports for these sample areas are included in Appendix 3. These findings include details about the geomorphology, soil types, detailed soil conditions, soil erodibility, vegetation cover and plant communities across the landscape.

The WebSoil Survey compilation shows the great variability in soil types, terrain steepness, and sparse vegetation types across the WBP planning area (Figures 3.24 through 3.26). A considerable area has rocky and highly erodible soils leading to rapid runoff (Figure 3.27). Sedimentary soils have variable K-factors and are in places susceptible to severe wind erosion as well as to water erosion where the soil cover factor (C) has been compromised. The soil loss tolerance factor (T) varies across the landscape as well. Due to the degraded state of much of the landscape and the impacts of climate trends, it may be advisable to consider the standard T-factors as being on the high end as guidelines for the soil recovery capacity in the future.

Figure 3.24. Overview of a sequence of typical upland terrain types from foothills with piñon and juniper (foreground) to steep sandstone cliffs (middle ground) and high mountain landscape (background).

Figure 3.25. View upstream into the landscape of the gorge of the Rio Embudo, just upstream from the confluence with the Cañada de Ojo Sarco.

Geospatial Modeling Findings

STEPL Modeling resulted in a tentative quantification of soil loss and sediment transport. Three baseline STEPL modeling exercises, one for each HUC area, resulted in a total sum, adjusted for the WBP planning area. The total estimated sum of **soil loss** for the WBP planning area based on STEPL modeling is 26,832.85 tons per year. This number should be considered a long-term average. The STEPL model includes a **sediment transport** (a.k.a. sediment flux) calculation, which resulted in an estimated sediment transport volume of 4,718.66 tons of sediment per year (25,855.68 lbs/day) discharged by the Rio Embudo into the Rio Grande (Table 3.3).

STEPL modeling for the 18,851-acre ***Arroyo La Mina-Embudo Creek sub-watershed (HUC 130201010909)*** conducted in 2019, based on the data output of the GIS-based weather modeling, generated an estimated average annual soil loss for the WBP planning area within this sub-watershed (91% of the HUC) of 8,666.0 tons per year (0.506 tons per acre per year). The STEPL model generated an average annual sediment transport estimate of 1,182.6 tons (6,479.95 lbs/day) of sediment discharged in the Rio Embudo. The STEPL model estimated that the sediment flux in this sub-watershed is approximately 13.75% of the estimated annual soil loss amount. On a per acre basis, this is 0.069 tons of sediment transported per acre per year (0.376 lbs/acre/day).

The estimates also include an estimated sediment reduction factor as a result of certain best practices that were assumed to have been applied in the watershed. Based on data inputs in the model, the modeled sediment reduction due to best practices was estimated to be approximately 16 tons or about 1.2% of the sediment transport. This sediment reduction estimate is reasonable and possibly rather low, if one considers that monitoring of forest and woodland restoration treatment conducted in 2015-2017 across 517 acres in the Copper Hill and across 50 acres in the Arroyo de los Pinos Reales generated an estimated soil loss reduction of 353 tons per year, based on RUSLE modeling of pre- and post-treatment soil loss rates (Jansens 2016-a and Jansens 2016-b). This equates to a sediment transport reduction of 48.5 tons per year if the same sediment reduction of 13.75% is applied (or 0.469 lbs per acre per day).

Figure 3.26. View south toward a mesa on USFS land at the watershed boundary (horizon) across the eroded sandstone landscape of the of the Arroyo La Mina-Embudo Creek sub-watershed. Note the scattered wetland valley bottoms (with cottonwood and willow trees: green arrows) that may serve as anchor points for future watershed restoration.

Additionally, erosion control measures implemented in 2013 accumulated an unknown volume of sediment over several years after project completion. Conservative estimates for this volume range between 500 and 1,000 tons of sediment retained. These sediment reduction examples offer a glimpse at the potential for the application of small, localized management measures aimed at reducing sediment transport.

STEPL modeling for the 13,843.41-acre ***Canada de Ojo Sarco sub-watershed (HUC 130201010907)*** conducted in 2019, and also based on the data output of the GIS-based weather modeling, generated an estimated average annual soil loss for this sub-watershed of 14,060.0 tons per year (1.02 tons per acre per year). The STEPL model generated an average annual sediment transport estimate of 2,038.8 tons (11,171.62 lbs/day) of sediment discharged in the Rio Embudo. The sediment flux is approximately 14.9% of the estimated annual soil loss amount. On a per acre basis, this is 0.147 tons of sediment transported per acre per year (0.807 lbs/acre/day). The model included an estimated sediment reduction as a result of best practices of 64 tons per year, or about 3% of the sediment transport, mostly due to ongoing forest restoration projects.

STEPL modeling for the 38,268-acre ***Canada de Ojo Sarco/Embudo Creek (Trampas) sub-watershed (HUC 130201010908)*** conducted in 2019, and also based on the data output of the GIS-based weather modeling, generated an estimated average annual soil loss for the 29,379-acre WBP planning area in this sub-watershed (77% of the entire HUC area) of 13,283.3 tons per year (0.45 tons per acre per year). The STEPL model generated an average annual sediment transport estimate of 1,497.3 tons (8,204.11 lbs/day) of sediment discharged in the Rio Embudo. The STEPL model estimated a sediment flux of approximately 11.34% of the estimated annual soil loss amount. On a per acre basis, this is 0.051 tons of sediment transported per acre per year (0.28 lbs/acre/day). The model included an estimated sediment reduction as a result of best practices of 54.2 tons per year, or about 3.6% of the sediment transport, mostly due to ongoing forest restoration projects.

STEPL modeling also estimated sediment flux originating from several land use types, based on 2000 County Census data for land use, as well as for gullies and stream banks, based on conservative estimates for gully and stream bank lengths. Results from the STEPL modeling output for these forms of land use are included in Table 3.4.

Comparing these findings with the ***US Forest Service data of the 2017 Environmental Assessment (EA)*** for the 5,718 treatment area of the Trampas forest planning assessment unit offers comparable results (USFS 2017-a). USFS sediment transport data modeling was conducted with the WEPP-FuME model. The EA states that the 5,718-acre treatment area on the national forest has an estimated "background" sediment transport rate of 533.8 tons of sediment per year, which equates to 0.093 tons per acre per year. Prorated over the entire 38,893-acre planning area for the Trampas watershed, the estimated sediment transport is 3,630.8 tons of sediment per year (19,895.0 lbs/day). Just for the 31,877-acre WBP planning area within this USFS forest planning area, the estimated sediment transport based on USFS data would be 2,975.9 tons per year (16,306.1 lbs/day). In comparison, STEPL modeling resulted in 2,444.6 tons per year (13,395.2 lbs/day) for the same WBP planning area within the USFS forest planning area.

The EA indicates that the proposed treatment would reduce sediment transport to 317.9 tons of sediment per year (0.0556 tons of sediment per acre per year). Forest roads, both low access and high access, are estimated to contribute about 18 tons of sediment per year to these numbers.

The STEPL modeling outcome of 1,182.6 tons of sediment flux per year for the modeled area is considerably lower than the empirically found sediment transport volume of 13,758 tons of sediment discharged in 2014 in the Arroyo La Mina-Embudo Creek sub-watershed (see next section). The reasons for this discrepancy are most likely both methodological and incidental to the extreme storm conditions in 2014. The STEPL model has certain methodological limitations that lead the model to generate only rough estimates that are at best within the order of magnitude of empirically found results. For example, the STEPL model does include options for modeling gully and stream bank erosion, but data on the number of gullies and streambank lengths in the WBP area is highly subjective and not easily aggregated in the STEPL model. Also, gully and bank erosion do not occur during normal, low-flow storm years, and are only triggered during high flow year, such as 2014. The phenomenon of dramatically increased sediment transport from gully and bank erosion is roughly quantified in the USPED model. A change in the variable m and n constants in the USPED model used to shift from conditions of sheet erosion and to those of rill erosion lead to an increase of estimated sediment transport by one or two orders of magnitude. In this way, USPED modeling helps quantify the rapid rise of soil loss and sediment transport estimates during high flows and seems to justify the assertion that the STEPL outcomes represent relatively low flow circumstances.

Table 3.3. STEPL Modeling Results by Source Area.

Source Area	% of Total Area	Sediment load (t TSS/y)	Sediment Load (lbs TSS/day)	% of Total Sediment Load	Sediment Load (lbs acre/day)	Notes
Cañada de Ojo Sarco	23%	2,038.8	11,171.6	43%	0.807	Rangeland, forest, fields, pastures, and streambanks
Cañada de Ojo Sarco/ Embudo Creek (including Rio de las Trampas)	49%	1,497.3	8,204.1	32%	0.280	Forest, fields, pastures, Streambanks, and alpine tundra; does not include Chamizal Creek
Cañada Aqua (Arroyo la Mina/Embudo Creek)	28%	1,182.6	6,480.0	25%	0.376	Rangelands, woodlands, fields, pastures, villages
Total	**100%**	**4,718.7**	**25,855.7**	**100%**	**0.428**	

Table 3.4. STEPL Modeling Results by Cause (Land Use Activity).

Cause	Sediment Load (t TTS/y)	Sediment Load (lbs TSS/day)	% of Total Sediment Load	Sediment Load (lbs acre/day)	Notes
Forest management in Cañada del Ojo Sarco	249.6	1,367.6	5.3%	0.128	10,702.5 ac (STEPL)
Forest management in Rio de las Trampas	343.7	1,883.2	7.3%	0.089	21,174.5 ac (STEPL and USFS data)
Forest management in Cañada Aqua (Arroyo la Mina/ Embudo Creek)	169.9	930.9	3.6%	0.115	8,103.4 ac (STEPL)
Total Forest Management	**763.2**	**4,181.8**	**16.2%**	**0.105**	**39,980.4 ac**
Woodland and range management in Cañada del Ojo Sarco	1,772.9	9,714.2	37.6%	3.215	3,021.7 ac (STEPL)
Woodland and range management in Rio de las Trampas	1,117.5	6,123.1	23.7%	1.234	4,962.3 ac (STEPL)
Woodland and range management in Cañada Aqua (Arroyo la Mina/ Embudo Creek)	991.7	5,433.8	21.0%	0.531	10,232.1 ac (STEPL)
Total Woodland and Range management	**3,882.1**	**21,271.2**	**82.3%**	**1.168**	**18,216.1 ac**
Pasture and cropland in Cañada del Ojo Sarco	4.7	25.8	0.1%	0.428	60.3 ac (STEPL)
Pasture and cropland in Rio de las Trampas	3.1	17.0	<0.1%	0.068	Approx. 250.0 ac (STEPL, estimate)
Pasture and cropland in Cañada Aqua (Arroyo la Mina/ Embudo Creek)	15.2	83.3	0.3%	0.309	269.5 ac (STEPL)
Total Pasture and Cropland	23.0	126.0	0.5%	0.217	Approx. 580 ac
Arroyos & streambanks in Cañada del Ojo Sarco	11.2	61.4	0.2%	87.4	1,000 ft x 30 ft arroyos; 100 ft x 6 ft streambank
Arroyos & streambanks in Rio de las Trampas	30.3	166.0	0.6%	192.8	1,000 ft x 35 ft arroyos; 500 ft x 5 ft streambank
Arroyos & streambanks in Cañada Aqua (Arroyo la Mina/ Embudo Creek)	4.3	23.6	0.1%	26.0	1,300 ft x 30 ft arroyos; 100 ft x 6 ft streambank
Total Modeled Arroyos & streambanks	**45.8**	**251.0**	1.0%	N/A	N/A
Urban Areas	**4.7**	**25.8**	0.1%	0.065	Approx. 400 ac
TOTAL	**4,718.8**	**25,855.7**	**100%**	**0.428**	**60,362 ac**

Additionally, STEPL and RUSLE modeling are based on the selection of a series of variables for the area. As discussed above, the variables are highly site specific. Especially the selection of an average for the C-factor (vegetation / soil cover) is highly subjective and variable from site to site and year to year. For example, if we had applied the default C value of 0.14 instead of the empirically found value of 0.026, the sediment transport outcome would have increased by nearly a factor of 5.5 for certain land use types. A GIS map image of qualitative RUSLE-USPED outcomes (unrelated to STEPL modeling) is included in Figure 3.27, and provides an overview of the most erosive areas in the watershed.

It is important to remember that the empirically found sediment discharge data were collected in a year with extreme rainfall intensity and abnormal rainfall distribution, as explained further on. In the month of July 2014 alone the modeling area received 55% of the annual precipitation, which was 254% of normal. This intense rainfall followed a dry year in 2013 and a dry winter of early 2014, which probably resulted in low soil cover across the landscape (a relatively high C-factor), and hence increased erosion and sediment transport potential. Given the clarifying analysis described above, the difference between an average sediment transport estimate for the lower HUC area of around 1,182.6 tons per year and the empirically measured sediment discharge of 13,758 tons in 2014 is within reason of the variability that can be expected in this area.

3.4. Field Sampling

Summary of Field Sampling Methods

The WBP research team's field sampling approach was based on direct automated field sampling and indirect estimation. The direct, automated field sampling focused on the turbidity threshold sampling (TTS) technique which included the use of automatic collection of water quality samples for estimating suspended sediment loads (using the ISCO sampler) tied to real-time measurements of optically-sensed turbidity, ultrasonically-sensed stream stage height, and precipitation (Figures 3.30 and 3.31). As described above, the research team collected rainfall information at each of the in-stream monitoring stations to help assess the relationship between in-stream turbidity and precipitation. Appendix 05 describes in more detail the methodology used for this sampling approach.

The research team also used manually-collected, isokinetic, depth integrated (DI) sampling to verify that the point samples obtained from the pumping sampling unit were representative of the suspended sediment concentration across the entire stream channel (Figure 3.29). The indirect suspended sediment estimation method relies on regression relationships between turbidity and laboratory-assessed suspended sediment concentrations to predict instream suspended sediment concentrations across a range of turbidity values. Please see Appendix 04 for a description of this additional sampling method[3].

[3] Appendix 04: pQAPP, specifically Element B2: Details of Manual Iso-kinetic Depth Integrated Sampling, and also Element B4: Sediment Rating Curve Production from Turbidity and Suspended Sediment Concentration Analysis for details establishing a valid comparison of data generated between these two sampling methods.

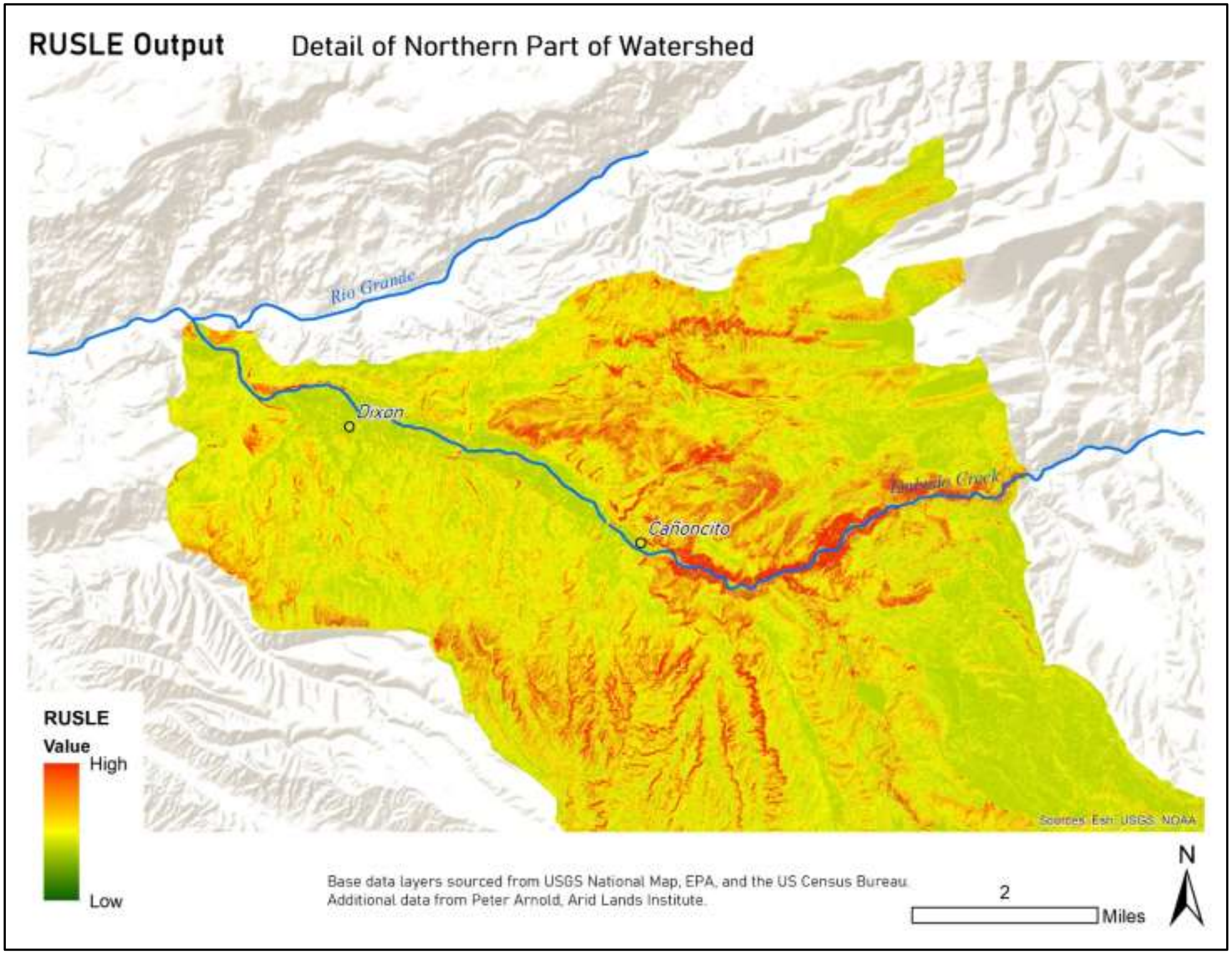

Figure 3.27. GIS-based map of the northern half of the WBP research area. The map methodology was based the application of RUSLE modeling. Green colors show areas of low erosion and high sedimentation rates. The color spectrum ranging from yellow to orange and red indicates an increasing rate of net soil loss over net sedimentation. Deep red areas are, therefore, highly erosive, typically steep, rocky, and exposed areas or streambanks.

From October 2013 – February 2015 the project team collected 661 unique samples in 79 sessions from eight sampling locations (Figure 3.28). All the sampling locations were positioned along the impaired reach of the Rio Embudo. The principle sampling focus, accounting for 98% of the overall sampling effort, occurred at sampling sites #1 and #2, (ARID1 and ARID2 respectively), where in-stream turbidity sensors and other monitoring equipment are permanently stationed. Sites 3a/b through 8 were used only for grab samples during periods of excessive runoff. A sampling session is defined as a discrete time period in which multiple samples are taken, such as a series of DI samples taken across the channel width at regular intervals or retrieval of collected auto-pumped samples from the ISCO sampler.

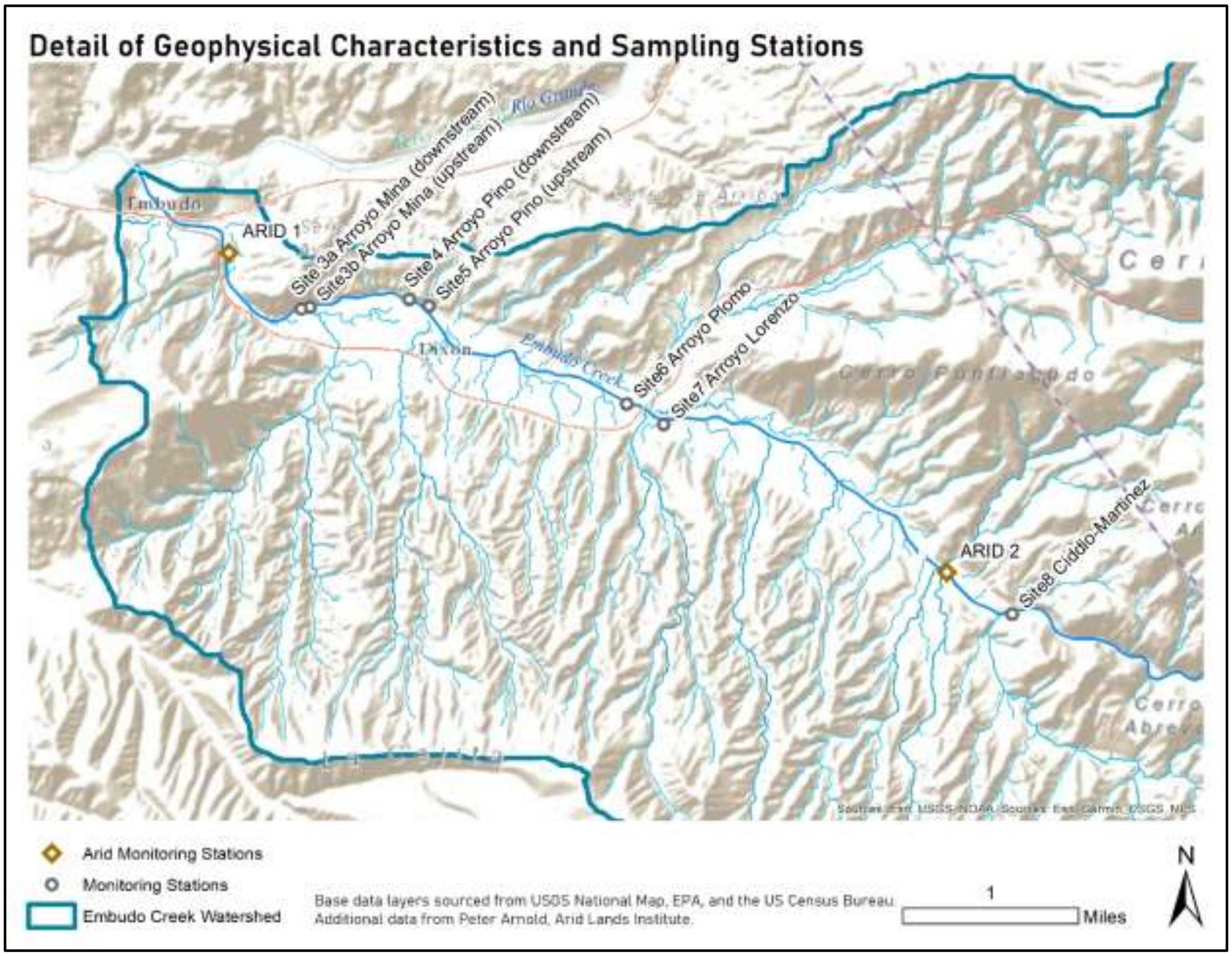

Figure 3.28. Project Sampling Sites.

The DI sampling program collected 77 usable cross-sectional samples during the fall of 2013 and the spring of 2014 at the ARID1 station. The sampling program did not collect cross-sectional DI samples during the monsoonal storm events of 2014 primarily due to safety issues (high stage and discharge rates during storm events). As a result, we assume (possibly incorrectly) that the bias correction relationship remains constant over time: all usable ISCO samples and DI point samples from the ARID1 station were corrected uniformly using a single regression model. The regression relationship between the mean cross-sectional SSC and the point samples' SSC, at the ARID1 station was found to be linear. Data used for the regression model, mean SSC from 77 cross sectional averaged samples, did not exceed 250 parts per million (ppm) with a mean value for all DI samples less than 80 ppm. In comparison, the mean SSC value from the ISCO collected samples (258 usable sample) was greater than 500 ppm. We can state with certainty that for all point samples less than 250 ppm, the channel mean bias correction is most likely valid; for samples greater than 250 ppm, the validity of the linear relationship is less certain.

Figure 3.29 (top). Demonstration of a DI hand-grab sampling sequence. **Figure 3.30 (bottom left).** Exterior of the ARID1 stationary instrumentation station. Note the telemetry, solar PV system, and rain gage on top of the instrumentation box. **Figure 3.31 (bottom right).** Interior of the ISCO sampler, which is located inside the ARID1 instrumentation box. The instrumentation box also includes a digital data logger.

In addressing representativeness of the DI sampling program, more than half of all samples were captured in conditions where suspended sediment levels were less than 100 ppm. Additionally, when the specific turbidity levels of all the DI samples (in-stream turbidity recorded at the time of sampling) are plotted against 2014 observed in-stream turbidity levels, the DI samples (from monitoring site ARID1) only capture a small portion of observed turbidity values from 2014. Thus, we report that the DI sampling program is not representative of observed annual conditions.

It is important to note that the DI sampling program was only designed to provide the mean cross channel bias assessment, involve citizen-scientists within the community, and promote awareness of the watershed impairment issues through direct participation of the community. To represent the observed in-stream turbidity and associated suspended sediment conditions within the Rio Embudo, we relied on the automated sampling program using the ISCO sampler and automatic, optical turbidity sensors.

As a central component to the overall monitoring program, this project recorded automated electronic in-stream turbidity readings from both permanent-monitoring sites ARID1 and ARID2. The collected, in-stream turbidity values were used (following extensive preprocessing) to derive multiple relationships between observed median turbidity and suspended sediment during the project period. The WBP team successfully collected automated, optical in-stream turbidity values from January 01, 2014 through December 31, 2014 (12 months), generating continuous data from the ARID1 and ARID2 permanent stations. The team also performed data quality assessments of the collected datasets and summarized the findings.

<u>Field Sampling Findings</u>

Stage Heights: The WBP planning team utilized two staff gages and two in-stream installed differential pressure transducers to record the changes in water pressure (stage height) and water temperature over time, each deployed at the permanent monitoring sites ARID1 and ARID2. During the course of the data collection period, the team calibrated the readings of the stage sensor with nearby installed staff plates. These “corrections” to the stage readings were noted within the record log as “stage offsets”. For the monitoring period of August 28 through December 20, 2013 a total of three offsets were required. Following December 20, 2013 and throughout 2014 a total of five more offsets were made to the electronic stage equipment at ARID1. Stage offsets were typically applied following significant storm events or when differences between the staff plate reading and the electronic stage instrumentation were observed.

During the 2014 data gathering period the monitoring site ARID1 experienced a series of storm events, most notably in early July and August, producing a maximum-recorded stage height of 7.26 ft (07/11/2014, 16:15) and 4.97 ft (08/01/2014, 20:15) respectively. The predicted maximum discharge from these two storms calculated from regression models were in excess of 16,000 cfs for 07/11/2014 (@16:15) and 4,600 cfs for 08/01/2014 (@ 20:15).

The WBP team utilized the discharge measurements from the nearby downstream USGS gaging site (#08279000) as a surrogate for predicting discharge values at monitoring site ARID1. This USGS site, approximately 1,550 feet downstream from the ARID1 monitoring equipment site, shares similar characteristics to the ARID1 site, including channel width, cross-sectional shape, and smooth laminar flow. The monitoring team also conducted independent stream discharge measurements throughout the project's sampling period for verification of the USGS discharge values. See Appendix 05 for details on the stream discharge measurement procedures and results.

The predicted discharge regression models, also known as "rating curves", used ARID1 corrected electronic stage (in ft) as the independent variable and USGS gaging site (#08279000) discharge data (in cfs) as the dependent variable. Further information Rating Curves from Regression Models R1-R6 @ ARID1 are included in Appendix 05. Calculation of stream discharge at the ARID2 monitoring site was accomplished using two techniques: (1) direct measurement for deriving a stage-discharge rating curve, and (2) using a discharge area ratio approach.

During 2014 the monitoring site ARID2 experienced a maximum-recorded stage height of 4.09 ft (09/22/14, 15:45 MST) producing a predicted maximum discharge of 346.34 cfs. The average measured stage height from 02/27/14 to 12/31/14 was 1.02 ft.; the minimum observed stage height was 0.52 ft (12/24/14 @ 13:45 MST). Stream stage data at ARID2 from January 01 – February 22, 2014 @ 15:15 MST was estimated using a regression relationship (Appendix 5, p122). Data used for this relationship was from the stable stream flow period between February 27, 2014 @ 15:30 MST and February 28, 2014 @ 23:45 MST. The regression model uses measured stage data at ARID1 (ft) as the independent variable and measured stage data at ARID2 (ft) as the dependent variable.

Further review of the USGS discharge data at the USGS Embudo gaging site (#08279000) reveals that the mean daily discharge amounts for July and August 2014 are far below the estimate flows based on the measured stage heights and regression analysis for these flows at ARID1 (Table 3.5). The gaging site's data show that the mean discharge for July 2014 was 29.8 cfs and for August 2014 it was 34.5 cfs. The difference with the measured data at ARID1 in 2014 seems to point at the extremely flashy storm behavior in these months.

Pollutant Load Quantities: Regression analysis was used to calculate Suspended Solid Concentration (SSC) levels in relation to measured turbidity at ARID1 and ARID2. In determining the estimated suspended sediment concentration (SSC) levels at the monitoring station ARID1, the team used the data from analyzed water samples taken by the ISCO sampler between January and December 2014, as calibrated by DI samples, to develop the raw turbidity versus mean suspended sediment concentration relationship. Regression analysis generated a series of suspended sediment concentration rating curves (Appendix 05).

In determining the estimated suspended sediment concentration (SSC) levels at the monitoring station ARID2, the team used DI samples collected from the April – August 2014 period to develop the raw turbidity versus mean suspended sediment concentration relationship.

In comparing the observed raw median turbidity to SSC relationship between both the upper monitoring site (ARID2) and the lower site (ARID1), we found several conditions of note:

1. *Generally, the upstream monitoring site, ARID2, produced less suspended sediment per unit turbidity than compared to the downstream ARID1 site*.

2. *<u>The raw turbidity to SSC relationship at the upstream monitoring site ARID2 was more stable and less volatile than during an identical time period as observed from the lower monitoring site ARID1.</u>*

When comparing the raw turbidity to SSC regression curves between both sites, the curve for ARID2, obtained from data over a five-month period (April – August, 2014) resembled the only applicable stable conditions seen during a two-month period (January – February, 2014) at the lower site. This was due to more rain (greater frequency and intensity of precipitation) occurring at the lower site (ARID1), producing higher SSC values per unit turbidity than observed from the upper site (ARID2). This pattern narrows the geographic relationship within the watershed where significant sediment production occurs and where action is required to mitigate its effects.

Table 3.5. Mean monthly discharge volumes (cfs) of the Rio Embudo (1923-2018) and the Rio Grande (1930-2018), based on USGS gaging station data for USGS Embudo (#08279000) and USGS Rio Grande at Embudo Station (#08279500).

Month	Rio Embudo Oct 1923-Nov 2018	Rio Grande Oct 1930 -Sep 2018	% of Embudo into Rio Grande
January	29	507	5.72%
February	31	576	5.38%
March	46	724	6.35%
April	135	961	14.05%
May	290	1890	15.34%
June	179	1800	9.94%
July	46	723	6.36%
August	47	436	10.78%
September	38	372	10.22%
October	37	420	8.81%
November	36	548	6.57%
December	31	518	5.98%

Samples collected from January through late February 2014 were not used to derive the April – August raw turbidity to SSC relationship at ARID2, as active collection of in-stream turbidity data did not begin until February 27th @ 16:00 MST. To provide an estimation of the missing turbidity readings at ARID2 from January – February, we developed a regression relationship using the downstream ARID1 turbidity data as a surrogate to predict the upstream (ARID2) turbidity data from Feb 27 @ 16:00 MST – Feb 28 @ 21:00 MST when both stations were fully functioning. Using this approach, we could confidently estimate the missing turbidity values at ARID2 using time-shifted turbidity readings from ARID1 (downstream). Time-shifting accounts for an upstream reading at ARID2 (t = 0 hrs) with a paired downstream reading at ARID1 (t = +3.6 hrs) using a mean stream velocity of 0.651 m/sec (predicted for this time period) with a distance traveled (stream centerline between ARID2 and ARID1) of 8,430 m.

Calculating SSL: Summary of Monthly and Seasonal SSL at ARID1 and ARID2: Suspended sediment loading (SSL) was calculated using the regression relationship between suspended sediment concentration (SSC) and turbidity in combination with stream discharge rating curves for each site ARID1 and ARID2. Via this method of direct and indirect environmental data collection, the resulting annual SSL for 2014 was conservatively calculated to be 18,991 tons (US) or 37,982,481 lbs/y (avg. of 104,061.6 lbs/day) at the downstream ARID1 site. At the upstream ARID2 site, the conservative calculation of annual SSL was 5,233 tons (US) or 10,466,075 lbs/y (avg. of 28,674.2 lbs/day). As a result, the net contribution of the sub-watershed of the Cañada del Aqua (Arroyo la Mina/Embudo Creek, HUC 130201010909) is the difference between the ARID1 and ARID2 values: 13,758 tons or 27,516,406 lbs/y (avg. of 75,387.4 lbs/day).

Measurements at monitoring station ARID1 for the period January 01 - December 31, 2014 conservatively measured a total annual yield of suspended sediment of 18,991 tons (US) or 37,982,481 lbs/y (Tables 3.6 and 3.7). As expected, the amount of suspended sediment produced throughout the year was largely a product of the summer monsoon-driven precipitation events from July, August, and September, which generated the majority (78%) of the annual suspended sediment yield discharged from the watershed (Figures 3.32 and 3.33). The month of July alone accounted for 62% of the annual total suspended sediment yield measured in 2014.

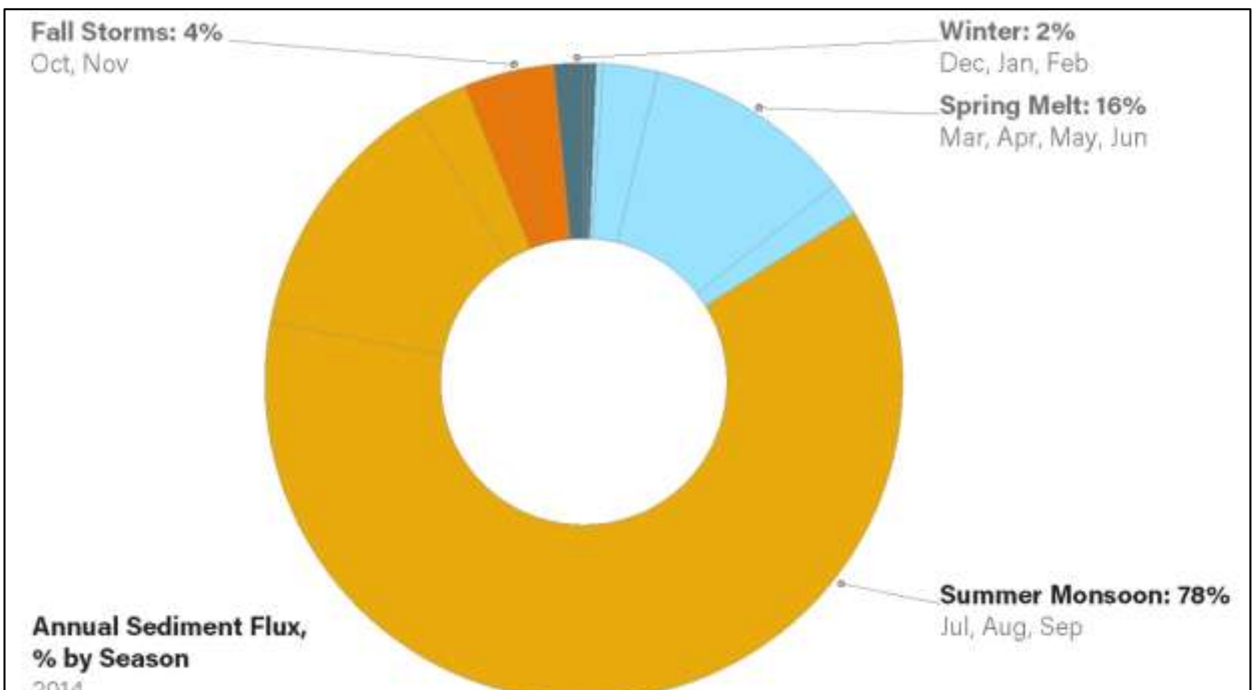

Figure 3.32. ARID1 Seasonal sediment flux as a percentage of yearly total.

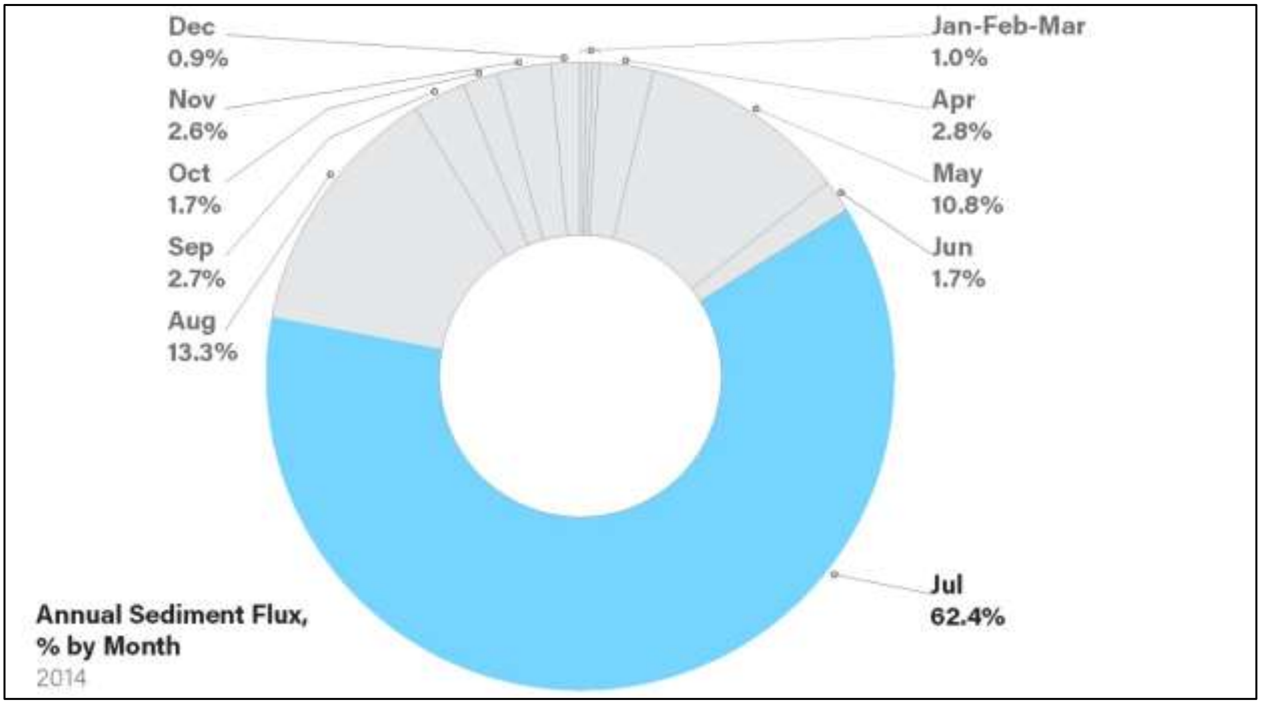

Figure 3.33. ARID1 Annual sediment flux by month as a percentage of yearly total.

Table 3.6. SUMMARY TABLE: Measured Seasonal Suspended Sediment Flux @ ARID1 (Sampling Site 1).

Season: 2014	**Subtotal** (tons-season/y)	**% / Season**
Winter: Dec, Jan, Feb	297.52	1.6%
Spring Melt: Mar, Apr, May, Jun	2,967.25	15.6%
Summer Monsoon: July, Aug, Sept	14,908.79	78.5%
Fall Storms: Oct, Nov	817.68	4.3%
Total Measured Suspended Sediment Flux**:**	18,991.24 (tons/y)	100%

Table 3.7. SUMMARY TABLE: Measured Monthly Suspended Sediment Flux @ ARID1 (Sampling Site 1)

Month-Year	Sediment Flux / SSC Regression Model	Subtotal (kg/month)	Subtotal (lbs/month)	Subtotal (tons/month)	% Total by month
Jan-14	SSC, model ver 9	57,339.8	126,412.5	63.2	0.3%
Feb-14	SSC, model ver 9	51,774.0	114,142.0	57.1	0.3%
Mar-14	SSC, model ver 9	58,808.2	129,649.7	64.8	0.3%
Apr-14	SSC, model ver 8	481,287.8	1,061,056.6	530.5	2.8%
May-14	SSC, model ver 8	1,855,528.8	4,090,735.9	2,045.4	10.8%
Jun-14	SSC, model ver 8	296,218.2	653,048.5	326.5	1.7%
Jul-14	SSC, model ver 8	10,757,695.8	23,716,631.2	11,858.3	62.4%
Aug-14	SSC, model ver 8	2,294,381.4	5,058,239.2	2,529.1	13.3%
Sep-14	SSC, model 1b, 3	472,969.3	1,042,717.5	521.4	2.7%
Oct-14	SSC, model 1b, 3	297,460.3	655,786.9	327.9	1.7%
Nov-14	SSC, model 1b, 3	444,326.8	979,571.8	489.8	2.6%
Dec-14	SSC, model 1b, 3	160,793.7	354,489.0	177.2	0.9%
TOTAL: (2014)	Sum (ensemble of models)	17,228,584 (kg/y)	37,982,480.9 (lbs/y)	18,991.2 (tons / y)	100%

Measurements at monitoring station ARID2 for the period January 01 - December 31, 2014 conservatively measured a total annual yield of suspended sediment of 5,233 tons (US) or 10,466,075 lbs/y (Figures 3.34 and 3.35, Tables 3.8 and 3.9). The pattern of suspended concentration produced seasonally at ARID2 differed from the seasonal production values from ARID1 with the summer monsoon accounting for 33% of yearly total and fall storms accounting for 36% yearly total. Monthly sediment production for ARID2 peaked in October accounting for one quarter (25%) of total annual production.

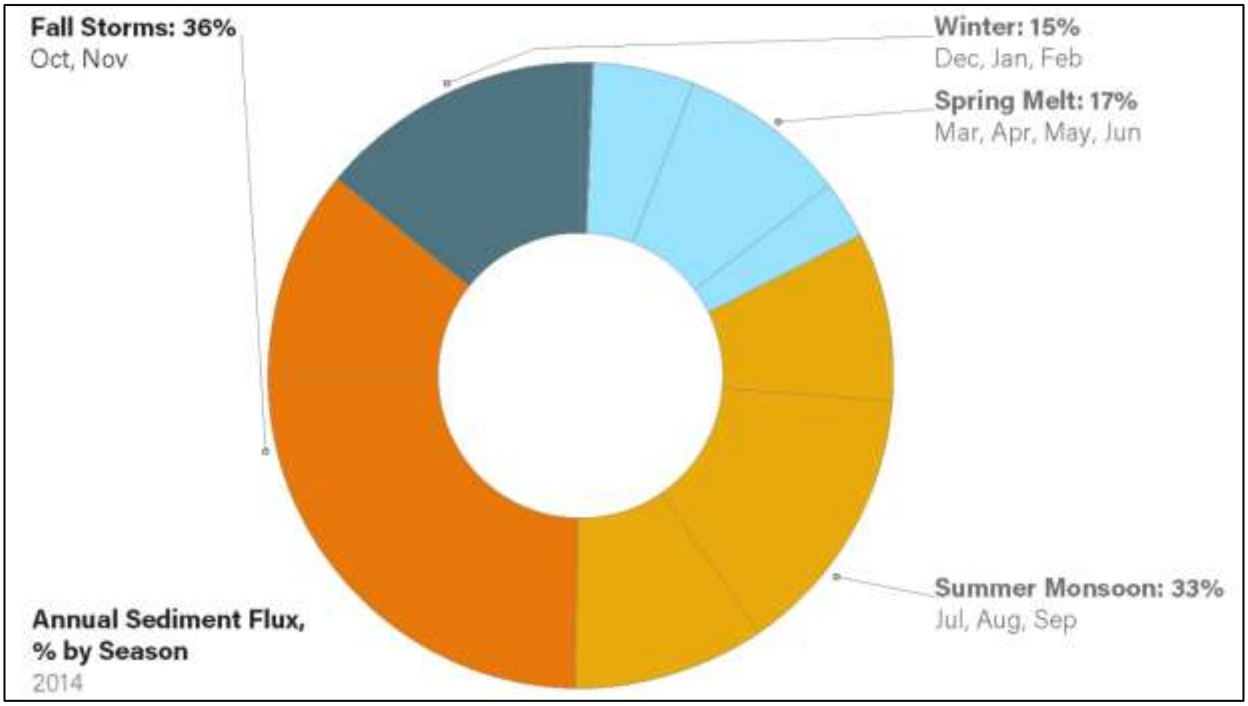

Figure 3.34. ARID2: Monthly and Seasonal Sediment Flux as a Percentage of Yearly Total.

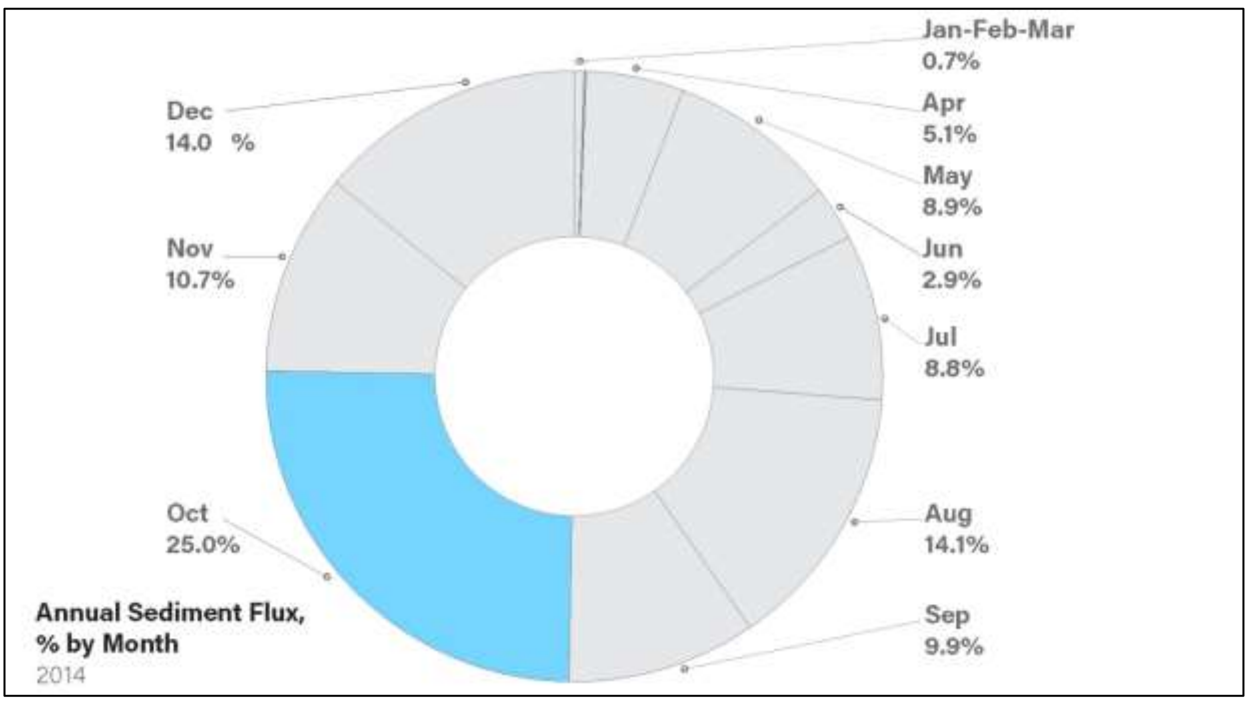

Figure 3.35. ARID2 Monthly and Seasonal Sediment Flux as a Percentage of Yearly Total.

Table 3.8. SUMMARY TABLE: Measured Seasonal Suspended Sediment Flux @ ARID2 (Sampling Site 2).

Season: 2014	**Subtotal** (tons-season/y)	**% / Season**
Winter: Dec, Jan, Feb	764.48	15%
Spring Melt: Mar, Apr, May, Jun	884.57	17%
Summer Monsoon: July, Aug, Sept	1,717.33	33%
Fall Storms: Oct, Nov	1,866.66	36%
Total Measured Suspended Sediment Flux**:**	5,233.04 (tons/y)	100%

Table 3.9. SUMMARY TABLE: Measured Monthly Suspended Sediment Flux @ ARID2 (Sampling Site 2).

Month-Year	**Sediment Flux / SSC Regression Model**	**Subtotal** (kg/month)	**Subtotal** (lbs/month)	**Subtotal** (tons/month)	**% Total by month**
Jan-14	SSC, Qu	24,137.7	53,214.4	26.6	0.5%
Feb-14	SSC, Qu	2,424.5	5,345.1	2.7	0.1%
Mar-14	SSC, Qu	2,598.6	5,728.9	2.9	0.1%
Apr-14	SSC, Qm	242,280.6	534,136.8	267.1	5.1%
May-14	SSC, Qm	421,174.7	928,530.2	464.3	8.9%
Jun-14	SSC, Qm	136,413.2	300,739.2	150.4	2.9%
Jul-14	SSC, Qm	416,716.7	918,701.9	459.4	8.8%
Aug-14	SSC, Qm	668,898.1	1,474,666.1	737.3	14.1%
Sep-14	SSC, Qm	472,326.4	1,041,300.2	520.7	9.9%
Oct-14	SSC, Qm	1,186,933.0	2,616,736.3	1,308.4	25.0%
Nov-14	SSC, Qu	506,474.4	1,116,583.5	558.3	10.7%
Dec-14	SSC, Qu	666,960.0	1,470,393.4	735.2	14.0%
TOTAL**:** (2014)	Sum (ensemble of models)	4,747,337.8 (kg/y)	10,466,075.8 (lbs/y)	5,233.0 (tons / y)	100%

Note: Qu: discharge calculated by discharge area ratio; Qm: discharge calculated by rating curve with smoothed stage.

Summary of the Bracketed Monthly and Seasonal SSL between ARID2 and ARID1

The subtraction of monthly SSL data of ARID2 from those at ARID1 reveals the relative contribution of the bracketed watershed area between ARID1 and ARID2, which largely encompasses the Cañada del Aqua (Arroyo la Mina/Embudo Creek, HUC 130201010909). The numbers show a gradually rising trend of net SSL in the first three months, followed by a rapid increase in April and May, a sudden temporary decline for June, followed by peak SSL in July. In August, the net SSL loading from the bracketed area returns to approximately the level of May, and then rapidly declines in September to be followed by a net exceedance of SLL inflow from the area upstream of ARID2 (Table 3.9). The latter was likely caused by fall precipitation concentrated in the higher elevations of the watershed rather than in the lower part of the watershed. Appendix 5 includes a table of sediment flux comparisons between the ARID1 and ARID2 stations in relation to data for coincident rainfall.

3.5. Conclusion of Causes and Sources of SSL and Opportunities for Sediment Retention

Stretches of the Rio Embudo have been listed as impaired for nearly two decades, with sedimentation/siltation and turbidity being the likely causes. The EPA and NMED-SWQB have identified sediment, specifically total suspended sediment (TSS), as the leading cause of river impairments (EPA 2000, NMED-SWQB 2005). Suspended sediment often acts as a transporting mechanism for carrying nutrients, trace metals, semi volatile organic compounds and pesticides (EPA 2000), which ultimately affect the ecological function of watersheds (Gao 2008). The WBP research phase confirmed that the cause of water quality impairment within the Lower Embudo Valley watershed is sediment-laden runoff, driven by short, intensive, seasonal precipitation events.

Sedimentation and siltation can have direct consequences on the residents of the Embudo Valley, in addition to their detrimental effects on ecological function. In the community of Dixon arroyos are often used as roads. During and after intense storm events that drive sedimentation, roads are often inaccessible until the sediment is excavated with heavy equipment, a measure that is both inconvenient and costly. Additionally, the Rio Embudo feeds into the Rio Grande, the fifth longest river in North America. While the Rio Grande has an extensive network of tributaries, USGS stream gage data for the Rio Embudo at Dixon (#08279000) and for the Rio Grande at the Embudo (#08279500) indicate that the Rio Embudo contributes 15% of the average daily stream flow to the early peak flow rises of the Rio Grande in May, 10% in June, 6.4% in July and 10.8% in August. July and August flows usually have high SSL rates. In extreme years, however, the Rio Embudo's proportional flows into the Rio have exceeded 30% for May and 22% for June (both in 1992), 22% for July (1998), and 36% for August (2010)[4].

[4] https://waterdata.usgs.gov/nm/nwis/monthly/?referred_module=sw&site_no=08279500&por_08279500_99708=558733,00060,99708,1889-01,2018-10&format=html_table&date_format=YYYY-MM-DD&rdb_compression=file&submitted_form=parameter_selection_list and https://waterdata.usgs.gov/nm/nwis/monthly/?referred_module=sw&site_no=08279000&por_08279000_99707=558732,00060,99707,1923-10,2018-12&format=html_table&date_format=YYYY-MM-DD&rdb_compression=file&submitted_form=parameter_selection_list

Table 3.9. Suspended sediment loading (SSL) between the two stations ARID1 and ARID2 (bracketed difference).

Month	Bracketing Relationship	Monthly Subtotal	kg / month		lbs / month		ton / month	% / month-yr	Sediment Loading Behavior
Jan-14	ARID1 - ARID2	33,202.14	kg / month	73.198.111	lbs / month	36.599	ton / month	0.30%	Discharged into Rio Embudo between ARID2 and ARID1
Feb-14	ARID1 - ARID2	49,349.52	kg / month	108,796.93	lbs / month	54.398	ton / month	0.40%	
Mar-14	ARID1 - ARID2	56,209.61	kg / month	123,920.83	lbs / month	61.96	ton / month	0.50%	
Apr-14	ARID1 - ARID2	239,007.11	kg / month	526,919.86	lbs / month	263.46	ton / month	1.90%	
May-14	ARID1 - ARID2	1,434,354.09	kg / month	3,162,205.71	lbs / month	1,581.10	ton / month	11.50%	
Jun-14	ARID1 - ARID2	159,805.03	kg / month	352,309.36	lbs / month	176.155	ton / month	1.30%	
Jul-14	ARID1 - ARID2	10,340,979.12	kg / month	22,797,929.38	lbs / month	11,398.97	ton / month	82.90%	
Aug-14	ARID1 - ARID2	1,625,483.36	kg / month	3,583,573.11	lbs / month	1,791.79	ton / month	13.00%	
Sep-14	ARID1 - ARID2	642.88	kg / month	1,417.31	lbs / month	0.71	ton / month	0.00%	
Oct-14	ARID1 - ARID2	-889,472.76	kg / month	-1,960,949.44	lbs / month	-980.48	ton / month	-7.10%	Detained within Watershed between ARID2 and ARID1
Nov-14	ARID1 - ARID2	-62,147.52	kg / month	-137,011.67	lbs / month	-68.51	ton / month	-0.50%	
Dec-14	ARID1 - ARID2	-506,166.34	kg / month	-1,115,904.44	lbs / month	-557.95	ton / month	-4.10%	
TOTAL: Jan-Dec-14	**Suspended Sediment Concentration Regression- ISCO**	**12,481,246.22**	**kg / yr**	**27,516,405.05**	lbs / yr	**13,758.20**	ton / yr	100.00%	
				75,387.41	lbs / day-yr	**37.69**	ton / day-yr		
								111.70%	

Therefore, much of the suspended sediment carried by the Rio Embudo will inevitably end up in the Rio Grande and have impacts far downstream.

Geospatial modeling and empirical field sampling and analysis revealed great variability in spatial and temporal factors that cause soil loss and sediment flux. Comparison of multi-year USGS data, field observations, STEPL modeling and the 2014 field sampling results indicate that years with low SSL are common and are occasionally interrupted by years with high SSL volumes due to unusual weather sequences impacting the Cañada del Aqua (Arroyo la Mina/Embudo Creek, HUC 130201010909), as witnessed in 2014. Based on STEPL modeling, it is likely that in years with precipitation concentrations over the Cañada de Ojo Sarco sub-watershed (HUC 130201010907) this area contributes to high SSL volumes as well. Climate trends indicate that unusual weather years, such as 2014, may become less unusual and that related annual SSL volumes are likely to increase in frequency and magnitude.

The cause of periodic high SSL volumes in the Rio Embudo are thus a result of erratic weather impacts on the severely degraded landscape of the lower part of the Lower Embudo watershed, combined with periodic sediment flux emissions from the upper parts of the Lower Embudo watershed as well as from the Upper Embudo watershed above the WBP planning area, as witnessed in the fall of 2014. The causes of high SSL volumes that are related to terrain features are in large part of natural origin, related to the geology, slopes, and soil conditions of the terrain and exacerbated by weather impacts. Additionally, legacy land uses, such as impacts from past tree harvesting, mining, and poorly managed grazing have likely contributed to the current degraded state of the landscape in the lower parts of the Lower Embudo watershed.

Cumulative effects of current land use, including the location of several county roads in the bottom of arroyos, off-road vehicle use in degraded terrain, residential development on highly erodible soils, and modifications to the Rio Embudo compound the sediment flux volumes, especially during years with unusual precipitation events. Finally, bank and gully erosion are likely an important cause as well during years of high flow events.

Under uncertain future climate trends, the future conditions of the Rio Embudo will become increasingly uncertain if left unmanaged. Droughts followed by intense monsoon seasons leave soils especially susceptible to erosion and may exacerbate the sedimentation/siltation and turbidity impairments of the river, further degrading ecological functions and human coexistence with the river.

Climate trends indicate that besides normal precipitation years and unusual ones, SSL peak volumes may occur during years with excessive rainfall and in years with upstream catastrophic ecosystem destruction, such as resulting from wildfire. The risk of massive runoff, soil loss, sediment flux, and stream flow events is increasing with the incidence of extreme drought and risk of wildfire. Such catastrophic causes will have their source predominantly in the Cañada de Ojo Sarco and “Rio Trampas” HUCs. Besides the natural causes of these projected catastrophic events, other causes continue to include the current state of forest management, woodland conditions, off-road vehicle use, and legacy stressors, combined with numerous miles of arroyos and streambanks.

Besides the daunting geo-physical trends and projected volumes of potential sediment flux and discharge in the Rio Embudo, the Lower Embudo watershed also exhibits many opportunities for sediment retention. Geospatial modeling, USPED theory, and field observations have confirmed that the landscape offers significant sediment buffering features. Sediment retention occurs where the energy necessary for sediment flux is lower than the energy associated with gravity and the roughness of the terrain.

Deposition of sediment occurs in particular at the following locations:

- toe of slope, alluvial terraces, alluvial fans
- broad arroyo bottoms and floodplains
- micro-topography: terrain depressions, natural swales, dense vegetation (stems), rock ledges, boulders
- stock tanks
- constructed sediment retention structures
- roads and bar ditches
- acequias
- culverts, bridges (and upstream of them in the streams)
- sediment accumulations behind buildings, walls, fences, and other built obstructions
- fields and pastures (terraces)
- alluvial fans, terraces, and floodplains in the Rio Embudo

It should be noted that sediment from these deposition area also tends to erode again in the course of time, especially when soil cover and terrain maintenance are insufficient. The listed sediment sink areas are therefore under circumstances of disturbance and severe stormwater runoff also sources of sediment that can lead to additional sediment loads in the stream.

Many of these possible sediment retention areas are located on private land or on public lands accessible from roads and private properties. These areas, therefore, are prime target areas for the implementation of management measures to retain the sediment and prevent it from renewed erosion and eventual discharge into the Rio Embudo. The next two chapters will discuss in depth how terrain modifications can be achieved through management measures aimed at retaining and stabilizing sediment, which holds the key toward achieving reduced SSL levels in the impaired Rio Embudo.

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4. TARGETS AND MANAGEMENT MEASURES

4.1. Needed Load Reductions and Effectiveness

Comparison of TMDL with Modeled and Empirical SSL Findings

The 2005 TMDL calculated a turbidity Load Reduction goal of 50,098 lbs/day. The TMDL used a Target Load of 22,173 lbs/day (approx. 4,047 t/y) and a critical flow of 97.5 cfs (63 mgd), corresponding with a Water Quality Criterion of 50 NTU (or 42.2 mg/l) (NMED 2005). The TMDL used a calculated Load Allocation of 16,630 lbs/day to allow for a safety margin of 5,543 lbs/day between the Load Allocation and the Target Load amounts. The TMDL stated a Measured Load of 66,728 lbs/day (approx. 12,178 t/y), based on the arithmetic mean of TSS values when measured turbidity exceeded the standard from a series of samples taken by NMED staff at the Highway 68 bridge in Dixon in 2001. The difference between the calculated Load Allocation and the Measured Load resulted in the Load Reduction goal of 50,098 lbs/day (approx. 9,143 t/y).

Comparison of the TMDL data with the 2019 STEPL modeling findings (25,855.68 lbs/day) shows that the TMDL Target Load is approximately 80% of the modeled sediment flux, but the Measured Load of 2001 is more than 2.5 times the STEPL outcome. As mentioned in Chapter 3, the modeled STEPL load is likely an example of a low flow condition because the sediment flux volumes related to arroyo and stream bank erosion were known to be low in the modeling.

In comparison with the empirically found data from 2014, the TMDL's Target Load of 22,173 lbs/day is only 21% of the suspended sediment load found that year for ARID1 and 77% of that for ARID2. The calculated mean daily suspended sediment flux was 104,062 lbs/day at ARID1 and 28,674 lbs/day at ARID2. The Measured Load found in 2001 is in the order of magnitude of the one found in 2014; it was 64% of the 104,062 lbs/day found for ARID1 in 2014.

The Measured Load of 2001 stated in the TMDL possibly represents a condition during or immediately after a spring runoff or monsoonal flow event, and does not appear to represent a long-term average, because a critical flow of 97.5 cfs compares only with mean monthly discharge volumes for the months of April, May and June and is more than twice the monthly mean for any other month (USGS Embudo #08279000) (see also Chapter 3, Table 3.5). As a result, the Measured Load and Target Load stated in the TMDL appear to be relatively high.

However, the TMDL may be a reasonable representation of a possible long-term mean of low-flow and high-flow years if excessive peak flows as experienced in 2014 continue to occur. If the 2014 empirical findings are any indication, the observations made regarding climate change impacts in the watershed area should caution us that it is likely that the TMDL Target Loads may over time be appropriate to meet the Water Quality Criterion in the long term. Following the completion of this WBP, a revision of the TMDL may be useful in the context of these comparisons and forecasts.

The 2014 study did not generate any quantitative data about sedimentation/siltation (stream bottom deposits or fines) in the system. However, given the representativeness of the TMDL regarding turbidity, for practical purposes this WBP assumes that the same conclusions apply to the Load Reduction goal for fines. Management measures aimed at reducing turbidity will also apply to reducing sedimentation/ siltation.

Relationships between Incidence of Sediment Emissions, expected Load Reductions, and Source Areas

The volumes of suspended sediment loads (SSL) found for the WBP planning area described in Chapter 3 provide a direction for updated and refined targets for pollutant load reduction strategies and the selection of management measures. Findings indicate that the pollution problems are three-fold:

1. **Annual, gradual (seasonal) sediment transport** from forest lands, rangelands, arroyos, streambanks, and dirt roads in the Ojo Sarco HUC and Cañada Aqua HUC, and to a lesser extent in the Trampas HUC (see also Table 4.1, below).

   Scale of sediment transport: 26,000 – 30,000 lbs/day (4,700 – 5,000 tons/year).

   This volume is less than half the measured load in the TMDL, but nearly double the load allocation.

2. **Periodic, high intensity sediment transport** from rangelands, woodlands, arroyos, streambanks and dirt roads in the Cañada Aqua HUC, and to a lesser extent in the Ojo Sarco HUC and Trampas HUC, especially after severe drought periods. The approximate frequency of these periodic and localized flow events are not well understood, and at this time they seem to occur irregularly with return intervals of several years and up to more than a decade Figures 4.1 through 4.4).

   Scale of sediment transport: 30,000 – 82,000 lbs/day or more (15,000+ tons/year)

   This volume is 123% of the TMDL's measured load.

3. **Future catastrophic flooding, debris, and sediment flow events** caused by high intensity wildfire in forests and woodlands, and/or landscape scale forest dieback due to beetle infestations and extreme drought.

   Scale of sediment transport: many times the volumes of scenarios 1 or 2 (hundreds of thousands of lbs/day, equivalent to many tens of thousands of tons/year)

As a result, the ***strategies to be addressed need to be multi-pronged***:

- **A. A program aimed at meeting the Load Reduction goals as per the TMDL**
- **B. A program aimed at buffering incidental sediment flows of more than 30,000-80,000 lbs/day**
- **C. A program aimed at preventing catastrophic debris and sediment flows related to catastrophic forest destruction upstream**

The erratic occurrence of extremely high suspended sediment loads in the Rio Embudo leads to the expectation that in some years water quality standards are being met, while in years with heavy runoff from areas with highly erodible soils, the standards are not being met. More research will be necessary to understand the frequency and intensity of the occurrence of heavy runoff years to develop long-term projections of the likelihood of meeting water quality standards with the current load reduction goals and target loads. While management measures aimed at achieving the Target Load Reduction may suffice, the incidental and catastrophic sediment and debris flows need management responses of a nature and magnitude that is different from those addressing the Load Reduction goals.


Figures 4.1 (left) and 4.2 (right). Periodic high flow events cause high sediment transport impacts, such turbid water quality (left) and cobble and sand banks in the river that split flows and lead to streambank destabilization (right).


Figures 4.3 (left) and 4.4 (right). Periodic high flow events also cause sediment transport that clogs head gates and *acequias* (left) and leads to high costs of excavating essential channels and culverts (right).

4.2. Indicators and Targets

Given the geographic differences in land ownership, land use, and terrain characteristics between the three HUC areas in the watershed and their response to weather and other causes of erosion and sediment transport, the development of indicators and numerical targets to determine whether load reduction targets are met is best done for each HUC area. Additionally, a more detailed look on a sub-watershed level is helpful as an example for the site-specific approach that will be necessary to effectively pursue load reduction goals.

In order to reach a Target Load of 22,173 lbs/day and an associated Load Allocation of 16,630 lbs/day for the entire watershed area, we compared the three HUCs and their current modeled sediment flux with the 2019 STEPL modeling and the empirical sediment flux data for 2014. The STEPL modeling and 2014 empirical data indicated that each sub-watershed has a different proportional sediment flux contribution. Based on the different sizes of each sub-watershed, the sediment flux contribution varies between each sub-watershed on a per acre basis. However, it also varies between different years, because between years and even between seasons the sediment flux varies largely from one sub-watershed to another.

As a result of the variations in sediment flux contributions in each sub-watershed, load allocations not only need to be weighted by acreage, but also by the relative sediment flux contribution of each sub-watershed in normal and in extreme years. While the STEPL modeling and 2014 empirical data offer precise numerical outcomes, their results can only serve as indications for the proportional allocation per sub-watershed. Approximations will be sufficient for practical purposes.

Table 4.1 provides an overview of suggested load allocations and load reduction targets per sub-watershed. The suggested load allocations are based on the STEPL modeling outcomes and are adjusted by the findings from the 2014 empirical data that describe that sediment flux conditions in extreme precipitation years will likely originate to a great extent from the Cañada Aqua (Arroyo la Mina / Embudo Creek) sub-watershed. The suggested targets were also informed by the estimated load reductions from feasible management measures described in Chapter 5. While the STEPL modeling indicated that the Cañada de Ojo Sarco has the highest per acre sediment flux among the three sub-watersheds, load reduction targets are set at a lower level for this sub-watershed, because terrain conditions and land management options in this sub-watershed will likely be prohibitive to realizing the needed load reductions with the total sum of suggested management measures.

4.3. Management Strategies

Several overall management strategies emerged in the course of the development of this WBP. These strategies can be grouped in three categories:

A. **Large, politically driven management strategies** for a long-term and permanent special area designation and for integrated land management programs, largely driven by financing mechanisms according to payment for ecosystem services and governmental financing
B. **Watershed-wide management strategies** specific for each jurisdiction and land use type, based on existing authorities and management frameworks, driven by existing and future spending authorities within government agencies and through and cooperative grants and agreement programs
C. **Focused, strategic, short-term and mid-long term interventions** in high priority areas, based on collaborative partnerships and a diverse set of public-private funding sources

Table 4.1. Overview of suggested load allocations, load reduction targets, and success indicators by sub-watershed.

Sub-watershed Name and WBP Acreage	HUC: 12-digit Hydrologic Unit Code	Sub-watershed approach	Indicators	Numerical targets for Load Allocations for each sub-drainage
Cañada de Ojo Sarco (Ojo Sarco drainage): 13,842 acres	130201010907	Focus on forest and private land in Cañada de Ojo Sarco (arroyo 118)	Reduction in sediment flux measured or modeled; largely related to a reduction of bare ground	**48% reduction** of the STEPL finding of sediment flux of 11,171.62 lbs/d (0.807 lbs/ac/d) to ***5,334 lbs/d*** **or 0.385 lbs/ac/d**
Cañada de Ojo Sarco / Embudo Creek (Rio de las Trampas drainage): ~29,379 acres	130201010908	Focus on forest and private land in Rio Trampas (arroyo 119) + Cañada de las Marias/ Cañada del Agua (arroyo 111)	Reduction in sediment flux measured or modeled; largely related to a reduction of bare ground	**>100% reduction** of the STEPL finding of sediment flux of 8,204.11 lbs/day (0.28 lbs/ac/day) **to 0 lbs/d or 0 lbs/ac/day**
Cañada Aqua (Arroyo la Mina / Embudo Creek) (small sub-watersheds in the north-western Embudo Valley): ~17,141 acres	130201010909	Focus on soil stabilization and road modifications in the largest of many small drainages; esp. arroyos #: 33, 75, 102, 112, 113, 114, 115, 116, and 117	Reduction in sediment flux measured or modeled; largely related to a reduction of bare ground (incl. dirt roads in arroyos)	**>100% reduction** of the STEPL finding of sediment flux of 6,479.95 lbs/day (0.376 lbs/ac/day) **to 0 lbs/d or 0 lbs/ac/day**
				***TOTAL load reduction: at least 20,521.7 lbs/d and up to 23,973 lbs/d**

*Note: These sub-watershed target amounts are brought in step with the load reduction targets supported by management measures described in Chapter 5. It must be observed that the total load reduction goal of 50,098 is not attainable, unless cumulative effects of management measures over many years bear out to occur. See chapter 5 for details.

A. <u>Large, politically driven management strategies</u>

The proportionally large volumes of sediment which the Rio Embudo periodically delivers to the Rio Grande should be considered a concern of state-wide impact, because the sediment affects stream health, reservoir management, drinking water installations, and irrigation districts downstream. Hundreds of thousands of residents in the state are affected and many millions of dollars are at stake in association with the Rio Embudo's sediment delivery to the Rio Grande.

Unlike other parts of the state, such as the Middle Rio Grande Irrigation District and the Elephant Butte Irrigation District, northern New Mexico is not included in any form of regional water management district. However, the Rio Embudo and many other northern New Mexico streams, along with the Rio Grande headwaters, are critical water source areas for the agriculture sector in northern New Mexico, including the traditional *acequia*-based irrigated agriculture, as well as for the all water distribution and irrigation districts downstream, including those associated with the Rio Grande Compact in Texas[1].

State residents and area residents have the power to work with the institutional sector in the state to petition lawmakers and other elected officials to establish a regional water management and irrigation district in northern New Mexico that is on par with those downstream. Land and water management systems could potentially be financed through a payment for ecosystem services scheme, not unlike the Rio Grande Water Fund and the New York State Association of Regional Councils (NYSARC) Water Resource Program that deliver clean water to New York City[2].

Such large politically driven management strategies could take various forms, including:

I. Large-scale, legislation-based interventions for the area, such as a new water management and irrigation district in the state on par with the Middle Rio Grande Irrigation District and the Elephant Butte Irrigation District
II. Large-scale, legislation-based, continuous intervention aimed at payment for ecosystem services to *acequia* associations, counties, and NMDOT for annually cleaning arroyos, *acequias,* roads, etc. as one part of reducing sediment entering the rivers, and thereby securing the production of water of higher quality to downstream beneficiaries
III. Interventions supported by the Rio Grande Water Fund
IV. Special management area designation at a state level for the Lower Embudo Valley, possibly in association with the Eastern Rio Arriba County and Taos County Soil and Water Conservation Districts, due to its history and risk for future dramatic sediment loss

The most appropriate strategy among these three examples depends largely on the political process that formulates the vision and navigates the process for its accomplishment. During a community meeting in Dixon on September 17, 2019, State Representative Susan Herrera expressed that she is a proponent of the development of a strategy along the lines of the first example (I). Watershed residents

[1] https://www.usbr.gov/uc/albuq/water/RioGrande/pdf/Rio_Grande_Compact.pdf
[2] http://www.cnyrpdb.org/nysarcwater/

can make a difference by working with their elected state and county officials to propose such ideas and promote their realization.

B. Watershed-wide management strategies

Each jurisdiction in the Lower Embudo Watershed has an existing set of authorities and management frameworks to implement multi-year land management projects. Many projects of this kind have management goals that indirectly and sometimes directly help reduce soil loss and sediment transport. Such projects include for example forest thinning projects to reduce wildfire, road maintenance and closure initiatives, and stream restoration programs (see also Chapter 2 for a description of ongoing and planned projects by public land management agencies).

Such watershed-wide management strategies could take a few different forms, including:

V. Strategies based on each jurisdiction's specific management authorities, approaches, and plans, and community involvement in and support for implementation of planned management actions

VI. Watershed-wide and locally controlled strategies in close collaboration with the Rio Grande Water Fund (perhaps related to strategies I, II and III)

The management actions of the public land management agencies are driven by existing and future spending authorities within each of the agencies. Additionally, the agencies sometimes offer cooperative grants and agreement programs to partner with non-profit or for-profit private contractors to achieve management goals. Similarly, Rio Arriba and Taos Counties and the NM Department of Transportation (NMDOT) have ongoing programs for the removal of sediment from roads, bar ditches and culverts. Furthermore, the two counties have the authority to direct zoning, flood management, and terrain management in ways that can reduce erosion and sediment transport. The area's Soil and Water Conservation Districts, EVRAA, and individual *acequias* also have authority and jurisdiction to acquire funds and implement projects.

Private landowners can work together through *acequia* associations, road associations, Soil and Water Conservation Districts, and other local collaborative groups to realize soil conservation projects on private land. When designed at a level of roads, streets, and neighborhoods (across property boundaries), efficiencies may be achieved in cost effectiveness and sediment retention effectiveness.

Straddling the scale of the large, politically driven strategies and the watershed-wide management strategies is an option for EVRAA or other local entities to participate in the Rio Grande Water Fund. This program is a public-private partnership between numerous conservation organizations, businesses, and government agencies, coordinated by The Nature Conservancy (TNC) in New Mexico. The Rio Grande Water Fund operates throughout the Rio Grande basin in northern New Mexico between Santa Fe and the Colorado border. The Fund is structured as a payment for the ecosystem services program and also receives federal grant funding for the implementation of multi-year and multi-partner forest and watershed restoration projects aimed at preventing wildfire and mitigating wildfire impacts from debris flows and flooding. At the time of this writing, efforts are underway to establish the Rio Embudo

Watershed Coalition, under the auspices of TNC. EVRAA and many public land management agencies active in the Lower Embudo watershed have signed on as partners to this initiative.

The strategies listed under V and VI are not mutually exclusive. In fact, they are complementary and mutually supportive. Land management strategies through public agencies are ongoing and can be further encouraged by local residents, and residents and local organizations can seek to participate in them as contractors offering labor and perhaps even plant supplies, such as seed and plant stock. At the same time, Rio Grande Water Fund projects are implemented in tandem with the various management programs of public agencies and in collaboration with a partnership of local and regional civic partners. At least one such program is being implemented in the upper Rio Embudo/Rio Pueblo watershed at this time.

C. <u>Focused, strategic, short-term and mid to long term interventions</u>

In the interest of time and in order to build local capacity and afford a gradual learning and development approach in the community, a feasible and practical strategy for sediment load reductions is the implementation of focused, short-term interventions. These activities are most effective if they are taking place in strategically chosen locations, have local capacity building components, and are well monitored for the purpose of adaptive management of future initiatives. Such interventions often take the form of projects based on collaborative partnerships with a diverse set of public-private funding sources.

Such focused, strategic, short-term and mid-long term interventions could take a few different forms, including:

VII. Focused, strategic short-term and mid-long term interventions in high priority areas
VIII. Pilot projects approach; ideally as a start-up phase to any of the strategies listed above

The selection of interventions must be tied to the identified source areas and causes of soil loss and sediment transport, as described in Chapter 3. In sum, the most important source areas are the many sub-watersheds and small drainages in the Cañada Aqua (Arroyo la Mina/Rio Embudo) and the Cañada de Ojo Sarco, and specifically the mid-elevation and lower elevation sedimentary (alluvial) areas (yellow colored areas in Figure 3.15). Additionally, arroyos, streambanks, and dirt roads are major pollutant contributors, because they function as conveyance zones for sediment transported from higher up and as independently eroding sediment source zones. Major causes of sediment transport, besides natural sources, are cleared areas, degraded riparian habitat, off-road vehicle tracks, grazed areas, fallow farm land, and disturbed forest and woodland area. These causes and associated detailed source areas are exacerbated when they coincide with soils that are highly erodible due to their natural soil structure and their lack of organic matter or stone components.

The suitability of implementing management measures in many critical areas is limited in the Lower Embudo watershed due to steep terrain conditions and lack of roads that can carry people, heavy equipment, and supplies to critical restoration areas. Additionally, the feasibility of work at such critical areas is limited due to their predominant location on federal lands, for which long regulatory processes are required before implementation can take place. Where these critical areas are located in the developed parts of the Lower Embudo watershed, a “checker boarded” fragmentation of private and public landownership may complicate planning and financing.

Furthermore, there is a need to raise funds, develop local and regional implementation capacity in agencies, in the land restoration industry, and in local communities, and conduct research and evaluation to ascertain the most appropriate management measures for each area (see Chapter 5). The latter is important in order to refine and tweak management measures (and their combinations) that can be replicated and scaled up for treatment across a larger part of the watershed area in the decades to come.

Therefore, it is important to analyze the landscape with a view toward the most feasible strategy for the implementation of focused, strategic, short-term and mid- to long-term interventions. Such an analysis also needs to consider how management measures can be scaled up over a larger area over time to achieve the greatest reduction of sediment loads toward meeting pollutant reduction goals.

Table 4.2 summarizes an assessment of the most suitable terrain conditions for strategic short- and mid- to long-term initiatives; in other words, the table sums up where terrain conditions offer “sweet spots” for the implementation of management measures. In this landscape analysis, critical areas are those areas that are accessible, feasible to treat with modest means, having a relatively high chance for success in a short-term period, and practicable for purposes of fund raising, capacity building, and public education. Such locations are also suitable for pilot projects where management measures can be tested and disseminated for application throughout the community. Areas that should be prioritized for short-term (a first phase, e.g., 2020-2023) intervention are in category A. Mid-term phases (2024-2027) could address priority areas B, while in the longer-term priority areas (C) should be addressed in a third phase (2028-2035). Certain landscape features and areas will be unsuitable for treatment altogether, such as steep rocky outcrops and remote upland areas; they are indicated as priority area D. Chapter 5 specifies the detailed, recommended project locations for the implementation of management measures and their prioritization.

4.4. Management Measures

The management measures presented in this section are derived from a review of existing management measures in the watershed combined with suggested management measures that have proven practicable elsewhere. Management measures and their estimated sediment load reduction potential are described in Appendix 6.

Given the unique relationships between landscape types, jurisdictions, and land use across the watershed, specific management measures are appropriate for specific land uses, land management areas, and jurisdictions. Table 4.3 provides an overview of management measures with an indication for which jurisdictions they are most appropriate, along with the expected load reductions over a period of approximately 20 years or less, and with citation references which are listed at the end of the chapter in association with Table 4.3. (See Figures 4.3-4.6 for several examples of locally appropriate and effective management measures).

Table 4.2. Assessment of terrain units and their suitability and feasibility for short-term rehabilitation success.

#	Terrain Unit Description	Suitable Management Measures	Land Suitability for Intervention	Feasibility of Management Measures	Priority Rating
A	Steep, rock capped, soft, rocky material, often bare, with long concave slopes; typical erosion (sediment) source areas	Engineered solutions, biotechnical slope control	Moderate	Very low	C (D)
B	Steeper mid-slopes, either long or short, poorly to moderately vegetated (cacti, brush and grass), concave, and erosive in the lower colluvium; intermediary transition areas	Revegetation, soil conservation techniques, prescribed-managed grazing, Keyline planning/terracing	Moderate	Moderate	B
C	Exposed, protruding, convex, dry, bare, long, mid-slope, erosive knobs and ridges	Engineering techniques, biotechnical slope protection, and rock structures	Moderate	Low	C (D)
D	Exposed, unconsolidated soils, well drained, somewhat vegetated, with short convex slopes (very erosive); often dissected colluvial material, halfway or 2/3 down the long slopes, and still above the arroyos or valley bottoms	Vegetative techniques and soil conservation structures	Low	Moderate	A/B
E	Exposed, bare sandy cliffs and short slopes above arroyos (arroyo top edges); poorly drained and eroded alluvial material	Soil conservation techniques and revegetation	High	High	A
F	Not very steep (moderately sloped), short or long slopes and terraces and alluvial areas with fine, erosive (loamy) material, including perched wetlands; often well vegetated (grass, brush, woodland). Alluvial and riparian or drier.	Revegetation, cultivation, grade controls, terracing, and soil conservation techniques	High	High	A
G	Flatter valley bottom lands and alluvial plains and terraces; loamy clays, and sandy loams; often plenty of vegetation; gravelly stream beds	Revegetation, terracing, buffer strips, etc.	Low	High	A/B

Figures 4.3 (left) and 4.4 (right). Example of sediment retention structures (picket and wicker weir) in a perched wetland site, which is a high suitability and high feasibility restoration site, with conditions after one year (in 2014, photo left) and after six years (in 2019, photo right).

Figures 4.5 (left) and 4.6 (right). Examples of relatively simple and highly effective soil stabilization and sediment retention techniques: a cover crop of native grasses, wheat, rye, and barley (left), and a rock bowl structure (right).

In practical terms, management measures are effective because they reduce any of the other erosion factors in the Revised Universal Soil Loss Equation (RUSLE) (see Chapter 3). Effective management measures may for example reduce the C-factor if greater soil cover by vegetation or mulch is achieved, or they reduce the LS-factor if shorter and lower grade slope segments are achieved. Management measures can even lower the K-factor, if they enhance the soil structure in such ways that the soil becomes less erodible, for example by adding organic matter, incorporating stones, or improving infiltration. In relation to the USPED (see Chapter 3), management measures can also reduce the upslope contributing area (A) and reduce rill and gully erosion, leading to increased sedimentation potential.

The combined load reduction value or efficacy of a management measure is expressed in the P-factor (Pf), or the Field Practices factor, as per Wischmeier and Smith's original definition of the P-factor in the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978)[3]. For example, a P-factor of 0.3 means that the soil loss estimate is reduced to 30% of the original condition.

The sum of these combined erosion and sedimentation factor changes due to a management measure is expressed in a P-factor for each management measure. P-factors have often been empirically established. They can in some cases also be calculated with the RUSLE equation (e.g., with STEPL modeling) based on assumptions and treatment targets for improved terrain conditions for a specific treatment (i.e., management measures).

Estimates for the efficacy of management measures is based on the best available information and estimation methods at the time of writing this WBP. Load reductions for many of the management measures used in this WBP were either calculated based on cited reference data, based on monitoring findings in various projects, or interpreted from references about the empirically found sediment retention efficacy. Table 4.3 provides an overview of management measures for each jurisdiction with the expected load reductions.

It should be noted that management measures do not generate sediment retention results in only one year. Their efficacy is dependent on weather, terrain conditions, and maintenance, and the indicated estimates for sediment load reductions are usually realized over many years (and up to several decades), especially where vegetation growth is the driving factor for their success.

Complex management measures (green highlighted in Table 4.3), such as individual stream and riparian habitat restoration interventions, invasive weed management projects, or higher-standard road maintenance and road management work, do not have any established P-factors. Their sediment retention efficacy will need to be estimated on a project-specific basis. For regulatory and socially-oriented management measures (yellow highlighted), such as signage, public education, enforcement, land use planning, or wildlife management interventions, no sediment efficacy estimates can be made. However, these management measures are included in the listing below, because they are critical to achieving success for many other, more tangible, hands-on management measures for which a sediment retention factor can be estimated. A special case of regulatory measures involves land use restrictions or area closures (for example through signage, conservation easements, fencing, etc.), where in theory the P-factor is 1, which means no change to the soil loss and sediment transport condition. However, access restrictions and area closures may have the side effect of natural plant regeneration leading to reduced C-factor levels and increased soil cover with organic matter leading to reduced K-factor levels, and thus to reduced soil loss over time. Area closures also tend to support the success of other management measures.

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[3] Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall and erosion losses: a guide to conservation planning. USDA Agricultural Handbook #537. Washington, D.C. [a.k.a.: USDA Soil Conservation Service. 1978. Predicting rainfall erosion losses: a guide to conservation planning. USDA Agricultural Handbook #537. Washington, D.C.]

Table 4.3. Overview of recommended management measures for the Lower Embudo watershed, their appropriateness for various jurisdictions and their expected Load Reductions over a 20-year period.

			Expected Load Reduction		
Management Measure	**Management Areas**	**Jurisdictions**	**P Factor**	**Citations**	**Optimization**
Forest Thinning (lop & scatter)	Ponderosa Pine & Mixed Conifer Restoration	USFS, BLM, STL	0.1	1, 2	ground cover > 80% for nearly flat terrain; and > 95% for slopes of 30%
Forest Thinning (biomass removal)	Ponderosa Pine & Mixed Conifer Restoration	USFS, BLM, STL	0.37	1	as above; leaving duff and leaving some slash in open patches
(Fire) Wood Removal/Harvesting	Ponderosa Pine & Mixed Conifer Restoration	USFS, BLM, STL	0.5	1	leaving slash and ensuring that slash is spread out
Timber Harvesting	Ponderosa Pine & Mixed Conifer Restoration	USFS, BLM, STL	0.15-1.00	1	leaving ground cover of slash or brush, but not beneath trees
Prescribed Fire/Pile Burns	Ponderosa Pine & Mixed Conifer Restoration	USFS, BLM, STL	0.37	1	with a ten-year recovery period (gradual reduction of C-factor)
Seeding	Ponderosa Pine & Mixed Conifer Restoration	USFS, BLM, STL	0.2	1, 3	sow just before rainy season
Woodland Thinning (lop & scatter)	Pinon/Juniper Woodland Restoration	USFS, BLM, STL, PRIV	0.1	1, 2	ground cover > 80% for nearly flat terrain; and > 95% for slopes of 30%
Woodland Thinning (biomass removal)	Pinon/Juniper Woodland Restoration	USFS, BLM, STL, PRIV	0.37	1	as above; leaving duff and leaving some slash in open patches
(Fire) Wood Removal/Harvesting	Pinon/Juniper Woodland Restoration	USFS, BLM, STL, PRIV	0.5	1	leaving slash and ensuring that slash is spread out
Prescribed Fire/Pile Burns	Pinon/Juniper Woodland Restoration	USFS, BLM, STL, PRIV	0.37	1	with a ten-year recovery period (gradual reduction of C-factor)
Seeding	Pinon/Juniper Woodland Restoration	USFS, BLM, STL, PRIV	0.2	1, 3	sow just before rainy season
Managed grazing, including water source constr./removal, fencing	Rangeland Restoration and Grazing Management	USFS, BLM, STL, PRIV	0.25	1	Full adherence to BMPs; proper monitoring and enforcement
Riparian grazing management; Riparian buffers; resting	Rangeland Restoration and Grazing Management	USFS, BLM, STL, PRIV	0.05-0.7	8, 9, 10, 12	Full adherence to BMPs; proper monitoring and enforcement

Table 4.3. – Continued

			Expected Load Reduction		
Management Measure	**Management Areas**	**Jurisdictions**	**P Factor**	**Citations**	**Optimization**
Stream/riparian restoration	Rangeland Restoration and Grazing Management	USFS, BLM, STL, PRIV	var		Monitoring to establish P factor for comparable lands
Resting (no grazing)	Rangeland Restoration and Grazing Management	USFS, BLM, STL, PRIV	1	1	Monitoring to establish P factor for comparable lands
Perennial plant revegetation on retired fields or rangelands	Rangeland Restoration and Grazing Management	USFS, BLM, STL, PRIV	0.2 (0.1-0.5)	4, 5, 13	Using contour plantings with intercropping techniques
Invasive spp/weed management	Rangeland Restoration and Grazing Management	USFS, BLM, STL, PRIV	var		
Signage/Interpretive or Interactive Public Education	Recreation and Travel Management	USFS, BLM, STL	N/A		
Road Maintenance / Runoff management	Recreation and Travel Management	USFS, BLM, STL, PRIV	var		
Road/Trail Construction	Recreation and Travel Management	USFS, BLM, STL	var		
Road/Trail Closures	Recreation and Travel Management	USFS, BLM, STL, PRIV	var		
Area Closure	Recreation and Travel Management	USFS, BLM, STL	1	1	
Restoring compacted soils	Recreation and Travel Management	USFS, BLM, STL, PRIV	var		
Wildlife culling/removal	Wildlife Management	USFS, BLM, STL	var		
Wildlife (re)introduction	Wildlife Management	USFS, BLM, STL	N/A		
Enforcement (policing)	Wildlife Management	USFS, BLM, STL	N/A		

Table 4.3. – Continued

			Expected Load Reduction		
Management Measure	Management Areas	Jurisdictions	P Factor	Citations	Optimization
Signage/Interpretive or Interactive Public Education	Planning & Regulation	USFS, BLM, STL, COUNTY	N/A		
Land Use Planning/Zoning	Planning & Regulation	USFS, BLM, STL, COUNTY	N/A		
Incentive Planning (e.g., targeted infrastructure layout)	Planning & Regulation	USFS, BLM, STL, COUNTY	N/A		
Enforcement (policing)	Planning & Regulation	USFS, BLM, STL, COUNTY	N/A		
Use Restrictions/ Regulations	Planning & Regulation	USFS, BLM, STL, COUNTY	N/A		
Cover crops	Land.Farm Management	PRIV	0.2	4, 5	
Contour buffer strips	Land.Farm Management	PRIV	0.3	4, 5	
Terracing	Land.Farm Management	PRIV	0.15	1, 5, 6, 7	
Riparian grazing management; Riparian buffers; resting	Land.Farm Management	PRIV	0.05-0.33-0.7	8, 9, 10, 12	
Soil Conservation Structures	Land.Farm Management	PRIV, NMDOT, UTIL	0.07-0.94	1, 3, 11	
Mulch, compost, soil cover	Land.Farm Management	PRIV	0.01	1, 3, 4, 5	
Soil amendments/fertilizer	Land.Farm Management	PRIV	var		
Road/Trail Construction	Land.Farm Management	PRIV	var		
Road Maintenance / Runoff management	Land.Farm Management	PRIV, NMDOT, UTIL	var		
Invasive spp/weed management	Land.Farm Management	PRIV, NMDOT, UTIL	var		
Area Closure	Land.Farm Management	PRIV, NMDOT, UTIL	1	1	
Road/Trail Closures	Land.Farm Management	PRIV, NMDOT, UTIL	var		
Restoring compacted soils	Land.Farm Management	PRIV, NMDOT, UTIL	var		
Stream/riparian restoration	Land.Farm Management	PRIV, NMDOT, UTIL	var		
Managed irrigation systems & irrigation management planning	Land.Farm Management	PRIV	N/A		

Table 4.3. – Continued

			Expected Load Reduction		
Management Measure	**Management Areas**	**Jurisdictions**	**P Factor**	**Citations**	**Optimization**
Seeding	Soil Conservation	PRIV, NMDOT, UTIL	0.2	1, 3	
Restoring compacted soils	Soil Conservation	PRIV, NMDOT, UTIL	var		
Stream/riparian restoration	Soil Conservation	PRIV, NMDOT, UTIL	var		
Road/Trail Construction	Access Management	PRIV, NMDOT, UTIL	var		
Road Maintenance / Runoff management	Access Management	PRIV, NMDOT, UTIL	var		
Area Closure	Access Management	PRIV, NMDOT, UTIL	1	1	
Road/Trail Closures	Access Management	PRIV, NMDOT, UTIL	var		
Invasive spp/weed management	Vegetation Management	PRIV, NMDOT, UTIL	var		

Jurisdictional abbreviations:

BLM: Bureau of Land Management

COUNTY: Rio Arriba or Taos Counties

NMDOT: New Mexico Department of Transportation

PRIV: Private landownership

STL: New Mexico State Trust Land (NM State Land Office)

USFS: USDA Forest Service – Carson National Forest

UTIL: Utility Companies

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5. PLAN DESCRIPTION

5.1 Watershed Restoration Strategy

The watershed restoration strategy for the Lower Embudo watershed consists of a phased plan approach that includes the following components:

A. **Developing and/or seeking collaboration with large legislative initiatives that protect water sources, water supplies, and water quality throughout northern New Mexico.**

B. **Developing and/or seeking collaboration with watershed-wide initiatives, especially in collaboration with public land management agencies**

C. **Developing many projects at a local scale to address site-specific sediment transport problems**

D. **Educating and providing incentives to private residents, landowners, and businesses to undertake best practices to stem soil loss and sediment transport and to provide supplies, labor, and other services to local restoration initiatives.**

All strategy components lean on the watershed restoration planning principles described in chapter 1. This Watershed-based Plan (WBP) will particularly address a series of recommended initiatives under plan components C and D, listed above. These initiatives revolve around targeted treatment areas (prioritized project sites), local capacity building, local stewardship work, and developing a collaborative work approach.

Key plan activities include:

A. <u>Building local capacity</u>

a. **Local leadership and local control:** EVRAA and individual landowners have stepped forward to take up this role and lead this key requirement.
b. **Building local knowledge:** Local leaders and residents will continue to gain knowledge of water quality impairments and their causes, appropriate management measures, and ways to monitor water quality and land management improvements. EVRAA, individuals, and the Embudo Valley Library have taken on an important role in acquiring, storing, and disseminating knowledge about the watershed.
c. **Management measures:** Local experience with management measures and land use practices must be further developed. All planning and project implementation must allow for local learning, trial and error, evaluation, and doing it again (i.e., adaptive management).
d. **Stimulating local community collaboration and broad stakeholder participation:** Local collaboration and broad participation is essential for private and public land restoration efforts. The local leadership and its outside partners will need to continue to grow their collaborative approach and optimize the inclusion of as many local participants as possible.

B. Building agency capacity and regional multi-stakeholder collaboration

e. **Governmental capacity building:** Government institutions will need to allocate resources to the goals of the WBP. Local residents and regional stakeholders will need to use the political process to advocate for capacity building within the government agencies to enable the agencies to pursue the WBP goals.
f. **Collaboration:** Local initiatives, agency activities, and projects in the area must seek to implement their work in a collaborative way. Government agencies, local landowners, and non-profit service organizations will need to support each other and seek collaborative approaches to their work.
g. **Local businesses:** Activities for the WBP should strive to include local businesses in order to establish and grow a local land restoration and stewardship economy that boosts the local and regional economy. This work would be part of the local economy for decades to come.

C. Growing soil and plants

h. **Soil development:** The basis for reaching Target Load Reductions is to improve soil conditions in critical areas to such levels that soil loss and downslope delivery in surface waters is reduced to target levels. This comes down to growing and modifying the soil in order to beneficially alter the land-cover and soil erodibility relationships that effect soil loss and erosion.
i. **Growing vegetation cover and diversity:** Diverse vegetation cover offers resilience to the landscape during severe weather events by stimulating sediment retention and by protecting the soil from erosion.
j. **Smart farming and acequia practices:** Sustainable, smart farming practices and acequia cleaning practices will help reduce sediment discharge in the Rio Embudo. These are ecosystem services that could possibly generate revenues from downstream beneficiaries. Such "payments for ecosystem services" would help maintain the financial viability of the acequia agriculture community and grow into a pivotal strategy for financing management measures in the WBP area. Ecosystem service activities could include cleaning *acequias* and roadways, performing land restoration and stewardship contract work, and producing plants, compost or seed for restoration projects.

D. Many small erosion control and water harvesting techniques

k. **Small projects:** Evaluation of past projects, a survey of local residents, and resident feedback during community meetings have indicated that small projects for sediment retention and erosion control are very effective and feasible in the WBP area. Individual structures can retain hundreds to thousands of tons of sediment each for a decade or more, especially when vegetation regeneration or other forms of soil cover are successfully realized.

At this time in the development of this WBP specific management plans have only been developed for the area managed by the US Forest Service. The BLM is in the process of a detailed plan of management measures. However, no other proposed activities with details on specific management measures are in place or have been approved within the watershed. The next section will describe approved and proposed activities.

The design of each project of management measures will need to specify the type and scale of each of the management measures selected. Appropriate management measures for the WBP planning area are listed in chapter 4 and described in Appendix 6. While each project will need to offer estimates of the SSL reduction of the selected management measures, the description of management measures in Appendix 6 provides indications of sediment load reductions that may be expected from each management measure.

5.2 Treatment Areas

This WBP proposes the development and implementation of projects with treatments on public lands, private lands, and on a combination of jurisdictions. Many projects, regardless of landownership will likely need to be supported through public-private partnerships with strong participation of local stakeholders, and with local leadership when appropriate.

Treatments on public land are typically established through agency-driven planning processes (see Section 5.3). Public participation and feedback on the planning processes varies with the size, scope, and location of the treatment or management proposals. Typically, these initiatives are multi-year endeavors that stretch across hundreds or even thousands of acres of public land.

Treatments on private land can be private initiatives as well as community-driven, collective actions in which multiple landowners participate for the benefit of the entire community, because expected results reach far beyond individual properties. This WBP advocates for the development of collaborative neighborhood projects on private lands with treatments that are driven by strong participation of local residents and local leadership.

The selection of treatment areas should focus on terrain units in the landscape that are most suitable for treatment, along with several other critical site selection factors that describe the feasibility of management measures in those terrain units, as outlined in Table 4.2, Chapter 4. Such factors include access for vehicles with equipment, supplies, and workers, educational potential for dissemination of results, regulatory requirements and limitations, and of course landowner motivation and agreement with the implementation of certain treatments or management measures. It is also important to consider the proximity of sediment transport areas to buildings and infrastructure. This latter factor holds considerable motivational and financial weight in prioritizing treatment areas.

Table 5.1 lists a limited number of new project recommendations based on suggestions by local residents and field review of projects completed between 2012 and 2016. Their locations are illustrated in Figures 5.1 and 5.2. The suggested projects have been evaluated for the feasibility of the recommended management measures for the selected areas and for their relevance at the suggested project site in relation to the treatment of root causes of sediment transport and the need to meet sediment load reduction targets. The project list identifies suggested treatment areas and recommended management measures for local multi-party project proposals in addition to those treatment areas and treatments which public land management agencies are planning to undertake. Local *acequias* and residents can play a key role in the suggested projects.

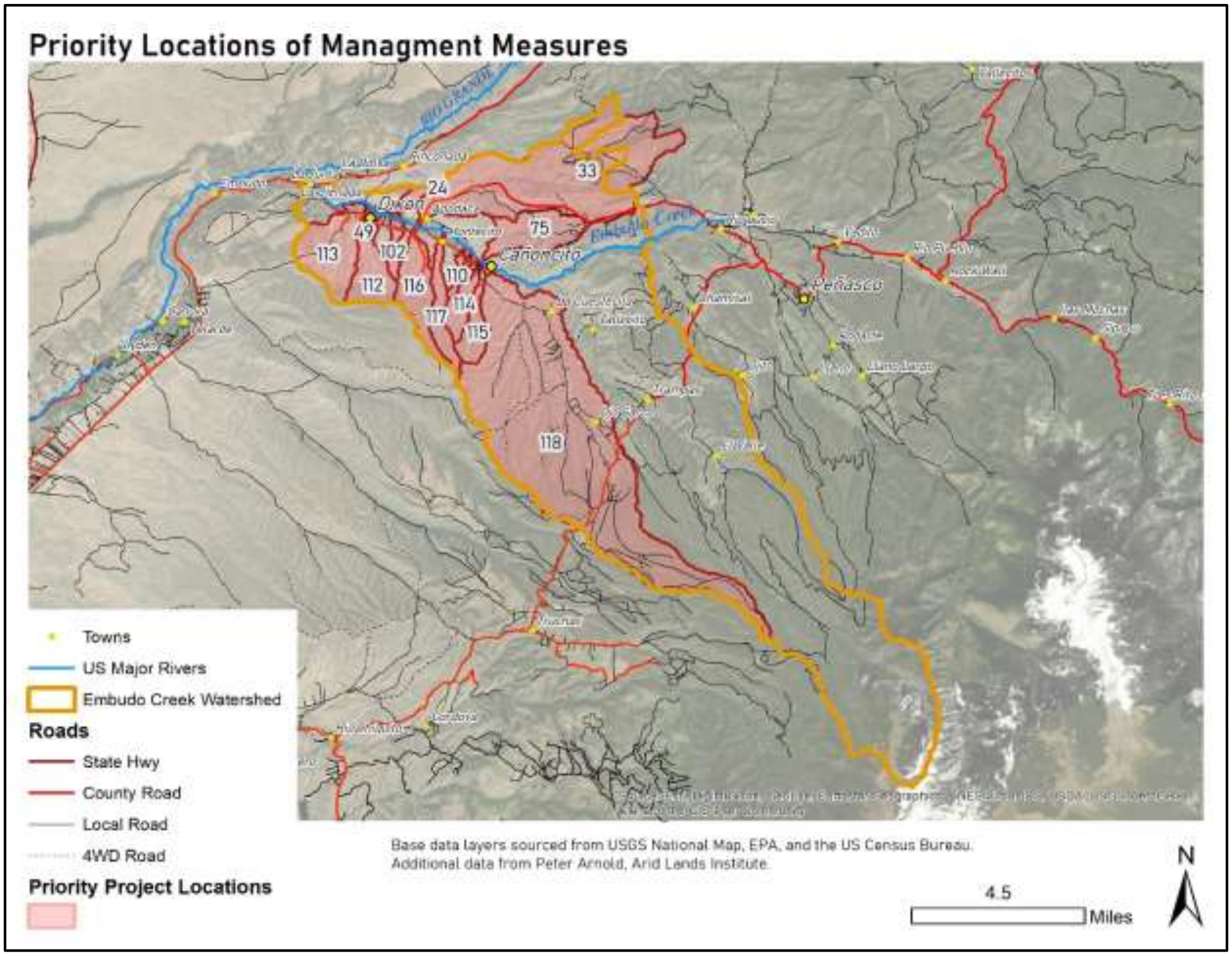

Figure 5.1. Overview map of priority locations by sub-watershed for the implementation of management measures.

Table 5.1. List of Suggested New Projects with Management Measures to Reduce Sediment Transport, in descending order of priority.

Project #	Project Name	Suggested Project Scope	Location Description/ Terrain Unit	Estimated Acreages	Ownership	Benefits / Purpose	Needed Action
1	Rio Arriba County Road 240 area	Streambank stabilization and arroyo drainage and sediment management	Confluence area of Arroyos 24 and 23 (Gonzales) and Arroyo 102	Arr-23+24: 208.8 ac, Arr-102: 287.4 ac; Total 496.2 ac	Rio Arriba County road; BLM	Road safety, public access, SSL reduction	Detailed area assessment and BLM and landowner support
2	Canadita del Agua	Close of ORV access; restore plan cover; restore wetland rock structures	Arroyo 105 - Canadita del Agua (just west of Arr d/l Pinos Reales	76.4 ac	BLM and SLO	Sediment reduction, land health	Initial workshop for restoration; area assessment
3	Arroyo de los Arellanos	close off ORV access remove Russian olive; restore log & stream stabilization structures	Arroyo 110 in Montecito	125 ac	BLM	Sediment reduction, land health	Initial workshop for restoration; area assessment
4	Perched wetland stabilization	Restore all perched wetlands in the area	All drainages west of Arr d/l Pinos Reales and Arroyo Lorenzo	total between 100-1000 ac	BLM and SLO	Maintaining stable spots that absorb sediment	Detailed area assessment and BLM and landowner support
5	Arroyo 94	Erosion control and sediment management in fields and arroyos	East of Arroyo de los Arellanos	60.3 c	BLM (upstream), private (down-	Road safety, sediment reduction, land health	Detailed area assessment and BLM and landowner support
6	Arroyo de los Pinos Reales east and west	Many small erosion control structures and repairs	Arroyo 114 and 115	Arr-114 (W): 552.3 ac, Arr-115 (E): 669.7 ac	USFS, BLM, SLO	Road safety, sediment reduction, land health	Detailed area assessment and BLM and landowner support
7	Acequias	Acequia improvements for sediment management	TBD	TBD	BLM	Land health and sediment management	Detailed area assessment and BLM, EVRAA, and landowner support
8	Canada de Ojo Sarco above confluence with Rio Embudo	Flood attenuation and sediment retention; through alluvial fan reconstruction and induced meandering	Arroyo 118 (HUC 130201010807)	approx. 100 acres at confluence	SLO (maybe BLM) and private	Road safety, sediment reduction, land health	Detailed area assessment and BLM and landowner support
9	Arroyo Lorenzo roads	County Road relocation and erosion control and revegetation	Arroyo 116	roads in a 1231.3 ac watershed	Private and BLM	Road safety; Separate drainage; sediment reduction; land health	Detailed area assessment and BLM and landowner support

Table 5.1. Continued.

Project #	Project Name	Suggested Project Scope	Location Description/ Terrain Unit	Estimated Acreages	Ownership	Benefits / Purpose	Needed Action
10	Arroyo Pino roads	County Road relocation and erosion control and revegetation	Arroyo 1122	roads in a 1047.2 ac watershed	Private and BLM	Road safety; Separate drainage; sediment reduction; land health	Detailed area assessment and BLM and landowner support
11	Arroyo la Mina roads	County Road relocation and erosion control and revegetation	Arroyo 113	roads in a 1741.8 watershed	Private and BLM	Road safety; Separate drainage; sediment reduction; land health	Detailed area assessment and BLM and landowner support
12	Arroyo Pino wetlands	Restore all perched wetlands in the area	Arroyo Pino (112)	total between 10-100 ac	BLM and SLO	Maintaining stable spots that can absorb sediment	Detailed area assessment and BLM and landowner support
13	Arroyo la Mina wetlands	Restore all wetlands in the area	Arroyo Mina (113)	total between 50-250 ac	BLM and SLO	Maintaining stable spots that can absorb sediment	Detailed area assessment and BLM and landowner support
14	Arroyo del Plomo	Close of ORV access; reation of sediment retention sites with small and medium dams and vegetation cover	Arroyo 33 (along SR 75 NE of Dixon)	7,266.1 ac (parts of it)	BLM, SLO	Road safety; Sediment reduction; land health	Detailed area assessment and BLM and landowner support
15	Arroyo 49 behind Library	Watershed stabilization	Arroyo 49 (ball field, behind Library and downtown Dixon)	63.8 ac	BLM	Road safety; drainage mgmt; sediment reduction; land health	Detailed area assessment and BLM and community support
16	Arroyo of interest of Joe Ciddio	Arroyo stabilization	TBD	approx 200 ac	BLM	Land health and sediment management	Detailed area assessment and BLM and landowner support
17	Arroyo de Montecito	Watershed stabilization	Arroyo 117	729 ac	BLM	Land health and sediment management	Detailed area assessment and BLM and, landowner support
18	Arroyo NW of Canoncito	Watershed stabilization	Arroyo 75	1395.9 ac	BLM	Land health and sediment management	Detailed area assessment and BLM and, landowner support
TOTAL ACREAGE				**17,179.30**			

5.3. Description of Planned and Recommended Treatments

Comprehensive Overview of all Recommended Management Measures

Expanding on the suggested new projects listed in Table 5.1., a comprehensive overview of all planned (committed) and suggested management measures and terrain treatments is listed in Table 5.2 and illustrated in Figures 5.1 and 5.2. The sum of the management measures achieves 10,574 lbs/day toward the Load Reduction Goal of 50,098 lbs/day, or 21.1% of the goal. However, over several decades, this Load Reduction Goal could possibly be achieved thanks to some potential, additional treatments in arroyos and on public forests and woodlands, and because of cumulative effects of all treatments across the landscape.

The projects listed in Table 5.2 indicate that the greatest sediment load reduction results could be achieved across BLM land and State Trust Land. Rigorous application of management measures on private properties and on unpaved County and BLM roads and driveways would likely also have a significant impact toward meeting sediment load reduction goals.

More treatment projects and management measures could possibly be identified, particularly on USFS land, to complement the currently committed and suggested projects. Table 5.3 summarizes the committed and suggested projects of Table 5.2 with a list of possible treatment projects and management measures that could be considered in the future (e.g., in phase 2 of the WBP timeline). The project ideas added to Table 5.3 are not included in Table 5.2., because there is insufficient data on current land health conditions and suspended sediment loads from the source areas related to these possible project ideas (see Chapter 3 on Data Gaps). There also is a lack of information on appropriate management measures and the associated load reduction potential from these areas, and many of these areas will need to be prioritized by the CNF and cleared under NEPA regulations. As a result, treatments leading to tangible load reduction estimates are uncertain and must be considered only as options for future project phases.

US Forest Service Treatments

The Carson National Forest (CNF) has outlined a series of forest health treatments in the October 2017 Trampas FONSI and EA (USFS 2017-a, 2017-b) as well as a number of separate fuelwood projects (USFS 2016-a, 2016-b). The projects described in the FONSI and EA started in 2018 and 2019, while the fuelwood projects in the Ojo Sarco and Entrañas areas started in 2016. The planned Trampas area forest health treatments include:

- ***Thinning and prescribed fire***: a variety of thinning and fuel reduction treatment prescriptions across several different forest types
- ***Road maintenance and repair***: road improvement treatments in the area to mitigate erosion from forest roads (temporary increase during implementation to be expected, but maintenance and later road closures would mitigate sediment transport in long-term)

The fuelwood projects include:

- ***A fuelwood block*** south of Ojo Sarco area of approximately 395 acres
- ***A fuelwood block*** in the Entrañas area of approximately 350 acres

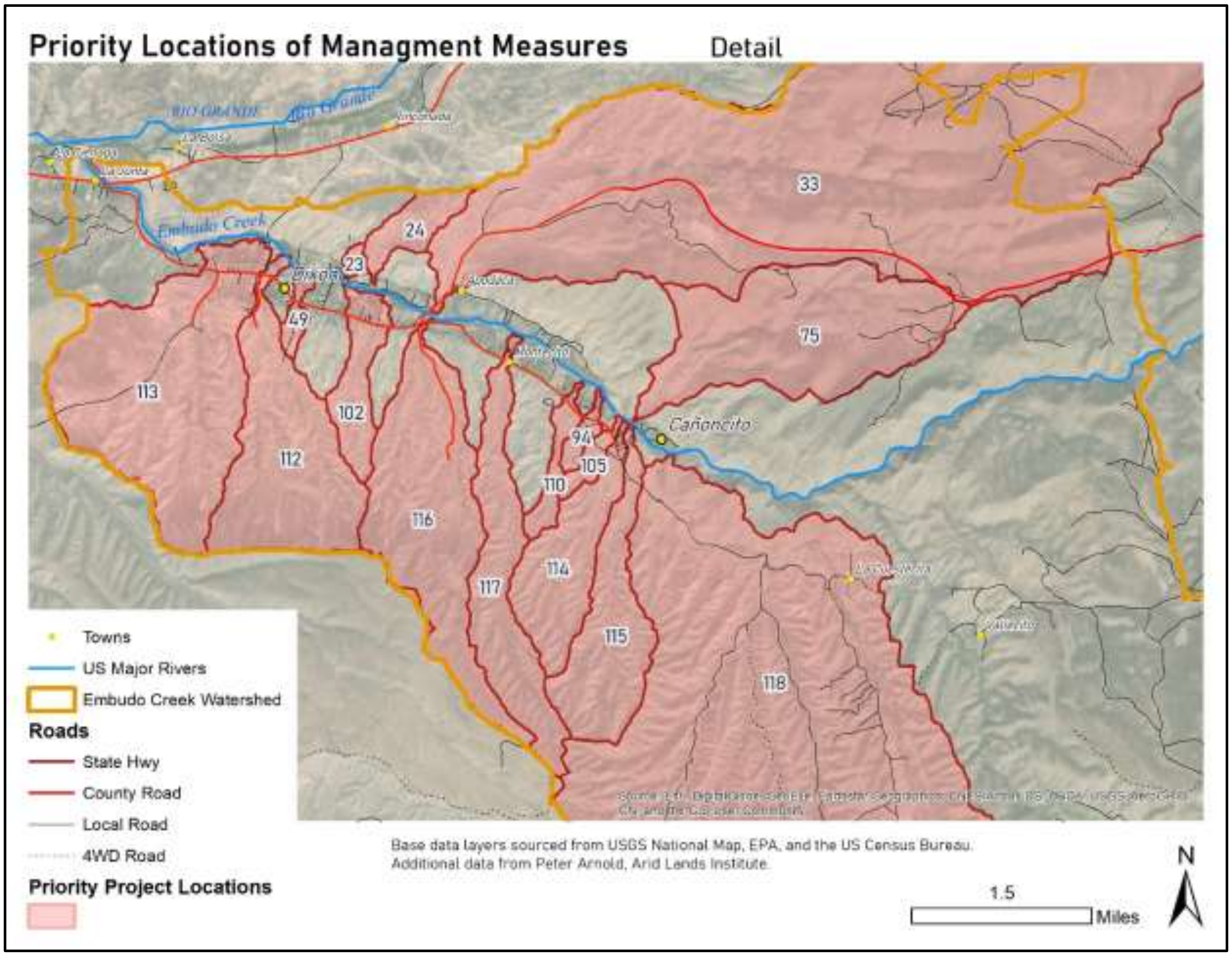

Figure 5.2. Map detail of priority locations by sub-watershed in the northern part of the Lower Embudo watershed for the implementation of management measures.

Details on project locations and estimated sediment reduction values are included in Table 5.2. The sediment load reduction data are based the USFS WEPP FuME modeling. To estimate the sediment yield and its load reductions for the two fuelwood blocks outside the EA area, the information from the EA was interpreted to apply to the fuelwood areas. The WEPP FuME sediment modeling on the national forest produced results that are close to those found in STEPL modeling for the same HUC areas, and are therefore adopted as the target values to be used in the WBP.

Table 5.2. Summary of Management Measures and Expected Sediment Load Reductions

Projects / Interventions	Management Measures	Jurisdiction	Phase	Acreage	Potential Partners	Load Reduction Estimate				Cost Range Estimate
						(Pf) %	lbs/ac/d	total lbs/d	Source	
Canada de Ojo Sarco (Ojo Sarco drainage): HUC 130201010907				**13,842**				**1,334.4**		
Trampas EA Thinning and Prescribed Burns	A: Forest Thinning and Prescribed Fire	USFS -CNF	1 + ongoing	340	Contractors, communities	40.4	0.207	70.4	USFS 2017-a	Unknown
Trampas EA Road Work and Erosion Control	G: USFS Roads	USFS -CNF	1 + ongoing	1,250	Contractors, communities	Unknown	0.155	193.8	USFS 2017-a	Unknown
Other Carson NF Treatments: Ojo Sarco N, S, and Entranas Fuel Wood Areas	B: Woodland Thinning and Wood Removal	USFS -CNF	1 + ongoing	910	Contractors, communities	40.4	0.207	188.3	USFS 2017-a; USFS 2016a, -b	Unknown
BLM EA Thinning and Prescribed Burns	A: Forest Thinning and Prescribed Fire	BLM	1 + ongoing	700	Contractors, NGOs	37	0.508	355.9	Appendix 7	Unknown
Canada de Ojo Sarco above confluence with Rio Embudo	H: Stabilizing Streams; Stream Channel and Bank Stabilization	SLO	1 or 2	~40	Contractors, communities, NGOs	avg. <25	0.605	24.2	Appendix 7	TBD
Arroyos in lower Canada de Ojo Sarco	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	SLO and BLM	1 or 2	~300	Contractors, communities, NGOs	avg. <25	0.605	181.6	Appendix 7	$100,000 to $300,000
Rio Arriba County Road Work	G: Unpaved Roads, Rio Arriba County	Rio Arriba County	1 + ongoing	~ 20 mi with 75 ac work area	Contractors, communities	Unknown	0.155	11.6	Appendix 7	TBD
Perched Wetland Stabilization (#4)	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	SLO, BLM, USFS	2 + ongoing	TBD (perhaps 10 acres)	Contractors, communities, NGOs	avg. <25	0.605	6.1	Appendix 7	$50,000 to $100,000
Private land treatments	F: Soil Conservation on Croplands and Pastures (cover crops, contour buffers, riparian buffers)	Private	1 + ongoing	aim at 500	Communities	avg. <25	0.605	302.6	Appendix 7	$250,000 to $500,000

Projects / Interventions	Management Measures	Jurisdiction	Phase	Acreage	Potential Partners	Load Reduction Estimate				Cost Range Estimate
						(Pf) %	lbs/ac/d	total lbs/d	Source	
Canada de Ojo Sarco / Embudo Creek (Rio de las Trampas): HUC 130201010908 (WBP planning area only)				**29,379**				**2,355.2**		
Trampas EA Thinning and Prescribed Burns	A: Forest Thinning and Prescribed Fire	USFS -CNF	1 + ongoing	3,293	Contractors, communities	40.4	0.207	681.4	USFS 2017-a	Unknown
Trampas EA Road Work and Erosion Control	G: USFS Roads	USFS -CNF	1 + ongoing	3,293	Contractors, communities	Unknown	0.155	508.9	USFS 2017-a	Unknown
Other Carson NF Treatments	B: Woodland Thinning and Wood Removal	USFS -CNF	1 + ongoing	1,370	Contractors, communities	40.4	0.207	283.5	USFS 2017-a	Unknown
BLM EA Thinning and Prescribed Burns	A: Forest Thinning and Prescribed Fire	BLM	1 + ongoing	2000	Contractors, NGOs	37	0.176	352.8	Appendix 7	Unknown
BLM EA Road Work and Erosion Control	G: BLM Roads	BLM	1 + ongoing	2,000	Contractors	Unknown	0.155	310.0	USFS 2017-a	Unknown
SLO Thinning and Prescribed Burns	B: Woodland Thinning and Wood Removal	SLO	1 + ongoing	500	Contractors, communities, NGOs	37	0.176	88.2	Appendix 7	$500,000 to $750,000
Taos and Rio Arriba County Road Work	G: Unpaved Roads, Taos and Rio Arriba County	Taos and Rio Arriba County	1 + ongoing	>40 mi with >150 ac work area	Contractors, communities	Unknown	0.155	23.3	Appendix 7	TBD
Perched wetland stabilization (#4)	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	BLM, USFS	2 + ongoing	TBD (perhaps 10 acres)	Contractors, communities, NGOs	avg. <25	0.210	2.1	Appendix 7	$50,000 to $100,000
Private land treatments	F: Soil Conservation on Croplands and Pastures (cover crops, contour buffers, riparian buffers)	Private	1 + ongoing	aim at 500	Communities	avg. <25	0.210	105.0	Appendix 7	$250,000 to $500,000

Projects / Interventions	Management Measures	Jurisdiction	Phase	Acreage	Potential Partners	Load Reduction Estimate				Cost Range Estimate
						(Pf) %	lbs/ac/d	total lbs/d	Source	
Canada Aqua (Arroyo la Mina / Embudo Creek) HUC 130201010909 (WBP planning area only)				**17,141**				**5,699.9**		
BLM EA Thinning and Prescribed Burns	B: Woodland Thinning and Wood Removal	BLM	1 + ongoing	13,400	Contractors, communities	37	0.237	3,174.2	Appendix 7	Unknown
BLM EA Road Work and Erosion Control	G: BLM Roads	BLM	1 + ongoing	13,400	Contractors	Unknown	0.155	2,077.0	USFS 2017-a	Unknown
SLO Thinning and Prescribed Burns	B: Woodland Thinning and Wood Removal	SLO	1 + ongoing	1,800	Contractors, communities, NGOs	37	0.237	426.4	Appendix 7	$1,800,000 to $2,700,000
Rio Arriba County Road Maintenance Work, incl. roads in Arr. Pino, La Mina, Lorenzo (proj. #9, 10, 11)	G: Unpaved Roads, Rio Arriba County	Rio Arriba County	1 + ongoing	>10 mi with >35 ac work area	Contractors, communities	Unknown	0.155	5.4	Appendix 7	TBD
Rio Arriba County Road Relocation in Arr. Lorenzo, (proj. #9)	G: Unpaved Roads, Rio Arriba County; H: Stabilizing Streams; Stream Channel and Bank Stabilization	Rio Arriba County	2	0.6 miles; approx. 7.9 ac	Contractors, communities	probably <25	0.282	2.2	TBD	$600,000 to $1,200,000
Rio Arriba County Road Relocation in Arr. Pino (proj. #10)	G: Unpaved Roads, Rio Arriba County; H: Stabilizing Streams; Stream Channel and Bank Stabilization	Rio Arriba County	2	0.7 miles; approx. 9.2 ac	Contractors, communities	probably <25	0.282	2.6	TBD	$700,000 to $1,400,000
Rio Arriba County Road Relocation in Arr. La Mina (proj. #11)	G: Unpaved Roads, Rio Arriba County; H: Stabilizing Streams; Stream Channel and Bank Stabilization	Rio Arriba County	2	1 mile; approx. 26.3 ac	Contractors, communities	probably <25	0.282	7.4	TBD	$1,000,000 to $2,000,000
NM DOT Road Work	H: Stabilizing Streams; Gully and Headcut Treatments: road side ditches and arroyos	NM DOT	1 + ongoing	approx. 24 mi of bar ditches; approx. 30 acres	Contractors, communities	probably <25	0.155	4.7	Appendix 7	Unknown

Projects / Interventions	Management Measures	Jurisdiction	Phase	Acreage	Potential Partners	Load Reduction Estimate				Cost Range Estimate
						(Pf) %	lbs/ac/d	total lbs/d	Source	
Canada Aqua (Arroyo la Mina / Embudo Creek) HUC 130201010909 (WBP planning area only)				**17,141**				**782.6**		
RA-CR 240 (#1)	H: Stabilizing Streams; Stream Channel and Bank Stabilization	Rio Arriba County + Private	1 or 2	470	Contractors, communities, NGOs	probably <25	0.282	132.5	Appendix 7	$470,000 to $940,000
Canadita del Agua (#2)	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	BLM, SLO	1	TBD (perhaps 100 acres)	Contractors, communities, NGOs	avg. <25	0.282	28.2	Appendix 7	$50,000 to $100,000
Arroyo de los Arellanos (#3)	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	BLM, SLO	1	125	Contractors, communities, NGOs	avg. <25	0.282	35.3	Appendix 7	$62,500 to $125,000
Perched wetland stabilization (#4)	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	BLM, SLO	2 + ongoing	~500	Contractors, communities, NGOs	avg. <25	0.282	141.0	Appendix 7	$2,500,000 to $5,000,000
Arroyo 94	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	BLM, SLO	1 or 2	60	Contractors, communities, NGOs	avg. <25	0.282	16.9	Appendix 7	$60,000 to $120,000
Arroyo de los Pinos Reales E + W	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	BLM, SLO	1	670	Contractors, communities, NGOs	avg. <25	0.282	188.9	Appendix 7	$335,000 to $670,000
Acequias	F: Soil Conservation on Croplands and Pastures (cover crops, contour buffers, riparian buffers)	Private	1 + ongoing	800	Communities and NGOs	avg. <25	0.282	225.6	Appendix 7	$400,000 to $800,000
Arroyo Pino wetlands	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	BLM, SLO	1 + ongoing	50	Contractors, communities, NGOs	avg. <25	0.282	14.1	Appendix 7	$250,000 to $500,000

Projects / Interventions	Management Measures	Jurisdiction	Phase	Acreage	Potential Partners	Load Reduction Estimate				Cost Range Estimate
						(Pf) %	lbs/ac/d	total lbs/d	Source	
Canada Aqua (Arroyo la Mina / Embudo Creek) HUC 130201010909 (WBP planning area only)				**17,141**				**401.6**		
Arroyo la Mina wetlands	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	BLM, SLO	1 + ongoing	150	Contractors, communities, NGOs	avg. <25	0.282	42.3	Appendix 7	$750,000 to $1,500,000
Arroyo del Plomo	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	BLM	2 + ongoing	500	Contractors, communities, NGOs	avg. <25	0.282	141.0	Appendix 7	$250,000 to $500,000
Arroyo 49 behind Library	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	BLM	1 + ongoing	64	Contractors, communities, NGOs	avg. <25	0.282	18.0	Appendix 7	$32,000 to $64,000
Arroyo Montecito	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	BLM, SLO	2 + ongoing	70	Contractors, communities, NGOs	avg. <25	0.282	19.7	Appendix 7	$35,000 to $70,000
Arroyo 75 NW of Canoncito	E: Bio-Technical Slope Stabilization + H: Stabilizing Streams; Gully and Headcut Treatments	BLM, SLO	2 + ongoing	140	Contractors, communities, NGOs	avg. <25	0.282	39.5	Appendix 7	$70,000 to $140,000
Private land treatments	F: Soil Conservation on Croplands and Pastures (cover crops, contour buffers, riparian buffers)	Private	1 + ongoing	aim at 500	Communities	avg. <25	0.282	141.0	Appendix 7	$250,000 to $500,000

Table 5.3. List of total load reduction targets for committed and suggested project (as per Table 5.2) and for additional, future project ideas with suggested management measures for each sub-watershed HUC.

Sub-watershed Name and WBP Acreage and HUC: 12-digit Hydrologic Unit Code	**Committed and Suggested Actions AND *New Project Ideas for Future Phases (in italics)***	**Numerical Targets for Estimated Load Reduction for each Sub-Drainage**
Cañada de Ojo Sarco (Ojo Sarco drainage): 13,842 acres; HUC: 130201010907	Forest thinning, prescribed fire, arroyo treatments, road work, wetland stabilization, and private land treatments	**12% reduction (1,334.4 lbs/d)** of sediment flux (STEPL-based) of 11,171.62 lbs/day (0.807 lbs/ac/day) to 9,837.2 lbs/d
	Additional forest thinning + prescribed fire	***9% reduction (1,000 lbs/d)***
	Recreation management on CNF (trails, trail head and parking areas, ORV management)	***4.5% reduction (500 lbs/d)***
	Additional treatment of unpaved roads and bar ditches	***4.5% reduction (500 lbs/d)***
	Additional Ojo Sarco river, arroyo, and wetland stabilization treatments	***18% reduction (2,000 lbs/d)***
	TOTAL	***48% reduction (5,334 lbs/d)***
Cañada de Ojo Sarco / Embudo Creek (Rio de las Trampas drainage): ~29,379 acres; HUC: 130201010908	Forest thinning, prescribed fire, arroyo treatments, road work, wetland stabilization, and private land treatments	**29% reduction (2,355.2 lbs/d)** of sediment flux (STEPL-based) of 8,204.11 lbs/day (0.28 lbs/ac/day) to 5.848.9 lbs/day
	Restoration or closure of grazing areas on the Trampas Allotment (12,502 acres)	**37% reduction (3,000 lbs/d)**
	Recreation management on CNF (trails, trail head and parking areas, ORV management)	**15% reduction (1,200 lbs/d)**
	Additional treatment of unpaved roads and bar ditches	**15% reduction (1,200 lbs/d)**
	Additional arroyo and wetland stabilization treatments	**30% reduction (2,500 lbs/d)**
	TOTAL	**>100% reduction (10,255 lbs/d)**
Cañada Aqua (Arroyo la Mina / Embudo Creek) (small sub-watersheds in the north-western Embudo Valley): ~17,141 acres HUC: 130201010909	Forest thinning, prescribed fire, arroyo treatments, small-scale repairs of older restoration project sites, road work (incl. road relocation), wetland stabilization, acequia improvements, and private land treatments	**>100% reduction (6,884 lbs/d)** of sediment flux (STEPL-based) of 6,479.95 lbs/day (0.376 lbs/ac/day)**, with additional reduction of 404 lbs/d during peak flow years**
	Additional arroyo and wetland stabilization treatments	**23% reduction (1,500 lbs/d)**
	TOTAL	**>100% reduction (8,384 lbs/d)**
	Required Cumulative Effects	**26,125 lbs/d**
	TOTAL Load Reduction (as per TMDL)	**50,098 lbs/d**

<u>BLM Treatments</u>

The Taos Field Office of the BLM aims to improve forest and woodland health as well as wetland health (Figures 5.3 and 5.4) by proposing thinning treatments in ponderosa pine forests and in woodlands with a ponderosa pine overstory. Additionally, the agency proposes to light prescribed fires in treatment areas after thinning, and to manage wildfire in such a way that it achieves goals of managed wildfire in the area. BLM also plans to remove invasive trees along the Rio Embudo and to improve and maintain rural dirt roads.

BLM initiatives focus on the eastern part of the Cañada Aqua (Arroyo la Mina/Embudo Creek) sub-watershed (HUC 130201010909) and the far northeastern part of the Cañada de Ojo Sarco/Embudo Creek (Rio Trampas) sub-watershed (HUC 130201010908). The proposed treatments in these areas would thin out part of the piñon and juniper understory in overstocked ponderosa pine stands to reduce stem densities and remove ladder fuels. An EA is being prepared at the time of the completion of the WBP and will detail specific treatment locations, prescriptions, and the timeline for the initiatives.

Figure 5.3. Example of a perched wetland on BLM land that was stabilized in 2013 and that retains thousands of tons of sediment in a small watershed on BLM and State Trust Land in the Cañadita del Agua in Cañoncito.

Figure 5.4. A view down valley to the southeast across the perched wetland on BLM land that was stabilized in 2013 with a background of its surrounding eroding sub-watershed area in the Cañadita del Agua in Cañoncito.

NM SLO Treatments

The NM State Land Office (NM SLO) intends to undertake small-scale treatments similar to those proposed by BLM, and possibly in conjunction with BLM treatments, in order to achieve a regional effect of the combined treatments of both agencies. NM SLO plans to work with private for-profit and non-profit partners to accomplish its planned forest and woodlands restoration work. Several proposals for this work are being developed at the time of this writing. However, only the Copper Hill area in the northeastern part of the watershed (just west of Picuris Pueblo) and approx. 150 acres of the parcel south of Cañoncito are cleared for cultural resources. As a result, implementation of proposed treatments hinges on the completion of cultural resource clearances for the remaining SLO acreage.

Private Property and Neighborhood Treatments

For private properties, *acequias*, and private land neighborhoods, this WBP provides suggestions for management measures that landowners can choose to implement on a voluntary basis. It should be expected that many of the voluntary private land management activities will need to flow from proactive public education, which is described below.

Management measures on private land will need to focus on soil stabilization, drainage channel efficiency, and sediment removal from critical infrastructure (Figure 5.5). Treatments on private lands will be most effective in the higher elevation communities of Ojo Sarco, Las Trampas, El Valle, and Diamante, because these communities are closely located to higher elevation source areas and there is greater sediment retention capacity higher up in the watershed.

Additionally, 2010 Census data reveal that the communities in the upper part of the WBP study area include a proportionally greater number of private landowners who own their properties and who are of a younger age than those in Embudo and Rinconada. Therefore, outreach for private land treatments will likely be more feasible in these upstream communities. Census data also indicate that there is a greater labor force in the upstream communities and possibly a greater economic need for and interest in technical and financial assistance.

Figure 5.5. Examples of management measures for private lands. Green oval= hedge row; Red oval= cover cropping or mulching on bare ground; Thin pink arrow= bar ditch; Orange arrow= drainage along unimproved roads or driveways; Light blue line= terrace

Treatments on private lands in the area between Cañoncito, Dixon, and Embudo will in many cases not address any significant sediment load interception, retention, and reduction, because the location of the private properties here is at the bottom end of the sediment transport pathway and there is limited space available on these private lands to store excess sediment. Furthermore, removal of sediment from private land will in most cases be cost prohibitive. Therefore, although of great social and economic importance to the affected landowners, management measures on these private lands are of relatively low priority from a watershed-wide perspective. Instead, management measures on these private lands should focus on keeping the soil covered, stabilizing headcut areas and drainage channels, and removing excessive sediment to maintain land productivity as well as infrastructure safety and functionality.

Private land and neighborhood treatments are most effective if conducted to a large extent in coordination and collaboration with land managed by public entities upstream. The suggested community projects (Table 5.1) include many suggested activities on which private landowners play a key role. Most of these project activities, however, need to occur on public land and with the support of county officials and state or federal agencies. EVRAA and other entities that are in a position to take a leadership role in proposing and managing collaborative initiatives are best positioned to initiate such projects.

5.4. Technical and Financial Assistance Needed for Implementation

Public Land Management Agencies

The USFS Carson National Forest (CNF), BLM, and NM State Land Office (NM SLO) manage more than 82% of the land in the watershed. Implementation of management measures on land managed by these agencies requires budget allocations and regulatory clearances, such as cultural resource clearance (all public lands) and NEPA clearances (federal lands and lands with federal grant funds). Depending on the specifics of the Clean Water Rule at the time of project implementation, many projects would also require Section 404 permitting from the US Army Corps of Engineers under the Clean Water Act.

Each public land management agency provides the technical support and financial resources to complete its regulatory requirements (e.g., cultural resource surveys, NEPA procedures) for the implementation of management measures as funds and staffing allow. Outside financial support and technical assistance from partner organizations that formulate grant-funded initiatives could help the agencies accomplish regulatory requirements and supplement their internal funding. Agency capacity and their anticipated technical and financial assistance to management measures in the WBP area is described in detail in Chapter 2. Additional technical and financial assistance needs and details for each agency are specified below.

US Forest Service: Implementation of planned activities on the USFS Carson National Forest (CNF) depends largely on the CNF annual budget allocations and the realization of NEPA cleared areas. USFS funds could be supplemented with funds from cooperative agreements, such as the Collaborative Forest Restoration Program (CFRP) and public and private grant funds. Public private partnerships could also help strengthen CNF capacity with additional staffing through partner organizations and data sharing agreements, such as for water quality monitoring data.

BLM: Similarly, implementation of planned activities on BLM lands depends largely on BLM annual budget allocations. These funds could be supplemented with funds from cooperative agreements, such as the Collaborative Forest Restoration Program (CFRP) and public and private grant funds. Public private partnerships could also help strengthen BLM capacity with additional staffing through partner organizations and data sharing agreements, such as for water quality monitoring data.

NM State Land Office (NM SLO): As with previous agencies, implementation on State Trust Lands depend on annual NM SLO budget allocations, which are in part dependent on priorities of the Land Commissioner. NM SLO depends on additional funds and technical support from partner agencies, such as BLM, CFRP grants, and for-profit and non-profit partners. The NM SLO also has to keep in consideration that it needs to generate funds from State Trust Lands. Assistance with activities that improve the productivity and real estate value and reduce any risk factors of the land are of importance to the agency.

Rio Arriba County and Taos County: The county Land Use Planning Departments would benefit from shared data and maps. They are also interested in coordination of educational outreach work. The Rio Arriba County Public Works Department would benefit from technical assistance with specific road grading and road management training to improve drainage and soil stability conditions on dirt roads.

Private Landowners and Acequia Associations

Private landowners and local acequias would benefit from a great variety of technical and financial assistance to help implement the proposed management measures. A social and economic survey among stakeholders of attitudes, knowledge and information flow about the Lower Embudo watershed and future restoration initiatives conducted for this WBP in 2014-2015 revealed the following needs for technical and financial assistance:

a. Information about appropriate funding sources for private landowners and *acequias,* including government cost-share funding, and education about requirements and restrictions of government grants and technical assistance programs
b. Labor assistance and access to information about available labor or approaches to finding sources of labor to implement management measures
c. Information about best practices and methods of implementing management measures, including references to service providers that can offer technical assistance for implementing management measures
d. Systems that offer access to equipment
e. Incentives in the form of information, successful examples, testimonials, trusted neighbors, and financial support to help convince landowners of the need and importance of certain management measures
f. Systems and procedures that distribute water needed to realize the management measures or innovations
g. Data-driven information and testimonials about the benefits of the management measures or innovations
h. Technical assistance that helps discern how to integrate management measures and innovations into the farming operation or property features
i. Technical assistance on required maintenance that goes beyond the landowner's capacity
j. A one-stop shop for information (for example at the Embudo Valley Library)

As pointed out above, landowners in communities in the upstream sub-watersheds may be primary targets for financial and technical assistance because a proportionally larger number among them owns their homes and land, they are of younger age, and their economic conditions seem to indicate that assistance may be welcome to them. Lands in upstream sub-watershed are also more suitable for sediment retention because of the available space and the strategic opportunity for early sediment retention rather than a last resort opportunity of retention downstream.

Approvals and Regulatory Requirements

Depending on the landownership, scale, scope, and funding sources of each land restoration initiative, certain approvals will be required to proceed. Such approvals may include permission from certain decision makers in public entities, permission from private landowners and easement holders, and permits or certifications from regulatory agencies. Customary requirements include cultural resource surveys and certifications, biological surveys and approvals, and water quality protection permits.

Certain permissions and regulatory requirements may require background research and surveys, engineering studies, fees, and public input processes. Such procedures can be costly and time consuming. Project initiatives need to investigate what regulatory requirements apply and what consequences this brings to project management and budgets.

Cost Estimates

It is very challenging at this time in the development of the WBP to estimate the costs of listed projects and management measures. However, rough cost ranges have been suggested in Table 5.2 to offer an idea of potential costs. These projected costs for the recommended management measures range between at least $10,779,500 and possibly as much as $20,579,000, not including internal costs borne by the government agencies.

The costs to government agencies have been indicated as “unknown” because of a lack of information about agency costs. Other costs were based on estimates for soil conservation work at $500-$1,000 per acre, forest and woodland treatments at $1,000-$1,500 per acre, and wetland and complex arroyo restoration treatments at $5,000-$10,000 per acre, based on the personal experience of the author of this WBP. The experiential knowledge of these cost estimates is based on the cost of forest thinning operations and soil conservation techniques applied in recent state and federally funded restoration programs in the Lower Embudo watershed and other areas in northern New Mexico.

Costs for educational outreach and technical assistance have not been included in the estimates. Such costs apply in particular to management measures on private lands and for projects in which a community collaboration is an important component. In those cases, the educational outreach costs might be anticipated to be in the order of 10% to 20% of the implementation costs.

Potential Sources of Funding

Many potential sources of funding exist for the suggested strategies and projects. However, the appropriateness of each source of funding varies by landownership. Table 5.4 lists the potential applicability of potential funding sources by landownership status and estimates of potential financial contributions by types of funding sources. These estimates serve as potential target amounts based on the magnitude of compensation such sources were able to provide in the recent past.

We know that common watershed restoration funding sources in the area offer grants and cooperative agreement support ranging from $10,000 (small grants and government programs), to $50,000 (NM River Stewards Program), $250,000 (EPA-Section 319 grants and Rio Grande Water Fund grants) and $360,000 (USFS Collaborative Forest Restoration Program – CFRP grants). Many sources of funding require matching funds from non-federal programs, private donations, and in-kind contributions by volunteers. Match amounts vary between about 25% and 40% of the total program costs.

5.5. Information and Education

Disseminating information and providing education to stakeholders will be one of the main tasks of the civic groups in the watershed. The EVRAA and Rio Embudo Watershed Coalition are the main organizing entities for watershed restoration activities. They have a schedule of regular meetings, which are open to the public, and though which public information is disseminated and public feedback is gathered. These entities can rely on the Embudo Valley Library in Dixon, the NM Acequia Association, the NMSU Field Station in Alcalde, and the Peñasco Public Schools for additional educational outreach support. Project teams that manage individual restoration programs could also bring capacity to offer focused educational outreach during their funding period.

As the main organizing entities for watershed restoration activities, EVRAA and Rio Embudo Watershed Coalition, along with the specific project teams of non-profit organizations and consultants, will continue organize meetings open to the public and produce public outreach (e.g., social) media to inform community members and watershed partners during the implementation of the project. Government agencies will pair such meetings with their own, according to the public information regulations of each agency. A steering team will need to be established for monthly or quarterly coordination meetings and for the coordination of public education activities and events. These structures will be indispensable to support the scope and scale of the anticipated watershed restoration efforts. The following sections will provide details on how information should ideally be disseminated and what the most effective dissemination methods are in the watershed.

<u>Information and Education Needs Prior to Implementation of Management Measures</u>

The proposed strategies, approaches, scale of implementation, and specific management measures are unprecedented for private landowners and civic groups in the area. There is little experience, expertise and other capacity among the landowners, residents, and institutions in the watershed community to take on the proposed strategies and management measures. Therefore, it will be necessary to build capacity in local communities and in agencies. Capacity building would need to include the transfer of information and specific educational outreach in order to clarify for stakeholders, land managers and landowners the specific findings, goals and strategies for meeting sediment reduction targets outlined in this WBP.

Table 5.4. Overview of potential funding sources for this WBP, estimated possible financial contributions per source, and their applicability for different landownerships.

Funding Source	Estimated Possible Financial Contributions Over 20 Years	Potential Non-Federal Match	Private Land-owners	Ace-quias	Non-Profit Entities	Counties	NM SLO	USFS	BLM
Agency-specific internal budgets	N/A			X		X	X	X	X
Charitable Foundation grants	$500,000	Y		X	X	(X)			
Corporate grant programs	$1,000,000	Y		X	X	(X)			
County-specific Special Assessment / Overlay Districts	N/A	Y				X			
Crowd funding (social media-based)	$100,000	Y	X	X	X	(X)			
National Association of Counties	$100,000	Y		X	X	X			
National and regional resource conservation groups (e.g., Trout Unltd., Ducks Unltd., Rocky Mnt Elk Fndn, Wild Turkey Fndn, Wildlife Conservation Society, National Fish & Wildlife Foundation, Audubon, etc.)	$2,000,000	Y		X	X				
NM Counties	$200,000	Y		X	X	X			
New Mexico Legislature – Special Appropriations	$1,000,000	Y		X		X	X		
NM Finance Authority/Water Trust Board – Water Fund	$1,000,000	Y		X		X			
NM Dept. of Game & Fish – various grant programs	$200,000	Y	X	X	X				
NM State Forestry Division – various programs	$250,000	Y	X	X	X	X	X		
NMED-SWQB – River Stewards Program	$250,000	Y	X	X	X				
Philanthropists/Private Donors	$20,000	Y		X	X				
Rio Grande Water Fund	$1,000,000	?		X	X	X			
Soil and Water Conservation Districts	$100,000	?	X	X	X	X			

Funding Source	Estimated Possible Financial Contributions Over 20 Years	Potential Non-Federal Match	Private Land-owners	Ace-quias	Non-Profit Entities	Counties	NM SLO	USFS	BLM
USDA Natural Resources Conservation Service (NRCS) – various programs	$500,000		X	X	X	X			
US EPA – Section 319(h) funds (through NMED-SWQB)	$750,000			X	X	X			
US FEMA	$1,000,000			X		X			
USFS - CFRP	$1,000,000			X	X	X			
US Fish & Wildlife Service – various grants and cooperative agreements	$100,000		X	X	X	X			
TOTAL	**$11,070,000+**								

Specific needs for dissemination and public education are formulated below based on a stakeholder survey conducted in 2014-2015 as part of this WBP update (Appendix 01). Comparison of stakeholder survey findings and field findings about causes and sources of impairment have revealed that additional information and education should focus on the topics and target groups summarized in Table 5.5.

Table 5.5. Overview of important educational outreach topics and their target audiences.

Education Topics	Target Audiences	Purpose
Causes of impairment	local residents	dispelling misunderstandings about turbidity and water temperature and the impacts of these pollutants on aquatic habitat and irrigation
Sources of impairment	local residents	addressing differences between findings in the field and popular perceptions and beliefs; helping people see and understand the problems
Management measures	Private landowners	Disseminating techniques for arroyo and stream stabilization, erosion control on fields, orchards, pastures, and for around homes and on driveways
Functions of traditional buffer strips	farmers and other landowners with fields, orchards, and pastures	Explaining and demonstrating the functions of traditional buffer strips in stabilizing soils
Simple soil and water conservation	farmers and other landowners	Disseminating and demonstrating simple earthen, rock, woody, and vegetation structures
Road maintenance	County Public Works staff and contractors	Disseminating and demonstrating rural road design and maintenance practices

Workshops in past years and the mentioned community survey revealed that many simple soil conservation techniques and structures described in regionally used publications (e.g., Zeedyk and Jansens 2006, Zeedyk and Clothier 2009, and Zeedyk et al. 2014) are not well known and rarely used in the Lower Embudo Valley. More educational outreach and hands-on workshops would be needed to popularize these management measures.

Rio Arriba County staff and residents have indicated that there is need for technical education of county road management staff, road management crews, and contractors regarding rural road design and maintenance practices, as in publications by Guenther (1999) and Zeedyk (2012). Additionally, during various community meetings over the years, community members have expressed that the county roads and driveways in the arroyo bottoms are likely an important contributor to sediment pollution and that these roads may need to be relocated. As a case in point, earlier in 2019, Dixon residents reported that Rio Arriba County has let landowners along arroyos with County Roads know that the County intends to end County Road maintenance on these roads. Rio Arriba seeks to privatize these County Roads, for example in local road associations. Therefore, it will be important to raise awareness among residents along arroyos of the finite role of arroyos as driveways and County Roads to access homes.

Educational outreach will need to be an ongoing effort simultaneously taken on with proposed management measures in each program phase. The focus of educational outreach needs to be responsive to community needs and assessments of discrepancies between required knowledge and know-how and knowledge realities in the community.

<u>Phase-1 Educational Outreach Needs for Private Landowners and Acequia Organizations</u>

A comparison of the 2014-2015 local stakeholder survey findings with the needs underlying the vision for *acequias* outlined above and the management measures proposed for the first phase helps clearly identify the specific educational outreach objectives for the first project phase (2020-2024). It is too early to define specific educational outreach needs for subsequent phases. Such needs will have to be assessed and formulated as phase 1 is underway.

In the first phase, proposed management measures on private lands focus on runoff and soil loss from pastures, orchards, and croplands (fields) both inside and outside the village areas. Therefore, recruitment of phase-1 implementers may include farmers, *parciantes*, *acequia* organizations, and progressive landowners who are familiar with the proposed management measures or who actively participated in developing this WBP update. Such early implementers could be engaged by enlisting them to host or attend specialist workshops on the development of terracing, contour buffer strips, riparian buffers or riparian grazing management, or the construction of small soil conservation techniques and self-draining, low-maintenance roads and driveways. Some local landowners could perhaps produce seed, plants, and seedlings for local restoration projects.

Additional first phase educational outreach would focus on local contractors and volunteers interested in learning soil conservation and forest and woodland restoration practices prescribed for public lands in phase 1 (2020-2023). Specialized workshops, work days, and apprenticeship programs for these target audiences would be needed to build contractor capacity and to develop capacity in acequia groups to participate in public land restoration project crews.

Another first phase educational outreach need would be to organize maintenance workshops for unpaved roads and driveways that target county road management staff, and their road maintenance crews and contractors in Rio Arriba County and Taos County Public Works Departments. Landowners who are individually responsible for private roads and who have an interest in maintaining or improving their roads in a cost-effective manner might also attend these workshops. Initial demonstration work done on county roads during the workshops, if successful, may attract the attention of road users and boost attendance of later workshops by individual landowners. In early 2015, a road drainage project on a private property in Rinconada was completed and this site could serve as a training demo as well.

<u>Specific phase-1 (2020-2023) capacity building at public land management agencies</u>

Most of the management measures proposed in this WBP-Update concern public land management agencies. Generally, public land managers are already knowledgeable about the management measures proposed in this WBP-Update and possess appropriate skills and knowledge of the affected ecosystems and interrelated resources. Similar to the situation described for the Santa Barbara watershed in the Upper Rio Embudo watershed (Environmental Health Consultants and NMED 2010), public lands in the

Lower Embudo watershed are managed through public processes, and public land managers strive to serve the needs of watershed residents and sometimes face strong criticism for decisions that have little local support. Concerns include the need for maintaining firewood harvesting areas, access to forest roads, smoke from prescribed fire, and the viability of grazing as a business. Public land management agencies would benefit from support from non-governmental organizations to overcome some of the identified challenges. Therefore, outreach to public lands managers will need to focus on ongoing collaboration on NEPA completion and options for partnership projects with non-governmental organizations.

Specific capacity building needs identified in meetings with agency staff pointed toward a general need to strengthen agency collaboration with non-governmental organizations and community groups. The most important forms of ongoing agency collaboration with non-governmental groups would include data sharing, exchange of technical assistance and co-funding mechanisms. Additionally, outreach to community organizations should aim at building trust and a new basis for collaboration with government agencies despite a sometimes controversial relationship history.

Specifically, non-governmental organizations and community groups are invited to reach out to, assist, and collaborate with government agencies in order to:

- Assist in securing funding for NEPA clearance of national forest lands, and particularly for initiatives that focus on the improvement of soil and water resources (particularly concerning special treatments in relation to roads, trails, riparian areas, and grazing areas).
- Share data (esp. regarding runoff and pollution levels), information, technical assistance (TA), and collaboration on soil and water resource management.
- Collaborate on on-the-ground treatments to compensate for governmental staffing limitations.
- Include permittees in land restoration projects and offer educational opportunities to them for better land stewardship.
- Develop collaborative stewardship projects with NM SLO that leverage outside funding for the agency and that focus on generating revenues for the NM SLO to meet the State mandate for supporting infrastructure needs. Activities on State Trust Lands need to improve the productivity and real estate value and reduce any risk factors of the land that are of importance to the agency.
- Develop collaborative stewardship projects with other public land management agencies in order to boost local economic development.
- Organize training workshops for design and maintenance of unpaved roads.
- Expand the areas that are NEPA cleared for forest and woodland restoration.

Ongoing Information and Education

During phase 1 (2020-2023) and subsequent phases of the proposed approach for achieving pollution reduction targets ongoing capacity building, information exchange, and public education will be necessary to ensure sufficient capacity in public land management agencies and among landowners to successfully reach the targets of each phase. Analysis of monitoring data and inclusion of lessons learned in educational outreach will be useful to improve the success rate of the proposed actions.

Projects on private properties and with acequia associations will need to focus on alleviating common barriers to the introduction of innovations and new management measures. Table 5.5 indicates important educational topics that focus on alleviating barriers to innovations which were identified in the 2014-2015 stakeholder survey. These barriers include:

- Lack of cash resources and lack of knowledge and networking to reach appropriate funding sources; lack of access to government funding for cost share, and barriers concerning real or perceived requirements and restrictions of government grants and programs.
- Lack of time to implement the management measures
- Physical health limitations
- Lack of know-how
- Lack of equipment and access to equipment
- No willingness to change (this may be related to lack of knowledge and insight about better management practices)
- Lack of water needed to realize the management measures or innovations
- Insufficient proof of the benefits of the management measures or innovations
- Difficulty to use proposed management measures in the farming operation or to use them within property features that are deemed incompatible with the management measures
- Required maintenance that goes beyond the landowner's capacity
- Confusion on where to get information or assistance
- General lack of information about management practices
- Unwillingness to participate in government programs

Survey responses showed that there is great variability in opinion about these barriers. However, most respondents agree that it's hard to know where to get information and/or assistance. Respondents have varying problems with access to equipment; some don't have this problem, while for others it's a great problem. Lesser barriers include the need to learn new skills or techniques, the lack of being able to see a demo, legal restrictions, concerns for reduced yields, or approval from neighbors.

Survey respondent analysis revealed that it should be expected that people with lower education levels, fewer years of farming experience, and lower income, will mostly likely have even greater challenges with the listed barriers than the relatively more affluent and higher educated respondents. There will most likely be less variability in opinion about the barriers and greater challenges with the implications of the barriers, access to information, and identifying opportunities for solutions among these more disenfranchised stakeholders.

The key barriers listed show that providing education and information is not the only solution to removing barriers. It will also be important to offer tangible technical assistance services. For example, specific assistance will need to be developed and made available regarding labor sources, equipment support, and technical guidance toward successful implementation or management measures and specific techniques.

It is also important to consider what information sources and messaging systems are most trusted with local stakeholders. The 2014-2015 survey indicated that the most trusted and respected sources and message carriers are (in decreasing order of importance):

- Personal observations and experience
- New Mexico Acequia Association (NMAA)
- Local watershed groups and projects
- Local Acequia Associations (including EVRAA)
- Local community leaders
- Environmental groups
- Neighbors and friends
- The TownCrier (the local list serve)
- University Extension services (e.g., the NMSU Alcalde Field Station)
- Magazines and newspapers
- Brochures, pamphlets, and flyers

Survey respondents indicated limited to no trust in various water and agriculture related government agencies (state and federal), the Internet, consultants and contractors, and Rio Arriba County. Respondents showed particularly little trust in information from the prominent federal land management agencies that manage lands across the Lower Embudo watershed.

In late 2014, nearly 80% of the respondents had Internet access and used e-mail often. Additionally, respondents seemed to communicate actively via Facebook about farm and (acequia) irrigation practices, land and water conditions, food uses and marketing, and other farming related topics.

Therefore, personally targeted outreach approaches by local entities and trusted non-profit organizations along with demonstration pilot projects and workshops may be useful to help alleviate some of the listed barriers. As suggested for the Santa Barbara watershed (Environmental Health Consultants and NMED 2010), participants should revisit past work, be presented with summaries of monitoring data indicating whether goals are being met, and progress should be reported on Facebook and in local newsletters to make this information more widely known. The growing Embudo Valley Library has begun to serve as a local repository and point of access of written information for local stakeholders.

A key aspect of encouraging widespread implementation is local coordination and continuity in commitment. Currently, coordination and commitment rest mostly with EVRAA. Additionally, in 2019, the Rio Embudo Watershed Coalition (REWC) has been established in the Peñasco area. This group expressed the goal to work in the Lower Embudo watershed area as well. EVRAA and REWC are well positioned to help build local capacity and take on the coordination of the proposed watershed restoration projects and educational outreach activities.

Feedback from Monitoring

A monitoring strategy for this WBP is presented in Chapter 6. However, dissemination of monitoring findings is essential for adaptive management through appropriate educational outreach.

Project monitoring and follow up stakeholder surveys can generate specific conclusions from comparing scientific findings about pollutant sources and the effectiveness of management measures with perceptions and knowledge in the community. The baseline Social Indicators Planning and Evaluation System (SIPES) survey technique for this project is set up to be followed with a post-implementation survey that can be analyzed by the same on-line methodology and web-supported program using the SIDMA software (Genskow and Prokopy 2011)[1]. The follow-up survey with the SIDMA tool can then be compared with the base-line documentation of 2014-2015 to identify differences in respondent perceptions, knowhow, and practices. In turn, this would be of great value to evaluate changes in land use and stewardship behavior, trust in management measures, and chances for successful replication, along with ongoing and new needs for educational outreach or collaboration.

It will be essential to identify effective demonstration projects that offer visible examples of successful management measures in order to convince late adopters among private landowners and contractors of new management measures. Monitoring data would help explain whether and to what extent the demonstration projects are successful. Field monitoring of the results of management measures would need to generate data-to-action reports that include lessons learned about the level to which management measures have helped meet pollution reduction targets. Such monitoring information would need to be distributed in ways that effectively reach the target audience. In combination with follow-up SDIMA surveys, field monitoring would help identify the targets, priorities and best methods for ongoing educational outreach and capacity building in phase 2 and subsequent project phases.

5.6. Implementation Schedule and Phasing

Proposed Phasing Approach

The implementation schedule for management measures in the Lower Embudo watershed will need to accommodate a variety of factors. Schedules are determined by factors, such as:

a. Required preparation time for project development, including fund raising, necessary time for local capacity building, developing collaborative relationships, disseminating information, and organizing project-specific public outreach and education
b. The irregular patterns in the recurrence of large flood events that move sediment and discharge considerable sediment volumes in the streams
c. Adequate periods for effectively measuring any discernable changes in measurable sediment transport or indicators that imply such changes
d. Land management agency timelines, including planning and public input schedules, set by public land management agencies
e. Cycles of funding sources for individual projects.

Analysis of these different cycles reveals that short phases require at least 3 or 4 years, and longer phases would require 6 to 10 years. These observations are based on the recognition that preparation time for project development typically takes between 1 and 3 years. A review of USGS stream gage information between 1987 and 2017 in the Rio Embudo (USGS #08279000) reveals that large monthly

[1] SIDMA: Social Indicators Data Management and Analysis, developed for EPA by Genskow and Prokopy (2011).

flow events in the Rio Embudo have return times between 1 and 7 years for the occurrence of at least one month with flows exceeding twice the long-term average during spring runoff or summer monsoon season, and between 4 and 7 years for the period after 1997. The return time of occurrences of at least two months with flows that exceed twice the long-term average ranges from 3 years to 16 years. Adequate monitoring intervals are therefore at least 4 years and, to be certain, have to be measured in decades. Land management agency timelines are typically defined by political and budget cycles of 2 to 4 years. Finally, cycles in contracts and grants range between 3 and 6 years.

Typically, phases are aligned with the need to build capacity for implementation, implement management measures, and subsequently maintain investments, monitor new conditions, implement repairs, and adaptively manage the new conditions. In the Lower Embudo watershed, however, public land management agencies and private landowners have been implementing land restoration projects and soil conservation measures for decades, and several projects are ongoing at this time.

An appropriate first phase would build on ongoing initiatives and forego a specific start-up phase. Gradually, the activities aimed at pollution prevention for the implementation of this WBP could be scaled up, based on continuous capacity building, educational outreach, monitoring, and documentation of experience gained with the most effective approaches and management measures.

For the WBP-Update in the Lower Embudo watershed, we propose five 4-year funding cycles over a 20-year period (2020-2040) to pursue 100% achievement of sediment load reduction goals. This offers opportunities for setting minor milestones every 4 years and major milestones every 8 or 12 years (see Chapter 6), coordinated with the recurrence of seasons with large flow events. The cycles are presented in the Table 5.6.

A continued phase beyond the 20 years focuses on maintenance, ongoing monitoring, and adaptive management. In this phase, the WBP would likely need to be updated again and new targets would need to be set. Additionally, during the early implementation phases for the realization of pollution reduction targets for turbidity and sedimentation/siltation, an addendum to this WBP update may need to be produced to address the recently identified temperature related water quality impairment of the Rio Embudo (NMED 2012).

As expressed in Table 5.6, forest health improvement activities on the USFS CNF are ongoing and will continue through the phases of the project. It is likely and desirable that the CNF review its activities at the onset of phase 2 and conduct adaptive management and/or preparations for additional management measures for forest health in phases 3 and beyond.

Similarly, the BLM will likely have its EA in place in the course of 2020 and begin the implementation of its management measures. It would be desirable if the BLM were to review and adapt its activities in the watershed in phase 2 and continue with adaptive management in subsequent phases across the entire BLM land area in the watershed.

NM SLO is conducting project development and implementation in shorter cycles on an ongoing basis. It would be desirable if the NM SLO continue this process throughout the life of this WBP.

Table 5.6. Overview of the timeline for the WBP in 5 phases in relation to the involvement of major actors in the Lower Embudo watershed for development and implementation of management measures by each of the actors.

Phase 1: Program Start Up, Development, and Early Implementation

Phase 2: Program Implementation and Further Development

Phase 3: Program Implementation and Adaptive Management

Phase 4: Program Implementation and Ongoing Adaptive Management

Phase 5: Program Implementation, Adaptive Management, and Completion

PHASE	**1**	**2**	**3**	**4**	**5**	**Ongoing**
AGENCY	**2020-2023**	**2024-2027**	**2028-2031**	**2032-2035**	**2036-2039**	**2040 ~**
USFS - implementation						
USFS – follow-up/adaptive management						
BLM – implementation						
BLM – follow-up/adaptive management						
NM SLO – development						
NM SLO – implementation						
Partnerships – development						
Partnerships – implementation						
Partnerships – adaptive management						
Private / acequias – development						
Private/ acequias – implementation						
Private / acequias – adaptive management						
County + NM DOT – implementation						
Legislative / policy initiatives – development						
Legislative / policy initiatives – implementation						

Collaborative partnership projects, as suggested in Table 5.1, would require several years to develop and would probably require most of the time of phase 1. Some projects may be able to get started during phase 1. Many of these projects would have a pilot character and will need to be monitored for adaptive management starting in phase 2.

Acequias and private landowners already conduct various management measures and this work would continue in support of this WBP in phase 1. However, any new projects and new approaches for management measures would need to be developed in phase 1, associated with appropriate educational outreach, and would likely be implemented in phase 2. Adaptive management and follow-up activities also would largely start in phase 2 for this segment of actors.

Road management by county maintenance programs and NM DOT would continue annually. However, work regarding road adjustments and road removal would begin in subsequent phases, and probably would take form under a collaborative partnership with residents, EVRAA, BLM and others.

Finally, large-scale legislative and policy initiatives for the area and the larger region would require thorough preparation during phase 1. The implementation of such initiatives could perhaps be expected to take place in phase 2 and beyond.

<u>Phasing in Relation to Sediment Load Reduction Targets</u>

The TMDL for the Lower Embudo watershed used a calculated Load Reduction Goal of 50,098 lbs/day (equivalent to 9,143 t/y), based on a Measured Load of 66,728 lbs/day, a Target Load of 22,173 lbs/day and a calculated Load Allocation off 16,630 lbs/day (see Section 4.1). By comparison, STEPL modeling for the WBP research area identified a total sediment flux of 25,855.7 lbs/day. Empirical sampling in 2014 found a total sediment flux of 104,062 lbs/day.

A careful, but probably conservative, estimate of the summed individual load reduction estimates of management measures listed in Table 5.2 suggests that over time, a total load reduction of around 10,574 lbs/day may be achieved. This estimate does not take into account the potential cumulative and landscape-wide additional effects (beyond the treatment areas) of the management measures (Figure 5.6). This means that the sum of the load reduction estimates of the proposed management measures would only amount to 21.1% of the TMDL Load Reduction goal and 40.9% of the sediment flux result through STEPL. In comparison with extreme sediment transport years, such as 2014, the management measures would at best stem 10% of the sediment volume in such years.

Table 5.2 indicates that the suggested management measures would generate the greatest sediment load reduction in the Cañada Aqua sub-watershed (HUC #130201010909). This is also the area where in years with heavy precipitation, such as 2014, the greatest sediment flux is to be expected. The proposed management measures for this sub-watershed would, when realized, theoretically achieve the sediment reduction needed to stem the sediment flux calculated through STEPL modeling. This would be a good beginning toward reducing sediment flux volumes during extreme years.

However, Table 5.2 indicates also that the estimated load reduction through the suggested management measures in the Cañada de Ojo Sarco sub-watershed falls far short of the need. The sum of the effects of the management measures would reduce the sediment flux by 1,334.4 lbs/day, which is only 12% of the sediment flux of 11,171.6 lbs/day resulting from STEPL modeling. More detailed terrain assessments and research will need to be conducted to ascertain whether more effective management measures are feasible for this sub-watershed.

The above analysis of the effectiveness of management measures for each sub-watershed suggests that the emphasis of interventions would need to be placed on work in the Cañada Aqua sub-watershed. Activities in the other two sub-watersheds is largely in the hands of the USFS CNF and BLM. Support for their work is of importance, and educational outreach to nurture public understanding and cooperation for the work of the agencies would facilitate their actions and results toward sediment load reductions.

Given the many uncertainties of community and agency capacity and the great disparity between the Load Reduction Goal of the TMDL and the load reductions that could possibly be realized with management measures, the identification of phased bench marks for load reductions becomes a theoretical exercise with little practical validity.

Figure 5.6. The slope wetland of the Ojito de los Arellanos in Montecito, one of the many perched wetlands (arroyo #110; proposed intervention area #3) shows the land regeneration potential that can be achieved through cumulative effects of restoration through thinning, erosion control structures, and road closures. The wetland area provides protection to an upstream watershed of about 100 acres.

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6. IMPLEMENTATION AND MONITORING

6.1. Milestones and Benchmarks

This chapter of the WBP-Update lists and describes major events and achievements that play a key role in establishing how proposed plan activities would contribute to realizing WBP objectives over time. Table 6.1 lists what milestones (i.e., major achievements) are selected on the path toward plan realization and what benchmarks (i.e., target indicators or signs for the level of achievement) are used to define success in plan realization for the various plan phases.

Some milestones are watershed-wide, such as those relating to capacity building, educational outreach, and the development of legislative policy initiatives, while other milestones are specific to sub-watersheds, such as forestry activities and off-road vehicle (ORV) removal from certain areas. Again other milestones are specific to drainages and smaller areas, such as road maintenance improvements, county road realignment, and management measures on private land.

Major milestones are the start and completion moments of each phase of projects and the occurrence of major flow events in arroyos and in the lower Rio Embudo below Cañada de Ojo Sarco. Years with major flow events will allow project managers and Surface Water Quality Bureau (SWQB) staff to evaluate the effectiveness of project accomplishments by analyzing TSS results from the stationary turbidity sensors ARID1 and ARID2. Turbidity data will need to be analyzed and expressed in Suspended Sediment Loads (SSL) based on the relationships established through regression analyses between turbidity and the sediment loads in grab samples completed in 2014 for each of the two gaging stations.

When milestones are not met and/or benchmarks are not measurable, it will be critical to identify the challenges or barriers to the effective measurement of achievements. Subsequently, it will be essential to resolve these barriers in order to enable accurate tracking of WBP success and update the proposed timelines.

This section also proposes a schedule with timelines for suggested milestones as a tentative guideline to track progress at specific moments. However, progress toward achieving WBP targets is dependent on many factors, and particularly those related to the development of and actions by local leadership entities, funding availability, scale of activities, and the ability to measure sediment loads given the low frequency and irregular recurrence of significant flow events.

The time schedule for this WBP spans five phases of four years leading to a recommended timeline of 20 years. This total WBP timeline is reasonable given the size and complexity of the landscape, the frequency of large flow events (a 16-year interval was the largest interval in the last 20 years) and the USFS expectation that forest treatments in the Rio Trampas and Cañada de Ojo Sarco sub-watersheds would lead to results in 10-20 years.

Table 6.1. Major milestones ***(bold italics),*** incremental milestones, their descriptions, benchmarks, and years in project phases.

Year	Milestones	Description	Benchmarks
PHASE 1: Program Start Up, Development, and Early Implementation			
2020	WBP distribution among partners	The WBP is distributed among all stakeholders and partners in the watershed as a basis for action	All key partners of the partners list received WBP documents
2020	Local acequia leadership and watershed coalition takes on WBP goals and activities	The leadership of EVRAA and the Embudo Watershed Coalition incorporate the recommendation of the WBP in their plans and programs	Inclusion of WBP activities on the meeting agendas and on websites of key watershed leadership groups
2020	Developing and implementing educational outreach	Lectures, walks, workshops, and other educational activities are being scheduled to educate stakeholders about key aspects of the WBP	Fifty people and groups are participating in one or more events
2020	Development of phase-1 project/action proposals	One or more project proposals are developed and submitted for funding in support of the WBP	Funding proposals submitted for 33% of phase-1 project sites listed by year's end
2020	Public-private partnership establishment	Local and regional community based groups establish partnerships with public land management agencies and regional collaboratives, e.g., Rio Grande Water Fund	One or more partnerships officially established to support actions (projects) for the WBP
2020	Governmental entities receive community support for WBP implementation	Local leadership and citizen action encourage agencies to take actions as stated in the WBP toward solutions that reduce sediment loads	USFS, BLM, SLO, and Rio Arriba County have received civic support and encouragement to act, respond with actions, and inform the public
2020	Local business mobilization	Local business are getting engaged in supporting and providing resources for WBP implementation	At least one business becomes engaged in restoration work as a supplier or contractor
2020	Repair of automated turbidity sensor equipment in ARID1+2	The automated gaging station equipment used for baseline data research will need to be restored and recalibrated for future follow-up monitoring	Achievement of full functionality and use of the ARID-1 and ARID2 turbidity sensors and stage height measuring devices
2020	***BLM and SLO begin woodland restoration work***	***Implementation of BLM and SLO treatments of woodland thinning and prescribed fire***	***Contractor or agency crews begin work in the field***
2021	***First funded projects begin implementation***	***Start of implementation of some of the projects as listed in the projects list for phase-1***	***A third of the proposed projects have started***
2021	Development of phase-1 project/action proposals	One or more project proposal are developed and submitted for funding in support of the WBP	Funding proposals submitted for 33% of phase-1 project sites listed by year's end

Year	Milestones	Description	Benchmarks
2021	***Community groups and BLM agree on closing off areas from ORV access***	***Agreements are made to close of areas on BLM land that have been degraded by ORVs to allow rest and erosion control projects to heal the slopes***	***At least one sub-watershed area closed off as a pilot project site for ORV exclusion on severely degraded BLM land***
2021	*Acequias* begin implementing sediment management	*Acequias* begin implementing best management practices along *acequias* and on land of *parciantes* to stabilize sediment and curtail erosion	At least one acequia-driven pilot project started with effects across at least 10 acres
2021	Plans for realignment of county roads in arroyos	Plans being developed between Rio Arriba County, residents, and BLM to place roads on upland terraces along arroyo and stabilize arroyos as storm drainages	Agreement and detailed plans completed for at least one County Road realignment project for approx. 0.5 miles
2021	***Legislative policy initiatives launched***	***A large-scale legislative policy initiative for the watershed or a larger regional area for water source protection, water conservation, and erosion and flood control***	***Legislation passes and an official institution for regional water management is established***
2021	***First private land pilot projects completed***	***Farmers and/or other private landowners have completed one or more pilot projects that showcase management measures on private land in support of the WBP***	***At least one private project accomplished covering at least 10 acres***
2022	Development of phase-1 project/action proposals	One or more project proposal are developed and submitted for funding in support of the WBP	Funding proposals submitted for 33% of phase-1 project sites listed by year's end
2023	***First series of projects completed and evaluated***	***Projects started in phase-1 have been monitored and are evaluated for lessons learned and identification of achievement of WBP targets***	***At least 66% of projects implemented and targets reached; adaptive management actions identified***
2023	***Interim results from USFS Trampas treatments***	***The agency's targeted acreage has been treated, roads stabilized or closed, and trailheads improved for 2018-2022***	***Phase-1 USFS-Trampas unit projects implemented and targets reached; adaptive management actions identified***
PHASE 2: Program Implementation and Further Development			
2024-2026	Start of development of phase-2 project/action proposals	One or more project proposals are developed and submitted for funding in support of the WBP	Funding proposals submitted for 33% of phase-2 project sites listed by year's end

Year	Milestones	Description	Benchmarks
2024	***Reporting of phase-1 project achievements and results from large-scale policy initiatives***	***Reporting of project achievements, monitoring results, and successes toward realizing WBP targets***	***Monitoring results show at least 10% realization of load reductions, as expressed in measured sediment loads (by turbidity sensors and data analysis), land cover increase, and arroyo dimension improvements; tangible priority activities and funding sources identified from the policy initiatives***
2024	***Completion of first County Road realignments***	***A Rio Arriba County Road pilot project has been relocated on higher ground and the arroyo in which it ran has been stabilized with structures that spread and slow water and retain sediment***	***At least one project completed over a length of 0.5 mile of arroyo***
2027	***Phase-2 series of projects completed and evaluated***	***Projects started in phase-2 have been monitored and are evaluated for lessons learned and identification of achievement of WBP targets***	***At least 66% of phase-2 projects implemented and targets reached; adaptive management actions identified***
2027	***Interim results from 1st decade of USFS Trampas treatments***	***Acres treated, roads stabilized or closed, trailheads improved for 2018-2027***	***Phase-2 USFS-Trampas unit projects implemented and targets reached; adaptive management actions identified***
PHASE 3: Program Implementation and Adaptive Management			
2028	***Interim evaluation and update of WBP after 2 phases***	***The WBP is evaluated to its effectiveness, targets, and timeline, and updated or revised as necessary based on lessons learned from phases 1 and 2***	***Monitoring results show at least 33% realization of load reductions, as expressed in measured sediment loads, land cover increase, and arroyo dimension improvements; actions show scaled up trend due to policy initiatives; WBP is updated with new targets and timeline and adaptive management actions***
2028	***Similar milestones as phase-2 first year***	***Similar activities are conducted to implement phase 3 as were done to start phase 2***	***Similar benchmarks as in phase 2***
2031	***Similar milestones as phase-2 last year***	***Similar activities are conducted to complete and evaluate phase 3 as were done to end phase 2***	***Similar benchmarks as in phase 2***

Year	Milestones	Description	Benchmarks
PHASE 4: Program Implementation and Ongoing Adaptive Management			
2032	*Interim evaluation and update of WBP after 3 phases*	*The WBP is evaluated to its effectiveness, targets, and timeline, and updated or revised as necessary based on lessons learned from phases 1, 2, and 3*	*Monitoring results show at least 66% realization of load reductions, as expressed in measured sediment loads, land cover increase, and arroyo dimension improvements; actions continue to show a scaled up trend due to policy initiatives; WBP is updated with new targets and timeline and adaptive management actions*
2032	*Similar milestones as phase-3 first year*	*Similar activities are conducted to implement phase 4 as were done to start phase 3*	*Similar benchmarks as in phase 3*
2035	*Similar milestones as phase-3 last year*	*Similar activities are conducted to complete and evaluate phase 4 as were done to end phase 3*	*Similar benchmarks as in phase 3*
PHASE 5: Program Implementation, Adaptive Management, and Completion			
2036	*Interim evaluation and update of WBP after 4 phases*	*The WBP is evaluated to its effectiveness, targets, and timeline, and updated or revised as necessary based on lessons learned from phases 1, 2, 3, and 4*	*Monitoring results show at least 85% realization of load reductions, as expressed in measured sediment loads, land cover increase, and arroyo dimension improvements; actions continue to show a scaled up trend due to policy initiatives; WBP is updated with new targets and timeline and adaptive management actions*
2036	*Similar milestones as phase-4 first year*	*Similar activities are conducted to implement phase 4 as were done to start phase 5*	*Similar benchmarks as in phase 4*
2039	*Similar milestones as phase-4 last year*	*Similar activities are conducted to complete and evaluate phase 5 as were done to end phase 4*	*Similar benchmarks as in phase 4*
2040	*WBP evaluation and revision*	*WBP is being revised based on lessons learned and new watershed conditions and trends*	*An entirely revised and renewed WBP with new targets, timeline, strategies, and management measures*

The major milestones over the 20-year timeline include benchmarks with load reduction goals that project a trend of gradual reduction of TSS levels by 10% after the first phase and a gradual increase in subsequent phases. After phase 2, the sediment load reduction target is set at 33%, growing to 66% after phase 3 and to 85% after phase 4. This trajectory of benchmarks would reasonably lead to the full 100% achievement of the load reduction goals by 2040.

At the beginning of each new phase, load reduction achievements for the previous project phase period would need to be evaluated by comparing before and after data. Feasible monitoring data sets would be (a) land cover percentages (based on transects and remote sensing data), (b) arroyo dimensions and related flow estimates from a selection of key arroyo tributaries, and (c) turbidity data trends measured at ARID1 and ARID2, and analyzed for the calculation of sediment loads. By comparing the sediment loads across the past phases, it would be possible to ascertain whether a load reduction has been achieved and what the trend of load reductions looks like. It would also be possible to identify whether load reductions were achieved in the lower elevation Cañada Aqua sub-watershed (Arroyo la Mina/Embudo Creek) below the Cañada de Ojo Sarco, or above this critical confluence.

If funds and personnel capacity allow, a third automated gaging station with similar instrumentation as at ARID2 (staff gage, rain gage, pressure transducer with thermometer, an optical turbidity sensor, and a data storage unit) could be installed immediately above the confluence of the Rio de las Trampas and Rio Embudo in order to track the turbidity caused by the sub-reach of the Rio Embudo that receives flows from the Rio Trampas and Cañada de Ojo Sarco. This new station (ARID3) could possibly be calibrated with the grab sample data collected for ARID1 and ARID2 in 2014 as a proxy, and manually corrected based on the differences found in the analysis for the calibration of ARID1 and ARID2. Unless significant research funds are made available, it needs to be understood that this calibration approach is flawed and that the relationship between turbidity and suspended solid loads in the stream is different for each point in the river, as was concluded for the conditions between ARID1 and ARID2 based on 2014 data analysis.

Estimates of direct, cumulative load reductions of all committed, proposed (see Table 5.1 and Table 5.2), and additionally recommended management measures (see Table 5.3) show that only about 48% of the overall load reduction target stated in the TMDL may be reached. Compared with the sediment transport estimated by STEPL modeling, approximately 93% load reduction may be achieved, while only a 23% reduction of the averaged out peak loads measured in 2014 (i.e., 104,062 lbs/day) would be achieved. The high costs of the recommended interventions ($10M-$20M) limits the feasibility of pursuing more management measures than the ones listed in this 2019 WBP-Update.

Yet, these estimates do not take into consideration that the management measures would likely have cumulative effects across the landscape that might lead to higher load reductions over time. Many land restoration practitioners have observed for example that successful soil stabilization structures typically build up a cone of sediment far upstream and rewet an area around them that subsequently recolonizes with vegetation and retains more sediment over time. A combination of structures and management measures will therefore have effects greater than the sum of their parts. This has also been calculated by the application of STEPL modeling and expressed in Appendix 6 for the load reduction effectiveness (P-factor) of several techniques.

Maintenance and adaptive management actions play a critical role in achieving the anticipated cumulative effects of any combination of management measures. There is insufficient research data to substantiate the expectation and any quantification of cumulative effects. Monitoring and research will be essential to ascertain the magnitude of this effect and how it can be enhanced and cultivated (literally and figuratively) over time and across the land, and to what extent it will live up to achieving about 52% of the load reduction targets, particularly in the forested, higher elevation sub-watersheds and in years with excessive, localized precipitation and flow events.

In case monitoring reveals that load reductions are not achieved and cumulative effects are not realized to a sufficient degree, it will be necessary to consider conducting a water quality attainability study, updating the TMDL, stepping up maintenance and community education, or modifying the WBP.

6.2. Monitoring Program

Project success is tracked by identifying milestones and benchmarks across the various project phases. Some milestones are incremental, providing building blocks to major milestones. Measurement of accomplishments at milestone moments is done through monitoring. Benchmarks (targets) are used to establish whether monitoring findings meet the expected results for the identified milestone.

Monitoring activities typically distinguish between milestones related to completion of scheduled implementation steps ("implementation monitoring") and milestones related to outcomes in relation to overall goals ("effectiveness monitoring").

The primary purposes of monitoring outlined in this plan are to measure progress of WBP implementation against the benchmark targets set in Table 6.1 and specified in individual projects. Monitoring must help with modeling sediment load reductions that are expected to accompany implementation (Table 5.2) and to detect changes in water quality over time. Eventually, monitoring must help determine whether water quality standards are being met in the Lower Rio Embudo.

Implementation Monitoring

This WBP proposes that incremental progress would be tracked by tallying the start and completion of individual WBP actions and management measures. At the project level, each management measure and each individual structure or area treatment would need to be photographed and designated with a tracking number and GPS position to enable follow-up monitoring. Over time, this information would help determine whether the management measure has been effective at its intended site-specific purpose (e.g., to sequester sediment on a slope, reduce sediment movement on a dirt road, or prevent bank erosion in a gully).

Implementation monitoring would provide photographic and numerical data as evidence that structures have accomplished their site-specific goals. The documentation and presentation of successful management measures would enable the work to serve as demonstrations for people who still need to be convinced to implement the management measures. Furthermore, the monitoring documentation would serve as a track record that can lead to new sources of funding.

Progress towards implementing and completing the identified actions, projects, and specific management measures, as specified in Table 5.2, would be tracked and reported in revisions of this plan at the beginning of each 4-year phase and in reports required by organizations which are funding the implementation of this plan.

Effectiveness Monitoring

Effectiveness monitoring addresses the impact of management measures on the land with a view toward achieving sediment load reduction targets. While the initial research for this WBP used complicated scientific sampling techniques and modeling approaches, it would be more cost effective and feasible for follow-up monitoring to use a selection of key indicators and simpler measurements.

Key indicators of sediment retention in the landscape, directly related to the RUSLE and USPED equations which were used to model sediment transport, are (a) soil cover by rock, mulch and vegetation and (b) slope length and steepness between a measuring point and a place where sediment settles or spreads out. An additional indicator involves the dimensions of tributary arroyos to the Rio Embudo. If an arroyo's bankfull width and depth decrease, its peak flows and its upstream erosive energy are reduced, and hence, its sediment transport capacity is reduced as well, which means that more sediment is retained in the landscape. It would be useful if these indicators could be monitored annually for the sub-watersheds in which management measures have been deployed in previous years.

Findings from this annual monitoring approach could be verified by using the automated turbidity sensors in the stream gaging stations ARID1 and ARID2, which bracket the Lower Embudo watershed's lower HUC (130201010909), the Cañada del Aqua (Arroyo la Mina/Embudo Creek), which include the most severely eroding areas of the WBP planning area, and the placement of a third gaging station above the confluence of the Rio de las Trampas, as suggested above (Figures 6.1 and 6.2). This approach reviews data from a specific area by measuring upstream and downstream from the target area and compares data from before and after treatment (Grabow at al. 1992).

Figures 6.1 (left) and 6.2 (right). Staff gage (left) and data logger (right) are standard components of the stationary gaging stations ARID1 and ARID2, and suggested for a new station ARID3.

Using the calibrations and correlations that resulted from the initial baseline research, State Surface Water Quality Bureau staff or consultants would periodically (e.g., every 4 or 5 years and particularly at the end of significant runoff events) need to analyze sensor data (using regression analysis) to calculate the suspended sediment loads in the Rio Embudo to verify whether indicators, such as ground cover and arroyo dimensions described above, along with photographic evidence collected at project sites are expressed in real, measured load reduction achievements.

Baseline monitoring in 2014 revealed that automated ISCO samples are the most accurate way of collecting data on suspended sediment in the Lower Rio Embudo. However, the ISCO sampling approach is not cost effective for repeat monitoring. The baseline monitoring experience revealed that manual sampling in the Rio Embudo is not effective because the manual depth integrated samples are not representative and effective sampling moments are hampered by flow intensities that render it too dangerous or too costly (e.g., in case of measurement from suspended cables) to take any samples. Therefore, measurements in the Rio Embudo will need to rely on automated turbidity samples. Details for this approach are specified in the 2013 project QAPP (NMED 2013)[1].

An alternative, community-based monitoring approach applicable to sub-watersheds that intersect with *acequias* could include the quantification of sediment removed from *acequias* in relation to precipitation data for the area. When a trend becomes visible that annual amounts of sediment removed from *acequias* decline proportional to local precipitation levels, it could be inferred that sediment loads are declining. When *acequia* associations are able to quantify the sediment loads removed from *acequias* each year, load reductions can be estimated more precisely. However, this method is probably quite inaccurate and only useful after data have been collected over a number of years because the relationships between annual (or even seasonal) precipitation depth and sediment removal volumes are not linear and are likely variable from place to place.

Coupled with a payment-for-ecosystem services program that remunerates *acequia* associations for cleaning their ditches and tracking sediment removal as a measuring component for the payment system, this monitoring approach may over time become more sophisticated and useful. Additionally, this approach could lead to results that can mobilize and interest the community in the efforts to improve water quality in the Lower Rio Embudo.

Any useful monitoring information will help indicate whether additional action is warranted, such as any maintenance or technical adjustments. In some cases, management measures will need to be modified and adapted to new insights and terrain conditions, also known as “adaptive management”.

6.3. Evaluation and Adaptive Management Process

At the beginning of each new project phase after phase 1, the steering group or management team of the leading watershed coalition (e.g., EVRAA, Rio Embudo Watershed Coalition, or a combination of groups) would evaluate the findings from implementation monitoring and effectiveness monitoring

[1] New Mexico Environment Department (NMED). 2013. Project Quality Assurance Project Plan: An Updated Watershed-Based Plan for the Lower Embudo Watershed, New Mexico. 31 July 2013, Revision 1: 16 August 2013. Arid Lands Institute, Burbank, CA, and NMED Surface Water Quality Bureau, Santa Fe, NM.

completed throughout and at the end of the previous phase. Achievements would be compared with benchmarks and reported to local constituents, funding agencies, and regulatory agencies, as necessary and appropriate. Success stories would be packaged for publication and dissemination to encourage replication and community support for the watershed restoration efforts.

Numerical results of the realization of target load reductions would need to be documented and reported to the NMED Surface Water Quality Bureau (SWQB). If targets are not met, the watershed steering group or management team would need to identify, perhaps in consultation with SWQB experts, what the causes would be of such a discrepancy and how to modify project strategies to achieve better results in the new project phase.

Ideally, at the end of the each phase monitoring results should show the targeted percentages of load reductions, as expressed in measured sediment loads (by turbidity sensors and data analysis), land cover increase, slope factor reductions, and arroyo dimension improvements. Tangible results should also be documented in photography. Additionally, monitoring results should show the realization of tangible priority activities and funding sources identified for future work based on the policy initiatives.

The first phase target has been set at a 10% achievement of load reductions. At the end of the second phase, monitoring results should show at least 33% realization of load reductions and actions should show a scaled up trend of funding and partnerships due to policy initiatives. At the end of the third phase, monitoring results should show at least 66% realization of load reductions and a continuation of the scaled-up trend of phase-2 results due to policy initiatives. At the end of the fourth phase, monitoring results should show at least 85% realization of load reductions and ongoing scaled-up trends and cumulative effects. At the end of the 20 year period, monitoring result should show 100% achievement of project goals and targets.

Lessons learned from the evaluation of each phase would need to be analyzed to discern the need for maintenance of and modifications to management measures that were implemented previously and for changes in the application of management measures in the future. If necessary key elements of the WBP, such as load reduction targets, treatment areas, selected management measures, or the timeline may need to be modified at the beginning of each new phase. WBP revisions and strategic improvements to the implementation of the WBP across the landscape are part of adaptive management of the watershed, in which lessons learned are disseminated and applied on the land in the form of updated management measures. Dissemination of lessons learned will follow the recommended practices for educational outreach described in Chapter 5.

After the completion of the five phases, or earlier when the evaluation of monitoring results demands it, and the WBP should be entirely revised and renewed with new considerations for targets, timeline, strategies, and management measures. Proper monitoring and evaluation over the years would help greatly in identifying the focus of the revisions of the WBP. Plan revision would ideally be undertaken by the key watershed groups that have been overseeing implementation of the WBP between 2020 and the revision date.

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