Exploring Springs and Wetlands and their Relationship with Surface Flows, Geology, and Groundwater in the La Cienega Area Santa Fe County, New Mexico

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Ecotone

Conservation Planning for Landscapes in Transition

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ACRONYMS*

asl	above sea level
bgs	below ground surface
CFC	chlorofluorocarbon
CIR	consumptive irrigation requirement
c.u.	consumptive use
CWA	Clean Water Act
DEM	Digital Elevation Model
DIC	dissolved inorganic carbon
EPA	Environmental Protection Agency
ET	evapotranspiration
Fm	Formation
ft/d	feet per day
ft/yr	feet per year
ft^3/s	cubic feet per second
FWS/OBS	United States Fish and Wildlife Service Office of Biological Services
GIS	Geographic Information system
GPS	Global Positioning System
H	hydrogen
LLC	Limited Liability Corporation
LMWL	local meteoric water line
Ma	millions of years
MDWCA	Mutual Domestic Water Consumers Association
NAIP	National Agriculture Imagery Program
NHD	National Hydrologic Dataset
NM	New Mexico
NMBGMR	New Mexico Bureau of Geology and Mineral Resources
NMED	New Mexico Environment Department
NMOSE	New Mexico Office of the State Engineer
NRCS	National Resources Conservation Service
NWI	National Wetlands Inventory
NWIS	National Water Information System
OSE	New Mexico Office of the State Engineer
pmC	percent modern carbon
RCYBP	radiocarbon years before present
SCS	Soil Conservation Service
SFG	Santa Fe Group
Spp.	species
SR	State Road
SSURGO	Soil Survey Geographic Database
SWQB	Surface Water Quality Bureau
TDS	Total Dissolved Solids
TOC	top of casing
TU	Tritium Units
US	United States
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VSMOW	Vienna Standard Mean Ocean Water
WPGD	Wetlands Program Development Grant
WWTP	City of Santa Fe Paseo Real Wastewater Treatment Plant

*Does not include wetland and riparian Classification Codes which are defined in Tables 2.1, 2.2, 2.3 and Appendix B; geologic units defined in Section 4.0; elements defined in Section 4.0; Wetland Indicator Status Codes defined in Appendix C.

EXECUTIVE SUMMARY

In 2009, in collaboration with Santa Fe County and Earth Works Institute, the New Mexico Environment Department Surface Water Quality Bureau (SWQB) Wetlands Program initiated a hydrogeological study of the La Cienega Area as part of the project "Comprehensive Wetland Protection and Restoration in Santa Fe County" (Clean Water Act Wetlands Program Development Grant). In order to carry out this comprehensive study, the "La Cienega Geohydrology Group" was formed, comprised of SWQB Wetlands Program, Earth Works Institute (and later Ecotone), New Mexico Office of the State Engineer, New Mexico Bureau of Geology and Mineral Resources, Santa Fe County Public Works, and the U.S. Fish & Wildlife Service, to study springs and wetlands and their relationship with surface flows, geology, and groundwater in the La Cienega Area.

The La Cienega Area is located in Santa Fe County, New Mexico just southwest of the City of Santa Fe. The La Cienega Area is characterized by the confluence of surface and groundwater flows that have supported the existence of extensive wetland areas. There is a concern that these wetlands have been degraded from of a variety of stressors, including development, surface water diversion, groundwater withdrawal, agricultural practices, hydro-modification in stream channels, and ecological changes. Projected development surrounding Santa Fe (Santa Fe County, 2010b), and potential changes in surface water flows and increased groundwater use could threaten the presence and condition of wetlands in the La Cienega Area. These wetlands support an important historical, acequia irrigation-based agricultural community; they are a significant ecological component to a nationally recognized wildlife corridor along the Western Wildway and the Central Flyway, and they provide regional open space and trails amenities as well. Wetlands also provide many chemical, physical and biological ecosystem services including streamflow maintenance, flood attenuation, native plant and wildlife habitat, and nutrient and carbon cycling. The loss and drying up of wetlands would constitute a serious loss of these ecosystem services as well as important community values.

The purpose of this study is to improve the understanding of groundwater sources that sustain wetlands and springs in the La Cienega Area. To accomplish this, wetlands were mapped, streamflows (in reaches downstream of wetlands) were evaluated, local geology was investigated, and groundwater levels and chemistry were studied. The study aims to provide information that is helpful for future wetland and water management in the La Cienega Area, to identify areas for long-term monitoring, to inform future actions for wetland restoration and protection, and to assist with future simulation of La Cienega spring flow in groundwater models for the Santa Fe Group aquifer. This study will also serve as a scientific model for the study of groundwater-supported wetlands in other areas.

This study completed:

- Detailed wetlands mapping by Jim Dick, Southwest Regional Wetlands Coordinator, US Fish and Wildlife Service, for the La Cienega Area between Cieneguilla and Bonanza Creek based on 2009 geo-spatial data, with an identification of wetland types and their approximate location in the landscape (Section 2.0). The study includes the status of wetland and riparian habitat, springs, wetland riverine features, seeps and hillside wetlands. The findings are documented in a suite of maps. A wetland plant species list compiled by Nancy Daniel (Santa Fe Botanical Garden) is included (Section 6.3, Appendix C).
- Karen Torres, Santa Fe County Public Works Department, completed a brief historical overview of acequia agricultural use of water resources in the La Cienega Area in relation to a summary of the water rights history and the 1976 Santa Fe River Hydrographic Survey for the area (Section 6.1, Appendix A).
- A surface water flow study was prepared by Laura Petronis and Jack Frost, New Mexico Office of the State Engineer, with contributions from Jack Veenhuis of NM Hydrologic, LLC (Section 3.0). The study also summarizes and evaluates previous surface-water investigations in the La Cienega Area.
- Peggy Johnson, Daniel Koning and Stacy Timmons, New Mexico Bureau of Geology and Mineral Resources, contributed a groundwater flow study with an overview of the hydrogeology of the area, including the geological setting and history, a description of the geological units in the La Cienega Area and their hydrological significance, and a stratigraphic and hydrological explanation of the Santa Fe Group (Section 4.0).
- Peggy Johnson and Stacy Timmons, New Mexico Bureau of Geology and Mineral Resources also completed a chemical characterization and age-dating of groundwater that evaluates major ion chemistry, water-type, isotopic characteristics, and groundwater residence time (Section 4.0).

The findings of this project are described below.

Wetlands Mapping. Of the 116,448.5 acres that were covered by the mapping study, 680.3 acres of wetland habitat were identified. Vegetated wetlands (emergent, scrub-shrub and forested) mapped as being associated with seeps and springs accounted for 388.9 acres (57% of all wetlands mapped). Other vegetated wetlands accounted for 104.4 acres. Man-made ponds impoundments and excavations accounted for 96.2 acres.

Arroyos and seasonal washes accounted for 93.8 acres. Non-vegetated wetlands (small, natural open water bodies and shorlines) accounted for 2 acres. Riparian habitat accounted for 115.2 acres, in addition to all wetland acreage.

Surface Flows. Springs and seeps contribute to streamflow in the La Cienega Area. Direct measurement of spring and seep flows is difficult because the area of discharge is diffuse. Several studies have measured streamflow in reaches within and downstream of wetlands and spring and seep discharge to assess areas of gaining and losing streamflow in the La Cienega Area. Many of the reported gains and losses are quite small. Additionally, regarding the lower Santa Fe River, daily fluctuations in streamflow can make computing streamflow a challenge.

Based on a study by NM Hydrologic, LLC and New Mexico Office of the State Engineer (NMOSE) (2012b), Cienega Creek streamflow increased in a downstream direction in the late winter prior to the irrigation season. In late February, 2012, the total flow in Cienega Creek just above the confluence with the Santa Fe River (when adding the streamflow measurement from Alamo Creek) was 1.9 to 2.0 ft^3/s.

Limited historical data exist to identify streamflow trends over time and conditions during the data collection may not be known. Streamflow variability during the non-irrigation season appears to occur not only month to month, but on an annual basis as well. Future monitoring and additional study of streamflow in the La Cienega Area is needed to better understand streamflow variations over time.

Hydrogeology. The exploration of springs and wetlands in La Cienega reveals a complex, three-dimensional groundwater system wherein groundwater discharge from multiple flow pathways in the Santa Fe Group regional aquifer sustains the wetland environment. The location of the wetlands is controlled by the geologic setting. Their sustenance depends on an adequate and stable water supply. The La Cienega wetlands water budget is dominated by groundwater inflow and surface water outflow, with seasonal water level and water storage fluctuations controlled by changes in evapotranspiration between growing and dormant periods.

Groundwater sustaining springs and wetlands originate from the Santa Fe Group regional aquifer system, which consists of the deeper sandy strata of the Tesuque Formation and the shallow, sand and gravel deposits of the Ancha Formation. As the Santa Fe Group aquifer becomes thin and pinches out over underlying low-permeability strata, groundwater is forced to the surface to discharge in spring and wetland zones and associated drainages.

The Ancha Formation directly feeds most spring and wetland zones. Storage of groundwater and saturation of the Ancha Formation is controlled by three factors: (1) permeability contrasts between the Ancha and pre-Ancha Formations; (2) the topography of the erosion surface at the base of the formation; and (3) sources of recharge or inflow to the formation. Paleo-valleys incised at the structural base of the Ancha Formation provide elevation-dependent drains that gather groundwater and concentrate groundwater flow and discharge to wetland and spring zones.

Two paleo-valleys — the El Dorado paleo-valley and the ancestral Santa Fe River — at the base of the Ancha Formation provide hydrogeologic and elevation control over locations of spring and wetland zones. The El Dorado paleo-valley controls the discharge locations for spring-wetland zones at Las Lagunitas in Guicu Creek and the Leonora Curtin Wetland Preserve in Canorita de las Bacas. The Cienega Creek spring-wetland zone is strongly aligned with paleo-channel fill that may be associated with another channel of the El Dorado paleo-valley. Sunrise Springs and other springs along the western slopes of Arroyo Hondo, above its confluence with Cienega Creek, are controlled by the paleo-valley of the ancestral Santa Fe River.

A water-table map of 2012 groundwater conditions shows groundwater entering the study area from the east and flowing westward toward the Santa Fe River and the Rio Grande. Flow-path analysis demonstrates groundwater discharge to wetland areas in Cienega Creek, Arroyo Hondo, Guicu Creek, the Santa Fe River, and Canorita de las Bacas. Aquifer recharge and discharge areas interpreted from the groundwater map are generally consistent with the stream losses and gains measured by NM Hydrologic LLC and the NMOSE (2012a and 2012b).

The 2012 water-table map delineates a recharge mound beneath the Santa Fe River that extends from its confluence with Arroyo Calabasas, upstream past the City of Santa Fe's current Paseo Real Wastewater Treatment Plant (WWTP), and beyond SR 599. Flow-path analysis indicates that groundwater flows from the recharge mound southward toward La Cienega and westward toward the Rio Grande. Southerly groundwater flow diverges at a paleo-topographic high on the Tesuque Formation east of Cieneguilla (delineated in mapping of the structural base of the Ancha Formation), where it either flows southward toward seeps and springs along Arroyo Hondo or westward towards the Rio Grande or the Santa Fe River canyon.

Seasonal water-level changes evaluated in 38 shallow wells between summer-fall of 2011 and winter 2012 showed a consistent increase in winter water levels of an average 0.77 ft in wetland zones. Declining water levels (-0.13 to -0.50 ft) occurred in wells located in desert uplands with a depth to water greater than 100 ft. A hydrograph and thermograph of continuous measurements from October 5, 2011 to October 2, 2012 in a well at Leonora Curtin Wetland Preserve show that wetland water levels are lowest during the growing season (June to late September) and highest in the winter dormant season (December to mid-April). Abrupt, synchronized and inverse changes in water level and temperature in November and April correspond to transitions between growing and dormant vegetation phases and illustrate the hydrologic response of the shallow groundwater system to changes in plant transpiration in the wetlands.

Long-term water level changes evaluated in 29 area wells with repeat measurements in 2004 and 2012 show persistent water-level declines in 76% of the measured wells, most of which occurred in and east of the La Cienega wetlands. Declines ranged from -5.03 to -0.10 ft, and averaged -1.16 ft for the 8-year period. Water-level rises (0.08 to 2.84 ft) occurred in wells near the WWTP, in the Ancha Formation near the Arroyo Hondo spring zone, north of El Rancho de las Golondrinas, and near upper Cienega Creek. Small fluctuations of a few tenths of a foot are within a normal seasonal or year-to-year fluctuation. Hydrographs for area wells show a persistent trend of declining water levels between 1973 and 2012, and where the measurement frequency is sufficient, also show the cumulative effects of seasonal water-level variations (winter highs and summer lows) and recharge events (spring 2005), superimposed on the likely effects of pumping and long-term withdrawals.

Groundwater Chemistry. Chemistry, isotope, and age (^{14}C and tritium) characteristics of groundwater verify that mixtures of multiple groundwater sources with distinct chemistries and residence times feed wetland zones east and west of Cienega Creek. Mixing occurs in various proportions between groundwater from deep regional flow paths through the Tesuque Formation and groundwater from local to intermediate flow paths within the Ancha Formation and uppermost Tesuque Formation. Wetlands east of Cienega Creek have notably younger ages, with greater amounts of modern recharge, than do springs and wetlands west of Cienega Creek and Arroyo Hondo. Wetland zones and stream valleys are areas of both discharging and recharging groundwater, which indicate that local hydrologic processes, such as bank storage during storm events and local recycling of discharged groundwater and surface flows, play an important role in wetland function.

1.0 INTRODUCTION

1.1 Purpose

A goal of the New Mexico Environment Department Surface Water Quality Bureau (SWQB) Wetlands Program is to restore and maintain wetlands in a sustainable way to allow wetlands to fully function under natural conditions. Currently SWQB Wetlands Program efforts concentrate on restoring surface hydrology as a means of restoring wetlands that depend on surface flow. Little is known in New Mexico about the hydrogeology of groundwater-supported wetlands.

As part of the project "Comprehensive Wetland Restoration and Protection in Santa Fe County" funded by Clean Water Act (CWA) Section 104(b)(3) Wetlands Program Development Grant, the SWQB Wetlands Program has brought together New Mexico experts in the "La Cienega Geohydrology Group" to undertake a hydrogeologic study of the La Cienega Area in Santa Fe County, New Mexico (Figure 1.1). The La Cienega Area is unique as a confluence of surface flows from storm water and snow melt and includes an exceptional concentration of seeps and springs, slope wetlands and "cienegas" (the Colonial Spanish word for marsh), which are primarily groundwater fed and flow at the surface. Mid-elevation, alkaline cienegas are created by springs and seeps that saturate surface and subsurface soils over a large area supporting a lush wet meadow (Sivinski and Tonne, 2011). An example of this type of wetland within the La Cienega project area is located at the Leonora Curtin Wetland Preserve, in the Canorita de las Bacas drainage (Figure 1.2). Groundwater-fed wetlands in semi-arid landscapes, especially those that form large cienega complexes, are among the most diminished and threatened ecosystems in the arid southwest. Of all the southwestern states, the cienegas of New Mexico are the least studied and documented in the literature (Sivinski and Tonne, 2011).

The purpose of this study is to develop and demonstrate an understanding of the contributions of surface and groundwater to sustaining wetlands in the La Cienega Area. The intention is to provide information that is helpful for future wetland and water management in the La Cienega Area, to identify areas for long-term monitoring, to inform future actions for wetland restoration and protection, and to assist with future simulation of La Cienega spring flow in groundwater models for the Santa Fe Group aquifer. This study will also serve as a scientific model for the study of groundwater-supported wetlands in other areas.

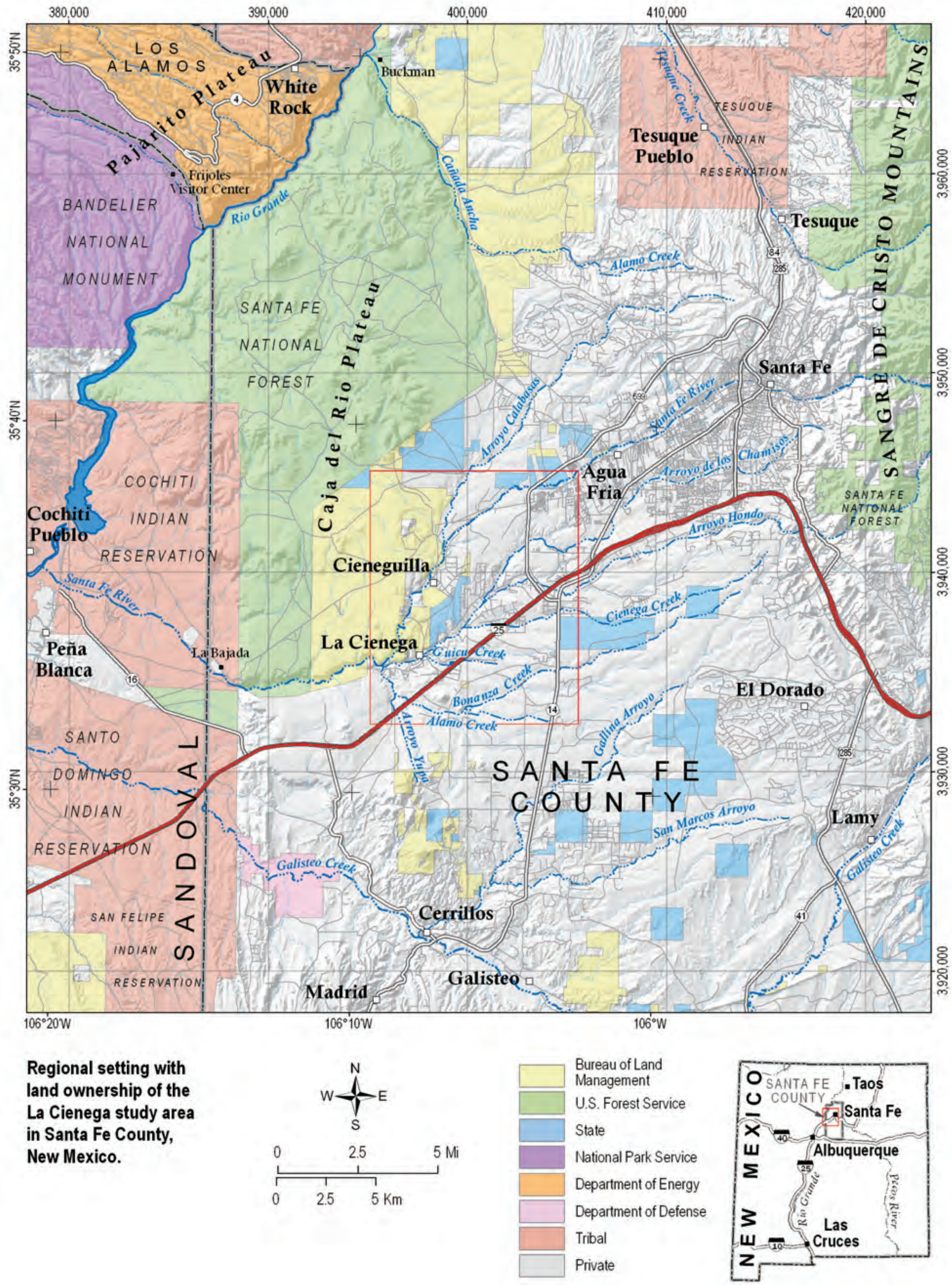


Figure 1.1: Regional setting of the La Cienega Area.

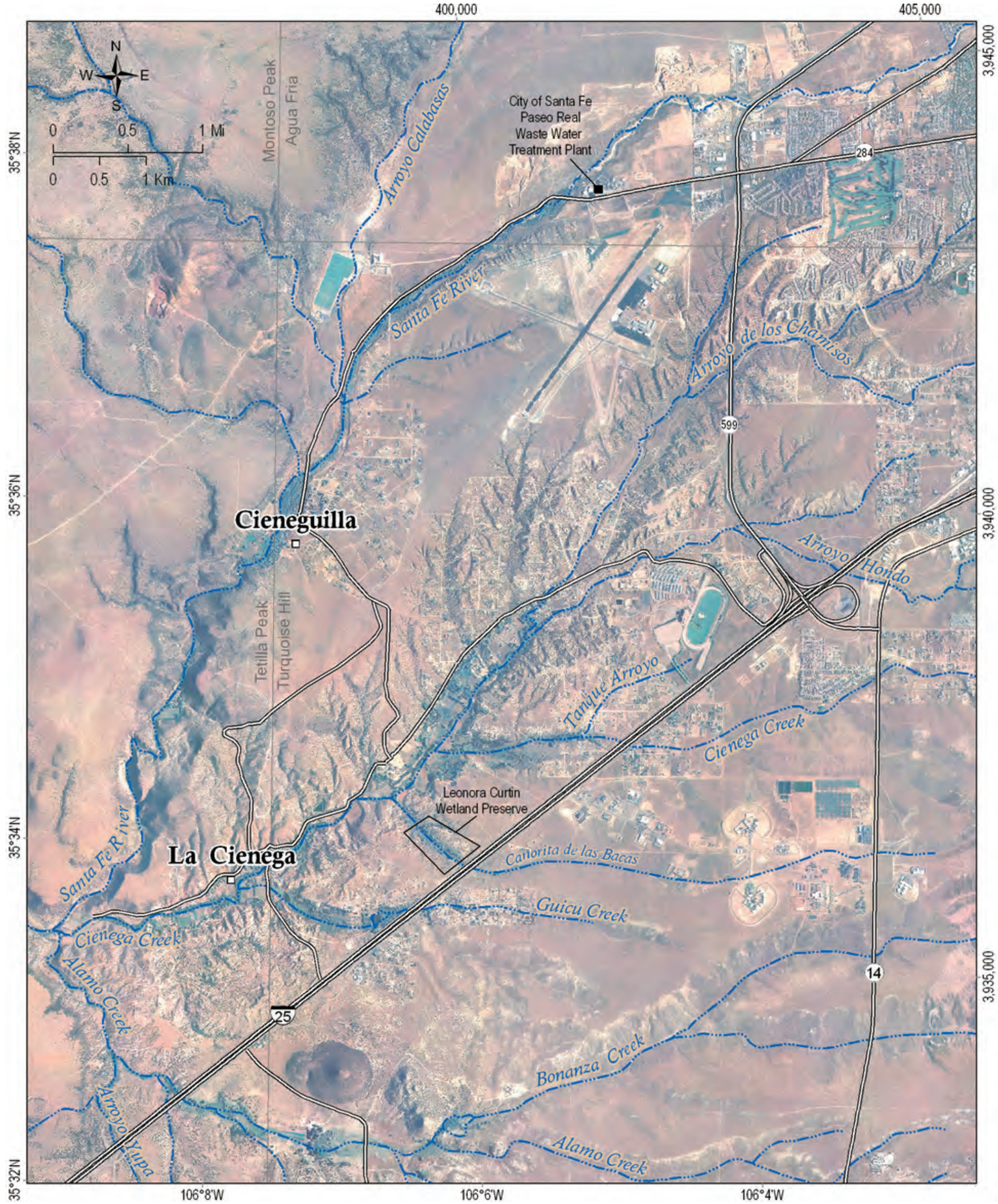


Figure 1.2: The La Cienega study area and identification of streams and named drainages converging in the La Cienega Area. The boundaries associated with USGS 1:24,000 quadrangles are also shown (Agua Fria, Turquoise Hill and Tetilla Peak Quadrangles). City of Santa Fe Paseo Real Wastewater Treatment Plant (WWTP) and the Leonora Curtin Wetland Preserve are also located.

1.2 Acknowledgements

This study is a collaborative initiative of the **"La Cienega Geohydrology Group"** whose members include:

- Maryann McGraw, SWQB Wetlands Program Coordinator, led and initiated the project and contributed to the introductory section.
- Jan-Willem Jansens of Ecotone, project contractor for SWQB, coordinated community relationships, project direction and the compilation of this report, and contributed to the introductory section.
- Jim Dick, Southwest Regional Wetlands Coordinator, U.S. Fish & Wildlife Service (USFWS), contributed Section 2.0 on wetland mapping.
- Laura Petronis and Jack Frost, Hydrogeologists, New Mexico Office of the State Engineer (NMOSE), contributed to the Previous Investigations section (Section 1.6) and to Section 3.0, which summarizes surface flow data in the La Cienega Area. Jack Veenhuis, NM Hydrologic, LLC, performed streamflow measurements described in greater detail in NM Hydrologic, LLC and NMOSE (2012a and 2012b) and information and language from those reports are included in Section 3.0.
- Peggy Johnson, Senior Hydrogeologist, Dan Koning, Geologist, and Stacy Timmons, Research Associate, New Mexico Bureau of Geology and Mineral Resources (NMBGMR), contributed Section 4.0 on geology, hydrogeology and chemistry of wetlands and springs. Peggy Johnson also contributed to Previous Investigations Section 1.6.
- Karen Torres, Hydrologist, Santa Fe County Public Works Department, contributed Appendix A on water sources for irrigation based on aerial photography and the 1976 Santa Fe River hydrographic survey (NMOSE 1976) mapping for the area.

The project team is grateful for additional support received from local landowners and for detailed information, feedback, and personal interest in the study. The project team is also very grateful for feedback and information received from the City of Santa Fe's Sangre de Cristo Water Division staff. SWQB is thankful for in-kind project support received from the NMBGMR, Santa Fe County, landowners, the City of Santa Fe, and Ecotone, which serves as valuable match for the Environmental Protection Agency (EPA) Wetlands Program Development Grant (WPDG). Furthermore, the project team wants to acknowledge the support received from the Aquifer Mapping Program at the NMBGMR and Healy Foundation (Taos, NM). Ground water chemistry analyses and surface flow data collection and analyses were funded in part by EPA Region 6 WPDG.

1.3 Issues of Concern

The La Cienega Area is located to the southwest of the City of Santa Fe, New Mexico, the state capital. La Cienega is a pre-historic settlement site of several early Native American and Puebloan cultures. La Cienega is also one of the oldest Hispanic settlements in New Mexico, dating back to the 1700s. Historically, La Cienega was primarily an agricultural community with its verdant water resources supporting farming, orchards and domestic livestock (Jansens, 2012). The community's traditional agriculture systems are supported by acequia irrigation - much of the irrigation waters are derived from the many springs in the area (see Appendix A for information on acequias, historical changes, and the 1976 Santa Fe River Hydrographic Survey (NMOSE 1976)).

Water resources that support the City of Santa Fe are limited and conservation measures are imposed on its citizens and businesses (see SFCC 1987 25-2.2, http://www.santafenm.gov/index.aspx?NID=2562). In order to address the complex water need and scarcity problems in Santa Fe County in a proactive manner, both the City of Santa Fe and Santa Fe County follow a conjunctive use principle in water supply planning. Both local government entities prioritize the use of surface water, combined with rainwater capture, the Buckman Direct Diversion (BDD) project (water from the Rio Grande), and water conservation measures. Groundwater will thus be saved as a backup for years of special or additional need, such as in years of droughts when surface water sources are inadequate (City of Santa Fe 2011, Santa Fe County 2010a). Recently, Santa Fe County has included several La Cienega Area wetlands in its growing network of County Open Lands and Trails for habitat conservation and/or public recreation.

The La Cienega Area is located along the Central Flyway and is in the heart of intersecting major wildlife corridors between three different ecoregions associated with the Western Wildway (a.k.a. the "Spine of the Continent"). The area serves as a part of an important functional wildlife pathway between the Southern Rocky Mountains to the north and the New Mexico Mountains to the south (Foreman et al., 2003). Water resources, such as those in La Cienega, are a critical part of these wildlife corridors in the arid west. The Santa Fe River which flows through the project area is primarily supported by flows from the upstream WWTP. These Santa Fe River flows may contribute to local aquifer recharge. Native vegetation and wetlands flourish from these constant flows and contribute significant wildlife habitat.

The wetlands in the area may be degraded by a number of sources of stress, including ditching, damming, vegetation removal, road and trail crossings, and draining and diversion (Jansens, 2012). On a broader scale, wetland and riparian resources have been affected over the last century or more as a result of population growth, development, groundwater pumping, water diversion, and ecological change.

The impacts of these stressors on wetlands may include:

- Dwindling, disrupted or erratic flows;
- Sheet and gully erosion resulting from past and current land use;
- Isolation and loss of habitat connectivity from development and infrastructure;
- Encroachment or invasion of non-native and invasive plant and animal species;
- Loss of biodiversity.

A number of initiatives have been undertaken to improve and restore these wetlands. However, if the wetland hydrology is disrupted or lost, these restoration measures will be in vain.

1.4 Setting

The La Cienega Area is located west of the City Santa Fe in the west-central portion of Santa Fe County, and is situated in the lower Santa Fe River watershed at the confluence of the Santa Fe River and several of its tributaries. The study area includes (1) a portion of the Santa Fe River main stem drainage area below the WWTP; (2) the subwatersheds of Cienega Creek in the northern part of the watershed; (3) Arroyo Hondo, Arroyo de los Chamisos, and Arroyo de los Pinos drainage in the southern part of the watershed; and (4) the Alamo Creek and Bonanza Creek drainage in the southwestern part of the watershed. Additionally, around La Cienega several smaller drainages flow into the lower main stem of the Cienega Creek/Arroyo Hondo/de los Chamisos drainages, such as the Guicu Creek and the Canorita de las Bacas (Figure 1.2).

The La Cienega Area lies along the southwest margin of the Española Basin, which is bordered by the Sangre de Cristo Mountains to the east and the Jemez Mountains to the west. The study area is situated within a geologic transition between the alluvial basin to the east and the basin's western structural boundary, the Cerrillos uplift. Groundwater discharge from the regional alluvial aquifer – known as the Santa Fe Group aquifer – is forced to the surface at the edge of the basin, near La Cienega, to feed springs and wetlands along slopes, valley bottoms, and streams that flow through the La Cienega Area and into the Santa Fe River.

While the surrounding arid landscape is dominated by a piñon-juniper shrub and grassland savanna, the bottomlands of the La Cienega Area consist of riparian and wetland ecosystems with predominantly native cottonwoods, willows, rushes, sedges, and cattails. The uplands have historically been used for dryland grazing, and the valley bottoms have been developed for acequia-irrigated agriculture and pastures (see also Appendix A). Development in the La Cienega Area is limited to the traditional linear village structure of La Cienega, a small subdivision (Las Lagunitas) and scattered home sites along the slopes of the tributaries east of the village. Future development in the La Cienega Area is limited to in-fill due to the predominance of public land surrounding the village.

Water needs in the La Cienega area include domestic drinking water and agricultural water for irrigation and livestock watering. Drinking water needs are supported by the La Cienega Owners Association Water System, the La Cienega Mutual Domestic Water Consumers Association (MDWCA), and numerous domestic wells. Additionally, the well fields of the Wild and Wooley Trailer Ranch and the Penitentiary of New Mexico exist within a radius of 5 miles of La Cienega. The Valle Vista Subdivision has recently been connected to the County water supply system (NMOSE, 2008) (Amy Lewis, Hydrological Consultant, Personal Communication, 2012).

1.5 Study Design

This report documents the findings of the hydrogeological relationships of groundwater and surface water flows in the La Cienega Area that sustain the springs and wetlands. This study builds upon and adds to previous investigations that have been conducted in the La Cienega Area with the purpose of improving current understanding of the La Cienega Area hydrogeology. Several specific tasks were conducted for this study and they include:

- Reviewing previous relevant investigations;
- Mapping wetlands;
- Summarizing and evaluating the streamflow data that have been collected along the Santa Fe River, Cienega Creek, and its tributaries;
- Creating a detailed (1:12,000) geologic map, geologic cross sections, and hydrogeologic framework for the major spring zones;
- Updating, compiling, and summarizing existing groundwater level and chemistry data in the greater study area;
- Age dating groundwater in the vicinity;
- Synthesizing all data into a hydrogeologic conceptual model of springs.

This report provides information that is needed for the management of water resources and wetlands in the greater Española Basin and the La Cienega Area. Information in this report will be helpful in identifying areas for long-term monitoring. Additionally, the results of the study may be employed to improve the simulation of La Cienega Area spring and streamflow in groundwater models of the Santa Fe Group aquifer system in the southern Española Basin.

1.6 Previous Investigations

Beginning in the 1950's, there have been many hydrogeologic studies of the southern Española Basin and the La Cienega Area. They range from regional studies that include information on hydrologic or geologic features in the La Cienega Area, to specific studies of the geology, surface water and groundwater of the La Cienega Area.

Multiple investigations conducted in the last decade by researchers at the United States Geological Survey (USGS) and the NMBGMR have improved our understanding of the hydrogeology of the Santa Fe area, including La Cieneguilla and La Cienega. The USGS quantified the thickness of basin fill and delineated buried faults and volcanic strata using a geophysical data model (Grauch et al., 2009). Geologic mapping by the NMBGMR updated geologic maps with detailed subdivisions of the Ancha and Tesuque Formations (Koning and Read, 2010). Recent studies of the Ancha Formation have produced a series of maps that depict the structural base, thickness, and extent of saturation for the formation (Johnson and Koning, 2012). The collective research has refined depositional and tectonic interpretations and updated the geologic framework of the Española Basin.

Several studies of groundwater conditions in the Santa Fe Group aquifer of the Española Basin have documented regional groundwater flow and included water-table maps of the La Cienega area (Spiegel and Baldwin, 1963; Mourant, 1980; Johnson, 2009). Water quality and geochemical characteristics of groundwater in the Santa Fe area, including La Cienega, have been examined by Johnson et al. *(in press)*.

Spiegel and Baldwin (1963) investigated the geology and water resources of the Santa Fe area with important summaries of the La Cieneguilla and La Cienega areas. This work included: (1) some of the earliest known streamflow measurements in the La Cienega area that were made between 1951 and 1953 along the Santa Fe River below La Cieneguilla and La Cienega; (2) the first investigations of the Ancha Formation and it's hydrologic significance; and (3) the earliest attempts at delineating groundwater basins that contribute discharge to the Santa Fe River and wetlands in La Cieneguilla and La Cienega.

On behalf of Santa Fe County, Fleming (1994) conducted an analysis of the supply and demand of groundwater resources and springflow in the La Cienega area; however it was limited to the 68-square mile area of the La Cienega creek watershed, which includes the Arroyo Hondo and Arroyo de los Chamisos. Included in Fleming's report was a listing of historical flow records from La Cienega Ditch (just below the diversion from Cienega Creek, where all of the flow was diverted into the ditch), which showed higher flows measured between 1966 to 1971 then than measurements that were made prior to 1992.

Spiegel (1975) was the first to propose that paleo-valleys at the base of the Ancha Formation influenced the locations of springs and wetlands, and also evaluated of the effect of wells at the Santa Fe Downs on the Acequia de La Cienega. Spiegel thought that buried channels in the Ancha Formation extended from the mountain front across the basin and that some conveyed water to the discharge area of Cienega Creek and tributaries.

The most recent hydrogeologic study of the La Cienega Area was completed by HydroScience Associates, Inc. (2004). This report was prepared for the Acequia de La Cienega to review contemporaneous geologic investigations taking place in the southern Española Basin, to update the hydrogeology of the La Cienega Area, and to explore the possible reasons for springflow decline. The author's important findings include the following:

- The La Cienega Area is an "altitude dependent drain for the southern portion for the Santa Fe Embayment" and that "water moving west and southwest through the [Tesuque and Ancha] aquifers is forced to the surface as the relatively impermeable Oligocene volcanics rise closer to the surface and the Tesuque/Ancha aquifer thins in the broad, southern part of [the] syncline. … [T]he general area in which discharge will occur is controlled by the presence and structure of the syncline, and the presence of the volcanics." (p. 26, HydroScience Associates, Inc. 2004).
- The source of water discharging from the springs was likely not limited to just the watershed encompassing the Arroyo de los Chamisos, the Arroyo Hondo, and Cienega Creek, but would be determined by the groundwater divide, which has probably been affected by human activities in the basin.
- The ditch measurements made on the Acequia de La Cienega in 2004 indicated an apparent slow decline between 1991 and 2003, but most of the decline occurred prior to 1991.

There have been other sources of information for springflow and streamflow data and interpretation of their trends in the La Cienega Area. In 1973, 1979, and 1980, the USGS conducted several seepage runs of the Santa Fe River in the months of June and July to provide information about gains and losses in the Santa Fe River (USGS, 1975; 1980; 1981). White and Kues (1992) inventoried the springs in New Mexico and reported twelve springs in the La Cienega and La Cieneguilla areas. Peery et al. (2007) reported a computed streamflow for 90-degree V-notch weirs installed in Cienega and Alamo Creeks on the Three Rivers Ranch (located at the confluence of Cienega and Alamo Creeks and the Santa Fe River) in January of 2007.

2.0 LA CIENEGA AREA WETLANDS

By Jim A. Dick, USFWS

The U.S. Fish and Wildlife Service's (USFWS) National Wetlands Inventory Program (NWI) is responsible for the collecting and distributing data and information concerning wetland and riparian habitats of the United States. Geographic information on types and locations of various wetland and riparian habitats provide invaluable information for resource managers and planners dealing with protecting our natural resources while providing for human development and growth.

Though relatively small, the La Cienega watershed, in Santa Fe County, is a unique area geographically and culturally. The area has a long history of human settlement, primarily because of the seep and spring wetlands that have been feeding the local drainages for centuries. As the population of the City and County of Santa Fe are projected to grow, demand may increase for drinking water extracted from local aquifers. Wetland inventories, such as this, will provide baseline data to monitor the conditions of these hydrologic features. Note that the wetlands mapped in this study do not replace the need for a separate jurisdictional determination for Clean Water Act permitting requirements.

2.1 Wetlands Mapping Methods

The wetlands mapping portion of this project involved conducting an area-wide inventory of wetlands and non-wetland riparian habitats using 2009 true color National Agriculture Imagery Program (NAIP) (URL: http://gis.apfo.usda.gov/arcgis/services) county mosaic aerial imagery. This approach is generally used for small geographic areas where more detailed investigations can be carried out. Digital identification and classification of wetland features was carried out in a "heads-up" environment (to digitize right onto a GIS display), using ESRI, Inc. ArcGIS software. To aid in the identification and classification of wetlands, several other data sources were referenced including, 2005 Color Infrared aerial imagery, USDA SSURGO digital soils data (Soil Survey Staff, 2008), and USGS National Hydrography Dataset (NHD) (URL: http://nhd.usgs.gov/index.html).

2.2 Definitions

Wetland Definition. The USFWS uses the Cowardin *et al.* (1979) definition for wetlands. This definition is the standard for the agency and is the national standard for wetland mapping, monitoring, and data reporting as determined by the Federal Geographic Data Committee. It is a two-part definition as indicated below:

Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Ephemeral waters, which are not recognized as a wetland type, and certain types of "farmed wetlands" as defined by the Food Security Act that do not coincide with Cowardin *et al.* definition were not included in this study.

Deepwater Habitats. Wetlands and deepwater habitats are defined separately by Cowardin et al. (1979) because the term wetland does not include deep, permanent water bodies. Deepwater habitats are permanently flooded land lying below the deepwater boundary of wetlands. Deepwater habitats include environments where surface water is permanent and often deep, so that water, rather than air, is the principal medium in which the dominant organisms live, whether or not they were attached to the substrate. All lacustrine and riverine waters are considered deepwater habitats.

Non-Wetland Riparian Habitat Definition. The USFWS has also developed a supplemental classification system to identify and classify non-wetland riparian areas (USFWS, 2009) (Section 6.2, Appendix B). These riparian areas are closely associated with water and topographic relief; they are distinct from either wetland or upland. Riparian areas lack the amount or duration of water usually present in wetlands, yet their connection to surface or subsurface water distinguishes them from adjacent uplands (USFWS, 2009). Riparian habitats are among the most important vegetative communities for western wildlife species. In Arizona and New Mexico, 80 percent of all vertebrates use riparian areas for at least half their life cycles; more than half of these are totally dependent on riparian areas (USFWS, 2009). These areas can also provide enhanced functionality to adjacent wetland habitats.

There are many riparian definitions used by government agencies and the private sector. Riparian initiatives often concentrate on either functionality or land use applications where an exact definition is not required. However, a riparian definition is essential for consistent and uniform identification, classification, and mapping.

Riparian areas are plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermittent lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one or both of the following characteristics: 1) distinctly different vegetative species than adjacent areas, and 2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetland and upland. Appendix B provides the Riparian Classification coding system used for this project.

2.3 Wetland Classification

The USFWS has made adaptations to the Cowardin classification system to accommodate the use of remotely sensed imagery as the primary data source. For example, water chemistry, salinity, water depth, substrate size and type and even some differences in vegetative species cannot always be reliably ascertained from imagery. Image analysts must rely primarily on physical or spectral characteristics evident on high altitude imagery, in conjunction with collateral data, to make decisions regarding wetland classification and deepwater determinations.

More information on the riparian and the wetlands classification can be obtained from the USFWS NWI webpage via these links:

http://www.fws.gov/wetlands/Documents/Classification-of-Wetlands-and-Deepwater- Habitats-of-the-United-States.pdf

http://www.fws.gov/wetlands/Documents/A-System-for-Mapping-Riparian-Areas-In-The- Western-United-States-2009.pdf

Limitations. National Wetlands Inventory digital data are derived from analysis of high altitude aerial imagery. Wetlands and riparian areas were identified based on vegetation, visible hydrology and geography in accordance with **Classification of Wetlands and Deepwater Habitats of the United States** (Cowardin et al., 1979) and **A System for Mapping Riparian Areas in the Western United States** (USFWS, 2009). There is a margin of error inherent in the use of aerial photos. Age, scale and emulsion of the aerial photos, as well as seasonal and climatic variations at the time of aerial photo acquisition may affect the way in which wetlands and riparian areas are identified. USFWS wetland data/maps contain no legal or jurisdictional information on wetlands.

2.4 La Cienega Study Area

Physiographic Form. The wetland mapping study area covers 116,448.5 acres (three USGS Quadrangles; Agua Fria, Tetilla Peak, and Turquoise Hill (Figure 1.2)) within northwestern Santa Fe County. The location of the La Cienega Area mapping boundaries is shown in Figure 2.1. The work area sits in a high basin (6000-8000 ft.) between two mountain ranges to the east and west. Major drainages include the Santa Fe River, Arroyo Hondo, Cienega Creek, and Alamo Creek, all flowing west southwest towards the Rio Grande. This region is rugged in topography and the climate is represented by considerable variations in both temperature and precipitation. The moisture regimes range from aridic ustic to typic ustic and the temperature regimes from mesic to frigid.

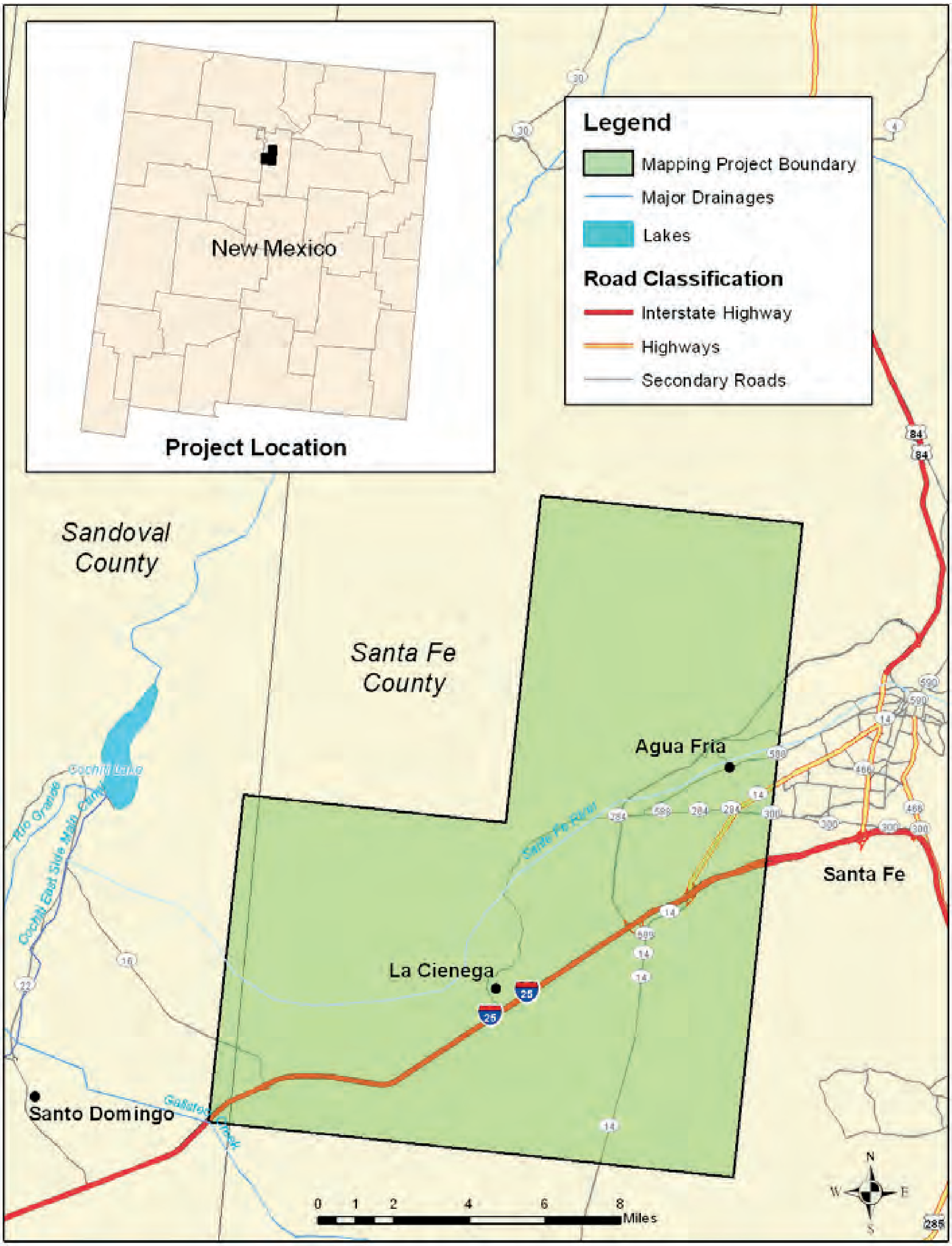


Figure 2.1: La Cienega Area wetland mapping project location.

General Wetland Habitats. A combination of factors associated with the groundwater hydrology and surface water hydrology in Santa Fe County have contributed to the existence of many small wetlands and riparian areas throughout the County. Most wetlands are riverine (streamside) wetlands along the major rivers and creeks flowing from the mountains, with the larger streams and rivers supporting more complex wetland/riparian systems. Additionally, the surfacing of the aquifers of the Ancha and Tesuque Formations support the existence of slope wetlands in the form of springs and seeps. Table 2.1 provides a representative classification of wetlands which could be present in this project area.

Table 2.1: Wetland classification codes and corresponding (general) community types for this project.

Wetland/Deepwater Feature*	Definition	Common Description	Community
Lacustrine			
L1UB (H)	Lacustrine, limnetic, unconsolidated bottom	Lakes, reservoirs deeper than 6 meters	none
L2UB (F)	Lacustrine, littoral, unconsolidated bottom	Lakes, reservoirs less than 6 meters deep	none
L2US (C, A, J)	Lacustrine, littoral, unconsolidated shore	Shallow lakes, reservoirs, shore, flats	none
Riverine			
R2UB (F, H)	Riverine, lower perennial, unconsolidated bottom	River	none
R2US (C, A, J)	Riverine, lower perennial, unconsolidated shore	Sand bar	none
R4SB (C, A, J)	Riverine, intermittent, streambed	Stream	none
Palustrine (Freshwater)			
PUB (H, F)	Palustrine, unconsolidated bottom	Ponds, basins	none
PUS (C, A)	Palustrine, unconsolidated shore	Flats, shallow basins, shore	none
PEM1 (F, E, C, B, A, J)	Palustrine, emergent	Marsh, prairie, basin, depression, spring/seep, wet meadow	*Typha latifolia* (cattail) *Cyperus spp.* (flatsedge) *Schoenoplectus spp.* (sedges) *Juncus spp.* (rushs) *Eleocharis spp.* (spikerush)
PSS1 (C, A, B, J)	Palustrine, scrub-shrub, broad-leaved deciduous	Shrub floodplain bottomland, spring/seep	*Salix exigua* (Coyote willow) *Salix irrorata* (Bluestem willow) *Elaeagnus angustifolia* (Russian olive)
PSS2 (A, J)	Palustrine, scrub-shrub, needle-leaved deciduous	Shrub floodplain, bottomland	*Tamarix spp.* (salt cedar)
PFO1 (C, A, J)	Palustrine, forest, broad-leaved deciduous	Forested floodplain, bottomland	*Populus spp.* (Cottonwoods) *Salix spp.* (willows) *Ulmus pumila* (Siberian elm) *Celtis spp.* (hackberry)

* Coding in parenthesis represent Water Regime Modifiers which describe flooding type/frequency; A-temporary, B-saturated, C-seasonal, E-seasonal/saturated, F-semi-permanent, H-permanent, J-intermittent.

2.5 Status of Wetland and Riparian Habitats, 2009

In this study, 680.3 acres of wetland habitat were identified. Vegetated wetlands (emergent, scrub-shrub and forested) mapped as being associated with seeps and springs accounted for 388.9 acres (57 % of all wetlands mapped). Almost all of these features were along Cienega Creek, Arroyo Hondo, and Alamo Creek near La Cienega, and along the Santa Fe River near Cieneguilla. Other vegetated wetlands accounted for 104.4 acres. The majority of these wetland features were associated with the Santa Fe River, above Cieneguilla and from the confluence with Cienega Creek and to the west. Man-made ponds impoundments and excavations accounted for 96.2 acres. Arroyos and seasonal washes accounted for 93.8 acres (polygonal features only, most were mapped with linear features). Non-vegetated wetlands (small, natural open water bodies and shorlines) accounted for 2 acres.

Riparian habitat accounted for 115.2 acres, in addition to all wetland acreage. These habitats are not flooded by surface flooding or groundwater discharge, but are directly associated with the drainages and their connected wetlands. Most of these riparian habitats were mapped in association with the lower sections of the Santa Fe River and its confluence areas with Cienega Creek and Alamo Creek.

Springs and Wetlands Associated with Riverine Features. As stated, almost all of the wetland habitats mapped for this project are associated with drainages and riverine features. As these drainages cut through the overlying sediment comprising the basin, they expose areas of a complex aquifer system within the basin-fill deposits. These discharge areas provide flow to the drainages and sustain vegetated wetlands. These vegetated wetlands vary in structure from emergent, to scrub-shrub, to forested, or any mix thereof. These wetlands are affected by both surface flooding at times (spring snow melt and summer thunderstorms) and this groundwater discharge. In the wetlands mapping, an attempt was made to distinguish these wetland habitats by using the flooding frequency modifier (Water Regime Modifier) "E" (Seasonally Flooded/Saturated) to capture the seasonal surface flooding and the saturation from the groundwater discharge. Emergent vegetation species might be characterized by sedges *(Cyperus spp.)*, rushes *(Juncus spp.)* and cattail *(Typha latifolia)*, scrub-shrub and forested by willow *(Salix spp.)* and Russian olive *(Elaeagnus angustifolia)*, cottonwood *(Populus spp,)*, and other species such as Siberian elm *(Ulmus pumila)* and hackberry *(Celtis spp.)*.

A list of representative wetland and riparian vegetation, provided by the Leonora Curtin Wetland Preserve can be found in Section 6.3, Appendix C.

Seeps and "Hillside" Wetlands. These wetland features are usually near to the major drainages, but may not have a surface channel flow into the drainage, though the slope or hillside is saturated from groundwater discharge. The structure of these types of wetlands is usually emergent or scrub-shrub, or a mix thereof. In the wetlands mapping, these habitats will be identified by using the flooding frequency modifier (Water Regime Modifier) "B" (Saturated) to indicate wetness from groundwater discharge. Emergent vegetation species might be characterized by sedges *(Cyperus spp.),* rushes *(Juncus spp.)*, and scrub-shrub by willow *(Salix spp.)*.

2.6 Wetland and Riparian Data and Maps

A generalized map showing the location of 14 selected plates displaying mapped wetland and riparian features is provided in Figure 2.2. Plates 2.1 through 2.14 cover the areas of highest habitat frequency. Some sections of the project area are not displayed due to the scarcity or small number of mapped wetland/riparian features. Wetland features that contain mixed wetland vegetation classes (EM1/SS1, FO1/SS2, etc…) are displayed in this report, based on the dominant wetland class (the first class listed). The entire wetland code is displayed in or near each wetland feature.

All wetland and riparian digital vector features throughout the study area can be viewed and/or downloaded from the USFWS NWI webpage: http://www.fws.gov/wetlands/. There are a variety of methods, to be found on this site, to view and download wetland and riparian data and metadata. Complete code descriptions can also be found on this site.

Table 2.2 provides all wetland codes used for this project, the generalized habitat description, and basic information on hydrology and flooding duration. Table 2.3 lists the riparian codes used for this project along with generalized riparian habitat type, dominant vegetation and wetland association. Appendix B provides a schematic of the Riparian Classification. Following the 14 wetland mapping Plates are photos and descriptions of typical wetlands found in the La Cienega Area (Figures 2.3-2.8).

Table 2.2: Descriptions of wetland features .

Wetland Code	Generalized Wetland Habitat Type	Basic Hydrology	Flooding Duration	Human Impact
PEM1/SS1A	Freshwater Emergent Wetland	Surface Flooding	Temporary	
PEM1/SS1B	Freshwater Emergent Wetland	Groundwater	Saturated/Slope	
PEM1/SS1C	Freshwater Emergent Wetland	Surface Flooding	Seasonal	
PEM1/SS1E	Freshwater Emergent Wetland	Groundwater & Surface Flooding	Saturated & Seasonal/ Drainage	
PEM1/SS1J	Freshwater Emergent Wetland	Surface Flooding	Intermittent	
PEM1A	Freshwater Emergent Wetland	Surface Flooding	Temporary	
PEM1Ah	Freshwater Emergent Wetland	Surface Flooding	Temporary	
PEM1B	Freshwater Emergent Wetland	Groundwater	Saturated/Slope	
PEM1C	Freshwater Emergent Wetland	Surface Flooding	Seasonal	
PEM1Cx	Freshwater Emergent Wetland	Surface Flooding	Seasonal	Excavated
PEM1E	Freshwater Emergent Wetland	Groundwater & Surface Flooding	Saturated & Seasonal/ Drainage	
PEM1Eh	Freshwater Emergent Wetland	Groundwater & Surface Flooding	Saturated & Seasonal/ Drainage	Impounded
PEM1Fh	Freshwater Emergent Wetland	Surface Flooding	Semi-Permanent	Impounded
PEM1Fx	Freshwater Emergent Wetland	Surface Flooding	Semi-Permanent	
PEM1J	Freshwater Emergent Wetland	Surface Flooding	Intermittent	
PEM1Jh	Freshwater Emergent Wetland	Surface Flooding	Intermittent	Impounded
PFO1/4B	Freshwater Forested Wetland	Groundwater	Saturated/Slope	
PFO1/ EM1B	Freshwater Forested/Shrub Wetland	Groundwater	Saturated/Slope	
PFO1/SS1A	Freshwater Forested/Shrub Wetland	Surface Flooding	Temporary	
PFO1/SS1B	Freshwater Forested/Shrub Wetland	Groundwater	Saturated/Slope	
PFO1/SS1E	Freshwater Forested/Shrub Wetland	Groundwater & Surface Flooding	Saturated & Seasonal/ Drainage	
PFO1/SS2C	Freshwater Forested/Shrub Wetland	Surface Flooding	Seasonal	
PFO1B	Freshwater Forested/Shrub Wetland	Groundwater	Saturated/Slope	
PFO1C	Freshwater Forested/Shrub Wetland	Surface Flooding	Seasonal	
PFO1E	Freshwater Forested/Shrub Wetland	Groundwater & Surface Flooding	Saturated & Seasonal/ Drainage	
PFO1J	Freshwater Forested/Shrub Wetland	Surface Flooding	Intermittent	
PSS1/2A	Freshwater Forested/Shrub Wetland	Surface Flooding	Temporary	
PSS1/2C	Freshwater Forested/Shrub Wetland	Surface Flooding	Seasonal	
PSS1/4B	Freshwater Forested/Shrub Wetland	Groundwater	Saturated/Slope	
PSS1B	Freshwater Forested/Shrub Wetland	Groundwater	Saturated/Slope	
PSS1Ch	Freshwater Forested/Shrub Wetland	Surface Flooding	Seasonal	
PSS1Cx	Freshwater Forested/Shrub Wetland	Surface Flooding	Seasonal	Excavated
PSS1E	Freshwater Forested/Shrub Wetland	Groundwater & Surface Flooding	Saturated & Seasonal/ Drainage	
PSS1J	Freshwater Forested/Shrub Wetland	Surface Flooding	Intermittent	
PUBF	Freshwater Pond	Surface Flooding	Semi-Permanent	

Wetland Code	Generalized Wetland Habitat Type	Basic Hydrology	Flooding Duration	Human Impact
PUBFh	Freshwater Pond	Surface Flooding	Semi-Permanent	Impounded
PUBFx	Freshwater Pond	Surface Flooding	Semi-Permanent	Excavated
PUBHh	Freshwater Pond	Surface Flooding	Permanent	Impounded
PUBHx	Freshwater Pond	Surface Flooding	Permanent	Excavated
PUBKx	Freshwater Pond	Surface Flooding	Artificial	Excavated
PUSAh	Freshwater Pond	Surface Flooding	Temporary	Impounded
PUSAx	Freshwater Pond	Surface Flooding	Temporary	Excavated
PUSC	Freshwater Pond	Surface Flooding	Seasonal	
PUSCh	Freshwater Pond	Surface Flooding	Seasonal	Impounded
PUSCx	Freshwater Pond	Surface Flooding	Seasonal	Excavated
PUSJh	Freshwater Pond	Surface Flooding	Intermittent	Impounded
R2UBH	Riverine	Surface Flooding	Permanent	
R4SBA	Riverine	Surface Flooding	Temporary	
R4SBC	Riverine	Surface Flooding	Seasonal	
R4SBJ	Riverine	Surface Flooding	Intermittent	

Table 2.3: Riparian codes and features.

Riparian Code	Generalized Riparian Habitat Type	Dominant Vegetation	Wetland Association
Rp1EM	Herbaceous grass	Unspecified	Lotic
Rp1EM/SS6	Mixed herbaceous grass/shrub	Grass/unspecified shrub	Lotic
Rp1EM/SS6RO	Mixed herbaceous grass/shrub	Grass/Russian Olive	Lotic
Rp1FO6CW	Deciduous forest	Cottonwood	Lotic
Rp1FO6MD	Deciduous forest	Mixed	Lotic
Rp1SS6MD	Deciduous scrub-shrub	Mixed	Lotic
Rp1SS6RB	Deciduous scrub-shrub	Rabbitbrush	Lotic
Rp1SS6RO	Deciduous scrub-shrub	Russian olive	Lotic

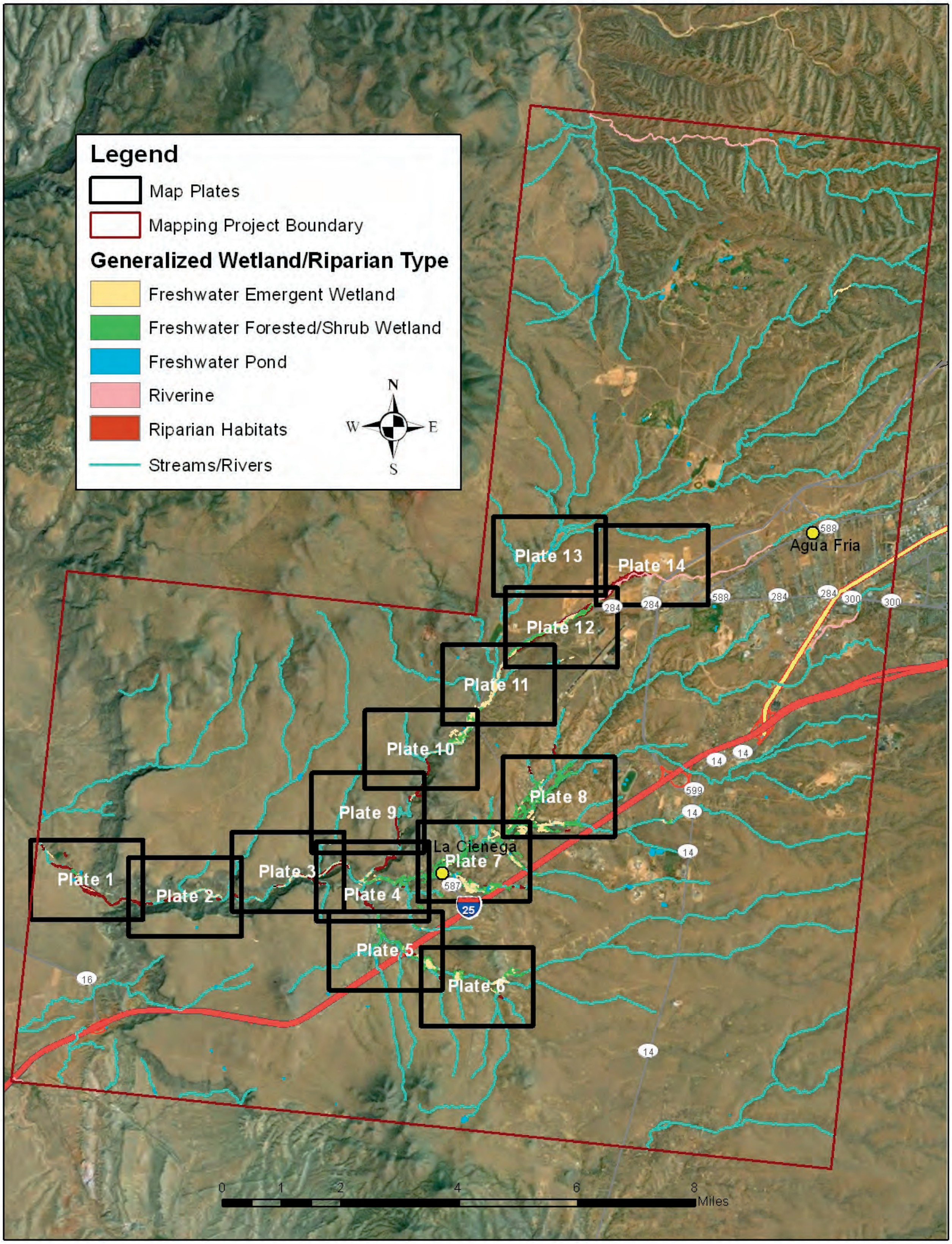
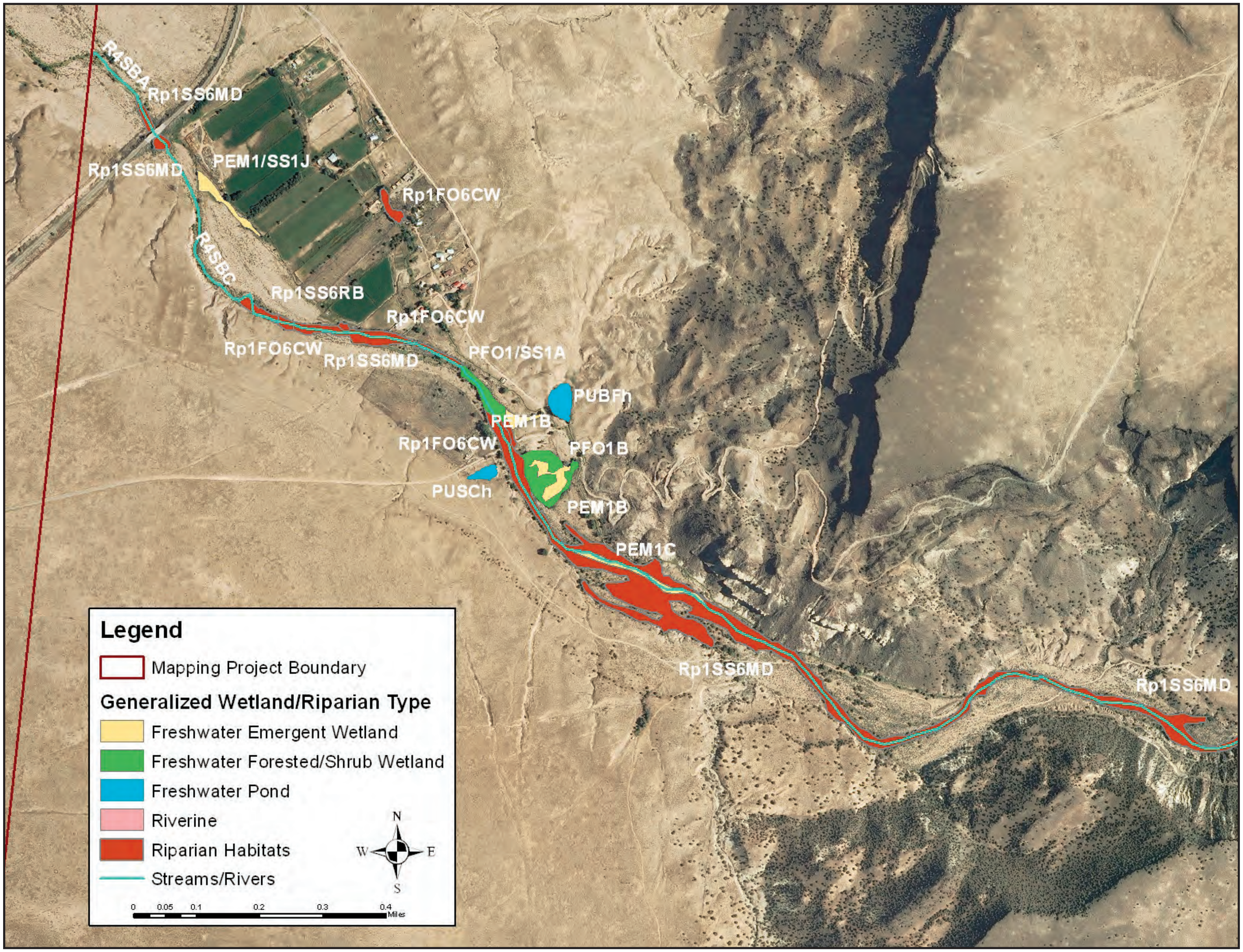


Figure 2.2: Layout of wetland and riparian data map plates.


R4SBA
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Rp1SS6MD
PEM1/SS1J
Rp1FO6CW
R4SBC
Rp1SS6RB
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Rp1FO6CW
Rp1SS6MD
PFO1/SS1A
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PEM1C
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Rp1SS6MD
Legend
Mapping Project Boundary
Generalized Wetland/Riparian Type
Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
Freshwater Pond
Riverine
Riparian Habitats
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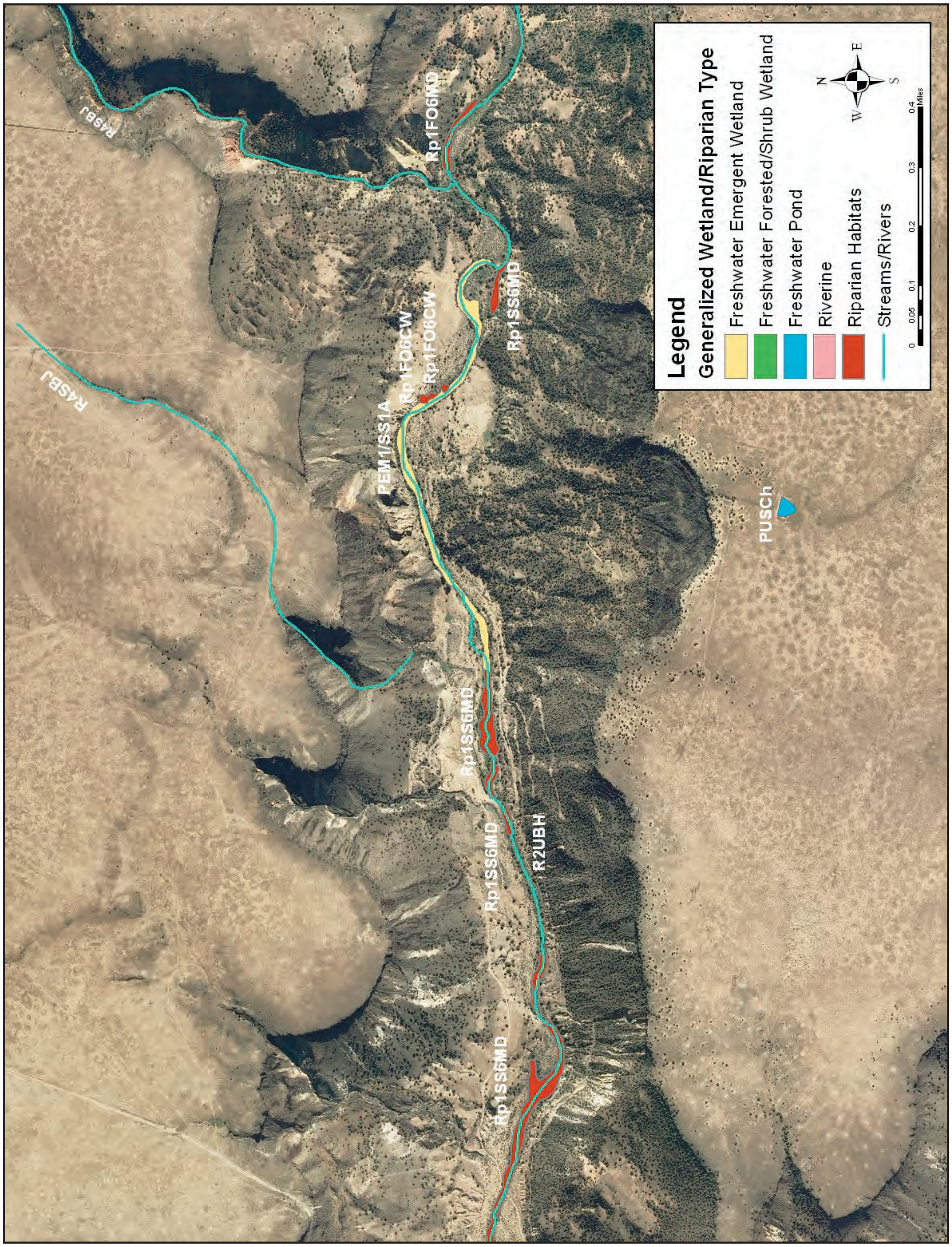
Plate 2.1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Rp1FO6CW
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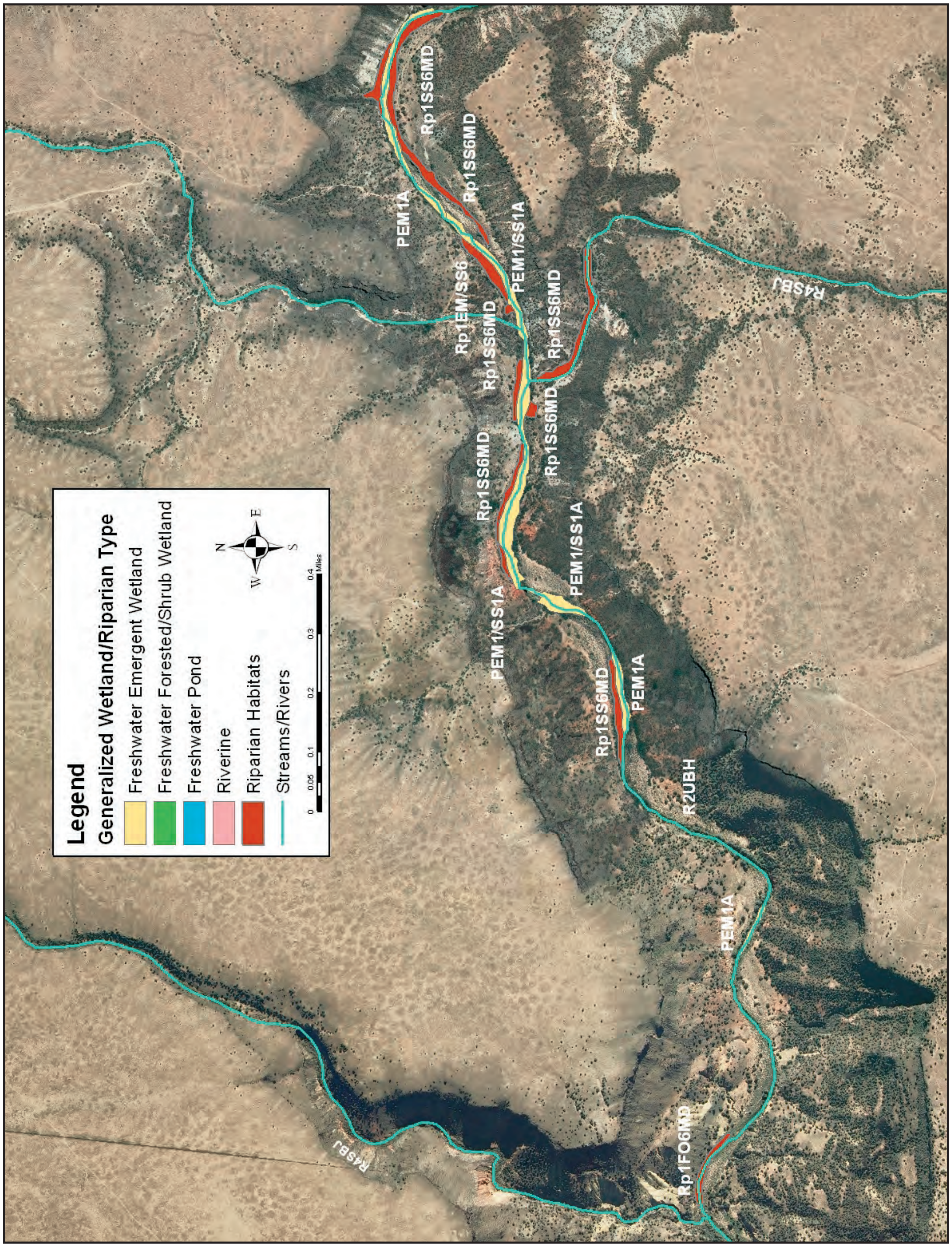
R2UBH
Rp1SS6MD

Plate 2.2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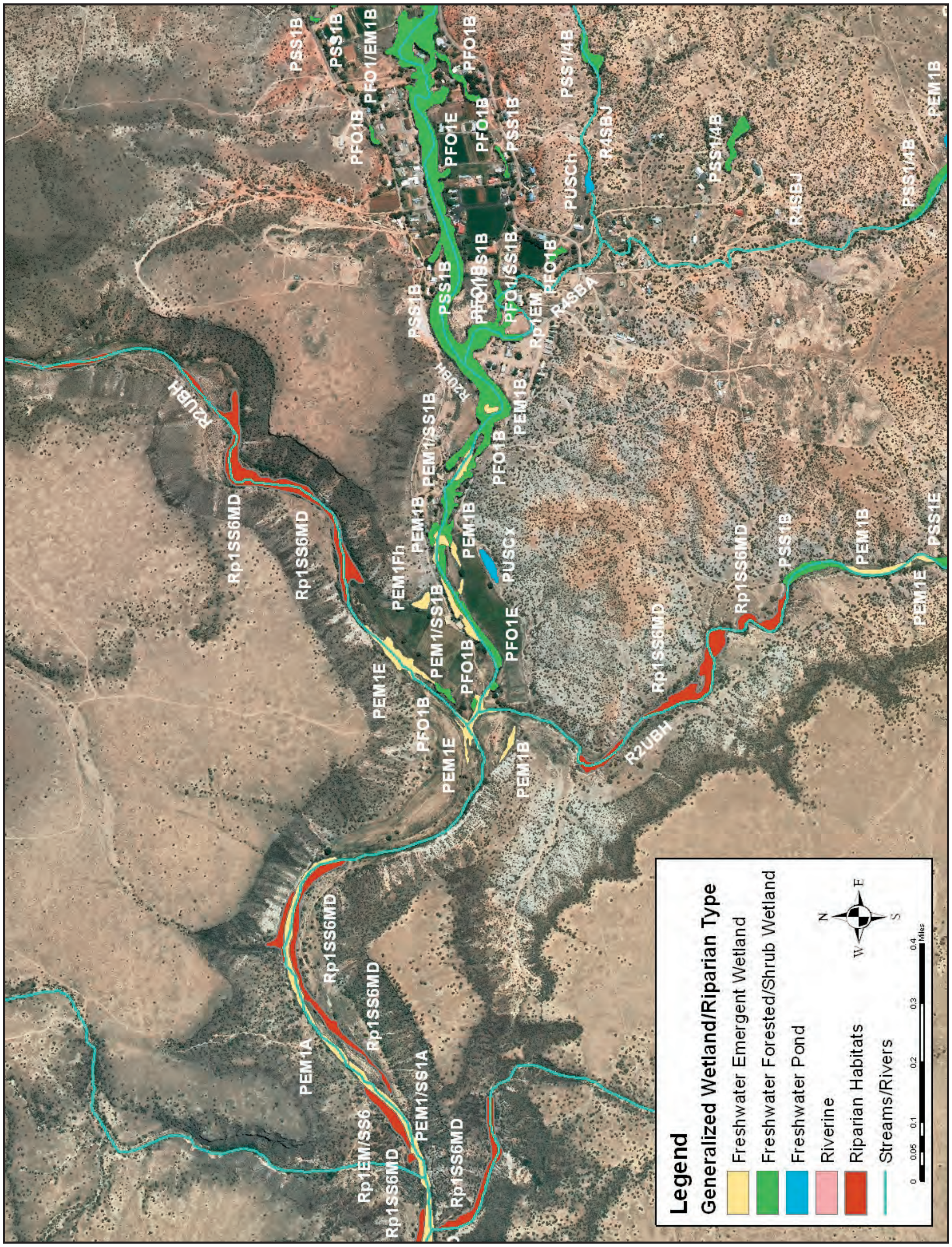
PEM1A
PEM1/SS1A
Rp1EM/SS6
Rp1SS6MD
R4SBJ
PEM1/SS1A
PEM1/SS1A
R2UBH
PEM1A
Rp1FO6MD
R4SBJ

Plate 2.3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Freshwater Pond
Riverine
Riparian Habitats
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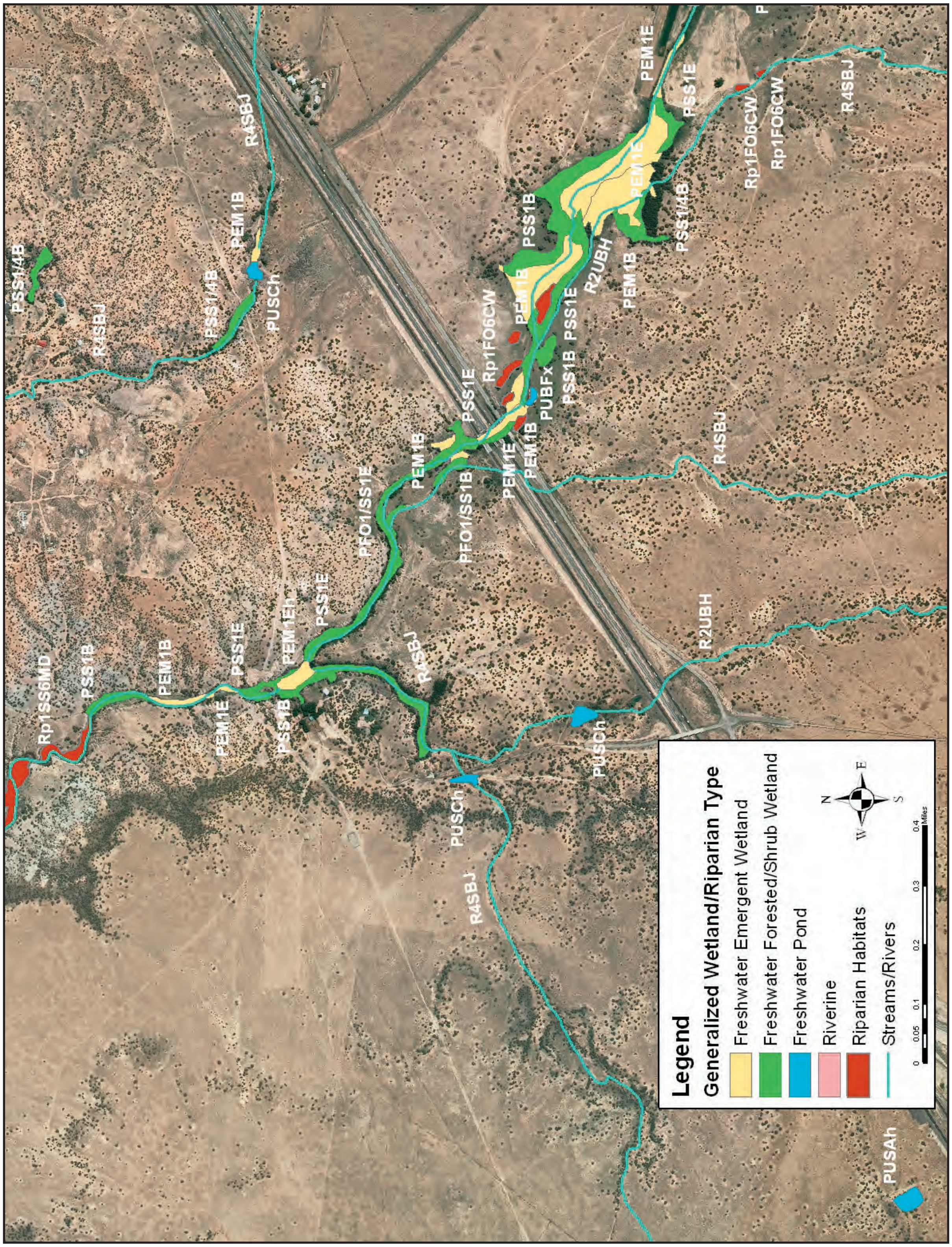
Miles

Plate 2.4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PUSCh
Rp1SS6MD
PSS1B
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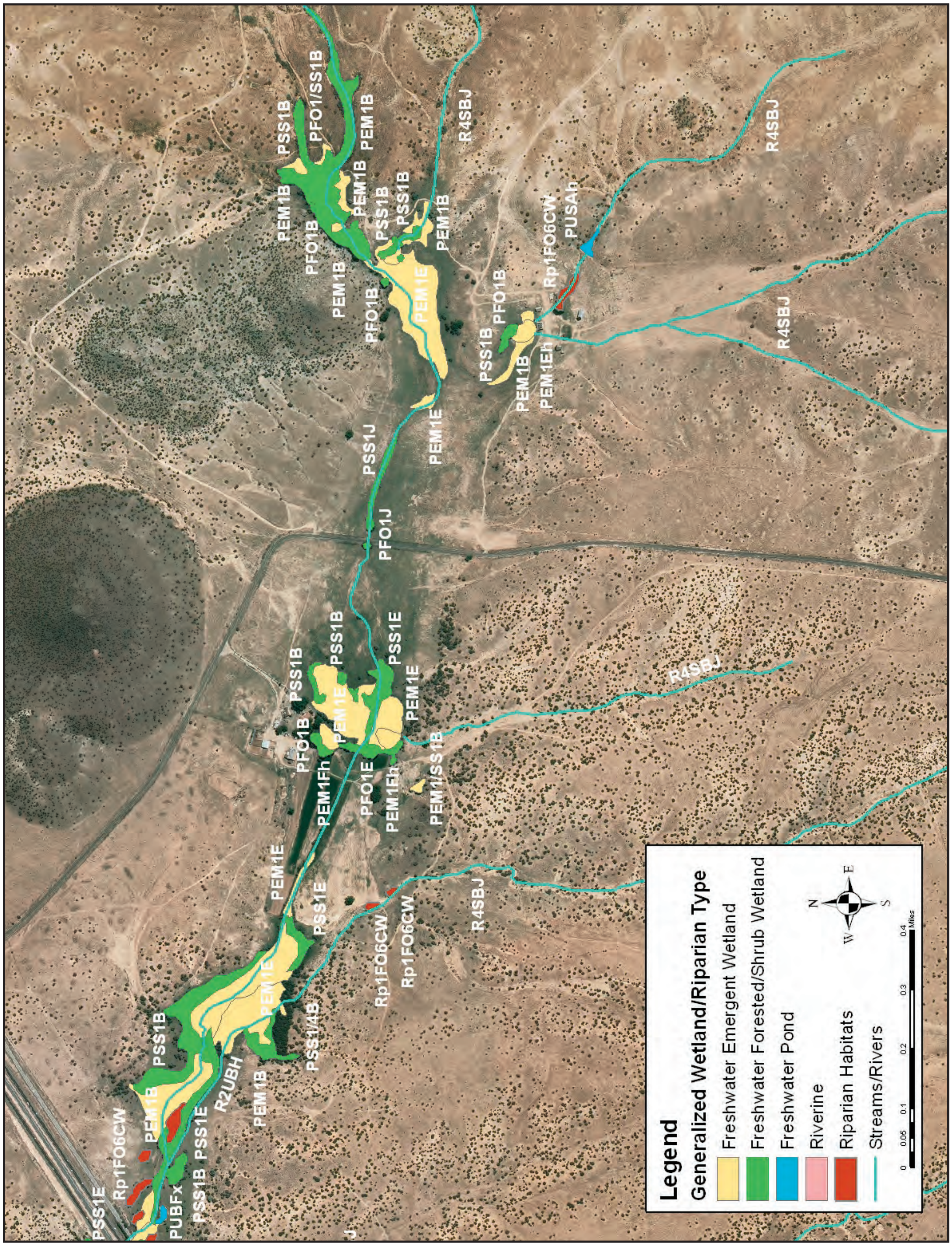
PEM1E
PSS1E
PEM1Eh
PSS1E
R4SBJ
PFO1/SS1E
PFO1/SS1B
R2UBH
PSS1/4B
PUBFx
Rp1FO6CW
R4SBJ

Plate 2.5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PFO1/SS1B
PEM1B
R4SBJ
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PFO1B
PSS1B
PFO1B
PEM1E
Rp1FO6CW
PUSAh
PFO1B
PSS1B
PEM1B
PEM1Eh
PSS1J
PEM1E
PFO1J
PSS1E
PEM1E
PEM1Fh
PFO1E
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PEM1/SS1B
PSS1B
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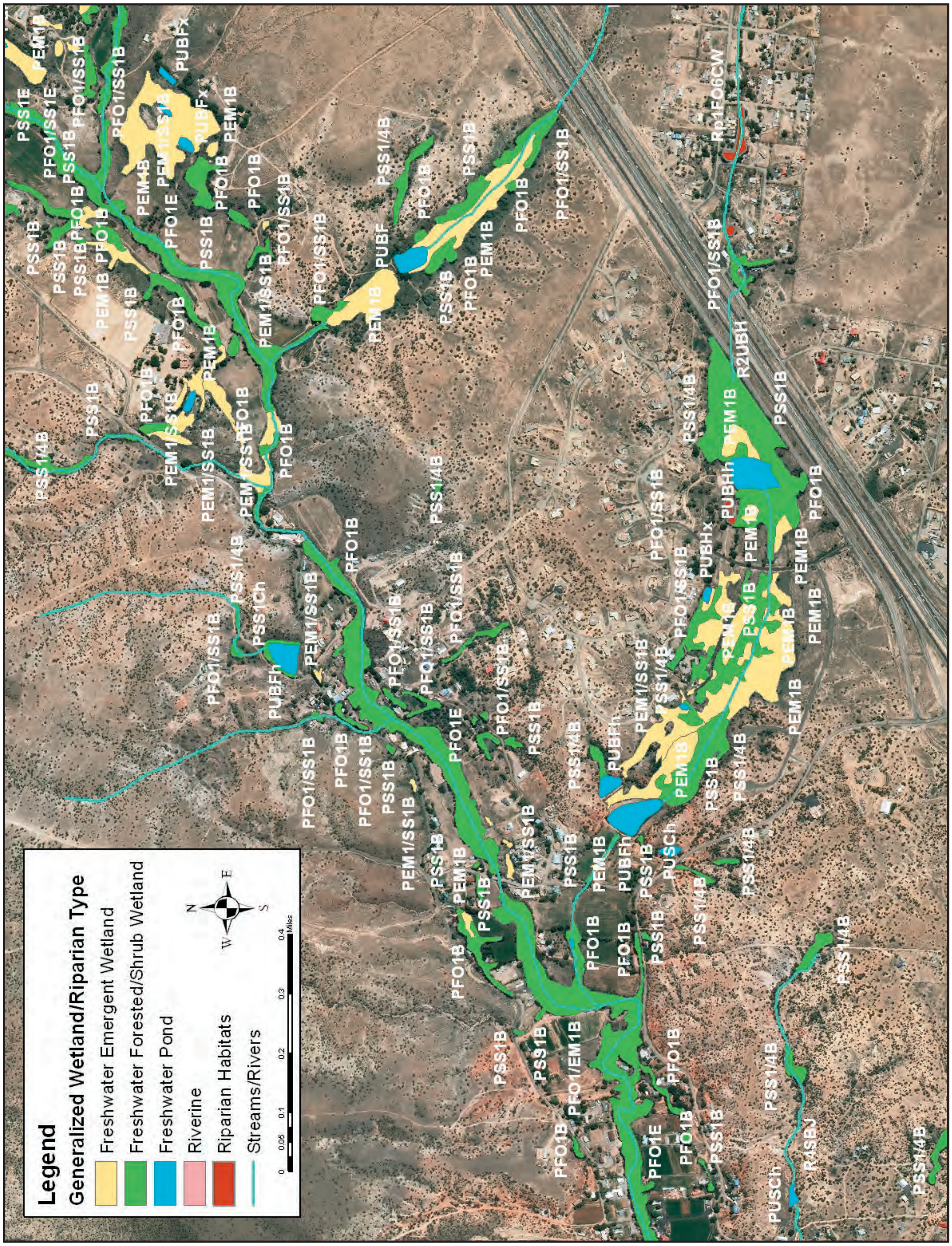
PSS1/4B
Rp1FO6CW
PUBFx
PSS1E

Plate 2.6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Generalized Wetland/Riparian Type
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Riparian Habitats
Streams/Rivers
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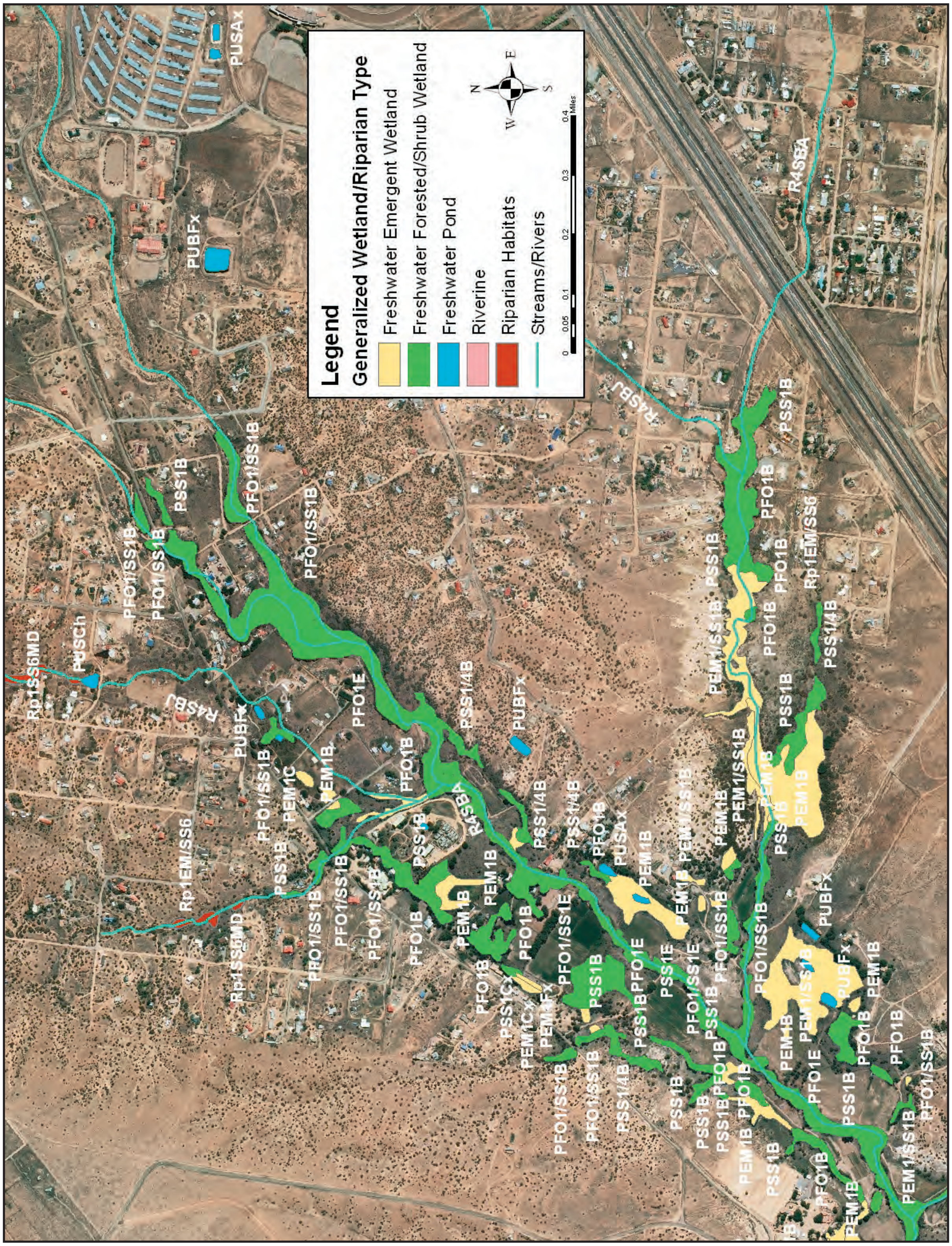
Plate 2.7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Generalized Wetland/Riparian Type
Freshwater Emergent Wetland
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Riparian Habitats
Streams/Rivers
0 0.05 0.1 0.2 0.3 0.4 Miles
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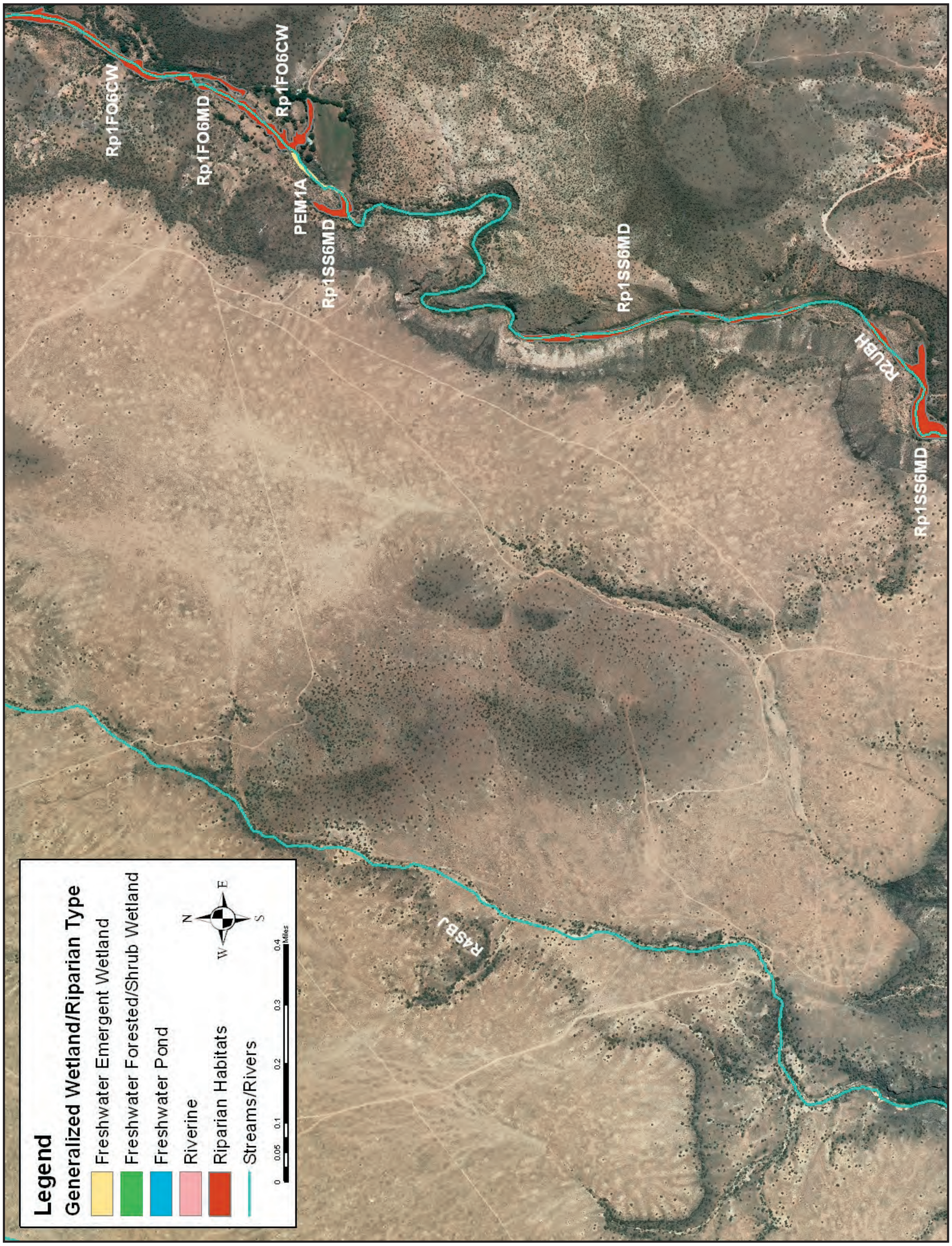
Plate 2.8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Rp1FO6MD
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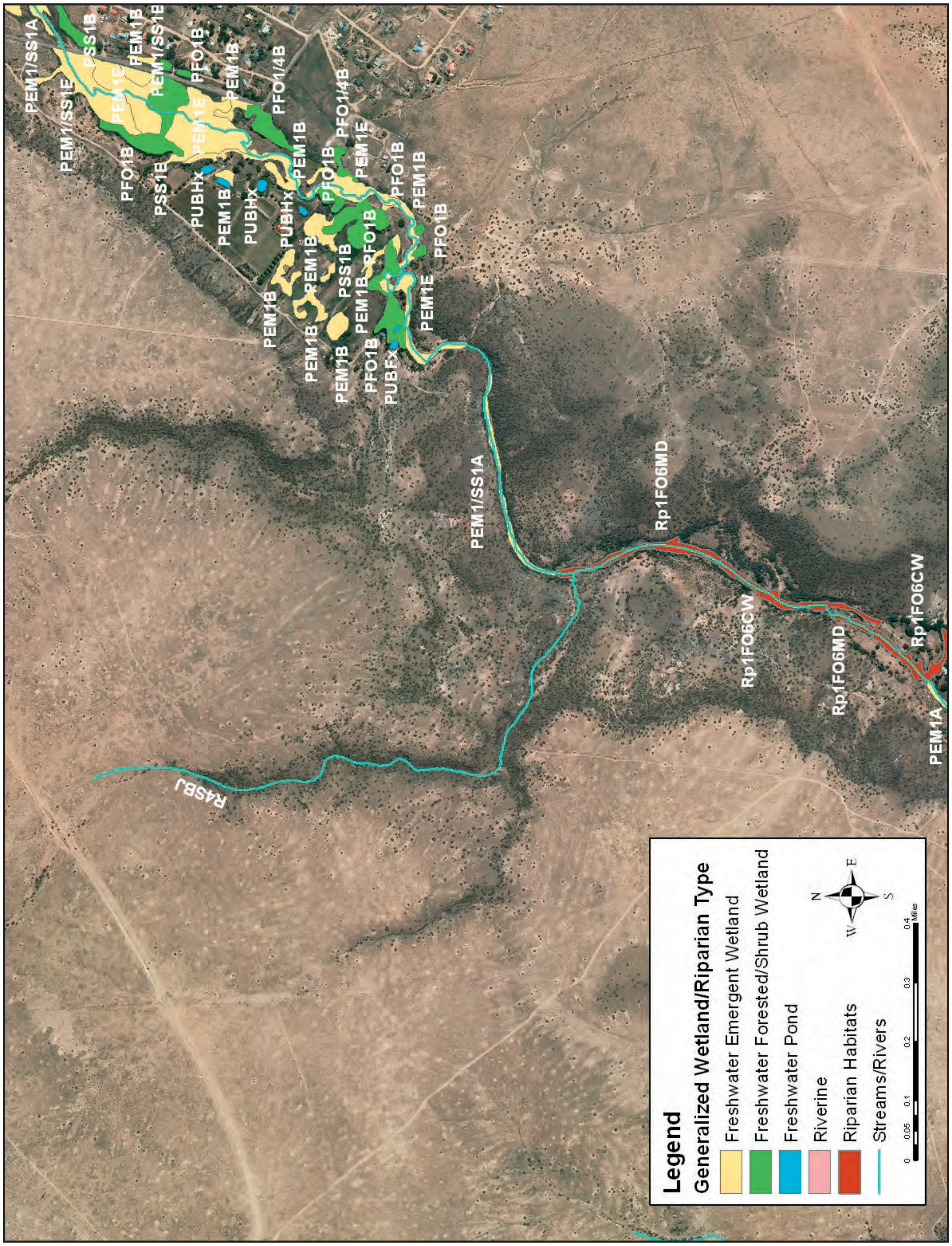
Rp1SS6MD
R2UBH
Rp1SS6MD
R4SBJ

Plate 2.9


Legend
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Freshwater Pond
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0.2
0.3
0.4
Miles
PEM1/SS1A
PEM1/SS1E
PSS1B
PEM1B
PEM1/SS1B
PFO1B
PFO1/4B
PSS1E
PUBHx
PEM1E
PUBFx
PEM1A
PEM1/SS1A
Rp1FO6MD
Rp1FO6CW
R4SBJ

Plate 2.10

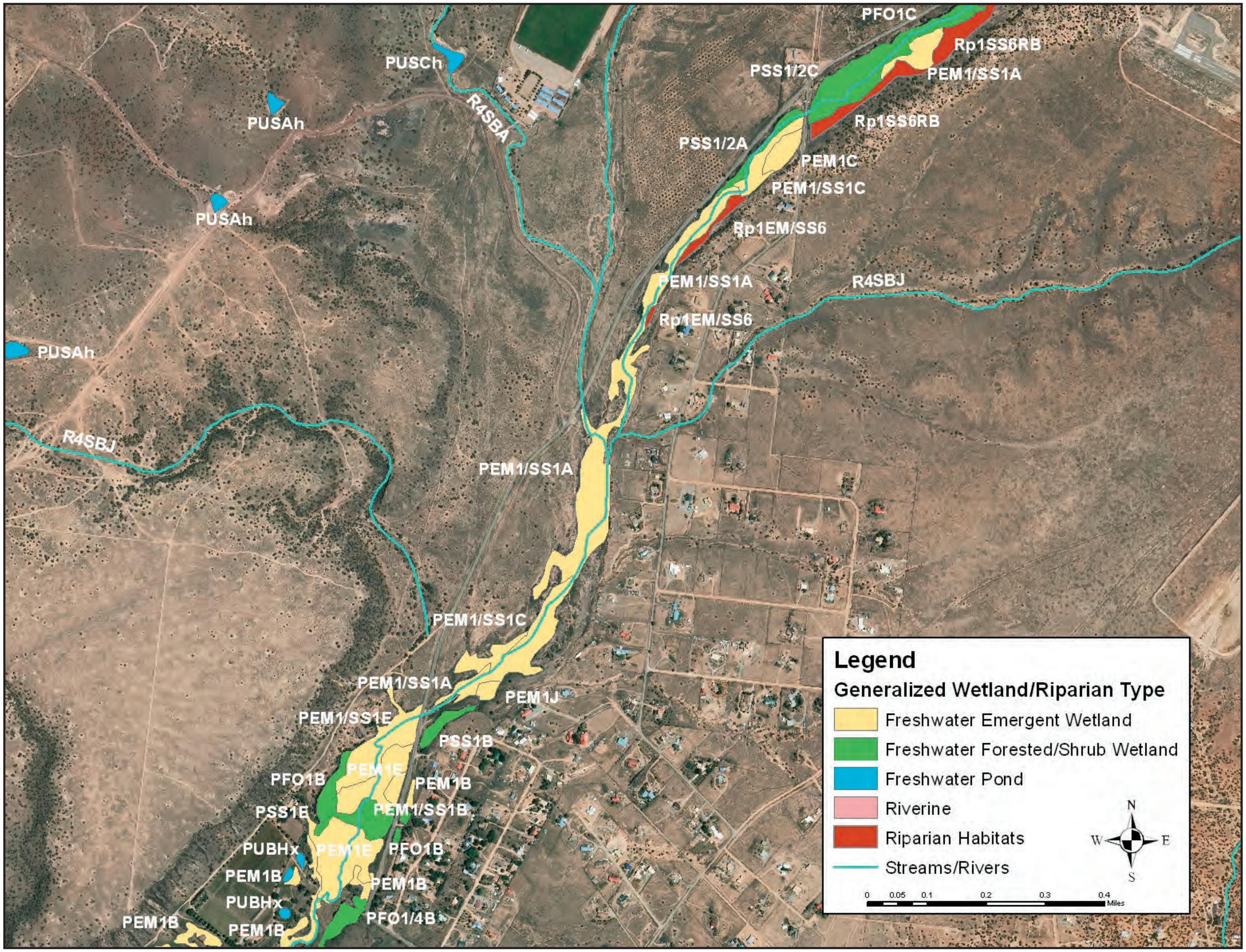
PFO1C
Rp1SS6RB
PEM1/SS1A
PUSCh
PSS1/2C
Rp1SS6RB
PUSAh
R4SBA
PSS1/2A
PEM1C
PEM1/SS1C
PUSAh
Rp1EM/SS6
PEM1/SS1A
R4SBJ
Rp1EM/SS6
PUSAh
R4SBJ
PEM1/SS1A
PEM1/SS1C
PEM1/SS1A
PEM1J
PEM1/SS1E
PSS1B
PEM1E
PFO1B
PEM1B
PSS1E
PEM1/SS1B
PUBHx
PEM1E
PFO1B
PEM1B
PUBHx
PEM1B
PEM1B
PEM1B
PFO1/4B
Legend
Generalized Wetland/Riparian Type
Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
Freshwater Pond
Riverine
Riparian Habitats
Streams/Rivers
N
W
E
S
0
0.05
0.1
0.2
0.3
0.4
Miles

Plate 2.11

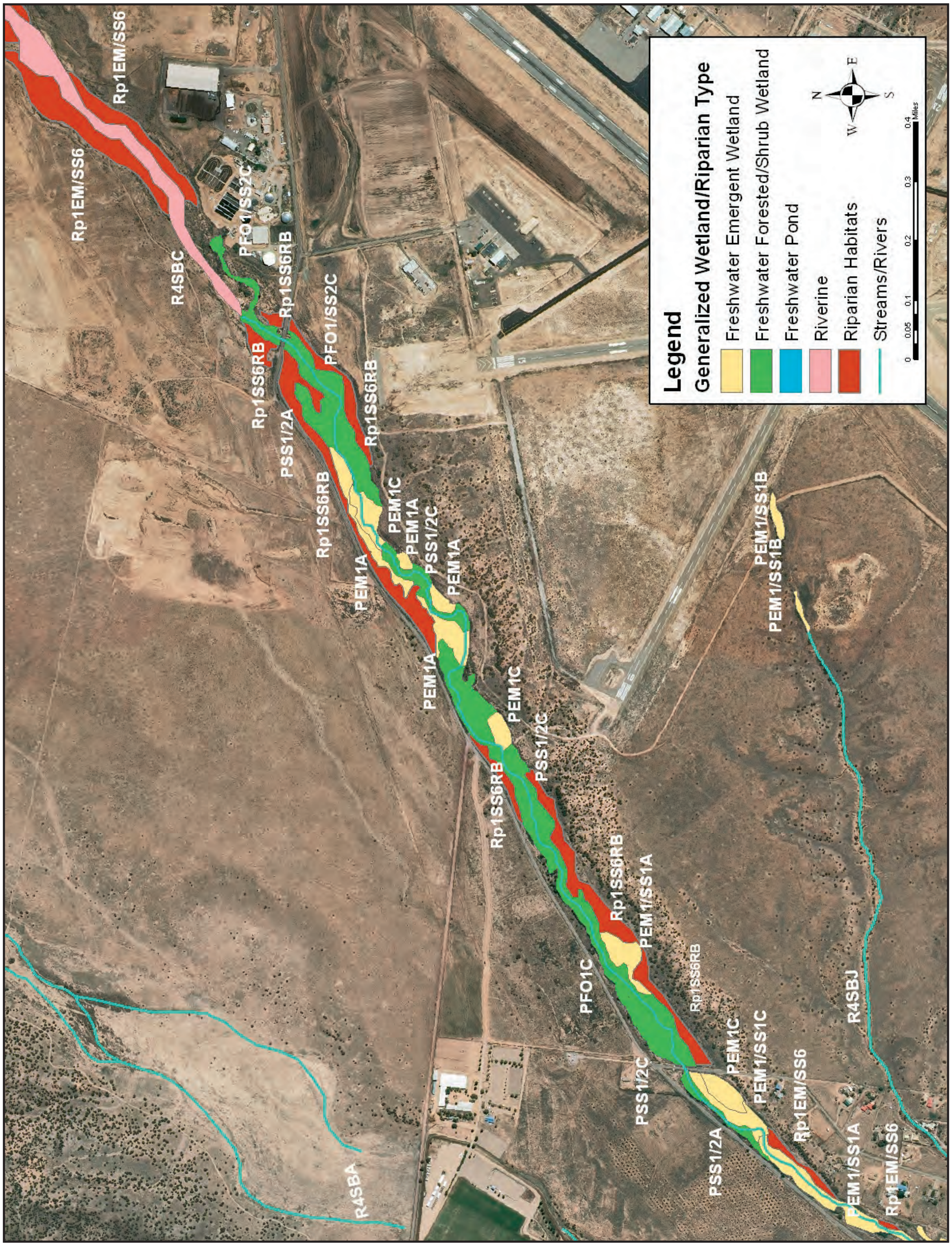
Legend
Generalized Wetland/Riparian Type
Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
Freshwater Pond
Riverine
Riparian Habitats
Streams/Rivers
N
E
S
W
0
0.05
0.1
0.2
0.3
0.4
Miles
Rp1EM/SS6
R4SBC
PFO1/SS2C
Rp1SS6RB
PFO1/SS2C
PSS1/2A
PEM1A
PEM1C
PSS1/2C
PEM1/SS1A
PFO1C
PEM1/SS1C
PEM1/SS1B
R4SBJ
R4SBA
PEM1/SS1A
Rp1EM/SS6

Plate 2.12

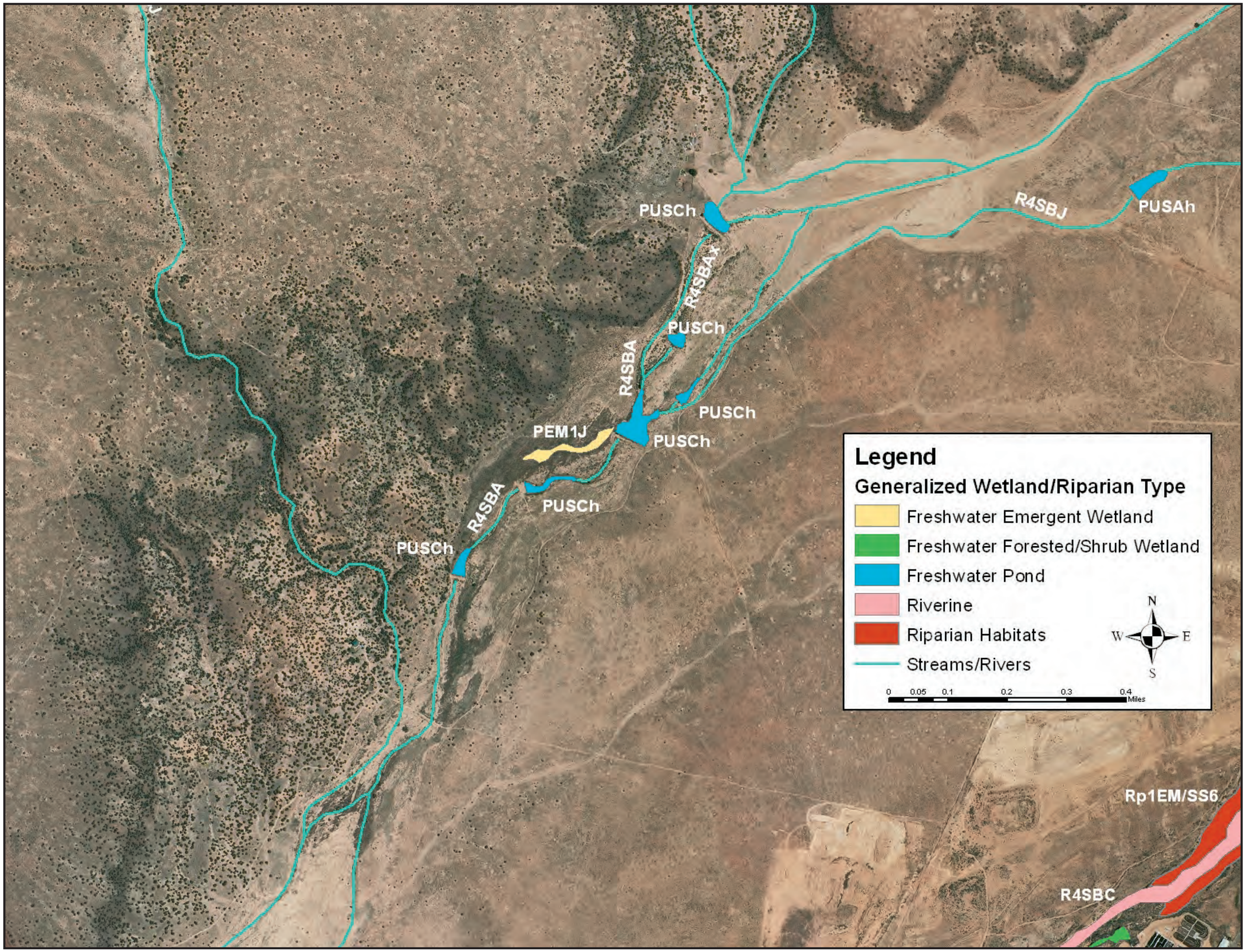
Legend
Generalized Wetland/Riparian Type
Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
Freshwater Pond
Riverine
Riparian Habitats
Streams/Rivers
N
W
E
S
0
0.05
0.1
0.2
0.3
0.4
Miles
PUSCh
PUSAh
R4SBJ
R4SBAx
R4SBA
PEM1J
Rp1EM/SS6
R4SBC

Plate 2.13

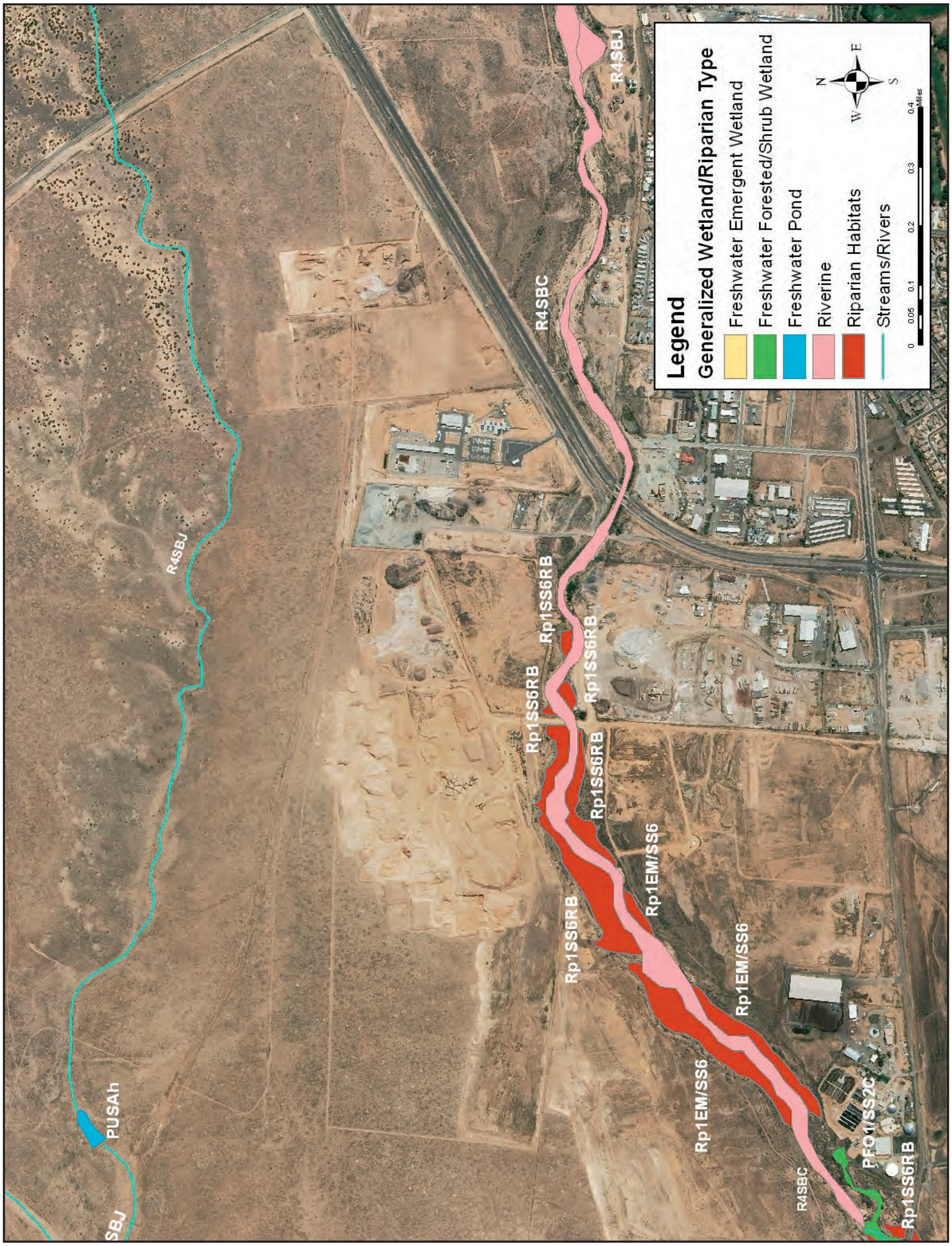
Legend
Generalized Wetland/Riparian Type
Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
Freshwater Pond
Riverine
Riparian Habitats
Streams/Rivers
N
E
S
W
0 0.05 0.1 0.2 0.3 0.4 Miles
R4SBJ
R4SBC
Rp1SS6RB
Rp1EM/SS6
PUSAh
PFO1/SS2C
SBJ

Plate 2.14

2.7 Wetland Habitats- Photographic Examples

Figure 2.3: Pond (PUBH) with emergent fringe (PEM1F) and forested/shrub mix (PFO1/SS1A) in the background. *Photo by Maryann McGraw*

Figure 2.4: Slope emergent and shrub wetlands (PEM1B and PSS1B). *Photo by Maryann McGraw*

Figure 2.5: Drainage is groundwater-fed, with seasonal surface flooding potential (PEM1E). Foreground is slope emergent wetland (PEM1B). *Photo by Maryann McGraw*

Figure 2.6: Another groundwater-fed drainage with evidence of seasonal surface flooding (PEM1/SS1E: note flood damaged vegetation and debris). *Photo by Jim Dick*

Figure 2.7: Forested wetland along groundwater-fed stream (PFO1E) with potential forested riparian fringe (Rp1FO6CW). *Photo by Maryann McGraw*

Figure 2.8: Man-made shallow pond (PUSCh) within hillside (slope) emergent scrub/shrub wetland (PEM1/SS1B). *Photo by Jim Dick*