

Cochiti Baseline Study

A Data Compendium



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Table of Contents

1 - Introduction	1
2 - Geospatial Data Sets	5
3 - Surface Water Quality Characterization	6
4 - Sediment Quality Characterization	10
4.1 Sediment Baseline Study Findings	12
4.1.1 Geophysical Characteristics	12
4.1.2 Metal Concentrations	13
4.1.3 Organic Chemicals	14
4.1.4 Radionuclide Concentrations	14
4.2 Risk Screening Approach	14
5 - Sediment Transport Modeling	18
5.1 Collection and Compilation of Data	18
5.1.1 Periodic Surveys	19
5.1.2 Geomorphic Investigation	19
5.1.3 Cohesive Sediment Transport Processes	23
5.1.4 Numerical Modeling	26
5.1.5 Conclusion	30
6 - Groundwater Investigations	32
6.1 Shallow Groundwater Level Monitoring	32
6.1.1 Shallow Groundwater Elevations	35
6.1.2 Shallow Groundwater Site Conceptual Model	35
6.2 Cochiti Dam Downstream Wellfield Camera Survey	37
7 - Ecological Resources	38
7.1 Mapping of Wetland and Riparian Vegetation	38
7.2 Wildlife Surveys	39
8 - Ecological Resources – Limnology and Fisheries	43
8.1 Cochiti Lake Limnology	43
8.2 Cochiti Lake and Rio Grande Fisheries	48
8.3 Fisheries Development	49
9 - Historic and Archaeological Data Sources	51
10 - References Cited	52

List of Tables

Table 1 – Summary descriptions for project sampling locations.....	17
Table 2 – Groundwater Well Categories.	33
Table 3 – Locations and methods of surveys for various wildlife groups in the vicinity of the Cochiti Dam and Lake Project, December 2011 through November 2012.	41
Table 4 - Fish survey results within the Pueblo de Cochiti boundaries.....	48

List of Figures

Figure 1 – Map showing the location of Cochiti Lake.	1
Figure 2 – Cochiti Dam and Lake in relation to Cochiti Pueblo and the study area.	4
Figure 3 – Abiquiu Lake and Rio Chama Water quality sampling locations, upstream of Cochiti Lake.....	8
Figure 4 – Cochiti Lake and Rio Grande water quality sampling locations.	9
Figure 5 – Sediment sampling areas.	11
Figure 6 – Upstream rangeline locations.	21
Figure 7 – Measured longitudinal profile upstream of Cochiti Dam.....	22
Figure 8 – Sampling locations and mobile flume deployment for Sedflume core experiments....	24
Figure 9 – Target sampling locations for PICS experiments. Measurements were only obtained at stations c01 - c11.	25
Figure 10 – Bed profile results from the calibrated HEC-RAS model for the calibration period, 1975 – 1998.....	28
Figure 11 – Bed profile results from the calibrated HEC-RAS model for the verification period, 1975 – 2005.....	29
Figure 12 – Subareas Showing Piezometer Network.	34
Figure 13 – Shallow Groundwater Hydrostructures.	36
Figure 14 – Wildlife survey locations throughout the study area (left) and in detail downstream from Cochiti Dam (right).	42
Figure 15 – Cochiti Lake average seasonal water temperatures (a-d) and dissolved oxygen (e-h) by depth. Thermal tolerance of potential sport fish species (i-l) compared with high summer temperatures (solid blue).....	45
Figure 16 – Annual trends in Cochiti Lake (2011) water temperature using continuous temperature loggers at the outlet, 0 and 15 m depth (near the dam).....	46
Figure 17 – Downstream flow and water temperature at Cochiti Lake outlet.....	47

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1 - Introduction

Cochiti Dam and Lake is located on the Rio Grande mainstem approximately 50 miles north of Albuquerque, New Mexico (Figure 1).

Construction and operation of Cochiti Dam was authorized by PL 86-645, PL 534 as amended, Senate Document No. 97, and PL 88-293. The facility is authorized to regulate Rio Grande flows for flood and sediment control. The facility is constructed on Pueblo de Cochiti (Pueblo) land and is managed by the Albuquerque District of the U.S. Army Corps of Engineers (USACE). The majority of lands associated with Cochiti Dam and Lake are held in trust by the United States for the beneficial use of the Pueblo de Cochiti, a federally recognized Native American Tribe. The flood pool includes flowage easements on lands managed by the State of New Mexico, the U.S. Forest Service, the National Park Service, and the Department of Energy.

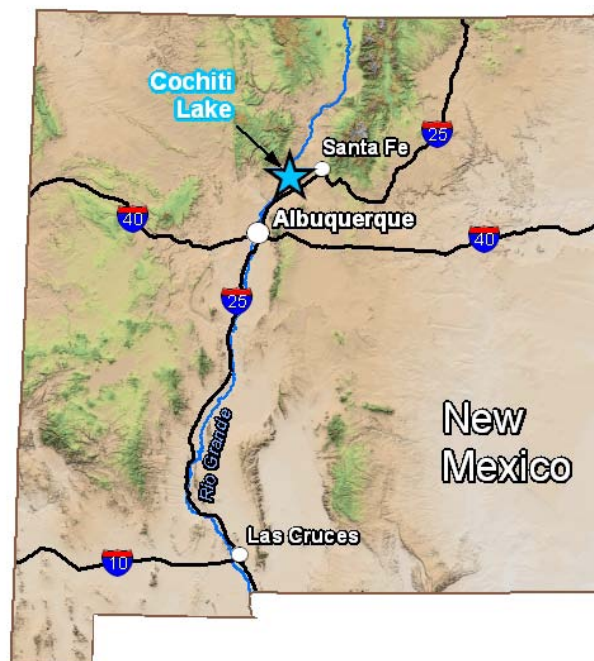


Figure 1 – Map showing the location of Cochiti Lake.

Beginning in the 1980s, there was increasing concern regarding the existing and future conditions of aquatic and riparian habitats in the Rio Grande (Crawford, *et al.*, 1993). In 1994, the Rio Grande silvery minnow (*Hybognathus amarus*) was added to the list of federally endangered species, with critical habitat for the minnow in the Rio Grande designated in 2003. Similarly, the Southwestern Willow Flycatcher (*Empidonax traillii extimus*) was added to the list of federally endangered species in 1995, with critical habitat designated in 2005. Regionally, water resources managers, including USACE, have had to better manage the increasingly scarce water resources of the region to balance ecological and water resources needs.

Cochiti Dam is the largest water control facility on the mainstem of the Middle Rio Grande. USACE operates the dam primarily for flood damage reduction and to meet recreational, and fish and wildlife development needs. During the drought year of 2002, water resource managers were seeking additional water sources to maintain downstream flows in the Rio Grande for the endangered Rio Grande silvery minnow. These changes included potential alterations to operations at Cochiti Dam. Other suggested changes by various interests ranged from adding significantly to storage in Cochiti Lake to completely draining the lake's 50,000 acre foot recreation pool.

However, both USACE and the Pueblo recognized that changes to water operations could not be undertaken without more comprehensive, systematic data on the natural, water and other resources at and around Cochiti Lake so that a more complete assessment could be made of the impacts of changes in lake operations on the area's natural, water, and other resources. The

Pueblo provided Congressional testimony stating that despite a significant amount of ecosystem research undertaken in the area, a comprehensive synthesis had not been developed that could be used to address how Cochiti Dam's operation might impact Tribal resources. The Pueblo proposed that the existing information be combined in a single database, analyzed to identify gaps in our knowledge, and studies conducted to fill those gaps in order to create the needed comprehensive synthesis. USACE, as operator of the facility, agreed that significant environmental analysis would be needed to evaluate any proposed changes.

The Cochiti Baseline Study (Study) was designed to gather data on the wide array of potential systemic interactions in this complex, lacustrine environment. The Study, which was developed by USACE and the Pueblo in coordination with neighboring stakeholders, sought to document the existing and historical environmental conditions of the project area, and to investigate and characterize past impacts that have occurred to resources on Pueblo de Cochiti and other lands from the operation and maintenance of Cochiti Dam and Lake. The Study was not undertaken with a specific management goal in mind, but rather sought to develop detailed background information required to make future water operations decisions.

Figure 2 shows the relevant extent of the Cochiti Baseline Study. Numerous factors contributed to discussions of how to define the Study area. When constructed, Cochiti Dam was the longest earthen dam in the world, impounding flows from two river systems, the Rio Grande and the Rio Santa Fe. The location of the facility at the downstream mouth of White Rock Canyon produces backwater effects many miles upstream of the structure itself. The result is dramatically wide footprint to the south with a long, narrow tail to the north.

The multidimensional character of natural and cultural variables required a fairly complex dialogue on the characteristics of systems and system boundaries. Debate ranged from the pragmatic (funding constraints and modern political jurisdictions) to the esoteric ('crisp' versus 'fuzzy' boundaries). Where possible, relevant historic data (i.e., extant sampling data at other reservoirs in the region) or data that could be acquired through economies of scale (e.g., aerial mapping) were sought and added to the data base. Expensive data collection, such as chemical testing, was by necessity limited to the immediate vicinity of Cochiti Lake.

The primary product of this Study is an extensive database of empirical observations on a variety of natural, water and other resource variables in Cochiti Lake and the surrounding region. The collected data is integrated in a comprehensive geographic information system (GIS) to facilitate data access, future analysis, and presentation of results. This report briefly summarizes initial observations on the data collected and provides future analysts with information on the nature and extent of the data collected, including assumptions about the variables and metrics monitored.

The analysis of the information provided by the Study has three major benefits: 1) Federal, Tribal and State resource managers have crucial information necessary to evaluate changing resource demands and to facilitate sound decision making regarding water and ecological resources; 2) the Federal government fulfills its Tribal trust responsibilities; and 3) by directly involving the Tribe in the conduct of the various investigations, the Pueblo de Cochiti has an opportunity to enhance its capabilities in the area of resource management and regional water operations.

During the current data collection effort, the Project Delivery Team (PDT) identified data gaps that will need to be addressed prior to substantive changes in operation at the Cochiti project. The PDT feels that these studies will be necessary to adequately understand the effects of Cochiti Dam on important resources in the project area. These future studies include a condition assessment of historic and cultural properties, characterization of post-fire impacts on surface sediments, groundwater level monitoring in upstream wetlands, a food-web analysis in Cochiti Lake, development of exposure pathway definitions specifically for Native American populations, human health and ecological risk analyses, fish tissue contaminant study, additional sediment transport model runs, and the development of a more appropriate 3D sediment transport model for the lake pool. Finally, the development of a database with the ability to securely house all of the data collected to-date as well as any future data generated for the project, would be integral to any analysis of resource management or water operations at Cochiti Dam and Lake.

USACE and the Pueblo entered into a Cooperative Agreement on June 17, 2008 in order to implement the Cochiti Baseline Study. Under this Agreement, the array of analyses to be undertaken for the Study would be conducted with the intent of characterizing the interaction of Cochiti Dam and Lake operations with not only regional, but more particularly, Tribal resources. The objective of the Study was to provide a full characterization of the interactions of Cochiti Dam and Lake within the local ecosystem. The analyses, developed in consultation with the Pueblo and other interested stakeholders, provide a baseline against which the impacts of any future changes at the lake may be evaluated. Investigations included: water quality analysis, analysis for potential sediment contaminants, sediment transport analysis, biological studies for habitat and species identification, analysis of potential cultural resource impacts, economic impact studies, integrated information management and mapping technologies, as well as independent technical reviews. The following chapters describe how these baseline studies were conducted and provide general overviews of the findings of these analyses.

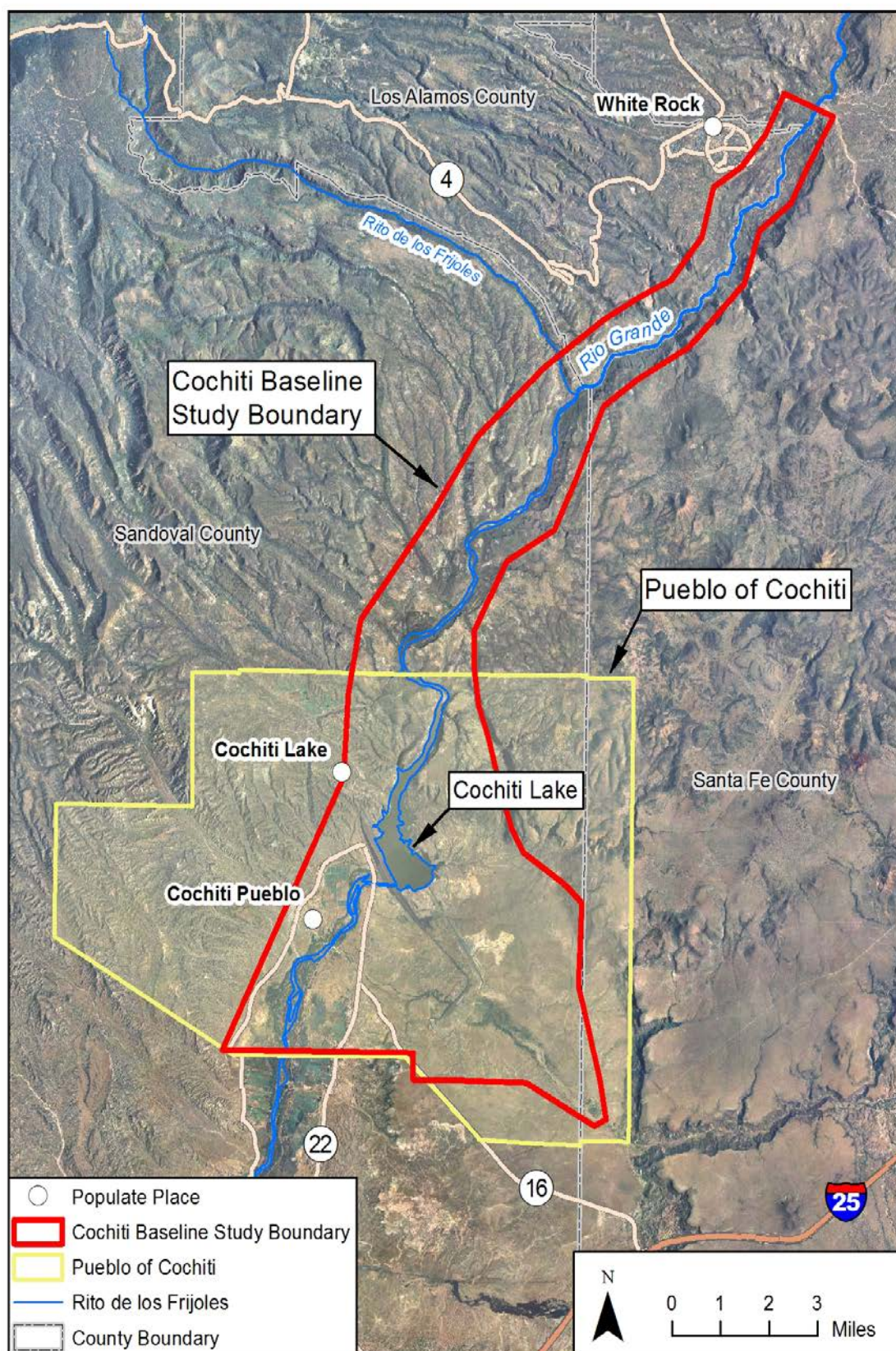


Figure 2 – Cochiti Dam and Lake in relation to Cochiti Pueblo and the study area.

2 - Geospatial Data Sets

The Cochiti Baseline Study has encompassed many subjects and scientific disciplines over the last decade. An essential theme for understanding the results of each sampling survey, inventory, and assessment is that of their geospatial relationships to the in situ environment and to each other, when relevant. Understanding that the geospatial component of all of the parameters being collected will reveal the important relationships that decisions will be based on, the data sets described in the sections that follow have all been orchestrated to include the attributes of location in three (3) dimensions (X,Y,Z) and four (4) dimensions where time is important (X,Y,Z,T). To allow for the analysis of data on a common platform, all in-house and contracted data collection and mapping has been compiled in Environmental Systems Research Institute (ESRI) geographic information system (GIS) data formats as shape files or file geodatabases. All GIS related analyses to date have used ESRI's ArcMap GIS software; versions 9.3.1 and 10.0.

The Geospatial Data and Services Unit (GDS Unit) worked with PDT members to identify the geospatial data and products required for their efforts on the project. The GDS Unit was also responsible for collecting and assembling a database of required spatial data from existing in-house and publically available sources and placing the data in a central location accessible by other PDT members. The development of the GIS data sets for this Study included the following tasks:

- Provided guidelines for details such as coordinate system, datum, and other standards that need to be met as well as ensured that all data complied with security/sensitivity requirements of the sponsor in handling geospatial data and products.
- Contracted geospatial services where existing data sources were insufficient, such as the acquisition of aerial photography and elevation surfaces.
- Verified or authored metadata, Federal Geographic Data Committee compliant when possible, for new geospatial data.
- Assisted with or performed geospatial analysis required by the project when requested by PDT members.
- Created cartographic and other geospatial visualization products requested by PDT members.
- Provided limited geospatial assistance to sponsoring agencies.

Data resulting from the studies described in subsequent sections of this document currently reside in a master data set located on USACE's NAS Device and two (2) sets of magnetic backup tapes in the Albuquerque District. All data having associated locations were collected in New Mexico State Plane Central projection, North American Horizontal Datum of 1983 (NAD 83) horizontal reference and, North American Vertical Datum of 1988 (NAVD 88) vertical reference. In all cases geospatial metadata was stipulated to be produced for, and accompany, each GIS data set, explaining the details of each, such as company or personnel involved, date and time of collection, methods used, map projection, horizontal and vertical datums, and map units used.

3 - Surface Water Quality Characterization

The goal of the surface water quality characterization was to develop information on baseline surface water quality conditions so that impacts of potential changes in Cochiti Dam operation could be assessed. This task was contracted to Tetra Tech, Inc. The primary report product is:

Tetra Tech Inc. 2011. Cochiti Lake Baseline Water Quality Characterization, Project Completion Report. Prepared by Tetra Tech, Inc., Albuquerque New Mexico. Prepared for the Pueblo de Cochiti.

Surface water sampling for the surface water quality characterization occurred between July 7 and November 16, 2011 following the Las Conchas Fire. The Las Conchas fire started on June 26, 2011, and burned some 153,593 acres in the Jemez Mountains, including intensive burning (crown fires) in watersheds upstream of Cochiti Lake. Periodic wildfires upstream of Cochiti Lake had occurred previously (La Mesa Fire (1977) 15,444 acres; Dome Fire (1996) 16,516 acres; Cerro Grande (2001) 48,000 acres). A majority of these fires impacted areas within the watershed discharging into Cochiti Lake, affecting sediment loads, sediment quality and surface water quality in the watershed.

The Las Conchas fire was an order of magnitude larger than previous fires and burned areas more intensely across most of the watersheds tributary to the west side of Cochiti Lake. It is anticipated that post-fire conditions in these watersheds include altered soil chemistry and stormwater runoff characteristics, resulting in adverse effects to downstream water quality. Combustion of plants and natural materials release metals, polycyclic aromatic hydrocarbons (PAHs), nutrients, organic pollutants, radionuclides and nitrogen compounds into the environment. Previous studies have found that dioxins are emitted, re-suspended and volatilized by forest fires. Increased sediment loads post-fire mobilize sequestered (in plant biomass, soil) and newly formed potential constituents of concern. Because sampling occurred immediately after the Las Conchas fire, these conditions do not represent baseline conditions, but provide a snapshot of surface water quality after a large wildfire, which periodically impact Cochiti Lake. Variations in chemical concentration between background locations are likely due to Cochiti Lake's more downstream position in the watershed, variation in parent geology, transport of legacy Los Alamos National Labs (LANL) contaminants, recent wildfires, and other sources.

A review of prior surface water quality investigations identified constituents that had been detected previously and were considered most likely to be detected again. Sample locations upstream (Abiquiu Lake (4 Sites) and Rio Chama (4 sites)), and downstream (the Rio Grande downstream from Cochiti Lake (2 sites)) enabled comparisons between background sediment concentrations in different portions of the study area. Sample locations are provided in Figures 3 and 4.

Sample parameters were analyzed by the following common groups: field parameters; general chemistry; nutrients; major cations and anions; metals; dioxins / furans; polychlorinated biphenyls (PCBs); pesticides; volatile and semi-volatile organic compounds (SVOCs); and radionuclides.

Maximum concentrations of suspended and dissolved materials tended to be higher in Cochiti Lake than in Abiquiu Lake. The larger size suspended solid fractions had higher concentrations at depth in Cochiti Lake sites with dissolved materials remaining uniform throughout the water column. Chemical oxygen demand and total phosphorus concentrations were synchronous along with suspended sediments entering Cochiti Lake.

Additional SVOCs were detected at the sampling sites, but did not have associated ecological screening values. PCBs were not detected in water samples from sites in the surface water quality characterization. Two pesticides were reported to have estimated concentrations in Abiquiu Lake and the Rio Chama; one of these plus seven others had estimated concentrations in Cochiti Lake, and seven were also reported in samples from the two downstream Rio Grande sites. Dioxins and furans were reported in detectable amounts at all surface water sample sites. Concentrations for dioxins and furans were higher in down-gradient sites of the study area; 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD), was detected in one of the deep water samples from Cochiti Lake remained below the maximum consumption level (MCL). Benzoic acid was the only SVOC detected in Cochiti Lake and did not exceed the ecological screening value. Thirteen analytes exceeded ecological screening criteria benchmarks: total and dissolved concentrations for aluminum, and total concentrations for boron, iron, lead, lithium, manganese, uranium, vanadium, 4,4'-DDE (1,1-*bis*-(4-chlorophenyl)-2,2-dichloroethene) 4,4'-DDT (1,1,1-trichloro-2,2-di(4-chlorophenyl)ethane), carbon disulfide and benzoic acid. However, the reported concentrations of boron, 4,4'-DDE, 4,4'-DDT, and benzoic acid are associated with data qualifiers and are included as estimated concentration. Concentrations for aluminum and uranium can be contributed by natural local background geology, thus may be the principal source for these two metals in this system. Several radionuclides were detected in surface water samples during this analysis. The maximum lead-210 concentration reported from the Cochiti Lake delta site in September 2011 exceeded the human health screening limits, but is considered to have a negligible hazard as the result is within a normal concentration range where naturally occurring uranium-238 contributes lead-210 as a decay product. The concentration distributions observed for, specifically, plutonium and americium appear to be likely associated with historic releases from Los Alamos National Laboratory (LANL), while distribution patterns observed for strontium and cesium appeared consistent with those reported for atmospheric deposition from historic open-air tests of atomic weapons.

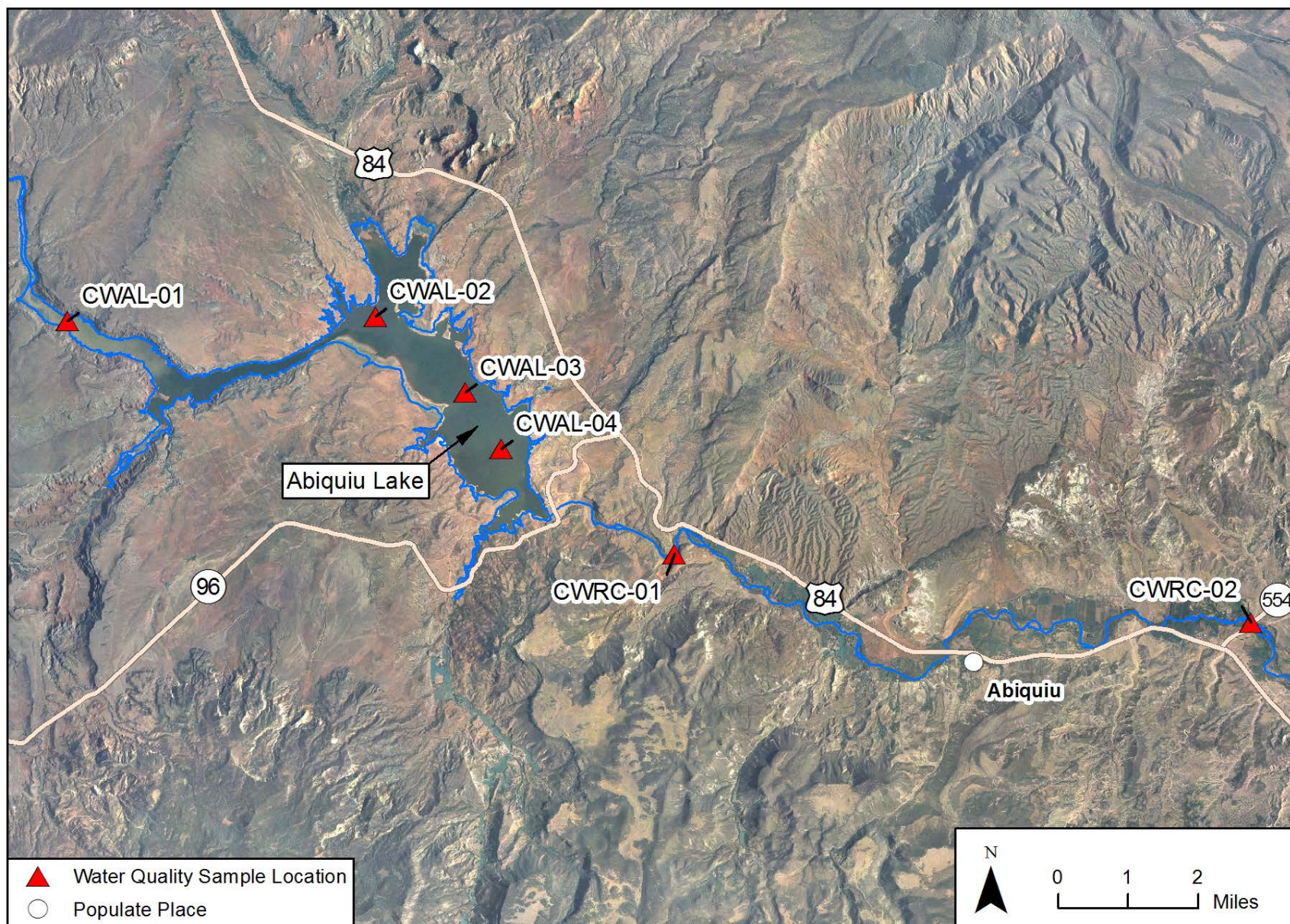


Figure 3 – Abiquiu Lake and Rio Chama Water quality sampling locations, upstream of Cochiti Lake.

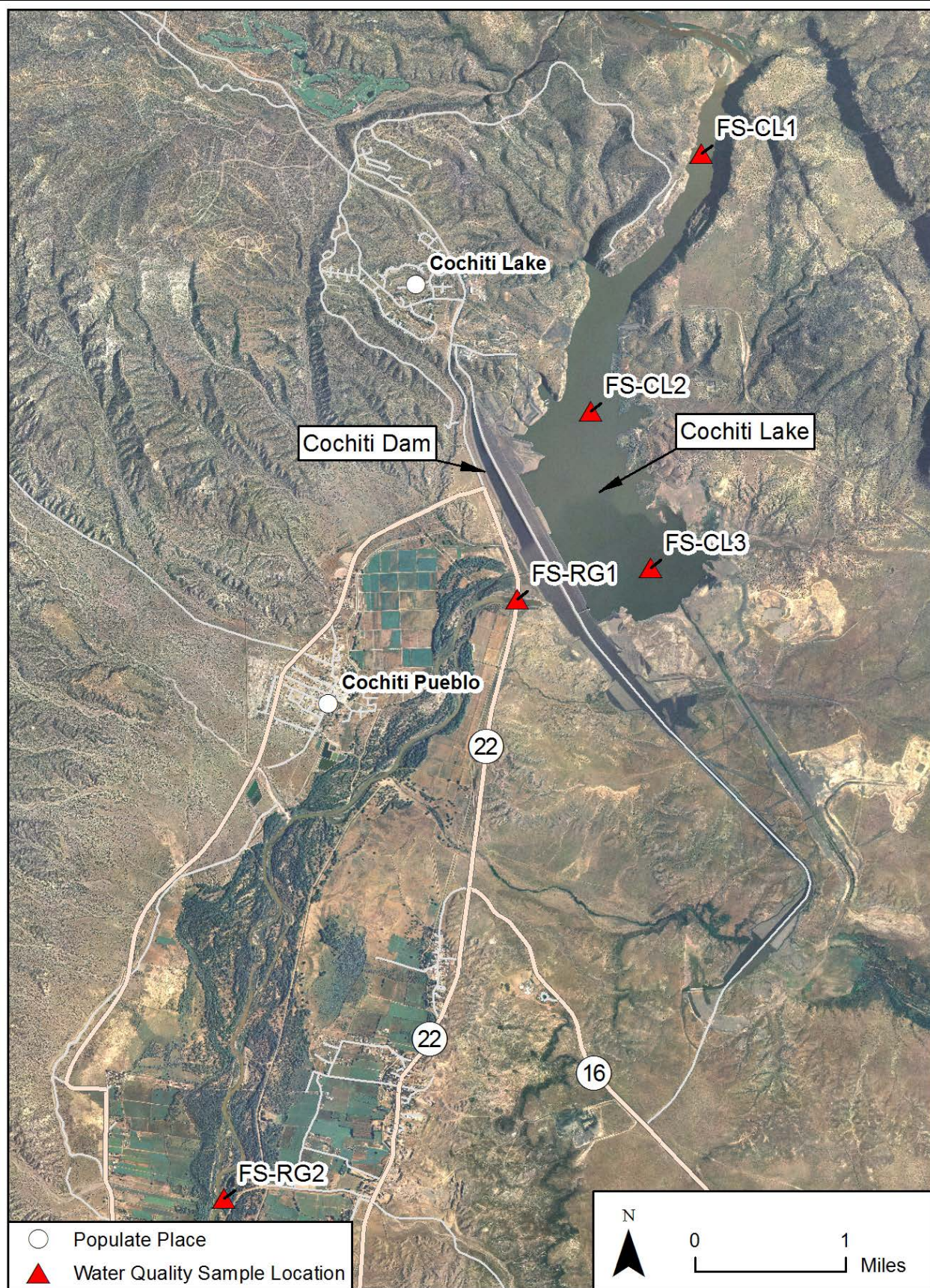


Figure 4 – Cochiti Lake and Rio Grande water quality sampling locations.

4 - Sediment Quality Characterization

The goals of the sediment quality characterization were to provide information on baseline sediment quality conditions that may have potential effects on Pueblo resources from Cochiti Dam, as well as recording existing concentrations for any future comparison. Additionally, a preliminary ecological and human health risk screening of existing sediment chemicals and radionuclides was conducted.

This task was contracted to Parametrix, Inc. The primary report product is:

Parametrix. 2011. Cochiti Lake Sediment Characterization Project Completion Report.
Prepared for the Pueblo de Cochiti.

A review of previous sediment investigations was performed. This review identified constituents that had been previously detected and were considered most likely to be detected again. Sample data provided comparisons between background sediment concentrations upstream using Abiquiu Lake and the Rio Grande in the Ohkay Owningeh reach; downstream to the six project areas starting in the upper reaches of White Rock Canyon, to the delta deposits at the head of and in the main body of Cochiti Lake, the lower Santa Fe River, and in the Rio Grande downstream from Cochiti Lake. Additional samples were collected from sediments in the Santa Fe River channel and wetland area, and in irrigation canals below the dam (Figure 5).

Sediment core samples and surficial sediment grab samples were collected during the summer of 2010. Random locations were selected for sediment grab and core sampling within each river and lake subarea as well as each reference area so that those samples could be designated as replicates representative of overall sediment conditions within each subarea or reference area (except for the irrigation canals downstream from Cochiti Dam due to limited deposition within the canal). In addition to chemical and radiological analysis, geophysical sediment analyses were conducted (sediment grain size distribution, particle density, moisture content, and total organic carbon). Field duplicate samples were collected at a frequency of one per 20 primary samples, to provide an indication of overall precision in the sampling and analysis process. The data collection was designed to be of sufficient quantity and quality to support preliminary ecological and human health screening-level assessments of potential risks from exposure to chemicals and radionuclides in the sediment, and provide a record of existing concentrations of these constituents for comparisons with the results of any future sediment characterizations.



4.1 Sediment Baseline Study Findings

4.1.1 Geophysical Characteristics

Geophysical characteristics of sediments are important to further understand the contaminant results and model sediment transport. The composition of sediments in terms of grain size classifications varied widely between subareas, and in some cases, within subareas (Table 1). The finest sediments were in Cochiti Lake where the average clay content was greater than 50 percent and sand fractions comprised less than 21 percent. In contrast, Abiquiu Lake sediments were more than 48 percent sand and less than 26 percent clay. Rio Grande sediments were much coarser with greater than 80 percent sand in all river reaches sampled, and greater than 97 percent sand below Cochiti Dam. The Canyon Delta area was intermediate between the lake and Rio Grande conditions, with averages of 13 percent clay and 64 percent sand, and included samples that were nearly all sand and other samples that were nearly all finer grain material. The Santa Fe River sediment samples included the wetland area that had up to 55 percent clay content and river channel areas with up to 91 percent sand. Clays, silts and organics are transported down the rivers and accumulate in Cochiti Lake and the Santa Fe River wetland area, generally not moving past the dam.

Table 2 – Composition of Sediments Sampled.

	CLAY	SILT	SAND
Abiquiu Lake	25.5	26.0	48.4
Ohkay Owingeh	5.60	13.8	80.6
White Rock Canyon	3.00	15.8	81.3
Canyon Delta	13.0	22.7	64.4
Cochiti Lake	50.9	28.7	20.5
Santa Fe River	31.3	18.2	50.7
Rio Grande Below Dam	1.90	0.33	98.2

4.1.2 Metal Concentrations

Cochiti Lake surficial sediment concentrations were found to be significantly higher for five metals in comparison to the Abiquiu Lake surficial sediment concentrations. Additionally, a few metals were also significantly higher in Cochiti Lake cores samples as compared to Abiquiu Lake's core samples. These differences may be due to the fact that Cochiti Lake sediments had higher clay and organic contents than those in Abiquiu, since metals bind preferentially to clay particles.

For the river reach subareas, statistical comparisons between surface grab sediment concentrations were performed in two separate groups because of differences in sample size (i.e. number of replicates): (1) the Rio Grande below the dam, and White Rock Canyon, which each had seven replicate samples; and (2) the Canyon Delta (at the head of Cochiti Lake) and the Santa Fe River, which each had five replicate samples. Samples from the Ohkay Owingeh subregion, located above the study area near Española, NM, were used as a comparative baseline since it is above potential sources of metal contamination.

For the first group, most of the metals were significantly higher in the Ohkay Owingeh reach compared to White Rock Canyon or the Rio Grande below the dam. For the second group, all metals, with the exception of antimony, were found to be significantly higher in Santa Fe River surficial sediments than in the surficial sediments of the Ohkay Owingeh reach. Santa Fe River sediment concentrations were three to four times higher than Ohkay Owingeh sediment concentrations for most metals, and 17 times higher for mercury. There were no significant differences between Ohkay Owingeh and Canyon Delta sediments. All of the core samples from different depths were pooled in statistical comparisons between sample concentrations in different subareas; therefore, there was no consistency in the number of replicates. In multiple comparison tests the concentrations in Santa Fe River sediment cores were significantly higher than core samples from other project subareas for all metals analyzed except antimony. The other major finding from multiple comparisons was that metals concentrations were not significantly higher in any project subareas compared to the Ohkay Owingeh reference subarea.

Earlier studies in the project area allowed for comparisons of metal concentrations found under this investigation. The results of these comparisons showed that overall, metal concentrations were very similar to the previous studies' results. All studies found elevated metals concentrations in sediments from Cochiti Lake and the Rio Grande, but metal concentrations were also elevated at Abiquiu.

Regional Statistical Reference Levels (RSRLs) were also used in comparing metal concentrations found under this investigation. The RSRLs used were obtained from an Environmental Surveillance report published by LANL and represent regional background levels that reflect the soils and atmospheric deposition characteristics of the region around the Pueblo. It was found that many metals were higher than RSRLs in both Cochiti and Abiquiu Lakes. Additionally, metals in Santa Fe River sediments were higher than RSRLs for all but two metals, while metals in the Rio Grande sediments were lower than RSRLs except for one metal in Ohkay Owingeh and one in the Canyon Delta subarea.

4.1.3 Organic Chemicals

Very few organic chemicals were detected in the lake and river sediment samples; in fact there were too few detections for statistical comparisons to the reference areas. Additionally, sample data from previous studies is extremely limited and thus comparisons cannot easily be made. Unlike metals and radionuclides that have documented RSRLs and naturally occurring concentrations in the region from parent materials and atmospheric sources, there are no organic chemical RSRLs currently available for comparison to sediment sample concentrations. The only sediment samples where PCBs were detected came from the wetland area of the Santa Fe River; PCBs were detected in the lakes. Additionally, while pesticides were found commonly in the Santa Fe River samples, none were found in the lakes.

4.1.4 Radionuclide Concentrations

Radionuclide concentrations in samples from the project area were generally close to background levels. Statistics showed that concentrations were significantly higher in several subareas and at several sample sites in Cochiti Lake. The radionuclide concentrations had a strong tendency to increase with depth below the lake sediment surface. This tendency was observed mostly in the Canyon Delta and Cochiti Lake subareas and was less pronounced in the river subareas with limited sediment depth. Radionuclides are more soluble at the sediment surface and are thus more mobile (readily erode and disperse). With erosion and dispersion; while with increasing sediment depth, the radionuclides are more reduced and more insoluble. Additionally, there was a general trend where total radionuclide concentrations increased downriver from White Rock Canyon through the delta into Cochiti Lake in the deeper sediments, which tend to have higher organic content and finer grain sizes. Radionuclides concentrations were higher at the following discreet locations:

- At the mouth of Frijoles Canyon where sediments had a high organic content and the mouth of Chaquehui Canyon where the sediments are high in clay and silt.
- At the mouths of Alamo, Capulin and Medio Canyons.
- In deep areas of Cochiti Lake, near the pre-dam river channel.
- At the pre-dam river channel sites below Cochiti Dam.

4.2 Risk Screening Approach

A risk screening was performed to determine whether the levels of metals, organics, or radionuclides in the sediments of Cochiti Lake and subareas could pose a potential risk to human health or the environment. Risk-based sediment benchmarks were compiled from several state and Federal sources for human and ecological receptors. The benchmarks focused primarily on direct sediment contact pathways for both people (recreational, future non-resident and resident) and aquatic ecological receptors (e.g., benthic organisms, aquatic birds). In an effort to screen the organic chemicals for potential food chain effects, bioaccumulative benchmarks were also compiled, where available. Regional reference levels for radionuclides in sediment were used to compare the results of this study.

For inorganic compounds, organic compounds, and radionuclides, the potential risks to human health were generally limited, with only arsenic and vanadium concentrations showing any pattern of consistent, widespread exceedances of the most conservative sediment benchmarks. Overall, there is a low risk potential for people exposed to sediment metal concentrations during *recreational activities* (such as swimming, boating), and that this exposure pathway likely does not require further evaluation. The exceedances of arsenic and vanadium *residential sediment benchmarks* support consideration of further evaluation for risks for future year-round residents in the Cochiti Lake area. For the detected organics ((semi-volatile organics (SVOC), pesticides, or polychlorinated biphenyls (PCBs)) there were no consistent patterns of sediment benchmark exceedances in Cochiti Lake or the surrounding river systems. There is a suggestion of pesticide exceedances in the Santa Fe River, but most of these chemicals were legacy pesticides with long half lives, and likely result from previous agricultural practices that have been discontinued. These concentrations could be considered to now form the background levels for this area due to their (1) low levels of exceedance, (2) somewhat random distribution across the landscape, and (3) long lived persistence in the environment. Overall, none of the organic chemicals detected in lake or river sediments warrant a more detailed screening level risk assessment.

In contrast to human health, there is a potential for risks to ecological receptors in Cochiti Lake from exposure to surface and sub-surface sediment metal concentrations, based on the most conservative ecological sediment benchmarks. However, there were limited exceedances of the most conservative ecological sediment benchmarks in the surrounding river systems. While there was a pattern of exceeding the most conservative ecological sediment benchmarks, it is important to note that these benchmarks exhibit a large of range of values for different metals, and can depend on the sensitivity of local flora and fauna. Further evaluation of the Cochiti Lake sediment metals and bioavailability could be undertaken in combination with the surface water characterization to determine the potential cumulative risk to specific ecological receptors.

For the measured radionuclides detected in lake and river sediments present in Pueblo de Cochiti lands, it was determined that the majority of these compounds are likely to be naturally occurring. While some scenarios developed in the risk screening indicated potential risks to humans from drinking water derived from these sediments, these risks were associated with the naturally occurring radionuclides deposited by the Rio Grande. For aquatic animals only the Santa Fe River scenario developed in the risk screening demonstrated an exceedance of screening limits for these organisms. While the radioisotopes contributing to these exceedances are ubiquitous in nature, there is a strong potential that the La Bajada uranium mine contributed significantly to the total dose. Overall, the radiation dose directly attributable to anthropogenic radionuclides exceeding the reference values were estimated to be only a small percentage of the overall total.

Developing a complete picture of risks to human health and the ecological community will depend on characterization of surface and groundwater, as well as body burdens in invertebrates and vertebrates for bioaccumulative chemicals. While concentrations of all organics were typically low geographically, individual detections were found of DDT and PCBs that have the potential to accumulate through the food web and pose potential risks to fish and wildlife in particular. Consequently, a limited investigation of tissue concentrations for these organics in the Santa Fe River should be considered in any further characterizations of risks to the ecological community. The characterization of surface water was performed under a separate analysis. To

determine the total exposure of local residents to arsenic and vanadium, the results of soil, sediment, surface water and ground water analyses, and diet should be compiled for further risk analysis. This focus would include a conceptual model of exposure pathways for residents to arsenic and vanadium sources in drinking water (particularly groundwater sources), surface water, lake sediments, and locally grown food and food preparation techniques. Identifying the complete sources of arsenic and vanadium and estimating their total doses will be an important step in determining a more realistic description of risks to local residents. For radionuclides, a more comprehensive screening-level assessment of risks from drinking water is recommended after the collection of surface water and groundwater samples from these areas. The data collected from the sediment and surface water investigations combined with future, more comprehensive sampling of foodstuff, soils, and biota could be used to characterize the cumulative risk to human health and the environment.

Table 1 – Summary descriptions for project sampling locations.

Sample Location and Type			Sample Sites Number	Site Description
Project Sub-Area	Discrete	Random		
*Abiquiu Lake	ALD-1		1	Delta at head of lake
		ALR-1 to -5	5	Random sites in the lake
Rio Grande below Cochiti Dam	*RGBDD-1, *RGBDD-3		2	Oxbow areas of river isolated from main flow since Cochiti Dam construction
		RGBDR-1 to -7	7	Bosque downstream from Cochiti Pueblo, recent deposition areas
Santa Fe River	SFD-1		1	Upstream of La Bajada Uranium mine
	SFD-2		1	Downstream of La Bajada mine
	SFD-3 to -5		1	Recent sediment deposition in Santa Fe River
		SFR-1 to -5	5	Random in constructed wetlands above Cochiti Dam
Cochiti Lake	CLD-1		1	Deepest part of lake
	CLD-2f to -2j		1	Swimming beach composite
	CLD-3		1	Previous sampling site (USGS Site B1)
	CLD-4 to -5		2	Offshore, near boat ramps
	CLD-6		1	Pre-dam active river channel
Canyon Delta		CLR-1 to -5	5	Random in lake
	CDD-1		1	Mouth of Medio Canyon
	CDD-2		1	Mouth of Capulin Canyon
	CDD-3		1	Mouth of Alamo Canyon
White Rock Canyon		CDR-1 to -5	5	Random in the canyon delta
	WRD-1		1	Immediately downriver of Buckman Direct Diversion
	WRD-2 to -6		4	High river flow fine deposits, lagoon areas/ sandbars
Irrigation Canal		WRR-1 to -7	7	Random in the canyon
	ICD-1 to -5		5	Recent sediment deposits, Cochiti Pueblo agricultural irrigation
Ohkay Owingeh Pueblo (was San Juan Pueblo)		SJR-1 to -7	7	No discrete samples

*Reference (or Background Location)

5 - Sediment Transport Modeling

Sediment transport studies allow for the determination of sedimentation rates into Cochiti Lake and the determination of sedimentation-related riverine behavior, such as aggrading and degrading stream channel responses in reaches above and below Cochiti Dam and Lake. Sedimentation comprises the processes of erosion, entrainment, transport, deposition, and compaction of sediment. Numerical sediment modeling was performed to simulate the first four of these processes, with understanding of the fifth process (compaction) gained through the data collection efforts. The numerical modeling, first calibrated to reproduce the measured responses observed in the study area, thereby provides a tool to help evaluate the potential sedimentation effects on Tribal resources that could result from possible future changes in operations at Cochiti Dam and Lake.

5.1 Collection and Compilation of Data

As a necessary prerequisite to the numerical modeling study described below, a review of existing information from prior studies and activities was performed in order to determine data gaps. To augment the available existing information and bridge these data gaps, a field reconnaissance was conducted by West Consultants, Inc., under contract to the Pueblo de Cochiti. During field reconnaissance, in addition to visual assessment and photographic documentation, additional data was collected including sediment samples. The general categories of information assembled from these activities include (West, 2012a):

- Basin characteristics, climate.
- Geology and soils.
- Physiography, planimetry and topography.
- Land use.
- Surface water hydrology.
- Stream channel dimensions, patterns and profiles.
- Sediment properties (*e.g.*, particle density, bulk density, particle size distributions).
- Sediment transport measurements.

Much of this information was available, particularly for the model reach downstream of the dam, at discrete time points over Cochiti Dam's history (or before) from existing reports and databases, as well as from recent data collection. Of particular usefulness for the numerical modeling, as well as the overall understanding of the sedimentary processes, are the periodically surveyed river and lake cross-sections. Both reaches have systems of monumented *rangelines* that are measured periodically and that present an intervallic timeline of profile and channel geometry evolution. This information, in addition to the field reconnaissance photographs, is contained within the *Data Compilation Report – Cochiti Baseline Study: Sediment Transport Modeling* (West, 2011), an intermediate delivery produced during the modeling study. It is also summarized, often in significant detail, in the *Hydraulic and Sedimentation Modeling in HEC-RAS Cochiti Baseline Study: Sediment Transport Modeling* (West, 2012a) final report.

5.1.1 Periodic Surveys

Of significant importance to the understanding of the long-term sedimentation associated with Cochiti Dam and Lake are the periodic cross-sectional surveys that have been conducted over the course of a project's life. A data base of aggradation rangelines (RLs) upstream of Cochiti Dam was available to provide discrete points with which to adjust model parameters to achieve calibration. The following RL surveys are currently available (though the last two listed did not become available in time for the mobile-bed modeling):

- 1972 (pre-closure) – RLs 1 – 8, 9.
- 1976 – RLs 1 – 8, 9.
- 1978 – RLs 1 - 8, 9.
- 1981 - RLs 1 - 16.
- 1986 – RLs 1 – 16.
- 1991 – RLs 1 – 16.
- 1992 – RLs 1 – 8, 9 – 16.
- 1998 – RLs 1 – 8.
- 2005 – RLs 1 – 16.
- 2011 – RLs 8 – 16.
- 2012 – RFs 8 – 16.

The locations of these are shown graphically in Figure 6. The longitudinal profile evolution upstream of the dam up through the most recent survey is shown in Figure 7.

In addition to the project-related periodic rangeline surveys described above, the sediment modeling study also assembled and made use of historic and recent topographic information. These included an ArcGIS triangulated irregular network (TIN) terrain model, produced from 1963 photogrammetry (supplemented with the above 1972 RLs), and used to develop pre-dam topography for the starting condition of the calibration modeling runs (West, 2012a).

Below the dam, a historic set of river aggradation/degradation rangeline cross-sections surveyed in 1972 was used as the basis for developing the starting geometry for the calibration numeric models. In addition, a digital terrain model (DTM), produced from aerial LiDAR data collected in 2010, was available for comparison of recent topography (West, 2012a). Finally, the river reach downstream of Cochiti Dam has been the subject of significant technical study and analysis, which not only aided in the understanding of the system and its response to the dam, but also permitted intelligent decisions to be made in the selection of modeling parameters for the numerical models discussed below.

5.1.2 Geomorphic Investigation

In order to analyze the geomorphology of the study reach and better understand the system being modeled, field reconnaissance and analysis of historic planform data was also performed. This included the rangeline information described above, but also included analysis of available historic aerial photography in order to quantify the magnitudes and rates of change of key

planform features and identify trends. This included characterization, delineation and quantification of the main channel, islands and floodplain areas at two discrete times – 1963 (pre-dam) and 1999 (post-dam) – for the upstream-of-dam study reach, along with comparison to other existing assessments. The results indicate an increase in the total area of apparent active inundation for the reach directly upstream of the lake (between RLs 8 and 12) in response to water storage, but were quite similar farther up the canyon (RLs 12 to 16) suggesting the relative limits of the lake’s longitudinal impact extent up the canyon (West, 2012a).

Downstream of the dam, the geomorphic investigation relied primarily on interpretation and synthesis of analyses performed by others, (West, 2012a). These existing studies served as an important guide for the types of morphologic trends that would be expected from a properly calibrated quantitative numerical model, in terms of channel widths, profiles, and bed material coarsening.

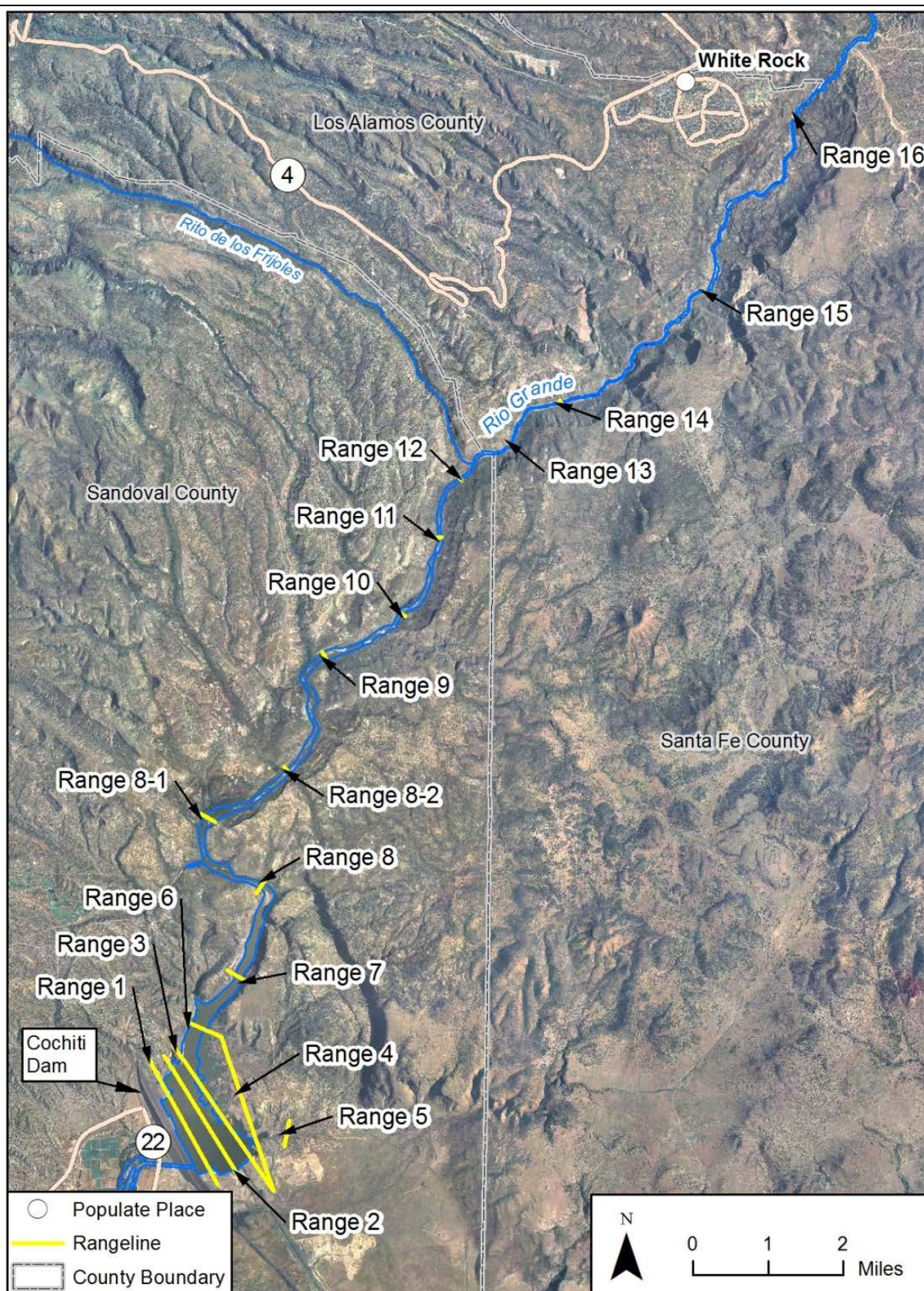


Figure 6 – Upstream rangeline locations.

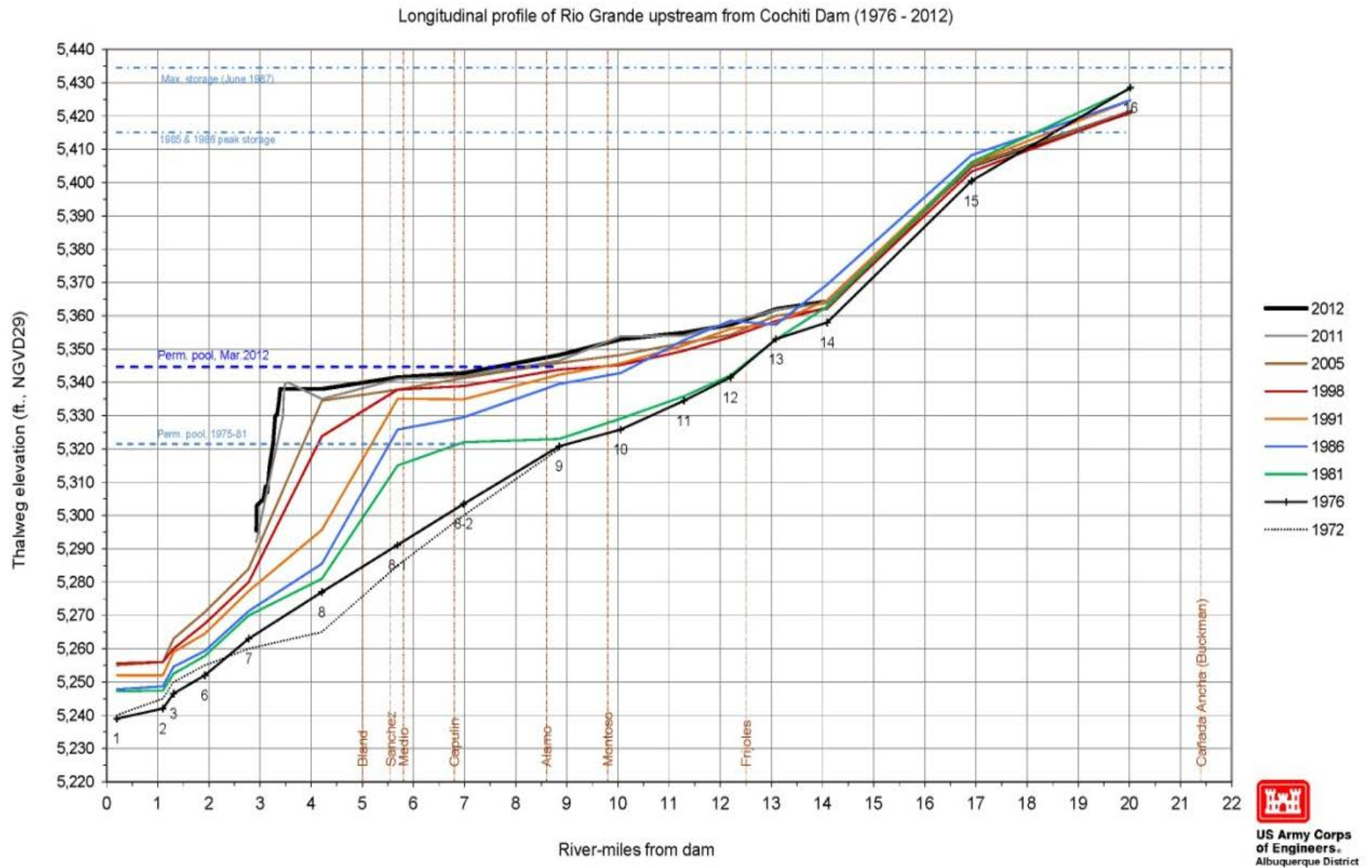


Figure 7 – Measured longitudinal profile upstream of Cochiti Dam.

5.1.3 Cohesive Sediment Transport Processes

The erosion rates of cohesive sediments generally cannot be effectively estimated using standard sand transport methods. Cohesive sediment erosion characteristics are highly dependent on a broad range of factors such as particle size, particle coatings, mineralogy, organic content, bulk density, gas content, pore water chemistry, and biological activity. Small changes in even one of these interdependent parameters can have a significant effect on the erosion rate and critical shear stress for erosion of these sediments (Smith and Norwood, 2011).

In preparation for numerical modeling, the Albuquerque District requested the assistance of researchers at the Engineering Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL), who conducted field experiments for determination of cohesive sediment erosion physical processes. These field experiments were of two types: 1) measurement of erosion rates of sediment cores collected within Cochiti Lake in response to imposed shear stress produced in a mobile flume (*Sedflume*), and 2) measurement of settling characteristics [*i.e.*, fall velocity, particle interaction (collision/flocculation), aggregate sizes and densities, etc.] in a field-deployable recording settling column (*PICS*). The locations where Sedflume cores were collected and analyzed are shown in Figure 8, below. Figure 9 shows the target locations where PICS experiments were attempted. Sites at the upstream end of the target area (identified as c12 through c16 on Figure 9) were inaccessible due to water levels and were not sampled (Smith and Norwood, 2011).

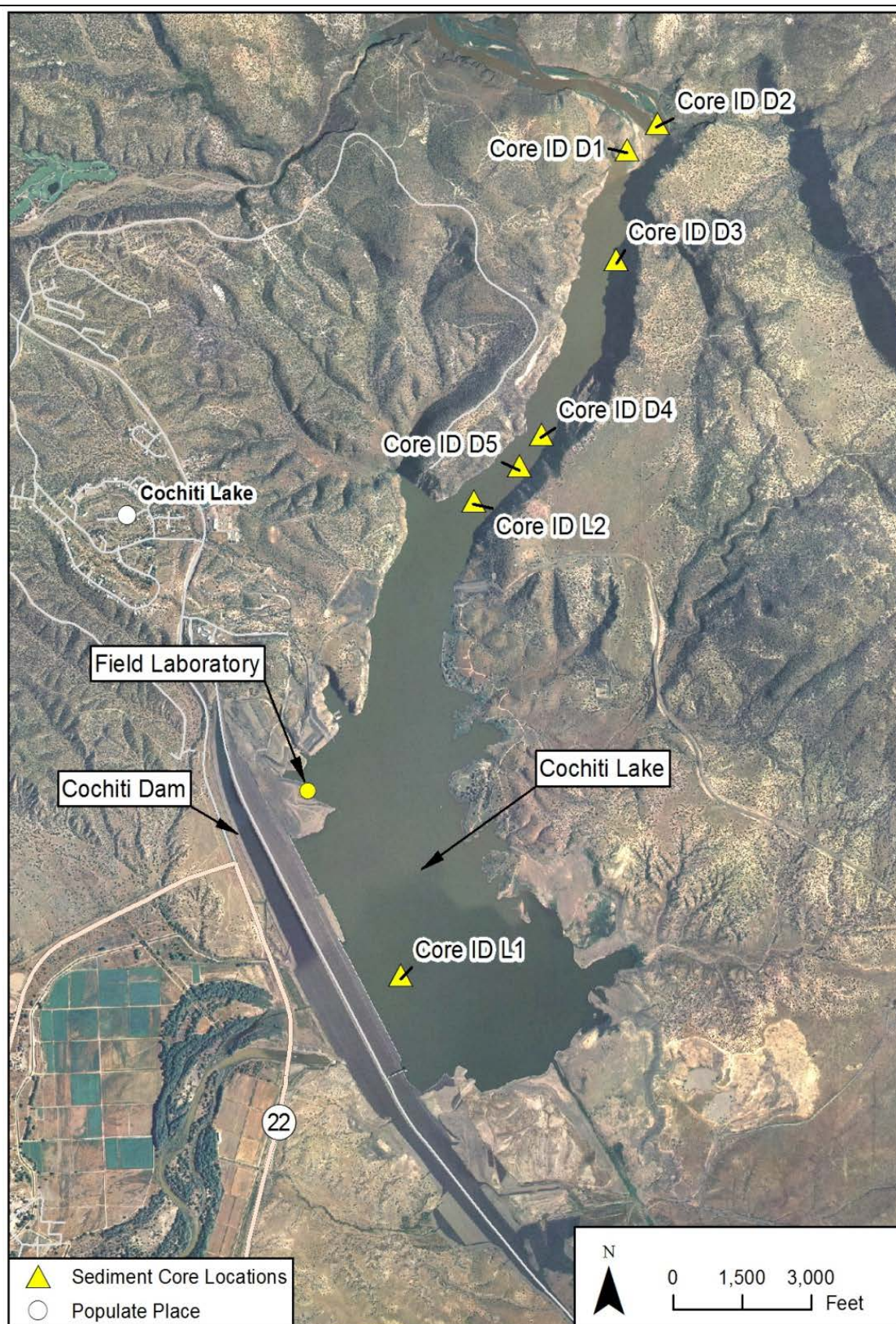


Figure 8 – Sampling locations and mobile flume deployment for Sedflume core experiments.

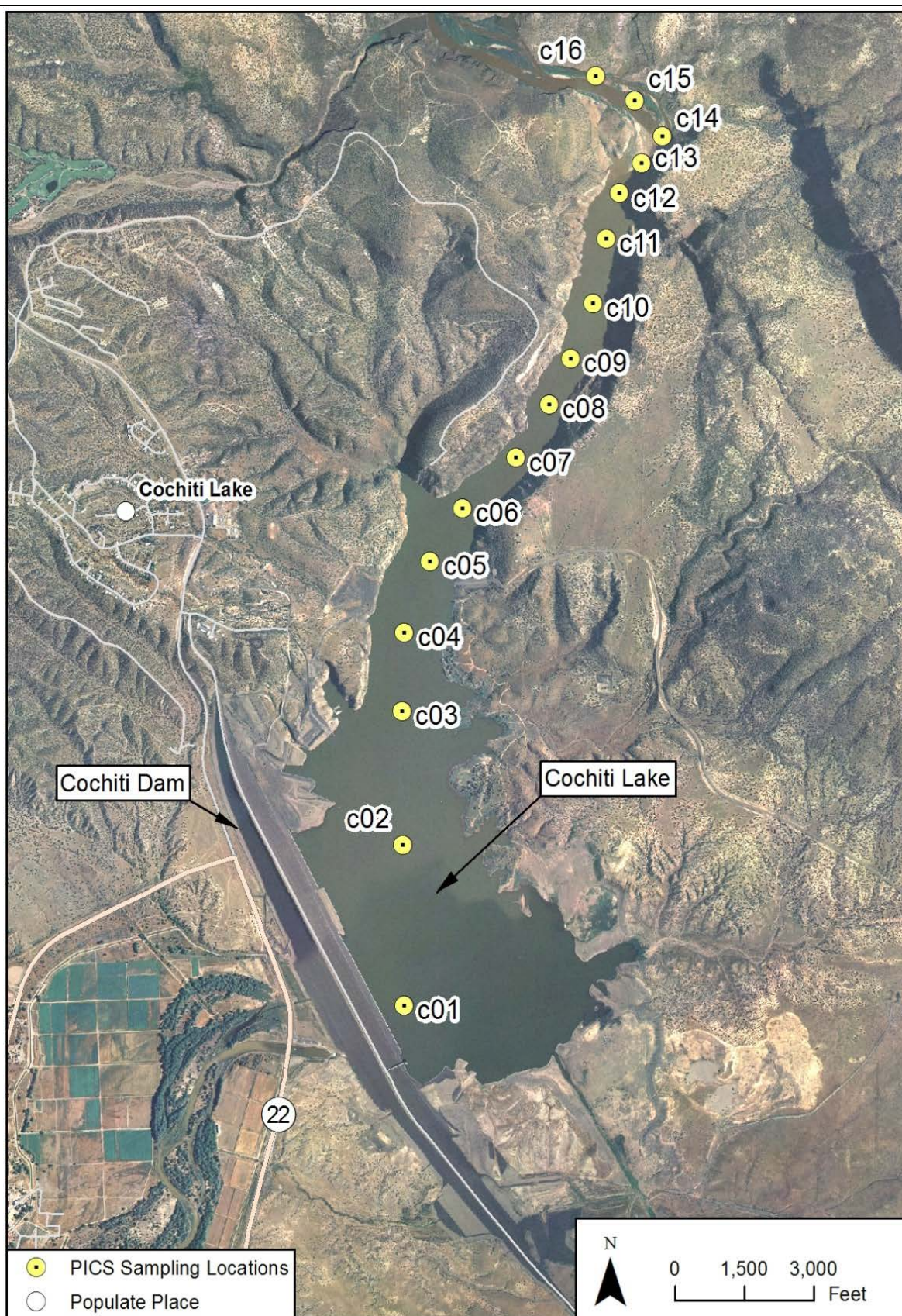


Figure 9 – Target sampling locations for PICS experiments. Measurements were only obtained at stations c01 - c11.

5.1.4 Numerical Modeling

The largest component of the sediment studies was a numerical sediment transport modeling study of the Rio Grande River upstream and downstream of Cochiti Dam. The modeling was performed incrementally, initially performing hydraulic computations in a *fixed-bed* mode, without erosion or deposition, in order to resolve basic hydrodynamic behavior within the modeling environment. The *mobile-bed* capabilities of the modeling program were then turned on as model construction proceeded. The numerical mobile-boundary hydraulic modeling was performed using version 4.2 *Beta* of the Hydrologic Engineering Center's (HEC) River Analysis System (RAS) modeling software (USACE, 2011). The modeling was broken into two reaches: 1) the river canyon and lake upstream of Cochiti Dam, and 2) the river downstream of the dam. This logical separation of the reaches helps in the evaluation of the sedimentation behavior associated with the dam.

5.1.4.1 Calibration and Verification

Models were developed, starting with conditions approximating the pre-Cochiti Dam channel geometries and slopes, hydraulic roughness, bed sediment makeup and inflowing sediment load for both the upstream and downstream reaches. Boundary conditions and constraints were imposed within the model to affect the flow regulation imposed on the system by Cochiti Dam; a series of historic flows were run through the models, and parameters were adjusted until the models' behaviors adequately reproduced the information on conditions (*e.g.*, channel bed profiles, bed sediment makeup) available for 1998 to produce a calibrated model. The flow series was then extended to 2009 and the models were run to the end of the period. The models' outputs were again compared to available information for the 2009 time point, in order to verify the models' abilities to represent what had been observed in the actual river and lake. These steps lend confidence in the models' abilities to make predictions about the response of the system to potential changes in the operation of the dam. Some of the calibration and verification model response results for the upstream-of-dam model are shown graphically in Figure 10 and Figure 11, respectively. Though not illustrated in this summary, acceptable calibration and verification responses were obtained for the downstream-of-dam model.

5.1.4.2 Predictive Capability

The sediment transport models will provide a tool for assessing potential changes to sediment erosion, transport, and deposition that could occur if alternative dam operations are implemented. The models will enable assessment of changes in the location and amount of erosion and deposition upstream and downstream of the dam. The models will also support future ecological and human health risk assessments, as needed. For example, the models may be employed as a tool for effectively assessing changes in riverine and lake hydraulic and sedimentary conditions under future proposed operational variations that could affect biological resources through impacts to velocity distributions, flow depths, bed sediment composition, etc. The potential uses for risk assessment are discussed later within this summary.

To demonstrate the utility of this capability, three conceptual operational scenarios were modeled:

- 1) A 50-year period (from 2005 start into the future) with a significantly higher normal lake elevation (5390.8 feet NGVD29).
- 2) A 50-year period with a significantly lower normal lake elevation (5323 feet NGVD29).
- 3) A 50-year period with seasonal oscillations in the normal lake elevation (5323 to 5340 feet NGVD29).

From the application of the models to representative project changes in the riverine and lake environments, the following summaries of general responses observed by West(2012a) are provided:

At the end of Scenario 1 (higher lake elevation, as above), the sediment deposition from the higher elevation is located significantly further upstream within the canyon than it was projected for a baseline future condition (normal operations). The bed profile upstream of the dam exhibits a much higher elevation topset slope, with an increase in the volume of sediment deposited, while the foreset slope remains similar to the current delta's. Downstream of the dam, the sediment transport model shows little further degradation of the river channel between the dam outlet and Arroyo Tonque, due primarily to bed armoring (selective coarsening), with limited degradation between Tonque and Angostura Diversion Dam associated with this operational change.

At the end of Scenario 2 (lower lake elevation), a somewhat lower elevation topset slope was predicted, resulting in less deposition within the canyon upstream of the lake. This also translates into somewhat higher concentrations of sediment passing through the dam to the downstream reach, though, from a practical perspective, the trapping efficiency of the lake is still quite high, and the response to the river downstream of the dam is only negligibly different (slightly more degradation) than for a future under normal operations.

Conditions at the end of Scenario 3 (seasonal fluctuation of lake elevation) were quite similar to those of Scenario 2, above. Conceptually, this appears to be reasonable, since the seasonal fluctuations modeled represent annual draw downs of the pool from the normal pool elevation to that of the lower elevation (5323 feet NGVD29). This annual cycling results in a somewhat higher topset slope elevation to the delta for Scenario 3, as compared to 2, while being quite similar to the baseline future condition. Sediment material is deposited somewhat farther downstream within the lake toward the dam outlet than under the other two scenarios, though the physics that can affect that end of the project extend beyond those that can be modeled through one-dimensional assumptions.

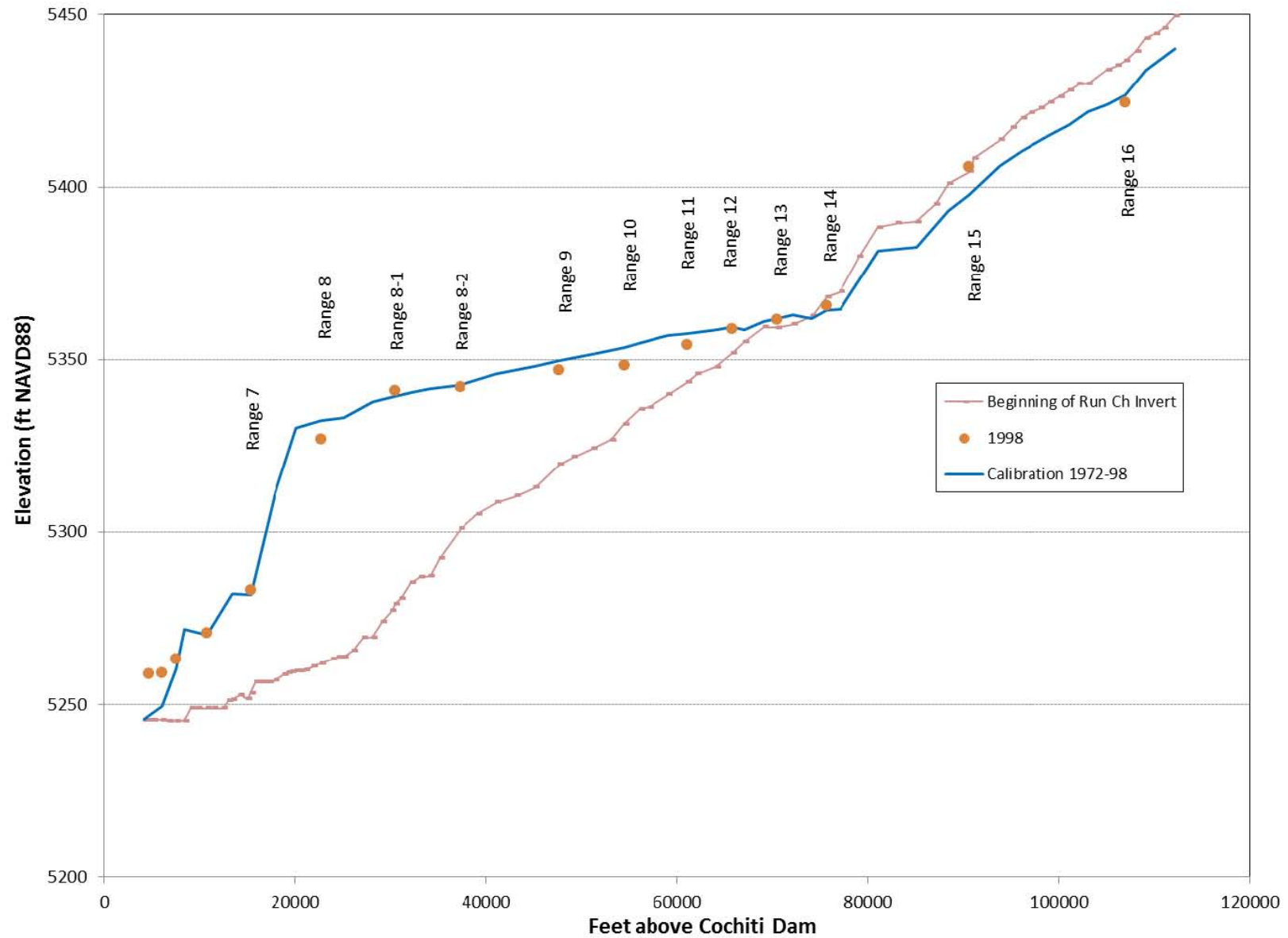


Figure 10 – Bed profile results from the calibrated HEC-RAS model for the calibration period, 1975 – 1998.

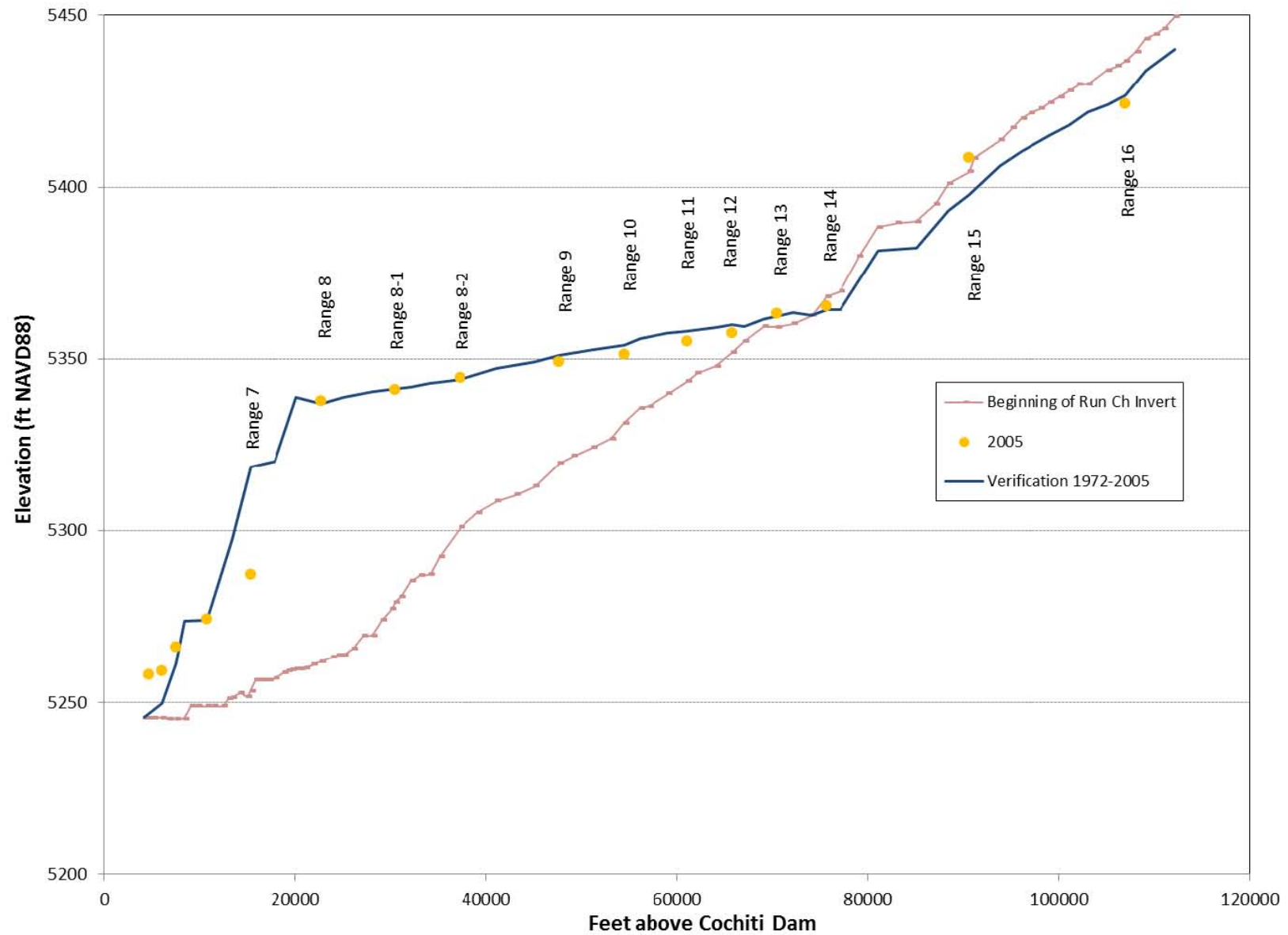


Figure 11 – Bed profile results from the calibrated HEC-RAS model for the verification period, 1975 – 2005.

In summary, the scenario modeling indicates that the amount of sediment and, perhaps more importantly, the distribution of this sediment within the lake body and the upstream canyon could be influenced significantly through changes in lake elevation stages and durations. However, these scenarios also indicate that there is only limited potential to effect the downstream river channel's trajectory through foreseeable changes in operations; modeling responses suggest the conditions in the Rio Grande downstream of the dam are primarily the product of the reduction in sediment supplied to the reach, which were not affected to a sufficient extent through the range of operational changes modeled to overcome this primary controlling condition.

5.1.4.3 Risk Assessment Support

As described above, the primary purpose of development of the numerical sediment models was for use as a tool for effectively assessing how changes in riverine and lake conditions, through hydraulic and sedimentary modification, could affect biological or cultural resources. Additionally, the models can also serve as a platform for generating information that could be used to support both human health and ecological risk assessments in the future.

Due to the interaction of sediment with constituents of potential concern (COPC) that have been identified within the influence area of Cochiti Lake, modeling the erosion and transport of sediment from specific locations within the canyon and lake would support future human health risk assessment for sediment impacted by COPC. It is important to point out that the limitations of the one-dimensional HEC-RAS model only predict sediment movement in the primary direction of flow, but do not model transverse sediment motion, nor density currents. Additionally, though not developed for the current investigation, the HEC-RAS modeling software also includes a water quality module that can be used to model solute transport from the hydraulic computations within HEC-RAS. Therefore, the water quality input files could be developed at some point in the future to support human health risk assessment, and added to the mobile-bed model developed under the current investigation.

Similarly, many of the modeling outputs could be used in support of ecological risk assessment, for many of the same reasons outlined above. A review of the modeling inputs, outputs and results, coupled with the associated geomorphic assessment, conducted for the current investigation would directly provide the majority of information associated with water and sediment processes envisioned for ecological risk assessment (such as conventional hydraulic (e.g., velocity, depth) and sediment properties (e.g., grain sizes, depositional features, rates, sediment concentrations)). In addition, this information could serve as a basis for computation of relevant variables, such as water temperature and water quality properties (West, 2012b).

5.1.5 Conclusion

Over the course of sedimentation studies conducted for the Cochiti Baseline Study, considerable information has been assembled to describe the hydrologic, hydraulic, geomorphic, and sediment characteristics, development and response that have led to the baseline conditions that currently exist. These comprise a database of the climatologic, hydrologic, and geologic characteristics of the watershed; riverine geomorphic, geometric, hydraulic, and sediment properties; and the lake's geomorphic, geometric, hydraulic, and sediment properties. This collection of information

was used, in turn, to assemble quantitative one-dimensional, mobile-bed numerical models of the canyon/lake reach upstream of the dam and the river reach downstream of the dam. The models were then used to project representative theoretical operational scenarios into the future and the responses evaluated.

In addition to helping to describe the current environment and the processes that have contributed to the project area's development, the numerical models produced under this investigation serve as a platform with which to assess the behavior and potential impacts and risks of any future proposed operational changes to the Cochiti Dam project.

This can now be conducted within a virtual and even 3-dimensional environment, thereby avoiding harmful responses to the actual environment, and permitting evaluation of (fully-reversible) impacts of not only the riverine, but also the lacustrine environs, and can be used as a tool for development of mitigation strategies.

6 - Groundwater Investigations

Data was collected on groundwater conditions in the study area in order to define the existing shallow groundwater conditions under current Cochiti Dam operations. This was accomplished via two separate endeavors. One task, completed by Integral Consulting Inc. (Integral), focused on the collection of data to support development of a shallow groundwater conceptual model, including groundwater sampling, surveying, estimation of drainage system discharges and collection of climate data. The second task is an ongoing USACE effort to establish depth to groundwater in the existing Cochiti Dam Downstream well field.

6.1 Shallow Groundwater Level Monitoring

The purpose of this study was to define the existing shallow groundwater baseline conditions of the study area. This task and results were documented in the project report:

Integral Consulting, Inc.(Integral). 2012. Cochiti Baseline Study Shallow Groundwater Level Monitoring. Integral Consulting, Inc., Louisville, CO.

Integral's original scope called for a network of 22 piezometers to be installed in five separate subareas in the study area (see Figure 12) using a combination of auger and slide-hammer methods. However, large cobbles and boulders in the shallow subsurface prevented installation by these methods. Eventually, a network of 15 piezometers was installed in four of the five subareas in June 2010 to monitor shallow groundwater level fluctuations resulting from Cochiti Dam operations. The installation was completed with a truck-mounted Geoprobe® direct-push drill rig in the subareas at locations clear of culturally sensitive areas and accessible by the truck. Ten of these piezometers were installed in the area downstream of the dam; four of these piezometers were installed west of the Rio Grande and six east of the Rio Grande. Five piezometers were installed along the Santa Fe River portion of the study area. Additionally, pressure transducers and data loggers were installed in 11 of those piezometers that had enough standing water to allow for continuous water level monitoring. Integral trained Pueblo staff to collect the data from the transducers and data loggers installed in these 11 piezometers. The Pueblo provided Integral with the data that was collected on an approximate monthly basis over 16 months from June 2010 through October 2011.

In addition to the 11 piezometers that Integral installed, there are 26 other shallow groundwater piezometers installed and maintained by either the Pueblo or USACE that provided supplemental data. The piezometers were characterized and grouped into classes according to the presence of data attributes such as water level, location and well construction information. Categories ranged from 1, a – e which contained piezometers that produced the most data, to categories 2, 3 or 4 which represent those piezometers with progressively less information (Table 2). The data collected from the 11 piezometers that Integral installed, in conjunction with the data provided from the Pueblo and USACE, were used to identify relationships between groundwater levels and vegetation and landforms; measure seasonal fluctuations in shallow groundwater; and support groundwater model efforts.

Table 2 – Groundwater Well Categories.

Well Category	Description
1a	All data available, including water levels, coordinates, screen intervals, ground surface elevation
1b	All data available except screen intervals; however, no screen exists according to survey comments
1c	All data available except screen intervals, and wells are less than 15 ft, indicating a acceptable piezometer
1d	All data available including water levels, coordinates, screen intervals except ground surface elevation
1e	Water level data and coordinates, but no screen intervals or ground surface elevation
2	Water level data, but missing well construction information such as coordinates, screen intervals and depths which prevents categorization
3	No water level data
4	Water level data and coordinates, but no screen intervals and wells are greater than 15 ft in depth

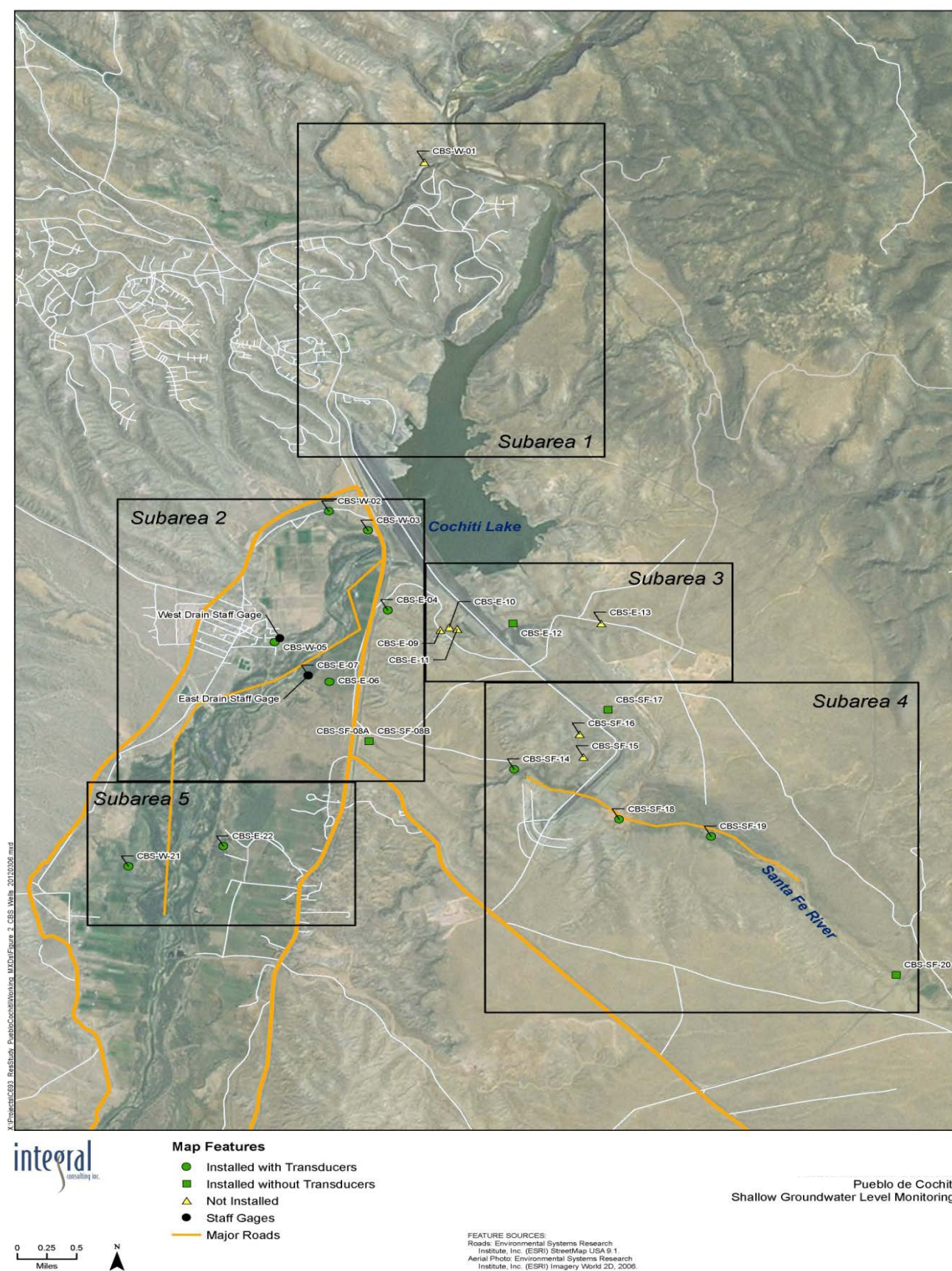


Figure 12 – Subareas Showing Piezometer Network.

6.1.1 Shallow Groundwater Elevations

Shallow groundwater elevations were established in order to understand how the current operations of Cochiti Dam may affect them. The groundwater potentials across the site, from Cochiti Lake to the areas downstream, provide context for shallow groundwater behavior in the presence of the dam. The potentiometric surface is a representation of the potential energy that is available to move the groundwater in an aquifer. A potentiometric surface is not necessarily the physical top of the water table, particularly in regions of an aquifer that are confined e.g. in the region beneath the dam. The piezometers and wells used to evaluate the shallow groundwater levels for this study are unconfined and water levels measured at these locations, for the most part, represent the water table. There are, however, areas in the study area that are confined and where groundwater potentials must be approximated for example at Cochiti Dam. This highlighted the importance of taking into consideration not only groundwater potential across, but also immediately downstream of Cochiti Dam when evaluating the effect of the dam on shallow groundwater levels.

Cochiti Lake pool elevations during this period of monitoring (June 2010 – October 2011) remained relatively steady at approximately 5,342 feet amsl. Shallow groundwater elevations also did not fluctuate much in the area downstream from Cochiti Dam. The greatest variability occurred in the Santa Fe River piezometers during the 1st and 3rd quarters of 2011. Similarly, potentiometric surfaces, and consequently the direction of groundwater flow, varied the most during the 1st and 3rd quarters of 2011. The potentiometric gradients are steepest close to the dam and flatten out with distance downstream from the dam. Site-wide water levels are highest near the upstream reaches of the Santa Fe River. Groundwater travels west-southwest from the Santa Fe River area towards the Cañada de Cochiti where it converges with groundwater from the Cochiti Dam. The two flow systems then coalesce and travel in south-southwest direction, providing recharge to downgradient basins.

6.1.2 Shallow Groundwater Site Conceptual Model

The Hydrologic and Environmental Systems Analysis (HESA) approach developed by Kolm and Langer (2001) is an approach used to conceptualize and characterize relevant features of hydrologic and environmental systems, integrating relevant considerations of climate, topography, geomorphology, groundwater and surface water hydrology, geology, ecosystem structure and function, and the human activities associated with these systems into a holistic, three-dimensional dynamic conceptual site model (CSM).

Based on the presence and orientation of various hydrogeologic and hydrostructural units, hydrography and topography, two CSMs were developed: one for the Rio Grande System and one for the Santa Fe River Corridor System. The general locations of the hydrostructures that influence shallow groundwater flow patterns are shown on Figure 13. The CSM for the Rio Grande System incorporates the Subareas 1, 2, and 5; from the Rio Grande delta downstream through the irrigated fields below the dam to the Peña Blanca subarea (refer to Figure 12). The second CSM incorporates Subarea 4; the Santa Fe River corridor, which also serves as an analogue for the Subarea 3; and the Cañada de Cochiti (refer to Figure 12).

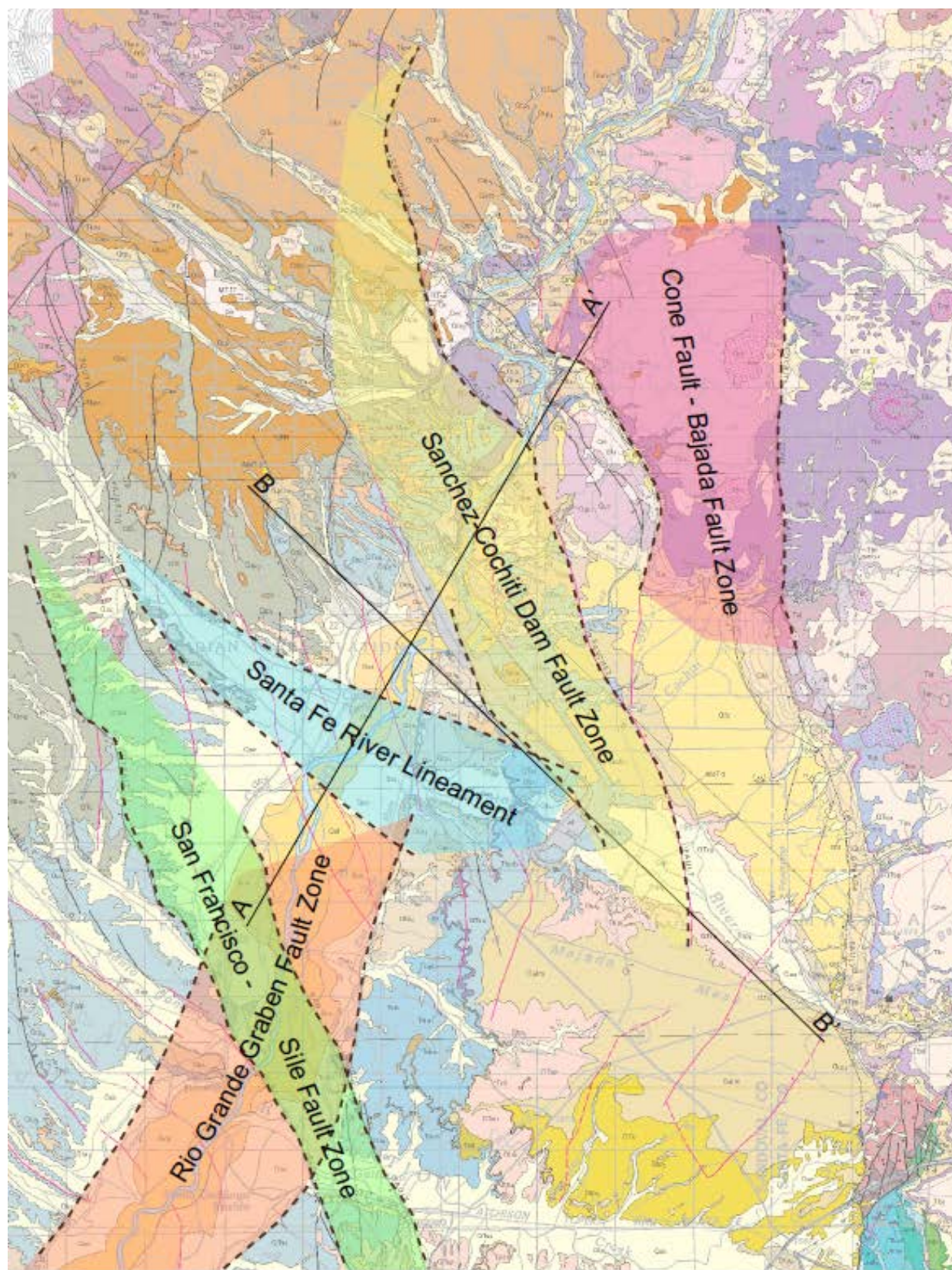


Figure 13 – Shallow Groundwater Hydrostructures.

Each of these subareas has a unique hydrogeologic setting and groundwater flow system. The shallow groundwater and surface water interaction in the areas downstream from Cochiti Dam is complex and with rapid changes in river stage due to changes in dam operations and the presence of the Cochiti Agricultural Drainage System (CADS) made interpretations regarding the CSM complicated. Furthermore, anthropogenic modifications of the natural hydrologic features in these subareas, including groundwater recharge from irrigation return flow and leaking irrigation ditches, groundwater discharge from wells, and modification of natural flow pattern by the CADS and Cochiti Dam, had to be taken into consideration in development of the CSM.

The Rio Grande System has several unique anthropogenic influences caused by water supply projects and agriculture, notably the Cochiti Dam, irrigation and irrigation ditches, the CADS, and wells. These infrastructures have altered the natural shallow groundwater flow regime such that shallow groundwater discharges at the dam are enhanced and the area of discharge is expanded relative to prior to its construction. The system returns to a more natural state, providing recharge to the Santo Domingo Basin, downstream from Peña Blanca. In general, the current operation of the Cochiti Lake magnifies hydraulic gradients in place before its construction and reinforces the groundwater flow paths that were already in place before the dam's construction.

The Santa Fe River Corridor System shallow aquifer is recharged by infiltration of precipitation, and when the Santa Fe River flows during an event, the drainage will function as a losing stream, locally recharging the groundwater system. However, an arm of the Cochiti Dam currently acts as a fixed or constant head above this subarea, and when the lake stage increases, surface water will collect behind this arm of the lake, enhancing the upwelling of groundwater immediately below the dam in the Cañada de Cochiti vicinity and the areas immediately downgradient. The lower part of the area Santa Fe River Corridor below the dam shows the Santa Fe River returning to be a losing stream before reaching the Rio Grande. Similar to the Rio Grande System, the current operation of Cochiti Dam reinforces the groundwater flow path that was already in place naturally. However, the operation of the dam has less of a magnifying effect on natural gradients than in the Rio Grande System, particularly in the areas immediately downstream of the dam.

6.2 Cochiti Dam Downstream Wellfield Camera Survey

The second task, completed by USACE's Geotechnical and Environmental Engineering Branch involved data collection from down-hole camera surveys of the wells located downstream of Cochiti Dam. The purpose of the survey was to determine the depth to water and screened interval in each of the wells. The wells provide information on groundwater levels which can be used to estimate seepage under the dam. A total of 69 wells were identified for down-hole camera survey, with inner casing diameters ranging from 1-3/8 to 2 in. In total 60 of the 69 wells were surveyed, the remaining 9 were either not found or were damaged. All surveys were recorded to DVD and the results of the down-hole camera survey are presented in a Memorandum for Record, titled Cochiti Dam Downstream Wellfield Camera Survey, which are held at the Albuquerque District Office in the Geotechnical and Environmental Engineering Branch.

7 - Ecological Resources

Baseline studies of non-aquatic ecological resources focused on riparian and wetland habitats in the vicinity of the Cochiti Dam and Lake Project, because these are much more likely to be affected by water operations than the surrounding upland habitat. Ecological studies consisted of mapping these vegetation types and conducting formal surveys of bird and small mammal communities.

7.1 Mapping of Wetland and Riparian Vegetation

The goal of this task was to identify and map wetland and riparian vegetation in the vicinity of the Cochiti Dam and Lake Project. The objectives of characterizing and mapping the baseline wetland and riparian vegetation conditions were:

- To understand the current presence, extent, and types of wetland within the project area.
- To understand the current presence and extent of native and exotic riparian vegetation within the project area.
- To develop baseline information that can later be used to predict and evaluate potential impacts to existing conditions due to possible future changes in lake management.

For ease of discussion and analysis, the project area was divided into four subareas:

- **Rio Grande through White Rock Canyon** — from the northern Cochiti Reservation boundary upstream to the Cañada Ancha confluence (at Buckman); approx 16.5 river-miles.
- **Cochiti Lake** — perimeter (dam to northern Cochiti Reservation boundary) and conveyance channel to the Santa Fe River.
- **Santa Fe River** — from Tetilla Peak Road downstream to the Rio Grande (spanning the dam); approx. 6.0 river-miles.
- **Rio Grande below the dam** — from the dam downstream to the northern boundary of Santo Domingo Pueblo; approx. 5.4 river-miles.

Existing digital orthophotos (2009), and existing vegetation maps and GIS coverages of the riparian and wetland vegetation in the area served as a basis for updating vegetation type classifications and delineations. Previously unmapped areas were comparably classified and delineated. Comprehensive field surveys in September through November 2010 characterized all wetland and riparian plant communities in the project area using two separate vegetation classification systems:

- **Hink & Ohmart Classification** — Riparian studies utilizing the Hink and Ohmart (1984) floristic / structural classification have been conducted throughout all of the middle Rio Grande valley in New Mexico, including the current study area. A distinct benefit of this classification system is the well-documented correlation with wildlife

abundance data established by previous studies. The Hink and Ohmart Classification task included the identification of suitable nesting habitat for the Southwestern Willow Flycatcher in the Cochiti Dam and Lake study area.

- **USFWS Classification** — The U.S. Fish and Wildlife Service Classification system combines the mapping and digitization standards of the National Wetland Inventory (Cowardin *et al.* 1979; USFWS 1994a, b) and the Services' riparian classification system for the western U.S. (USFWS 1997). Utilization of this classification system facilitates the comparison of wetland and riparian resources in the study area on a regional and national scale. Additionally, direct comparisons can be made with existing mapping based on 1935, 1989, and 2002 conditions in the study area.

It should be noted that the contracted task did not include the delineation of jurisdictional wetlands pursuant to Section 404(b)(1) of the Clean Water Act. However, the task's deliverables do provide baseline information that could facilitate the delineation of jurisdictional wetlands in the study area in the future.

This task was contracted to Parametrix, Inc. The primary report product is:

Parametrix. 2011. Mapping of Wetland and Riparian Vegetation; Pueblo de Cochiti. Parametrix, Albuquerque, NM.

The main report describes the field methods used, and summarizes and interprets results for each of the four subareas. Additional deliverables included:

- Separately bound hard-copy maps.
- Geodatabases for each classification system, including classifications, delineations, and all attributes recorded on field data forms.
- All raw and summary data spreadsheets, digital photographs, and GIS files.
- Federal Geographic Data Committee (FGDC)-compliant metadata for all geo-referenced products.
- Original field data forms plus two legible copies.

7.2 Wildlife Surveys

The goal of this task was to characterize riparian wildlife communities in the project area to provide baseline information so that impacts to these populations from potential future lake management activities can be predicted. Additionally, these surveys mark the initiation of long-term monitoring activities by which the Pueblo de Cochiti and USACE will be able to track animal populations and their distribution over time through periodic future resurveying.

Survey and monitoring activities focused on the following wildlife groups: avifauna, waterbirds, small mammals, and other species. All surveys were conducted between December 2011 and November 2012.

Table 3 summarizes the sampling design and methods for the various wildlife groups. Figure 14 depicts the locations of survey points and transects.

In addition to the specific count data discussed above, less formal observations of other animal taxa were recorded. During all field surveys and site visits, biologists made annotated observations of amphibians, reptiles, raptors, bats, and medium- and large-mammals encountered within the project area. Additionally, bird species commonly observed in adjacent non-riparian habitat were recorded in a list.

As appropriate for each group, survey data were collected or analyzed to determine the species, sex, and age class of individuals; and species richness, absolute abundance, relative abundance (density), and ecological diversity of subsets. Results are far too detailed and extensive to summarize here. Some late-summer avifauna counts in White Rock Canyon were slightly influenced by birds dispersing from the area of the Las Conchas Fire (which started June 26, 2012), and vegetation at the mouths of both Alamo and Capulin canyons was disturbed by debris shortly after the fire. Photographs characterizing all sampled areas (on repeated occasions at some) are included in an appendix to the main SWCA (2012) report.

This task was contracted to SWCA Environmental Consultants who utilized the expertise of Hawks Aloft, Inc., for avifauna and waterbird surveys. The primary report product is:

SWCA Environmental Consultants. 2012. Pueblo de Cochiti Wildlife Surveys: Baseline Sampling Report. SWCA Environmental Consultants, Albuquerque, NM. 106 pp.

Additional deliverables included: geodatabase of sampling locations; databases compiling survey counts and data collected; and copies of field survey forms.

Table 3 – Locations and methods of surveys for various wildlife groups in the vicinity of the Cochiti Dam and Lake Project, December 2011 through November 2012.

Subarea and location	Avifauna		Waterbirds ^d	Small mammals ^e
	Point-counts ^a	Transects ^b		
White Rock Canyon: Rio Grande corridor from Pueblo de Cochiti upstream to Alamo Canyon.	4 stations; at confluences of Alamo (1), Capulin (1), and Medio (2) canyons. Winter surveys excluded.			
Cochiti Lake: Riparian habitat adjacent to and supported by Cochiti Lake or the Conveyance Channel.	3 stations		3 locations along shoreline	2 locations
Santa Fe River: Riparian corridor from the dam upstream to Tetilla Peak Rd.	3 stations			2 locations
Cochiti Pueblo Bosque: Riparian woodland from the dam downstream to the Pueblo boundary.	15 stations: 3 stations along each of 5 interior transects ^c	6 transects: 5 in the interior of the bosque, and 1 along the drain	3 locations along Rio Grande	4 locations

^a **Point-counts** consisted of 10-minute, variable-distance counts of all visual and aural registrations within a 125m radius. Twelve surveys were conducted over a calendar year (except winter surveys were excluded in White Rock Canyon).

^b **Transects surveys** consisted of variable-distance counts all of visual and aural registrations within 125m of the 2,500ft (762m) long transect. Counts were made along both sides of the 5 interior transects, but along only one (vegetated) side of the transect paralleling the riverside drain. Methods and locations replicate surveys conducted in 1981-82 (Hink and Ohmart 1984).

^c To allow direct **comparison of the two avifauna survey methods**, 3 point-count stations positioned along each of the 5 bosque-interior transects were surveyed on the same morning as the respective transect survey.

^d **Waterbirds** were counted 12 times over the year from 6 shoreline or riverbank locations in areas of relatively high-quality habitat.

^e **Small mammals** were live-trapped & released on 3 consecutive nights in each of May and September at 8 locations. At 7 locations, 50×50m grid arrays of 25 Sherman traps (at 10m intervals) were sampled. One location along the riverside drain consisted of a line of 10 traps (at 10m intervals).

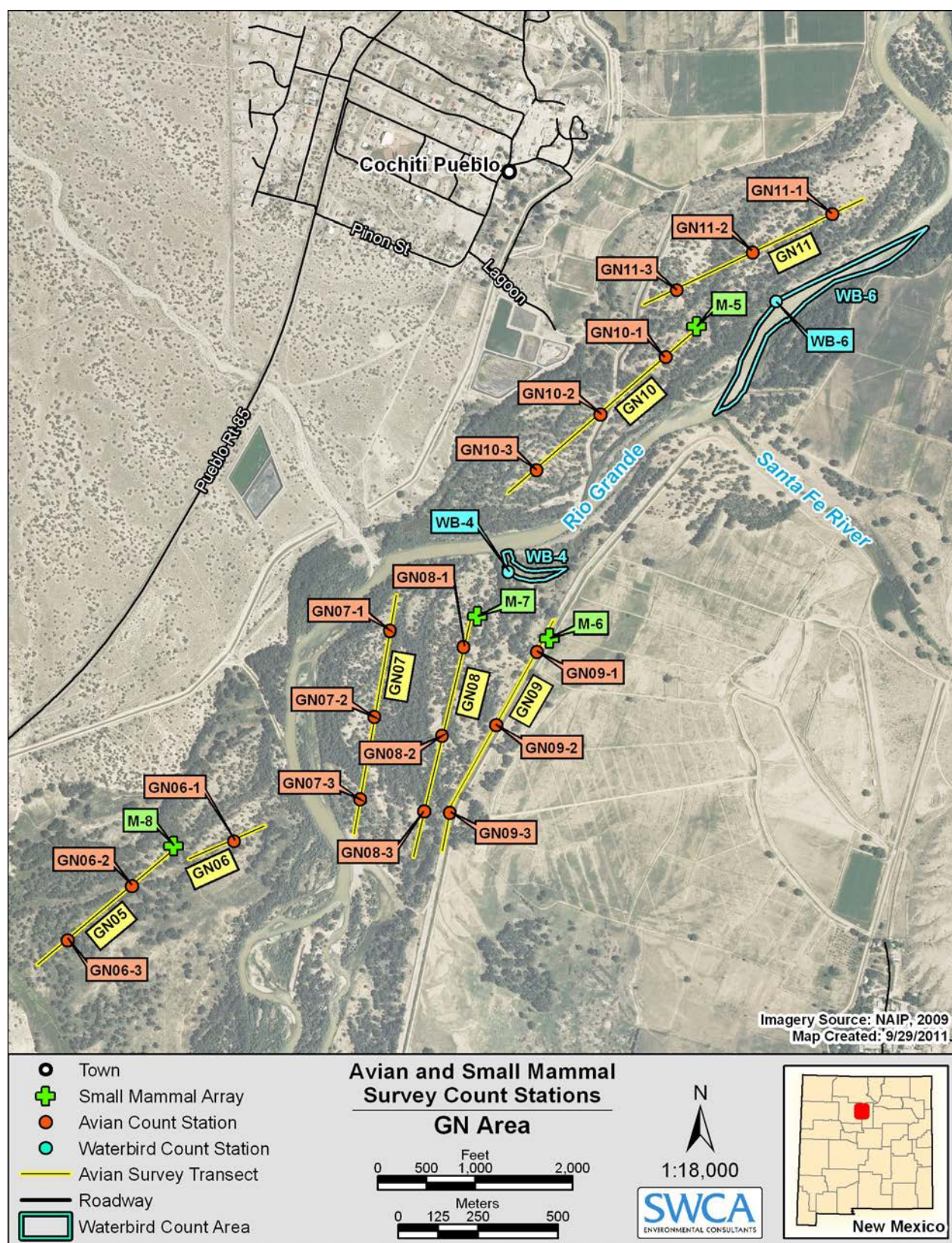


Figure 14 – Wildlife survey locations throughout the study area (left) and in detail downstream from Cochiti Dam (right).

8 - Ecological Resources – Limnology and Fisheries

Periodic surveys of aquatic resources at the Cochiti Dam and Lake Project have been conducted by the New Mexico Department of Game and Fish (NMDGF), the U.S. Bureau of Reclamation (Reclamation), and USACE. The surveys consisted of monthly water quality monitoring (USACE) and fisheries surveys (NMDGF and Reclamation).

8.1 Cochiti Lake Limnology

Temperature and dissolved oxygen are important parameters for determining environmental suitability for fisheries. Lake temperature throughout the year is an important factor for determining successful management strategies for sport fish.

Water temperature in Cochiti Lake produces a temperature gradient in the water column during the summer (Figure 15) resulting in thermal layers suitable for a variety of fish species. Monthly water quality data from the mid-lake station have a minimal gradient for temperature (Figure 15a-d). Water temperature peaks during the summer while dissolved oxygen is at a minimum, particularly at greater depths. Down canyon winds create a seiche (standing wave) at the dam, periodically increasing outlet water temperature slightly above the 15 m depth. Strong up canyon winds may produce a stronger seiche at the Rio Grande confluence with Cochiti Lake, resulting in increased circulation of the water column above 15 m depth (Figure 16). The increased water column circulation disrupts the thermal gradient for a few days.

Dissolved oxygen levels are consistent throughout the water column during the fall, winter and spring (Figure 15e, f, h), and vary by depth during the summer months (Figure 15g). During the spring and fall, lake circulation distributes oxygen throughout the water column. Dissolved oxygen in the summer months decreases with depth. The lower oxygen levels at depth limits the distribution of coldwater fish.

Sport fish may be classified as coldwater (i.e. trout), coolwater (i.e. walleye), or warmwater (i.e. black bass and catfish) species based on the effect of temperature on their life history (Hayes, et al. 1999; Heidinger, 1999). Coldwater fish have optimal temperatures between 10-20°C, with thermal maxima (Figure 15i) below 30°C (Hayes et al 1999). The optimal temperature range for coolwater fish (Figure 15j) is generally higher than coldwater species. Temperate warmwater fish can overwinter near-freezing water temperatures, and summer temperatures above 30°C. Warmwater species require water temperatures above 15-20°C for reproduction, with optimal temperatures for growth above 25-30°C (Figure 15k-l).

Water temperature at the outlet appears to be determined by the layer below 15 m in depth near the dam (Figures 16 and 17). This establishes a cooler water temperature regime downstream of the dam compared to the reach upstream of the lake. The recreation pool produces a reasonably stable water column and temperature gradient for release downstream. While the summer water temperature downstream of Cochiti Dam overlaps ecological parameters for cold, cool, and warm water fisheries (Heidinger, 1999), the water is likely cooler than the pre-dam conditions.

The cooler water released from Cochiti Lake may reduce habitat suitability for warmwater fish species, compared to warmer upstream reaches (see Table 4).

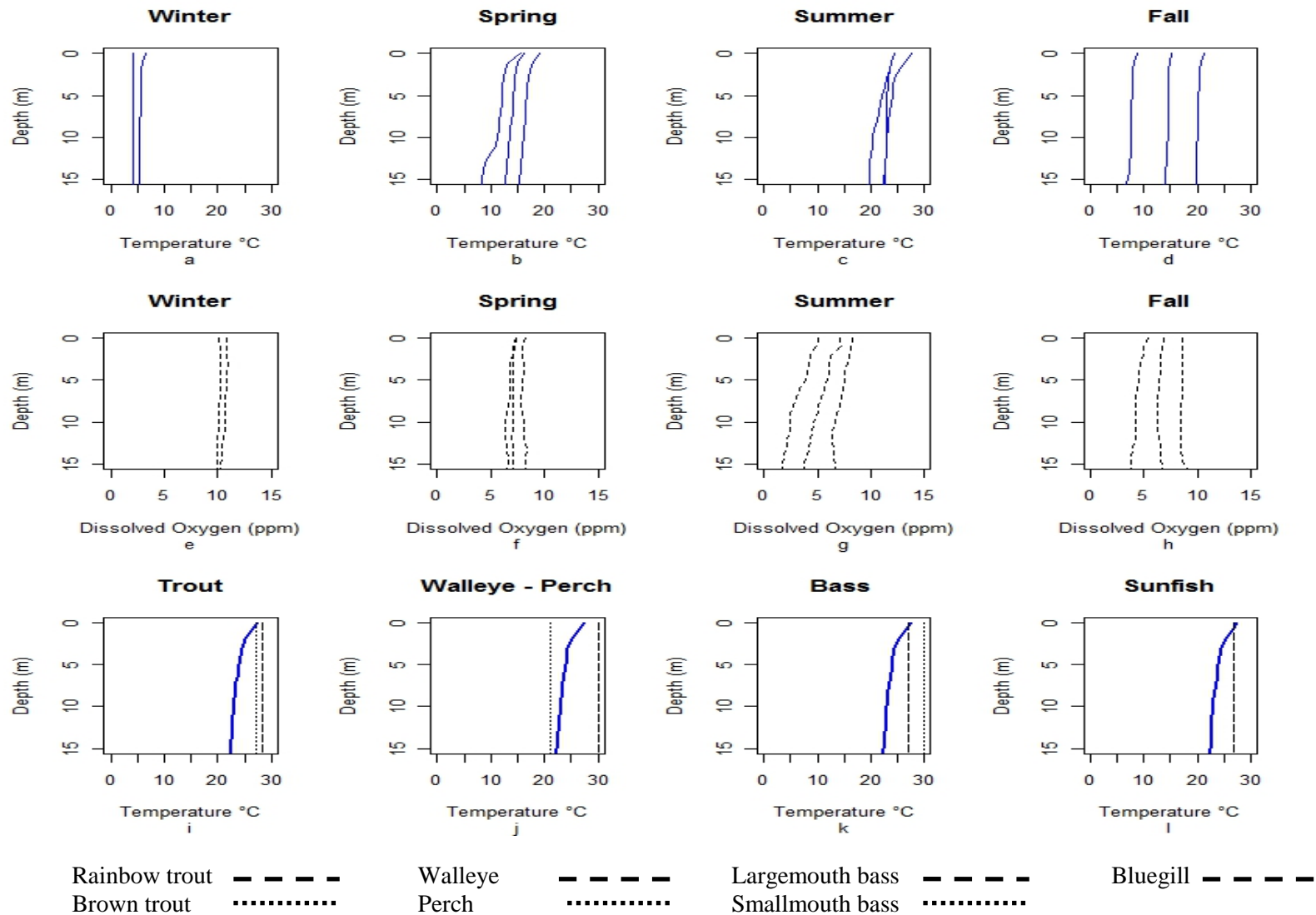


Figure 15 – Cochiti Lake average seasonal water temperatures (a-d) and dissolved oxygen (e-h) by depth. Thermal tolerance of potential sport fish species (i-l) compared with high summer temperatures (solid blue).

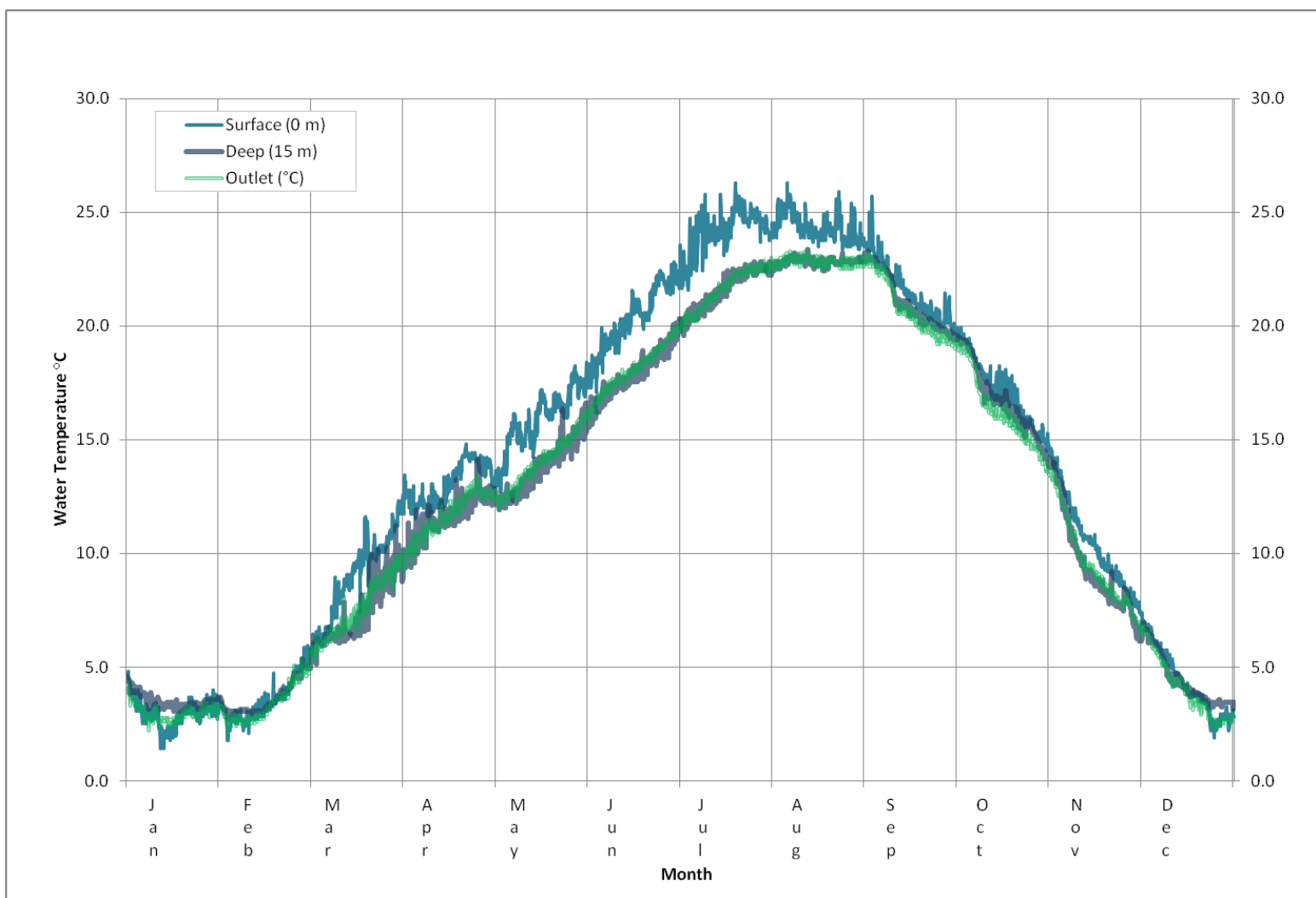


Figure 16 – Annual trends in Cochiti Lake (2011) water temperature using continuous temperature loggers at the outlet, 0 and 15 m depth (near the dam).

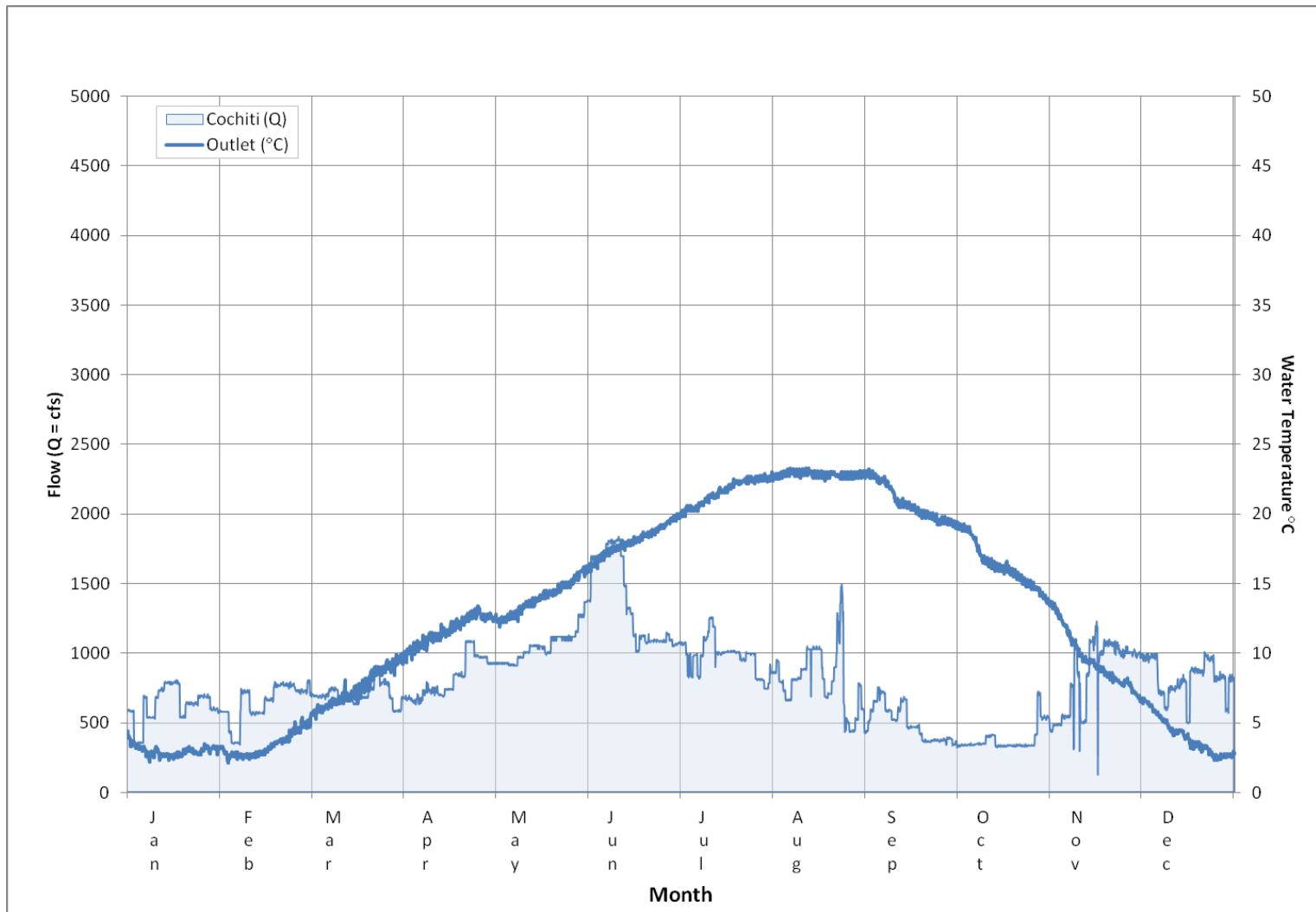


Figure 17 – Downstream flow and water temperature at Cochiti Lake outlet.

8.2 Cochiti Lake and Rio Grande Fisheries

The thermal gradient in the lake contributes to lower water temperatures downstream of the dam providing conditions suitable for cold, cool and warm water fisheries in the lake, and downstream in the Rio Grande (Heidinger, 1999). Though these thermal regimes may allow for a broader diversity of sport fish, they also impose limitations on forage species which support the fisheries. Fish surveys conducted in 2009 and 2010 are reported in Table 5.

Table 4 - Fish survey results within the Pueblo de Cochiti boundaries

The riverine fish surveys were conducted in August 2010. The Cochiti Lake fish surveys were conducted by New Mexico Department of Game and Fish in May 2009 and 2010.

Cool/Coldwater Species	Introduced (I) / Native (N)*	Total	Downstream	Lake	Upstream
<i>Catostomus commersoni</i>	I	97	95		2
<i>Esox lucius</i>	I	3		3	
<i>Oncorhynchus mykiss</i>	I	2	1	1	
<i>Perca flavescens</i>	I	21		21	
<i>Salmo trutta</i>	I	1	1		
<i>Sander vitreus</i>	I	10		10	
Subtotal		134	97	35	2
Warmwater Species		Total	Downstream	Lake	Upstream
<i>Ameiurus natalis</i>	I	1			1
<i>Carpionodes carpio</i>	N	2	2		
<i>Cyprinella lutrensis</i>	N	9			9
<i>Cyprinus carpio</i>	I	31	16	8	7
<i>Gambusia affinis</i>	N	1			1
<i>Ictalurus punctatus</i>	I	17	10		7
<i>Lepomis cyanellus</i>	I	19		18	1
<i>Lepomis macrochirus</i>	N	115	3	107	5
<i>Micropterus dolomieu</i>	I	2	2		
<i>Micropterus salmoides</i>	I	2	2		
<i>Morone chrysops</i>	I	10		10	
<i>Pomoxis annularis</i>	I	2			2
Subtotal		211	35	143	33

* based on Sublette et al. 1990.

Based on data from 2010, lake and river water temperatures rise above 15°C in late May and are between 20-23°C from mid-June to October (~100 days). These summer temperatures are below

the lethal maximum temperatures for rainbow (*Onchorhynchus mykiss*) and brown trout (*Salmo trutta*) of 25-27°C (Sublette et al. 1990). Optimal water temperatures for trout are 13-21°C for rainbow trout and 12-19°C for brown trout (Sublette et al. 1990). The availability of forage fish to support trout populations may be limiting. The three most common species (92% of fish sampled) downstream of the dam are white sucker, common carp and channel catfish. These species may rely on body size to reduce predation by trout. Submerged structural habitat including wood and boulders may also limit trout densities in the river reach downstream of Cochiti Dam.

The water temperature range is generally suitable for northern pike (*Esox lucius*). Northern pike spawn at temperatures between 6-18°C over flooded vegetation or muddy bottoms (Sublette et al. 1990). Eggs hatch in 5-26 days depending on temperature and the larvae associated with submerged vegetation. Faster water velocity may limit habitat for this species.

Suitable temperatures for Rio Grande silvery minnow spawning (15-20°C) overlapped the spring hydrograph above 2000 cubic feet per second (cfs) for 15-17 days. The riparian areas in the Cochiti Reach that were inundated at 2000 cfs may have suitable water temperatures for silvery minnow spawning and rearing. Currently the Cochiti Reach requires flow about 4000 cfs for significant overbank inundation, while flows above 2000 cfs results in 400 or more acres of in-channel flooded habitat (islands and bars). Constructed backwater habitats within the reach may provide sufficient habitat for recruitment in localized areas.

NMDGF has stocked two fish species into Cochiti Lake since 1990. Channel catfish (*Ictalurus punctatus*) fingerlings (~19,765) were stocked in 1990. Walleye (*Sander vitreus*) fry (5.8 million) have been stocked in six years between 2000-2010.

8.3 Fisheries Development

The small numbers of small-bodied forage fish species in Cochiti Lake likely limit the growth and survival of game fish species. There are no pelagic forage fish species in the lake to support the walleye and trout fishery. Bluegills (*Lepomis macrochirus*) are the major forage fish in the lake, principally found near the shallow shoreline. Transfer of gizzard shad (*Dorosoma cepedianum*) from downstream in the Rio Grande may contribute to a larger food base within the lake consuming open water phyto- and zooplankton.

Increasing the water surface elevation during flood control (and deviation) operations inundates terrestrial shoreline vegetation (Hayes et al. 1999), increasing the allochthonous inputs (including nutrients for the lake food web). Quantifying zooplankton seasonal densities in response to lake operations is the first step toward managing the food base for sport fisheries. Targeted measures for increasing plankton may consider use of hay bales to provide supplemental nutrients as the bales disintegrate and are consumed by microbes and invertebrates.

The small numbers of small-bodied forage fish species in the Rio Grande likely limit the growth and survival of game fish species. The availability of suitable habitat structure for cover and food may be limiting on both forage and sport fish species in the Rio Grande. More research is needed to understand the interactions of sport fish with native riverine species. The lack of woody debris

may limit invertebrates as well. Development of riverine fisheries should start by mapping habitat types and quantifying invertebrate species. Projects in the Santa Fe River between Cochiti Dam and the Rio Grande for trout fishing should focus on construction of pools for trout habitat and quantifying the invertebrate food base.

9 - Historic and Archaeological Data Sources

The Historic and Archaeological Data Sources section contains an examination and discussion of our current understanding of the archaeological and historical past of the Cochiti Lake Project area, and a discussion of the sources of archaeological and archaeologically relevant information currently available to us.

Because of the culturally sensitive nature of some of the information contained in the section, and because the public disclosure of archaeological site locations is federally prohibited by 16 USC 470hh (36 CFR 296.18) and prohibited by New Mexico law by Section 18-6-11.1 NMSA 1978, that section has been removed from public versions of this report.

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