City of Albuquerque Bosque Management Plan: Central Avenue to Campbell Road

Prepared for:
City of Albuquerque
Open Space Division
3615 Los Picaros SE
Albuquerque, NM 87105

Prepared by:
GeoSystems Analysis
3150 Carlisle Blvd. NE,
Albuquerque, NM 87110
www.gsanalysis.com

THIS PAGE INTENTIONALLY BLANK

DOCUMENT CONTROL SUMMARY

Title:	City of Albuquerque Bosque Management Plan: Central Avenue to Campbell Road		
Client Company:	City of Albuquerque Open Space Division		
Client Contact:	Dr. Matthew Schmader		
Status:	Draft		
GeoSystems Analysis Job #:	1609		
Project Manager:	Todd Caplan		
Author(s):	Chad McKenna, Todd Caplan		
Revision Number:			
Notes:	Client review draft		
Date:	June 30, 2016		
Checked By:			
Distribution	Client	Other	GSA Library
(Number of Copies):	1 electronic copy		

THIS PAGE INTENTIONALLY BLANK

DRAFT: City of Albuquerque Bosque Management Plan:

Central Avenue to Campbell Road

Citation

GeoSystems Analysis 2016. DRAFT: City of Albuquerque Bosque Management Plan: Central Avenue to Campbell Road. Prepared for City of Albuquerque Open Space Division. Prepared by GeoSystems Analysis, Inc. Albuquerque, NM. June 2016.

Name	Affiliation	Role
Todd Caplan	GeoSystems Analysis, Inc.	Project Manager
Chad McKenna	GeoSystems Analysis, Inc.	Principal Investigator
Lindsey Bunting	GeoSystems Analysis, Inc.	Soil Scientist
William Widener	GeoSystems Analysis, Inc.	Botanist

THIS PAGE INTENTIONALLY BLANK

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

The City of Albuquerque Open Space Division (OSD) contracted GeoSystems Analysis, Inc. (GSA) to develop a habitat restoration plan for a 170-acre portion of the Rio Grande bosque between Central Avenue Bridge and Campbell Road (**Figure 1**). This area is an OSD management priority for several reasons, not the least of which includes the site's proximity to the Albuquerque Aquarium and BioPark, its high public visitation and visibility, and its need for prescriptive management due, in part, to its history of catastrophic fires and relatively expansive patches of annual weeds. The project area has also hosted a number of revegetation and habitat improvement projects implemented by others over the past decade, including exotic tree thinning, cottonwood and riparian shrub plantings and several bankline lowering and backwater channel projects (**Figure 2**). AOS's vision is to expand upon the successes of these previous projects, beginning with a comprehensive restoration plan for the entire site.

The purpose of this project is multi-fold:

- Assess the vegetation, soils, and groundwater hydrology as a foundation for determining management needs and restoration opportunities;
- Develop a comprehensive geo-spatial database of baseline site conditions;
- Identify a range of restoration options and spatially explicit management recommendations;
- Provide a phased implementation schedule with the goal of completing the restoration work within a 10-year time frame.

The information collected and presented in this report is intended to provide the foundation for systematic restoration management of the project site. Additional detailed data beyond the scope of this project may be required in some instances to bring certain projects ideas (e.g., off-channel aquatic or seasonally flooded habitats) from a general conceptual-level to more detailed design-level, especially to guide construction and support any requisite environmental permitting.

FIGURE 1. PROJECT AREA MAP

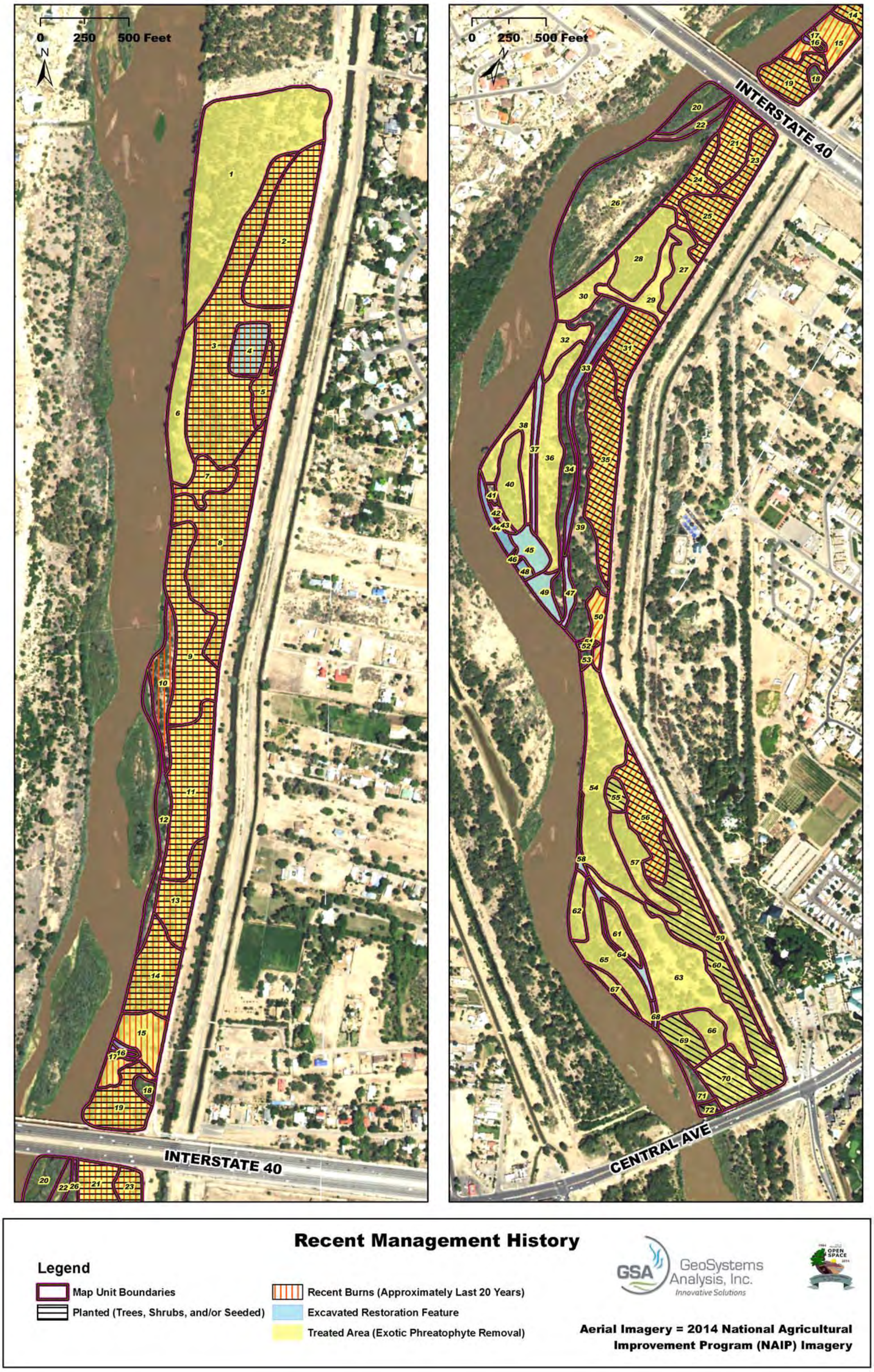

FIGURE 2. MAP SHOWING PREVIOUS FIRES AND RESTORATION ACTIVITIES

METHODS

FIELD SURVEY

At the beginning of this project, GSA staff met with OSD for a “project kickoff meeting” to discuss OSD management objectives, priorities, and implementation schedule. Following that meeting, GSA allocated a team of field staff including two field ecologists, a botanist, and a soil scientist to perform various field assessments during periodic site visits conducted through the spring of 2016. As discussed in the following sections, major field activities included:

- Map unit delineation;
- Soils assessment;
- Noxious weed survey

MAP UNIT DELINEATION

Detailed mapping of the site was completed during spring 2016. During this effort, the site was initially divided into unique vegetation assemblages according to a modified Hink and Ohmart vegetation classification system. This vegetation classification system distinguishes vegetation community types based on species dominance, woody plant canopy cover and canopy height diversity. A total of six structure types are used in this classifications system to describe woody plant canopy height and percent aerial cover. Dominant and co-dominant tree and shrub species are listed for both the overstory (canopy) and understory layers. In both layers, any woody plant species with greater than 25 percent cover is included in the community name (see Hink and Ohmart 1984 for more information). During post-processing, the Hink and Ohmart type was simplified for display and summary purposes but electronic data that accompany this report contain the full Hink and Ohmart vegetation type.

The modified Hink and Ohmart classification system also provides suffix categories for open water, marsh habitats, and wet meadows, which are labeled as “OW”, “MH”, and “WM”, respectively. Open, barren areas that are sparsely vegetated by woody plants, lack an abundance of perennial grasses, and lack wetland herbaceous species are described as type “OP”. Recently formed, unvegetated sandbars are marked as type “SB” while grasslands are labeled as “G”.

For the purpose of our site assessment, vegetation types were then further subdivided into multiple "map units" based upon differences in dominant soil condition, the presence of a unique hydrologic or geomorphic traits (like an abandoned backwater or side channel, pools of water, swale depressions, or high terraces), and/or major shifts in annual weed cover. This mapping approach yielded 72 individual map units at the site (**Figure 3**) of variable size and dimension. Mean and median map unit size were 2.4 acres and 1.6 acres, respectively. Individual map unit area ranged from less than a tenth of an acre to greater than 12 acres.

Field data were captured using a custom mobile app that was developed to record map unit assessment data for this project using the Fulcrum® mobile platform. Data were logged using an Apple® iPad® connected to a Bluetooth GPS rated at +/- 10 foot horizontal accuracy. The primary data elements recorded at each map units included:

- General background information such as, observer, date, map unit number;
- Total canopy cover in four height classes: >40 ft, 20-40 ft, 5-20 ft, <5 ft;
- Relative canopy cover by species (i.e. species composition) in overstory layers (>20 ft) and understory layers (<20 ft);
- The Hink and Ohmart vegetation type;
- Recent major disturbances and management activities that affected the vegetation type designation including fuels reduction treatments (thinning of exotic trees and shrubs), revegetation, and fire;
- Aerial cover by perennial graminoids, annual weeds, and plant litter;
- Dominant perennial graminoid species;
- Hydrologic indicators including: surface water present, moist soil, debris and/or watermarks on vegetation, sediment deposits, drainage patterns;
- General map unit notes, as well as, maintenance and management notes and opportunities for habitat enhancement;
- At least one representative photograph of the map unit.

Ocular estimates of tree and shrub canopy cover were recorded for each map unit according to the standard Hink & Ohmart cover class categories: 0%, <1%, 1-5%, 6-25%, 26-50%, 51-75%, >75%. These data were recorded for total cover and relative species cover within each canopy layer (i.e., >40 ft., 20-40 ft. <20 ft.) so that Hink and Ohmart vegetation and structure types could be determined. Cover for other "non-woody" plant material such as annual weeds, litter, perennial forbs, and perennial graminoids were recorded using slightly different cover classes: <5%, 6-10%, 11-25%, 26-50%, 51-75%, 76-90%, and >90%.

FIGURE 3. MAP UNIT, SOIL, VEGETATION SAMPLING LOCATION MAP

SOILS ASSESSMENT

Soil characteristics were documented by a soil scientist at a total of 35 auger locations distributed according to variations in site topography and vegetation type (**Figure 3**). At each auger location, a hole was augered from the soil surface down to the alluvial aquifer (groundwater), or until rocks, cemented layers, or sand caving prevented auger advancement. The soil profile was segregated into discrete layers having similar soil conditions (e.g., according to textural differences) and the beginning and ending depth (i.e. depth interval) was measured for each layer. Excavated material was emptied into a five-gallon bucket until a different soil layer was encountered and the soil scientist described the following soil characteristics for that layer in accordance with standard practices for describing and identifying soils:

- Moisture content (dry, slightly moist, moist, wet, saturated) per the feel method;
- Estimated percent sand, silt, clay, and gravel;
- Sand fraction (very fine, fine, moderate, coarse, very coarse);
- HCl reaction (none, weak, moderate, strong);
- Color;
- Presence of redoximorphic features;
- Depth to groundwater;
- Other site notes and comments.

Soil characteristics were entered into an iPad® via a custom electronic field form developed for this project that utilizes the Fulcrum® mobile app. Data were exported from Fulcrum® and post-processed in Excel®. Percent sand, silt, and clay was gravel corrected and used to assign the appropriate U.S. Department of Agriculture soil texture class (e.g. sand, loamy sand, sandy loam, silt loam, loam, sandy clay loam, silty clay loam, clay loam, sandy clay, silty clay, or clay) during post-processing.

NOXIOUS WEED SURVEY

A botanist conducted a noxious weed survey of the site during May 2016 via traversing regularly spaced transects (approximately 100 feet apart) across the site. When herbaceous noxious weeds were encountered, the perimeter of the patch was recorded with a sub-meter rated GPS unit equipped with ESRI® ArcPad®. During the survey, the botanist searched for herbaceous species that have Class A or B management status according the New Mexico Department of Agriculture (NMDA), for federally-listed noxious weeds, and for tree of heaven (*Ailanthus altissima*). Tree of heaven (listed by NMDA as Class B) populations were included in the survey because successful control of that species requires more specialized, repeated, and intensive management than other tree species common to the bosque such as Siberian elm (*Ulmus pumila*), saltcedar (*Tamarix* spp), and Russian olive (*Elaeagnus angustifolia*). Individual saltcedar, Russian olive, and Siberian elm plants were not recorded as part of the noxious weed survey, but spatial distribution of larger groupings (i.e., ≥ 25% canopy cover) of these species were documented at the map unit scale during Hink & Ohmart vegetation mapping.

DATABASE DEVELOPMENT

After field data collection was completed, raw field data were exported from Fulcrum® into Excel® and ArcGIS Desktop® where they could be post-processed and used as a spatially explicit management and decision-making tool. The resulting geo-database serves various purposes including;

- Spatially document current ecological conditions,
- Detecting maintenance and management needs,
- Ranking management and maintenance priorities for each map unit, and
- Predicting habitat potential on a map unit basis.

The data format and structure also allows the geo-database to serve as a useful tool for estimating the quantities and costs of maintenance, management, and other various actions such as exotic plant species management, revegetation, and wetland creation. During this geo-database development process, combinations of specific field attributes were used to assign a priority class for various management and maintenance needs, as well as, restoration opportunities using classes that rank map units relative to other map units through the site (see the class definitions in various tables included in the results section).

GROUNDWATER INTERPOLATIONS

In riparian areas, phreatophytic trees and shrubs depend on moist soil conditions, particularly in the unsaturated soil zone immediately above the groundwater table to meet their water demands for survival and growth. Estimates of seasonal groundwater depth, particularly under typical "low water" growing season conditions, combined with knowledge of overlying soil characteristics, serve as essential guides for prescribing spatially explicit plant palettes, plant material types/sizes, planting densities, and for determining need for and approach to supplemental irrigation during the plant establishment period.

Intensive, high resolution groundwater modeling was outside the scope of this project, and previous riparian groundwater models are outdated, low-resolution, and not calibrated to nearby wells, so to better understand low water growing season conditions, we utilized a relatively simple GIS process to predict depth to groundwater. A combination of recent (2012) Light Detection and Ranging (LiDAR) data and depth to groundwater measurements recorded at U.S. Army Corps of Engineers (Corps) monitoring wells in and around the project site were used to spatially predict depth to groundwater. Well measurements recorded during typical base flow (600 to 650 cfs) conditions were used to interpolate a groundwater surface in the Spatial Analyst® extension for ESRI® ArcGIS®. The result of this interpolated surface was then subtracted from the LiDAR derived ground elevation to predict depth to groundwater through the project site when Rio Grande discharge equals approximately 650 cfs (as measured at the USGS Gage at Central Ave).

RESULTS

VEGETATION TYPES

Approximately 46% of the site (78.5 acres) was generally described as a forest type with a relatively dense understory (**Table 1**). Forests with little to no understory spanned 61.7 acres, as the second most common type described at the site. Shrublands are uncommon at the site. Portions of the site that lacked an overstory canopy layer were typically barren. About 21 acres, or 12%, of the site was described as Open Area / Barren. As described in the following sections, the open and barren areas are recommended as highest management priorities for site restoration.

TABLE 1. GENERAL VEGETATION TYPE SUMMARY TABLE

General Map Unit Category	Acres	Number of Map Units
Forests with relatively dense understory	78.5	34
Forests with little to no understory	61.7	16
Dense shrublands	4.4	8
Sparse shrublands	1.8	1
Open/Barren areas	21.2	9
Open water	1.0	3
Sandbar	1.0	1

Rio Grande cottonwood (*Populus deltoides*, ssp *wislizeni*) was the most common species included as a (co-) dominant species at the site (30 of the 72 map units). Cottonwood-dominated map units covered about 61% of the total project site acreage (**Table 2**). Russian olive and Siberian elm were the second and third most common species, respectively, as determined by vegetation type at the site. Native understory shrubs were very uncommon and patches were generally widely spaced. In fact, coyote willow (*Salix exigua*) was the only native shrub species that was included as a co-dominant species at the site (the only exception was fourwing saltbush [*Atriplex canescens*], which was a co-dominant in only one map unit). Given this observation, re-establishment of native understory species across the site is recommended as a mid-term restoration goal, as discussed later in this report.

A list of the vegetation types described for the site along with their total area and the number of map units assigned to this vegetation type are included in **Table 3**. The most frequently encountered and largest (by area) type was a cottonwood overstory with little understory. That type spanned 54 acres of the site and is particularly common in pole planted portions of the I-40 burn (**Figures 4 and 5**). Cottonwood overstory with various (typically exotic dominated) combinations of understory species were also common throughout the site. Non-native woody species were variable in size and well represented in both the overstory and understory layers throughout the site.

TABLE 2. DOMINANT SPECIES ACREAGE SUMMARY

Species	Acres	Number of Map Units
Rio Grande cottonwood	104.2	30
Coyote willow	31.4	20
Russian olive	74.7	29
Siberian elm	46.7	24
Saltcedar	12.8	5
Tree of heaven	0.3	1
Fourwing saltbush	1.6	1
Mulberry	6.2	3

TABLE 3. DETATILED VEGETATION TYPE SUMMARY

Vegetation Type	Acres	Number of Map units
Cottonwood - Russian olive overstory / Coyote willow understory (Dense)	0.3	1
Cottonwood - Siberian elm - Russian olive overstory / Coyote willow - Siberian elm understory (Dense)	3.2	1
Cottonwood - Siberian elm overstory / Siberian elm - mulberry - Russian olive understory (Patchy understory)	1.6	1
Cottonwood overstory with little understory	54.4	13
Cottonwood overstory / Coyote willow understory (Dense)	0.9	1
Cottonwood overstory / Russian olive - coyote willow understory (Dense)	2.1	1
Cottonwood overstory / Russian olive - mulberry understory (Patchy understory)	3.4	1
Cottonwood overstory / Russian olive - Siberian elm - coyote willow understory (Patchy understory)	1.1	1
Cottonwood overstory / Russian olive - Siberian elm - Saltcedar understory (Patchy understory)	8.8	3
Cottonwood overstory / Russian olive understory (Patchy understory)	14.1	3
Cottonwood overstory / Saltcedar - Russian olive - Siberian elm understory (Patchy understory)	2.6	1
Cottonwood overstory / Siberian elm - Russian olive understory (Patchy understory)	7.6	1
Cottonwood overstory / Siberian elm understory (Patchy understory)	3.9	2
No overstory / Coyote willow understory (Dense)	2.6	6
Grassland	1.8	1
No overstory / Mulberry - Siberian elm - Russian olive understory (Dense)	1.2	1
Open Area/Barren	21.2	9
Open Water	1.0	3
Russian olive - cottonwood - Siberian elm overstory (Sparse)	4.9	1
Russian olive - cottonwood overstory / Coyote willow understory (Patchy understory)	1.0	1
Russian olive - Saltcedar overstory with little understory	1.3	1
Russian olive - Siberian elm overstory / Coyote willow understory (Dense)	2.4	2
Russian olive - Siberian elm overstory / Coyote willow understory (Patchy understory)	0.2	1
Russian olive overstory / Coyote willow understory (Dense)	15.6	3
Sandbar	1.0	1
Siberian elm - cottonwood overstory / Russian olive - Siberian elm - coyote willow understory (Dense)	1.7	1
Siberian elm - cottonwood overstory / Siberian elm understory (Patchy understory)	2.2	1
Siberian elm - Russian olive overstory with little understory	1.1	1
Siberian elm - Russian olive overstory / Coyote willow understory (Patchy understory)	2.7	3
Siberian elm - Russian olive overstory / Siberian elm understory	0.2	1
No overstory / Siberian elm - Russian olive understory (Dense)	0.1	1
Siberian elm overstory / Fourwing saltbush understory (Patchy understory)	1.6	1
Siberian elm overstory / Siberian elm understory (Patchy understory)	1.6	1
No overstory / Siberian elm understory (Dense)	0.6	1
Tree of heaven overstory / Coyote willow - tree of heaven understory (Dense)	0.3	1

SOILS ASSESSMENT

Based on results of the soil survey, soils were relatively coarse textured through the site (**Table 4**). The majority of augered holes contained a relatively high percentage of sand size (0.05 to 2.0 millimeters [mm]) soil particles, which placed most of them into the loamy sand (70-85% sand) or sandy loam (50-70% sand) USDA soil texture classes. The soil texture data presented in **Table 4** reflects average soil texture for each auger hole, weighted by depth interval. The detailed soils information for each depth interval is provided in Appendix X.

Soil texture serves as a proxy for soil water availability following rain or irrigation events, which in turn provides a useful guide for prescribing revegetation prescriptions. The general lack of variability in soil texture across the project area simplifies revegetation prescriptions, meaning that based on soil texture alone, many of the same native plant species could be used across the majority of the site. In locations with similar soil texture, therefore, the more important factor influencing site specific plant palettes (seeding mixes, shrub species) will be amount of overstory canopy cover (i.e., shade) and seasonal depth to groundwater. That said, soil textures in a few map units were composed of pure sand (≥ 85% sand through the entire soil profile) or higher percentages of silt or clay sized soil particles, and revegetation prescriptions at these map units will need to be adjusted accordingly.

TABLE 4. SOIL TEXTURE RECORDED AT AUGER HOLES

Auger ID	Map Unit	Depth to groundwater (cm)	Profile weighted soil texture, %				USDA texture[1]	Comments
			Gravel	Sand	Silt	Clay		
1	1	>180	2	69	20	9	sandy loam	clay loam 115-145 cm*
2	2	>90	0	90	8	1	sand	no confining layers
3	4	110	2	93	5	0	sand	homogenous sand
4	5	160	0	80	13	7	loamy sand	clay loam 0-15 cm
5	3	132	1	54	28	18	sandy loam	SiCL top 70 cm
6	6	120	0	49	33	18	loam	clay loam 35-73cm, SiCL 80-95 cm*
7	7	155	0	82	14	4	loamy sand	no confining layers
8	8	155	2	71	18	9	sandy loam	no confining layers, shallow fines
9	9	156	2	75	16	7	loamy sand	no confining layers, shallow fines
10	11	205	2	73	17	8	sandy loam	no confining layers, shallow fines
11	13	165	0	82	13	6	loamy sand	no confining layers, shallow fines
12	14	>215	0	74	19	7	sandy loam	Clay loam from 130-145 cm*
13	14	195	0	72	21	7	sandy loam	SiCL from 140-150 cm*
14	15	180	0	58	32	11	sandy loam	Confining layer 120-130 cm*
15	15	180	0	63	27	10	sandy loam	SiCL from 90-120 cm*
16	70	120	9	73	13	4	loamy sand	no confining layers, historically disturbed
17	69	110	0	61	24	15	sandy loam	SiCL top 50 cm*
18	66	133	0	55	29	16	sandy loam	fine textured top 75 cm
19	60	213	0	78	16	6	loamy sand	no confining layers
20	63	150	4	85	8	2	sand	no confining layers
21	63	165	2	72	19	6	sandy loam	no confining layers
22	64	70	0	69	21	10	sandy loam	Fines 0-6 cm and 30-40 cm*
23	63	170	0	86	11	3	loamy sand	no confining layers
24	57	>120	0	72	20	9	sandy loam	SiCL top 30 cm
25	57	>100	0	83	13	4	loamy sand	Clay loam top 8 cm
26	56	165	1	90	7	1	sand	no confining layers
27	55	100	0	10	45	45	silty clay	uniform silty clay to groundwater
28	56	>215	4	92	4	0	sand	no confining layers
29	21	238	2	71	20	7	sandy loam	no confining layers
30	25	210	0	82	12	6	loamy sand	clay loam 10-30 cm*
31	27	>210	0	67	20	13	sandy loam	fine textured top 50 cm
32	28	135	2	31	30	36	clay loam	silty clay 0-15 cm and 25-90 cm*
33	33	55	0	49	27	25	sandy clay loam	silty clay top 10 cm
34	32	155	6	86	7	1	sand	no confining layers
35	37	75	8	82	8	2	sand	no confining layers

[1] Estimated from material < No 4 sieve, not gravel weighted percentages as shown in table.
* Confining soil layers at depth may prevent shrub plant roots from elongating towards the groundwater table. Consider planting longstem tall pots in these map units.

GROUNDWATER INTERPOLATIONS

Given the variable topography through the site, depth to groundwater predictions produced a wide range of predicted depths from pooled water on the surface down to 16+ feet deep. **Figure 6** displays the results of the GIS analysis. As would be expected, areas predicted to have standing water were located in the stormwater outfall channel, irrigation return, and isolated grid cells along the river margin. Berms, spoil piles, and levee slopes had the highest predicted depth to groundwater values. Mean depth to groundwater across all cells in the site was predicted to be 5.0 feet at 650 cfs. Under those conditions, much of the site is expected to be favorable for tree pole planting and potted shrub installation, provided the shrubs are adequately irrigated through the establishment period during the first growing season.

We also compared the interpolated depth to groundwater predictions to depth to groundwater measured during soil sampling at the site. Rio Grande discharge as measured at the Albuquerque gage (which is directly across the river from this site) was approximately 1,000 cfs while soil sampling occurred. The GIS analysis was designed to predict depth to groundwater when discharge at the USGS Albuquerque gage was 650 cfs, so we adjusted augered groundwater depth to reflect the difference in surface water elevation between 650 and 1,000 cfs (which typically differ less than a half foot). The results between the GIS predictions and field observations were generally consistent and confirm that the GIS predictions are probably a reasonable guide for the particular application in this report. If all soil sample locations are considered, regardless of whether the GPS point appears to plot inaccurately based on offsets from narrow depressions or other geomorphic features targeted during the field assessment, the mean difference between measured depths to groundwater and predicted is 0.2 feet. When what appear to be slightly inaccurate GPS locations are removed, the mean difference between observed and predicted depth to groundwater is 0.06 feet.

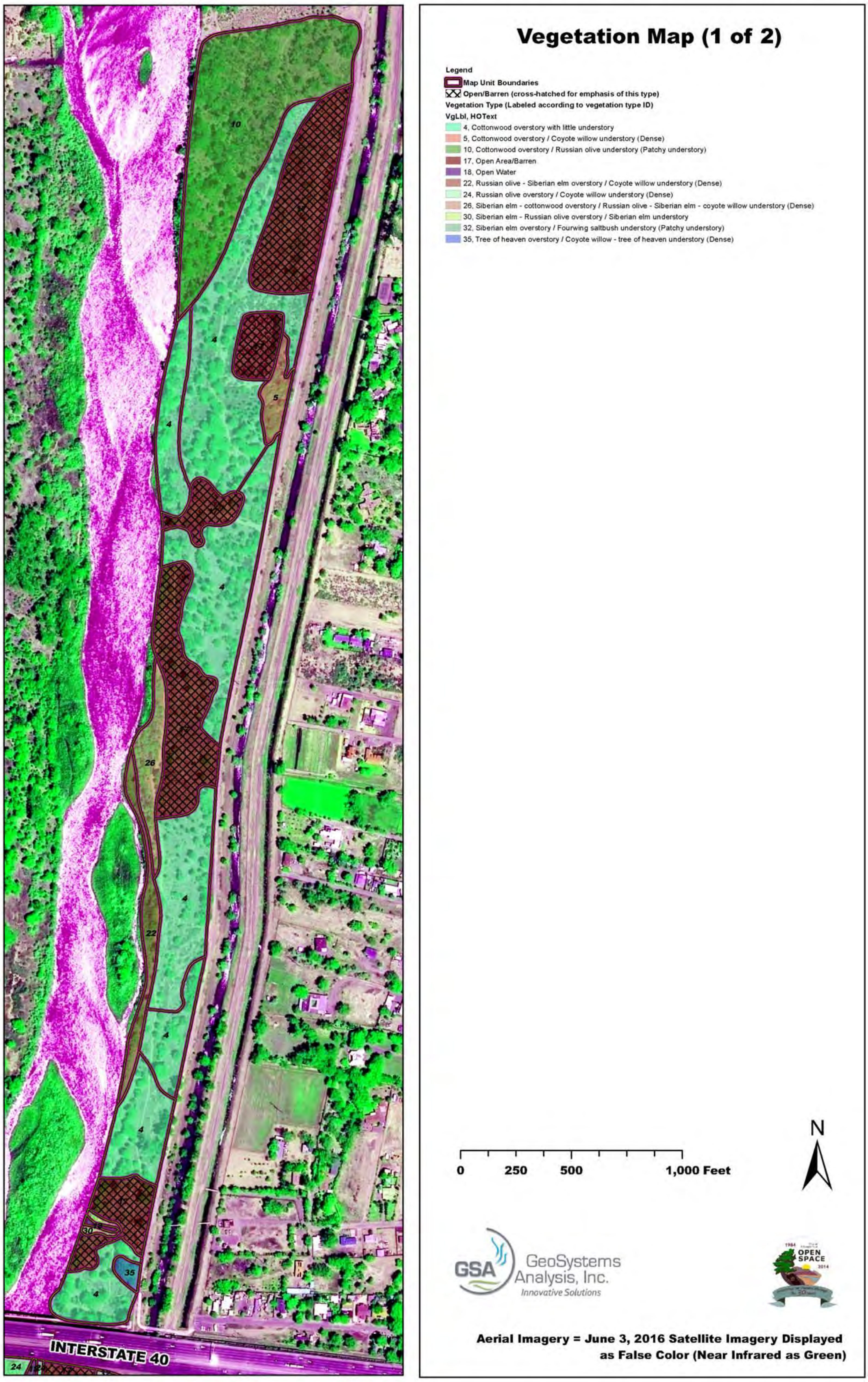

FIGURE 4. VEGETATION MAP (1 OF 2)

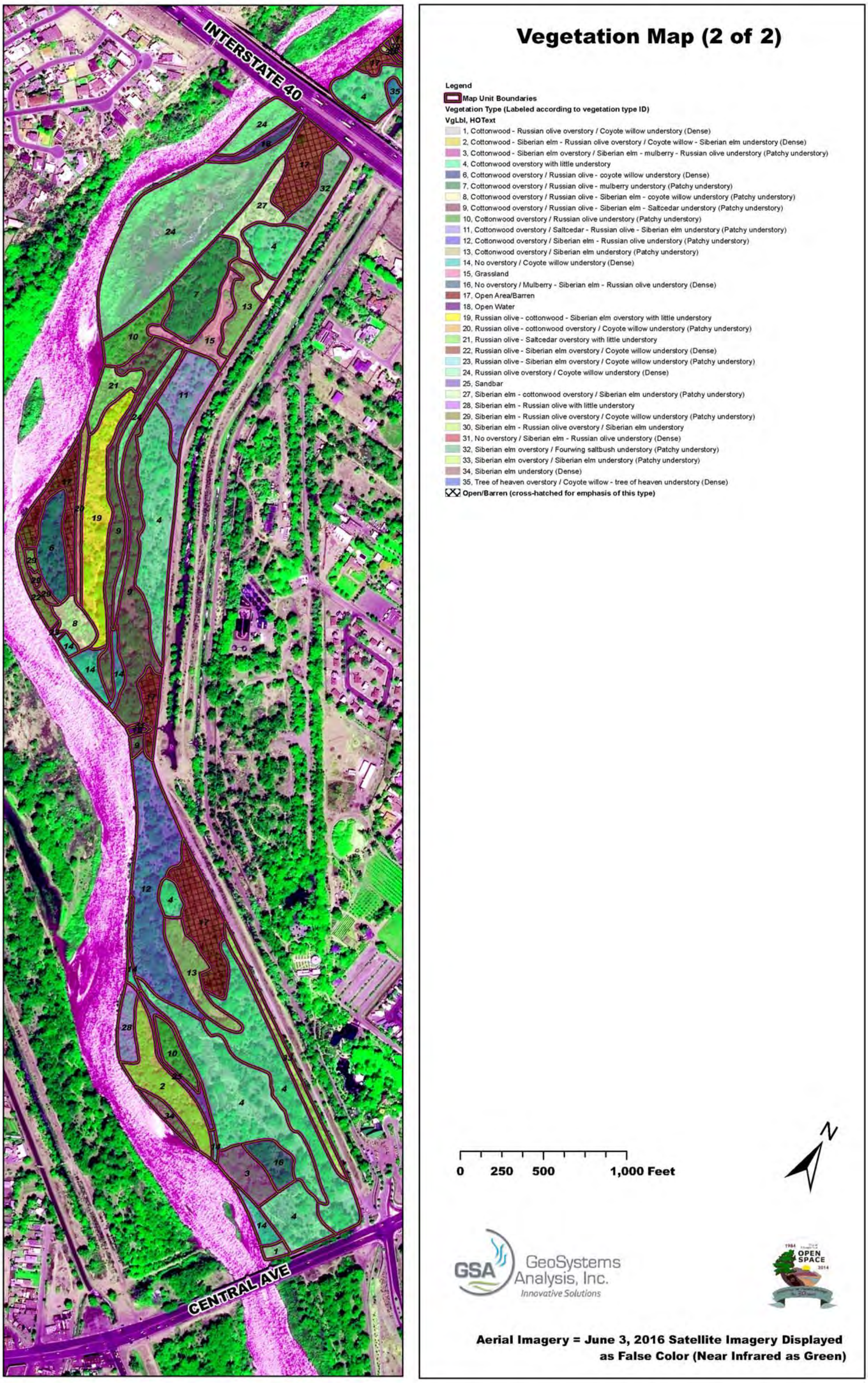

FIGURE 5. VEGETATION MAP (2 OF 2)

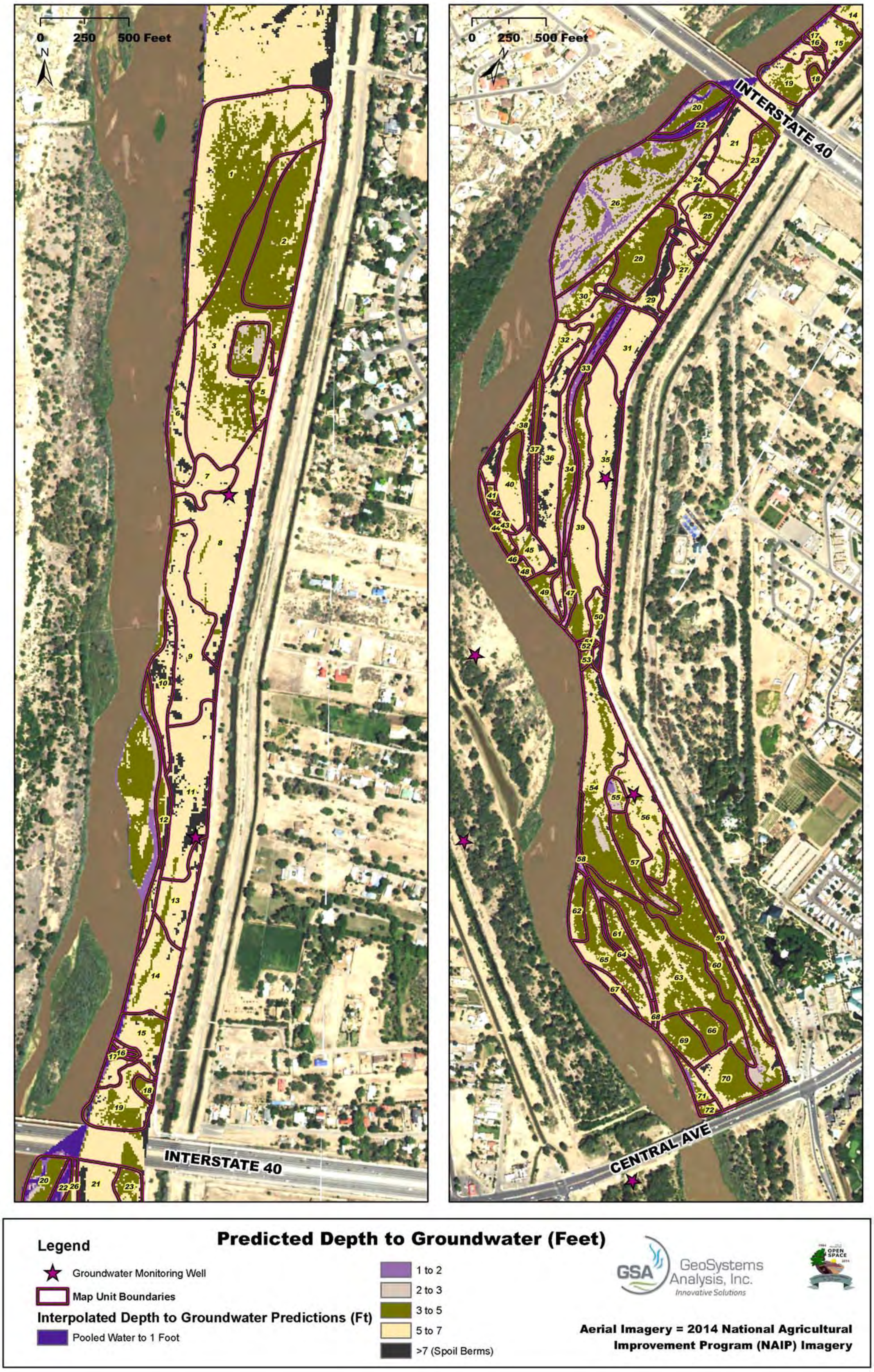

FIGURE 6. GROUNDWATER INTERPOLATION MAP

PRIMARY MAINTENANCE AND MANAGEMENT NEEDS

ANNUAL WEEDS

Kochia (*Bassia scoparia*) and tumbleweed (aka Russian thistle; *Salsola tragus*) are the principal annual weeds of management concern within the project area. The amount of kochia and tumbleweed cover across the project area varies by map unit, and for management purposes have been grouped according to low, moderate and high management priority classes (**Table 5**). Spatial distribution and areas of high, moderate and low treatment priority are displayed in the map in **Figure 7**.

Both kochia and tumbleweed pose threats to land managers, including increased fire hazard, harboring harmful insects and pathogens, and competing with desirable plants for limited resources. Seeds of both species germinate in the spring through summer, and each plant can produce thousands of viable seed by late summer. Viable seeds are distributed when plants dry and fall over, are blown across the landscape ("tumbleweeds") or if they are mechanically mowed. Studies have found that Kochia seeds can remain viable for three years, although seed viability can be reduced significantly if buried up to 10 cm or more (Zorner et al, 1984[1]).

Both species thrive in areas of high disturbance, so prevention or reduction of disturbance is considered critical for preventing persistence and spread of these weeds. In addition to minimizing disturbance, control and management of these species should ideally focus on manually uprooting new seedlings in spring/early summer while the plants are of manageable size and well before they set seed, and by establishing relatively dense native ground cover to promote competition for light, water and nutrients. More specific management recommendations are discussed in **Table 7** below.

---

[1] Zorner, P.S., R.L. Zimbahl, and E.E. Schweizer. 1984. Effect of depth and duration of seed burial on Kochia (Kochia scoparia). Weed Science, Vol. 32: 602-607.

TABLE 5. KOCHIA AND TUMBLEWEED PRIORITY CLASSES AND DEFINITIONS

Management Priority Class	Class definition	Acres	Number of Map Units
Low	Annual weed cover currently less than 10% and probability of increased annual weed expansion is low	87.8	42
Moderate	Annual weed cover currently greater than 10% but less than 25% with potential for increased weed expansion but site variables such as shade and litter cover are likely to prevent severe invasion of annual weeds (e.g. >50% cover) relative to other portions of the site	39.8	11
High	Annual weed cover currently greater than 25%, site has low cover of native species competition, annual weeds predicted to dominate the map unit for the foreseeable future without aggressive management	42.7	19

SIBERIAN ELM

Siberian elm (*Ulmus pumila*) is native to northern China, eastern Siberian, Manchuria and Korea and is believed to have been introduced to the Middle Rio Grande Valley sometime in the 1930's. Siberian elm is now one of the most common non-native trees in the Albuquerque Reach of the Middle Rio Grande bosque, and is one of several exotic tree species of management concern. Siberian elm is a fast growing tree that reaches heights of 50-70 feet. Seed production peaks in March prior to leaf-set later in spring. The seeds are dispersed by gravity and wind so dense seedling colonies may establish in close proximity or relatively far distances away from the parent trees. Siberian elm is shade tolerant and in a relatively short period of time can form dense thickets below the canopy of native cottonwood trees. As Siberian elm stands develop, particularly in concert with other non-native trees (e.g., Russian olive), they contribute significantly to bosque ladder fuel build-up, thereby posing a severe fire hazard to the native forest and adjacent municipal infrastructure.

Siberian elm is widespread across the project site, although size class and density varies across different map units. **Table 6** shows the number of map units and combined acres where Siberian elm falls into different management priority classes and **Figure 8** shows the spatial distribution of these classes to help guide management need and schedule. More specific management recommendations are discussed in **Table 7** below.

TABLE 6. SIBERIAN ELM PRIORITY CLASSES AND DEFINITIONS

Management Priority Class	Class Definition	Acres	Number of Map Units
Low	Siberian elm cover currently low (e.g. <5% relative canopy cover), current vegetation conditions.	41.3	18
Moderate	Siberian elm present in the map unit but not currently considered a (co-) dominant species in the vegetation class defined for the map unit.	43.5	19
High	Typically defined as a unit where Siberian elm is currently considered a (co-) dominant species in the vegetation type defined for the map unit but in isolated cases, the map unit also received a "high" ranking because the map unit contained large seed trees and/or an abundance of young elm plants suggesting that Siberian elm will become a (co-) dominant component of the vegetation type within a few years.	85.5	35

TREE OF HEAVEN

Tree of heaven (*Ailanthus altissima*) is native to China and was introduced to the United States sometime in the late 1700's. Tree of heaven is relatively common in the Middle Rio Grande bosque, although stands are usually concentrated in dense patches and are generally not as pervasive as other non-native trees like Russian olive and Siberian elm. Nonetheless, tree of heaven is an extremely vivacious tree that is can be exceedingly difficult to kill. It is a prolific seed producer and persistent stump and root sprouter that aggressively competes with surrounding native vegetation. Flowering typically begins in early summer and has been recorded occurring on seedlings as soon as six weeks following germination.

A total of 46 tree of heaven patches spanning 3.4 acres were identified and mapped within the project area (**Figure 9**). Because the patches are relatively small, species management is assigned to each patch rather than according to map unit. Tree of heaven management primarily involves herbicide treatment, which is described below in **Table 7**. Given the propensity for patch expansion and difficulty in controlling, all tree of heaven patches are considered *high management priority*.

RAVENNA GRASS

Ravenna grass (*Saccharum ravennae*) is a large, nonnative, perennial grass that is becoming increasingly invasive along the Middle Rio Grande, most notably throughout the Albuquerque Reach. Due to its rapid spread, this species was added to the New Mexico Department of Agriculture (NMDA) noxious weed list in 2009 and is classified as a Class A noxious weed. Ravenna grass is particularly invasive on sand bars and relatively low-set floodplain terraces in the project site and spreads rapidly via seed.

A total of 91 Ravenna grass patches spanning 7.6 acres have been mapped within the project site (**Figure 9**). The patch densities are highly variable within the site, and due to its propensity for rapid spread, management should focus on complete eradication. Unlike Siberian elm, therefore, all patches are ranked as *high management priority*. Ravenna grass control methods include combinations of manual treatments (e.g., hand digging) and herbicide applications. Detailed management recommendations are described below in **Table 7**.

WHITE TOP

Whitetop (*Lepidium draba*) (aka Hoary cress [*Cardaria spp*]) is a non-native, perennial herbaceous plant listed by the NMDA as a Class A noxious weed. A close relative to perennial pepperweed (*Lepidium latifofoium*), whitetop is relatively widespread along irrigation canals throughout Bernalillo County, but is not currently widespread in the Albuquerque bosque. In fact, only one whitetop patch (0.1 acres) was mapped in the project site (**Figure 9**).

Given its Class A status and current limited distribution in the project site, the species is considered *high management priority* and the OSD should focus on prompt action and complete eradication. Treatment methods involve herbicide application, as described below in **Table 7**.

OTHER EXOTIC PHREATOPHYTES

In addition to Siberian elm and tree of heaven, several non-native trees have become widespread in the Albuquerque Reach of the Middle Rio Grande bosque, namely saltcedar (*Tamarisk sp.*), Russian olive (*Elaeagnus angustifolia*) and mulberry (*Morus spp*). Saltcedar is very widespread throughout the Rio Grande watershed, and forms particularly dense monotypic stands further south in the San Acacia Reach. However, saltcedar is relatively uncommon and sparsely distributed in the project site and is currently considered a low management priority.

Both Russian olive and mulberry are fruit-bearing trees of considerable value to wildlife, particularly as nesting substrate and as an important food source for fruit-eating birds. Given the low numbers of native fruit bearing shrubs in the project site, these non-native trees are believed to contribute substantially to avian diversity, and until relatively high numbers of native fruit-bearing species (e.g., New Mexico olive [*Forestiera pubescens*], wolfberry [*Lycium torreyi*) become well established through revegetation, it may be prudent to selectively thin Russian olive and mulberry trees rather than focus on eradicating them from the project site. While management philosophies about how to manage these species differ among MRG restoration practitioners, for the time-being the OSD has expressed interest in leaving the majority of these non-native trees in-tact at the project site. As such, this report does not address control methods for either of these species (or saltcedar). However, management approach to these species should be revisited after other restoration management priorities and been addressed and native plant establishment progresses over time.

TABLE 7. RECOMMENDED NON-NATIVE SPECIES TREATMENT SPECIFICATIONS

Target Exotic Plant Species	Recommended Treatment Specification
Ravenna Grass	Option 1 (preferred): Hand excavate all live plants. Option 2: using a backpack sprayer, apply a 2% solution of imazapyr mixed with 5% solution of glyphosate plus non-ionic surfactant per label instructions (typically 0.5%) and a blue dye. Herbicide should be applied on all live leaf tissue, if possible. All herbicides should be approved for aquatic use. Bag and remove all live seed regardless of whether shovel removal or herbicide application occurs.
Kochia	Regularly monitor the site for seedling germination during peak germination seasons (March through May and August through September). Option 1 (preferred): Using hand tools (e.g. hoop hoes, shovels, and/or hoes) or via manual pulling, remove seedlings before they reach 6 inches tall, if possible. Live root tissue should also be removed as the seedling is pulled. Option 2: If large scale seedling emergence occurs before or after the April 15 - August 15 MBTA non-treatment window or if plants have not reached full maturity before August 15, mow live plants before plants mature and set seed. While mowing, cut plants as low to the ground as possible. Option 3: apply a foliar herbicide application of various herbicides (glyphosate, imazapyr, or triclopyr) using lowest mixing concentration recommended for foliar, backpack sprayer application per the manufacturer's label.
Tumbleweed	Regularly monitor the site for seedling germination during peak germination seasons (March through September). Option 1 (preferred): Using hand tools (e.g. hoop hoes, shovels, and/or hoes) or via manual pulling, remove seedlings before they reach 6 inches tall, if possible. Live root tissue should also be removed as the seedling is pulled. Option 2: If large scale seedling emergence occurs before or after the April 15 - August 15 MBTA non-treatment window or if plants have not reached full maturity before August 15, mow live plants before plants mature and set seed. While mowing, cut plants as low to the ground as possible. Option 3: apply a foliar herbicide application of various herbicides (glyphosate, imazapyr, or triclopyr) using lowest mixing concentration recommended for foliar, backpack sprayer application per the manufacturer's label.
Tree of Heaven	A two-phased herbicide treatment approach is recommended for tree of heaven. First, an initial hack-and-squirt treatment with triclopyr (50% solution) should be applied to all live stems. Hatchet frills should be cut at a downward angle at a depth that only penetrates the bark into live cambium tissue immediately below the bark layer. On very small diameter stems where the hatchet will slice all the way through the stem, a knife can be used to peel away bark. The hack-and-squirt incisions should be spaced evenly about 1 inch apart around the entire circumference of the stem. The initial hack-and-squirt treatment will trigger dieback to ground level and resprouting from below ground. The second herbicide application phase then occurs during subsequent growing seasons. Apply a foliar treatment of imazapyr at 2% concentration plus surfactant to all resprouted stems. The foliar application should be reapplied during subsequent years until no live shoots occur (typically 2-3 growing seasons after the initial treatment). A basal bark application with an ester triclopyr formulation (e.g. Garlon 4) can be substituted for the hack-and squirt treatment, if desired. Blue dye should be mixed with herbicide to ensure full coverage during application.
Siberian Elm	Trees larger than 10 inches basal diameter should be treated using a girdle technique. Girdling can be completed with a hatchet, handsaw, or chainsaw but chainsaw is typically the preferred method. Regardless of the tool used, at a convenient height, cut a perpendicular groove around the entire circumference of the tree that is approximately 2 inches deep. At that same depth, cut another groove approximately 6-10 inches above or below the first groove, depending on the size of the tree. Then remove only the bark and outer cambium tissue between the two grooves by cutting, frilling, or peeling the outside 0.5 to 1.5 inch of the tissue off the tree. Immediately apply a triclopyr formulation (at 25% concentration) to the freshly exposed tissue. A cut stump treatment is recommended for trees with a basal diameter of 1 to 10 inches. Cut stump treatment involves cutting stems as low to the ground as possible and chipping the material, typically onsite. After the cut is made, immediately (within 5 minutes) apply triclopyr at 25% concentration to the cut stump. In non-wetland areas, stems less than one inch at base can be treated using a basal bark application of an ester-type triclopyr formulation (e.g. Garlon 4) mixed at 25% triclopyr concentration with an oil. Only Garlon 3A (or similar aquatic approved, water soluble triclopyr product) should be used in locations requiring an aquatic use approved herbicide, thus, cut stump treatment is recommended in wetland areas, regardless of stem size. If chipping onsite, wood chip depth should not exceed 2 inches. Surfactant and/or adjuvant are also recommended per manufacturer recommendations for the particular application technique utilized. All herbicides should be mixed with blue dye. Note that this treatment specification can also be used on most exotic phreatophytes found in the bosque (e.g. Russian olive, saltcedar, mulberry, etc.) but different techniques are recommended for tree of heaven, as described for that species. Girdling is not recommended for saltcedar or Russian olive.
White top	Using a backpack sprayer, apply imazapyr based herbicide at 2% concentration during the rosette to flowerbud stage. Mix herbicide with non-ionic surfactant per manufacturer label instructions and blue dye.

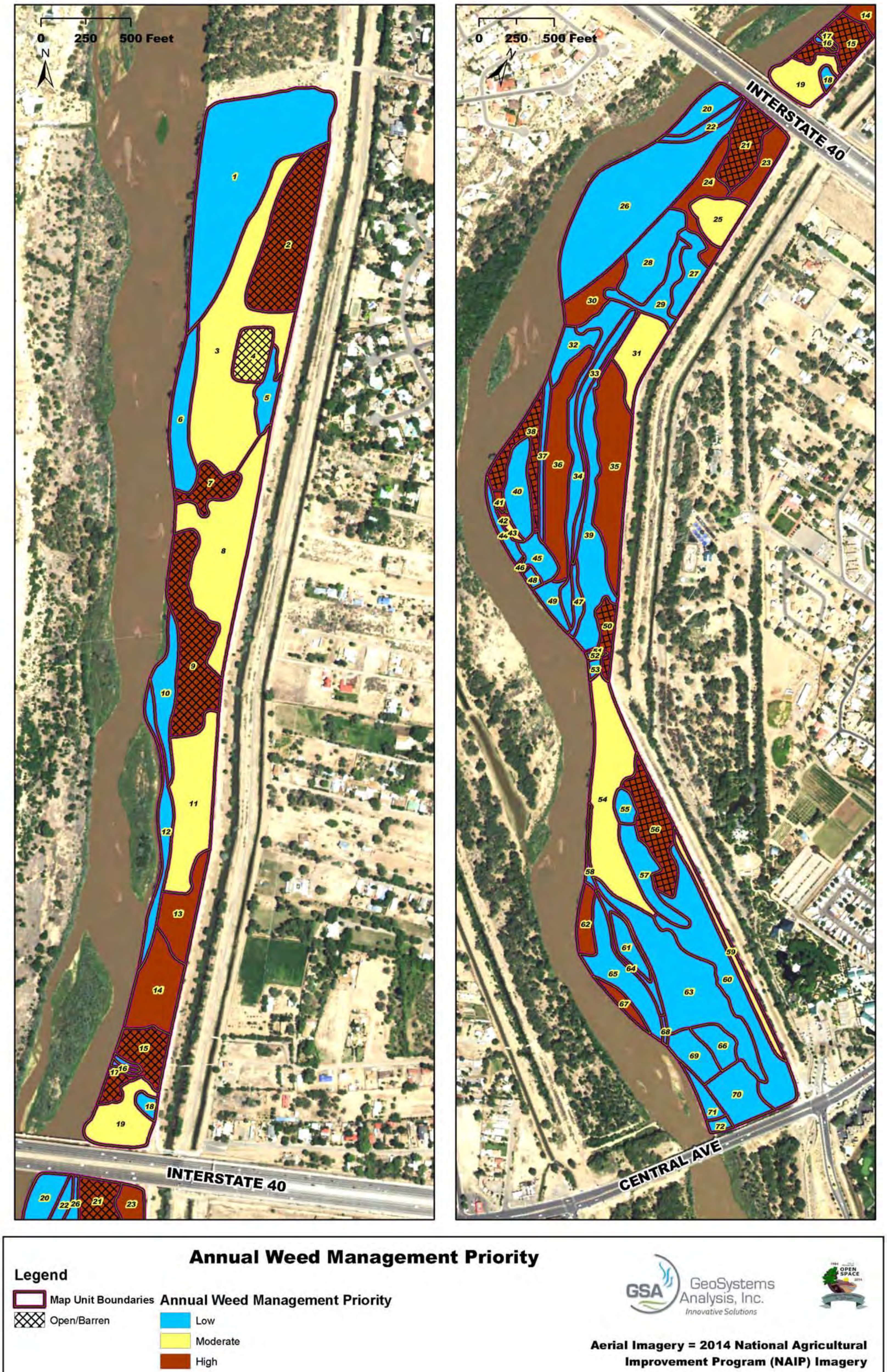

FIGURE 7. ANNUAL WEED DISTRIBUTION AND TREATMENT PRIORITY MAP

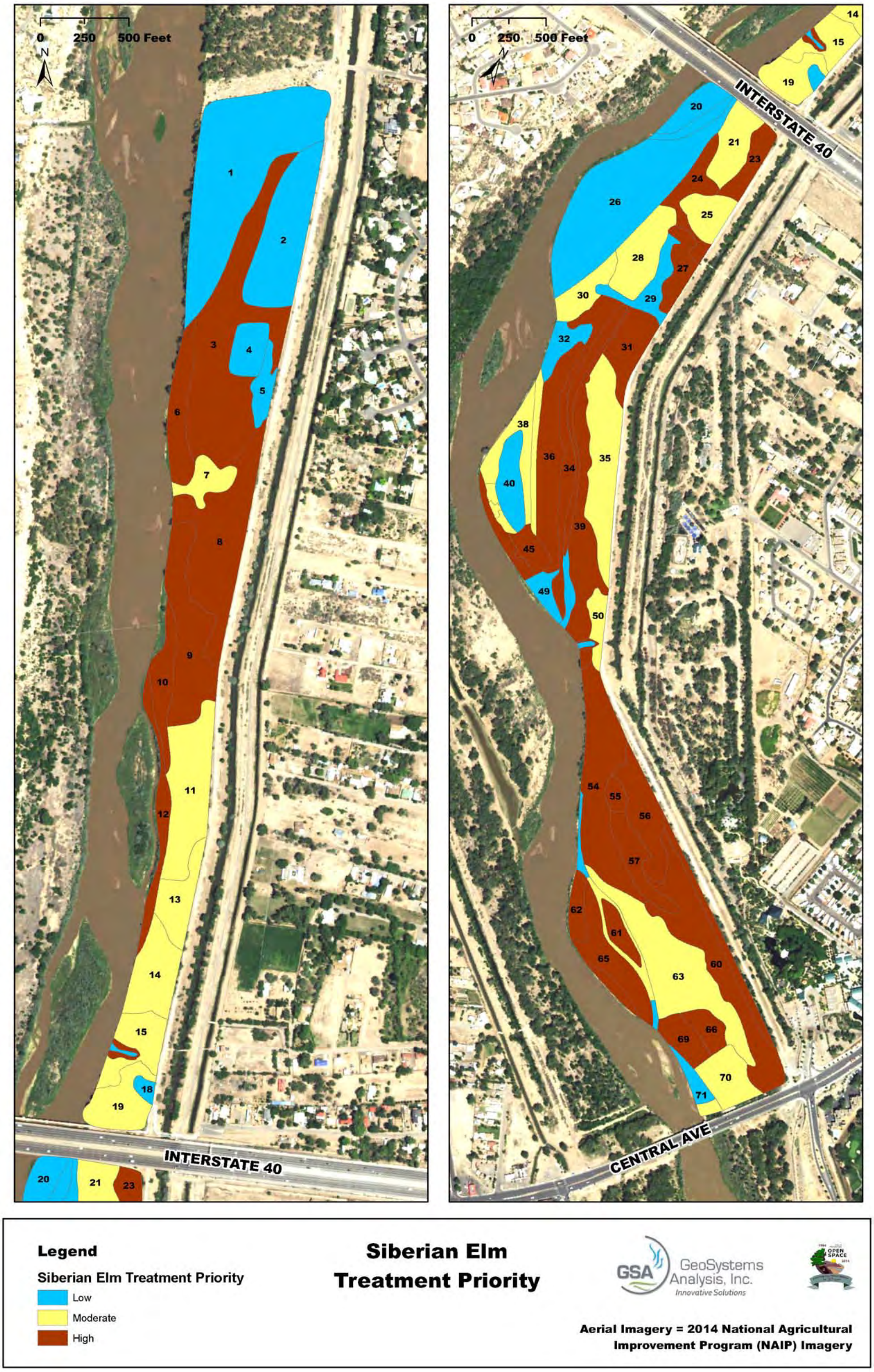

FIGURE 8. SIBERIAN ELM TREATMENT PRIORITY AND DISTRIBUTION MAP

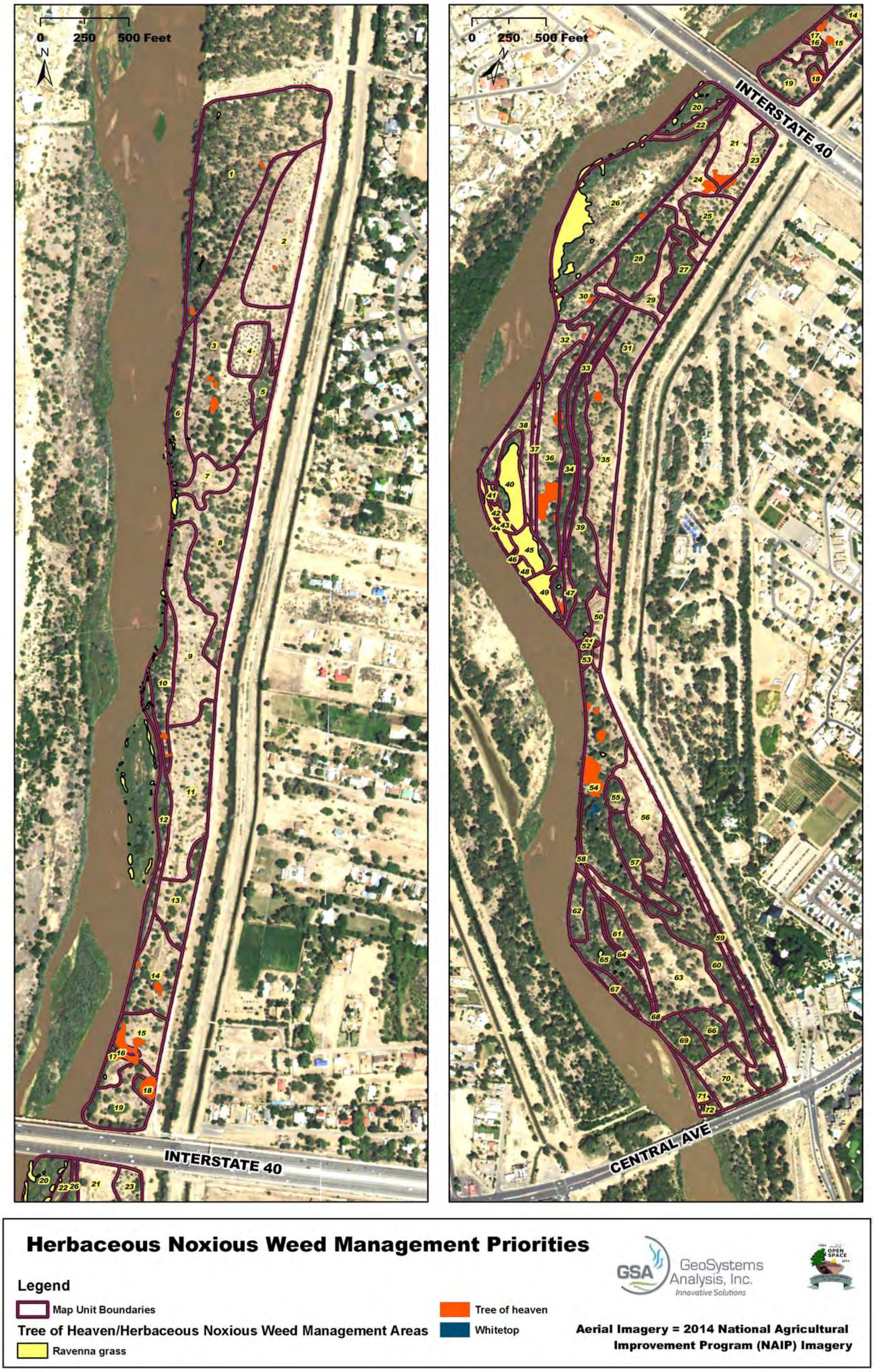

FIGURE 9. TREE OF HEAVEN, RAVENNA GRASS, AND WHITE TOP DISTRIBUTION MAP

REVEGETATION RECOMMENDATIONS

GRASS AND FORB SEEDING

One of the most important management steps to improving ecological conditions in the project area is to establish ground cover by seeding native grasses and forbs. This is particularly important in areas currently dominated by non-native kochia and tumbleweed plants (**Table 8**). The map in **Figure 10** identifies priority seeding areas, with the highest priority focusing on sites that currently lack overstory plant cover. A recommended seed mix is presented in **Table 9**.

Mechanical seeding methods using tractors mounted with a rangeland seed drill or an imprinter have been used on previous bosque revegetation projects with mixed success. One of the principal challenges of mechanical methods in the bosque is the need for maneuvering around existing native shrubs and trees, and with getting even seed distribution in sites with hummocky topography.

The principal alternative to mechanical seeding methods is to utilize hand crews armed with bags of seed and hand rakes to manually apply native seed. This manual seeding approach may be more practical at the project site and is recommended for several reasons:

1. The OSD does not own a rangeland seed drill or imprinter, so this equipment would need to be purchased or a seeding contractor with this equipment would need to be hired;

2. The high-priority seeding areas are relatively small and could be efficiently seeded using manual methods by volunteer organizations (e.g., Bosque Youth Corps crews) under expert supervision;

3. Even though most high-priority seeding map units are classified as "Open/Barren" (see **Figure 10**), most of these map units have some native shrubs (e.g., 4-wing saltbush) and/or uneven topography, so manual seeding methods will enable more precise and even seed application.

Seeding treatments should be closely coordinated and timed following recommended management of non-native herbaceous plants (see *Schedule of Major Activities* and *Implementation Sequence* sections below). Once non-native weeds have been removed in spring/early summer, seeding with native grasses and forbs should commence at the onset of the typical summer monsoon season (i.e., early-mid July). Timing seeding with summer monsoons is recommended to improve potential for adequate soil moisture needed for seed germination and seedling establishment. However, monsoon rains are highly unpredictable and inconsistent. One important risk of relying on rains is that seeds may germinate following a sufficient rain event, only to have the seedlings desiccate because too much time passes between subsequent rainstorms. The best way to mitigate this scenario is to provide supplemental irrigation after the first major rain event. Given the variable size and spacing of seeding areas across the project area, supplemental irrigation may be best applied by pumping water from the Albuquerque Drain and aerially spraying the water using a fire hose with a dispersing nozzle attachment. Irrigation frequency and other application recommendations are addressed further in the *Schedule of Major Activities* section below.

TABLE 8. SEEDING PRIORITY CLASSES AND DEFINITIONS

Grass/Forb Seeding Priority Class	Class Definition	Acres	Number of Map Units
Low	Site potential not perceived to be grassland or savannah due to well established native overstory and/or site already contains abundant native grasses in cases where the site conditions are suitable for grassland/savannah.	83.7	39
Moderate	Native grass diversity and cover lower than site potential and seeding is expected to improve habitat quality but currently considered a lower priority relative to other units within the site that warrant more significant management attention	32.7	15
High	Site potential is perceived to be a grassland or savannah but map unit currently lacks significant native grass cover (less than 10% and oftentimes even less than 1%). Typically units that received the "high" class designation were dominated by annual weeds or barren.	53.9	18

TABLE 9. RECOMMENDED SEED MIX

Common Name	**Species Name**	**Rate (PLS LBS/Acre)**
Indian ricegrass	*Achnatherum hymenoides*	3.5
Four-wing saltbush	*Atriplex canescens*	0.1
Side oats gramma	*Bouteloua curtipendula*	1.5
Blue gramma	*Bouteloua gracilis*	0.5
Rocky mountain bee plant	*Cleome serrulata*	0.5
Bottlebrush squirreltail	*Elymus elymoides*	2.0
Annual sunflower	*Helianthus annuus*	2.5
Green sprangletop	*Leptochloa dubia*	0.5
Hooker evening primrose	*Oenothera hookeri*	0.5
Pale evening primrose	*Oenothera pallida*	0.5
Western wheatgrass	*Pascopyrum smithii*	4.0
Galleta	*Pleuraphis jamesii*	1.5
Scarlet globemallow	*Sphaeralcea coccinea*	0.5
Alkali sacaton	*Sporobolus airoides*	0.5
Spike sacaton	*Sporobolus contractus*	0.5
Sand dropseed	*Sporobolus cryptandrus*	0.5
Mesa dropseed	*Sporobolus flexuosus*	0.5
Giant dropseed	*Sporobolus giganticus*	0.5
Giant sacaton	*Sporobolus wrightii*	0.5
		21.1

POTTED SHRUB INSTALLATION

Vegetation mapping results discussed previously found that native shrub diversity and densities were generally low across the project site. Accordingly, revegetation with native shrubs is considered a *moderate* or *high management priority* in approximately 80% of the 170-acre project site (**Table 10 and Figure 11**). A variety of different shrub species are recommended, but the species assemblages and planting densities vary by map unit (**Figure 12**) depending upon site-specific abiotic factors including soil texture, depth to groundwater and amount of shade provided by existing overstory tree cover.

Tables 11 and 12 list several recommended shrub species and are separated according to preference for relatively moist ("Riparian", **Table 11**) or dry ("Xeric", **Table 12**) map unit conditions. Planting density also varies by map unit and is influenced largely by the amount and assemblage of existing vegetation. Shrub planting density recommendations for different map units, therefore, are provided in **Table 13**. The same abiotic factors that influence shrub species map unit assignments (soil texture, groundwater depth, and overstory shade) also drive the need, amount, and frequency of supplemental watering. Supplemental irrigation water is recommended for all shrub plantings during installation, but subsequent watering schedules vary by map unit and recommendations for subsequent watering through the first growing season is provided in **Table 14 and Figure 13**.

The OSD has established a native plant nursery and are planning to custom grow most, if not all of the shrubs needed for revegetating the site over the five year life of this project. Once shrub seedlings are of sufficient size, we recommend they be transplanted from seedling containers to 1-gallon tallpots (i.e., comparable to 1 gallon, D-60 deep-pots from Stuewe & Sons https://www.stuewe.com/products/deepots.php). These deep-pots are recommended because they are designed to promote root elongation towards the water table. With supplemental watering, plants transplanted from these pots will reach the moist-soil zone above the groundwater table (the capillary fringe) more quickly than if plants are grown in standard 1-gallon pots. Furthermore, we recommend OSD consider growing a subset of shrubs as long-stem tall pots (http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/nmpmcbr7106.pdf). The advantage of using longstem tallpots is that these shrubs can be planted with their roots directly in the capillary fringe, thus avoiding the need for supplemental watering. The planting method is similar to pole planting that utilizes a tractor-mounted auger to drill a hole to the water table. The primary difference is that, unlike pole planting, the longstem tallpots are rooted, so the roots should not be planted directly into the water table. The main disadvantage of longstem tallpots is that they require 3-4 years in the greenhouse before the stems are long enough to have roots installed the capillary fringe and have at least 2-3 feet of stem and apical branches at least 2 feet above the ground surface. Several species listed in **Tables 11 and 12** can be successfully grown as longstem tallpots, most notably seep willow, willow Baccharis, New Mexico olive, and false indigobush. At minimum, we recommend that longstem tallpots be grown for revegetating map units with confining soil layers (i.e., fine textured soil layers that may prevent root elongation to the water table via supplemental irrigation - **see Table 4 in the Soils Section above**).

TABLE 10. SHRUB PLANTING PRIORITY CLASSES AND DEFINITIONS

Potted Shrub Installation Priority Class	Class Definition	Acres	Number of Map Units
Low	Site already contains native shrub cover that nears predicted site potential.	35.2	18
Moderate	Native shrub diversity and cover lower than site potential and planting is expected to improve habitat quality. However, map unit currently considered a lower priority relative to other units within the site that warrant more significant management attention.	87.3	39
High	Site currently lacks significant native shrubs and increased shrub cover is expected to provide competition for species difficult to manage (e.g. annual weeds) and shift the near term trend (e.g. 5-10 years) into a more resilient native plant assemblage.	47.8	15

TABLE 11. RECOMMENDED RIPARIAN SHRUB SPECIES

Riparian Shrub Species Mix	
Common name	**Scientific name**
New Mexico olive	*Forestiera pubescens*
Golden currant	*Ribes aureum*
Silver buffaloberry	*Shepherdia argentea*
Wolfberry	*Lycium torreyi*
Woods rose	*Rosa woodsii*
False indigobush	*Amorpha fruticosa*

TABLE 12. RECOMMENDED XERIC SHRUB SPECIES

Xeric Shrub Species Mix	
Common name	**Scientific name**
Seep willow/mule fat	*Baccharis salicifolia*
Willow Baccharis	*Baccharis salicina*
Woods rose	*Rosa woodsii*
Threeleaf sumac	*Rhus trilobata*
Apache plume	*Fallugia paradoxa*

TABLE 13. SHRUB PLANTING DENSITY CLASSES AND DEFINITIONS

Recommended Shrub Planting Density	**Class Definition**	**Acres**	**Number of Map Units**
None	No supplemental shrub planting is recommended in the map unit because existing cover and diversity nears predicted site potential.	35.2	18
Low	Shrub installation recommended at a rate of 75 shrubs per acre which is predicted to increase native understory cover by approximately 5% within 10 years. This class was applied to map units where 1) current site conditions (soils, shading, and or depth to groundwater) are most suitable for grassland/savannah, or 2) areas that currently support a developing native understory where supplemental planting will accelerate native understory establishment and increase diversity.	12.9	12
Medium	Shrub installation recommended at a rate of 150 shrubs per acre which is predicted to increase native understory cover by approximately 10% within 10 years. This class was assigned to map units due to a number of potential scenarios including: 1) pole planted portions of burn areas or existing gallery forest that are slightly deeper to groundwater (typically > 5 feet) than units where a high shrub density is recommended. These units also did not typically have narrow depressions that could be targeted for high density planting during installation.	66.0	22

High	Shrub installation recommended at a rate of 300 shrubs per acre which is predicted to increase native understory cover by approximately 20% within 10 years. This class was assigned to map units where current site conditions (soils, shading, and or depth to groundwater) are expected to support a high density of shrubs. We predict that these locations will also be prone to consistent reinvasion of exotic phreatophytes (elm and Russian olive predominantly) and a dense native understory will provide competition. This class was also assigned to burn areas where pole planting has been successful and conditions are currently favorable for shrub establishment. Oftentimes units receiving this class also contained narrow depressions where little watering is expected to be necessary for successful establishment.	56.2	20

TABLE 14. SHRUB IRRIGATION CLASSES AND DEFINITIONS

Recommended Irrigation Intensity Class in Shrub Planting Areas	Class Definition	Acres	Number of Map Units
N/A	No shrub planting recommended	35.2	18
None	Potted shrub roots should be in contact with soil water during installation and throughout the year. Consider watering the shrubs during installation but no supplemental irrigation is necessary.	2.0	5
Low	Interpolated depth to groundwater analysis predicts that mean depth to groundwater ranges from 3 to 5 feet at approximately 650 cfs. In most cases the map unit also contains dense native overstory canopy cover, and soil samples detected loamy soils with sufficient water holding capacity and soil water available within the top 2-3 feet below the surface. Generously water shrubs during installation and then periodically monitor for indications of moisture stress (yellowing and/or wilting) but infrequent need for supplemental irrigation is expected as long as high spots (and previous spoil areas) are avoided during planting.	14.8	7
Medium	Interpolated depth to groundwater analysis predicts that mean depth to groundwater ranges from either 4 to 6 feet during typical low flow growing season conditions (approximately 650 cfs). Several map unit specific considerations warranted this class assignment, including; available shade will be reduced after exotic phreatophytes (primarily elm) are removed, native canopy was patchy and highly variable, soils were typically coarse textured, and small, shallow depressions available for planting were not common or widespread. Generously water shrubs during installation and then provide supplemental irrigation at least once monthly during May through July. Periodically monitor for indications of water stress (yellowing and wilting) through the first growing season and water as needed. Little to no supplemental irrigation will be necessary following the first growing season post-installation. Target shaded areas during planting.	69.4	23
High	Interpolated depth to groundwater analysis predicts that mean depth to groundwater exceeds 6 feet at approximately 650 cfs in the map unit but the map unit contains at least pockets of available shade produced by native overstory species. Soils are typically dominated by coarse textured soils. Generously water shrubs during installation and then irrigate at least once monthly through the first growing season (April through October) and monitor biweekly for indications of moisture stress between May through July. Map units assigned with this class typically contain at least isolated narrow depressions where depth to groundwater will be less than 5 feet. Those depressions should be targeted during planted and planted with a higher shrub density during installation.	34.1	12
Very High	Interpolated depth to groundwater analysis predicts that mean depth to groundwater exceeds 6 feet at approximately 650 cfs in the map unit and the map unit contains little to no overstory canopy cover. Soil textures were coarse through the profile and previous revegetation efforts have not been successful in these map units. Generously water shrubs during installation. During the first growing season, at minimum, irrigate shrubs at least once monthly through the growing season (April through October and biweekly during the hottest, driest months (May through July). Additional watering may also be necessary during the second growing season. Target shallow depressions during planting, as available.	14.8	7

TREE POLE PLANTING

Cottonwood and Gooding's willow (*Salix gooddingii*) pole planting are recommended in portions of the project area (**Figure 14**), although planting densities and target species vary depending upon map unit conditions (i.e., primarily soils, depth to groundwater, and existing vegetation attributes) (**Figure 15**). Pole planting priority and recommended planting densities are presented below in **Tables 15 and 16**. The OSD has extensive experience and expertise with pole planting procedures, so this report does not elaborate on plant harvesting, handling and planting methods.

TABLE 15. TREE POLE PLANTING PRIORITY CLASSES

Tree Pole Installation Priority Score	Acres	Number of Map Units
Low	105.8	35
Moderate	23.7	16
High	40.9	21

TABLE 16. TREE POLE PLANTING CLASSES AND DEFINITIONS

Recommended Tree Planting Density Class	Class Definition	Acres	Number of Map Units
None	No supplemental tree planting is recommended in the map unit because existing cover and diversity nears predicted site potential.	105.8	35
Low	Tree installation recommended at a rate of 12 trees per acre to increase native overstory cover by approximately 5% within 10 years. This class was typically assigned to map units with a well-established cottonwood overstory or a dense coyote willow understory. Supplemental Gooddings willow planting is recommended in order to diversify species diversity and foliage distribution. This class was also applied to one open/barren map unit where buried debris and rubble were frequently encountered during soil sampling.	32.5	20
Medium	Tree installation recommended at a rate of 25 trees per acre to increase native overstory cover by approximately 10% within 10 years. Class predominantly assigned to barren map units with coarse soils and deep groundwater (e.g. > 6 feet through most of the map unit). Site potential in these zones was typically considered a cottonwood savannah.	23.0	12
High	Tree installation recommended at a rate of 50 trees per acre to increase native overstory cover by approximately 20% within 10 years. Class assigned to barren map units with shallow groundwater (e.g. 3-5 feet) or units with favorable cottonwood/Goodings willow growing conditions that currently support a dense exotic overstory.	9.1	5

EXCAVATION OPPORTUNITIES

Potential opportunities for excavation of new moist soil features (backwaters, terraces, swales, etc.) were assessed during this project and located at several map units (**Figure 16**). Five map units (4.1 acres) had high excavation potential while 18 map units (19.5 acres) were classified as moderate potential (**Table 17**). Additional map units met the defined criteria for high excavation potential but we consider map units 15 and 17 (adjacent to the storm water outfall approximately 500 feet north of I-40), as the first candidates for excavation because the location is accessible for heavy equipment, surrounds a perennial open water feature, and lies in one of the most degraded portions of the site where previously management actions (weeding and plant establishment) have been difficult. Two locations were identified where previously constructed channels can be enhanced by replacing the crusher fine trail with pedestrian bridges (map units 47 and 49). If new moist soil feature construction at this site is a high priority for OSD, several locations for further consideration were located but significant additional analysis, planning, and design work will be required to develop formal engineering plans, permit the project(s), analyze water depletions, etc.

TABLE 17. BACKWATER WETLAND HABITAT / EXCAVATION POTENTIAL SUMMARY

Excavation Potential Class	Class Definition	Acres	Number of Map Units
Low	Map unit Distance to the channel, high excavation volume, and/or existing desirable habitat limits excavation potential	146.7	49
Moderate	Areas received this score include 1) Barren or exotic dominated areas, that are at least partially connected to the channel that appear to require significant excavation (e.g. > 4 feet) or, 2) existing habitat creation features that can be enhanced and/or maintained via additional excavation	19.5	18
High	Barren areas directly connected to the channel where new overbank features can be constructed with what appears to be a reasonable excavation volume.	4.1	5

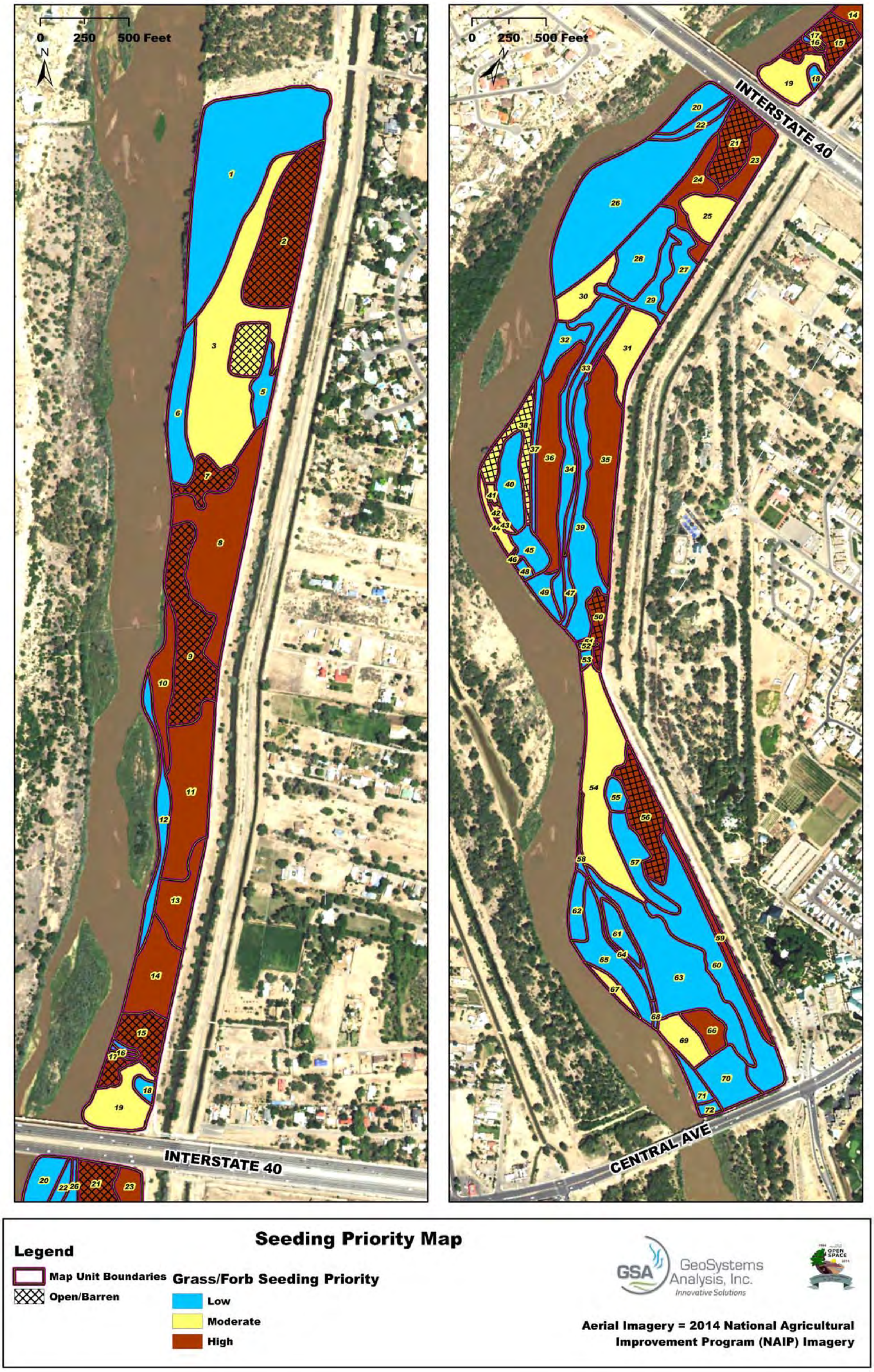

FIGURE 10. SEEDING PRIORITY MAP

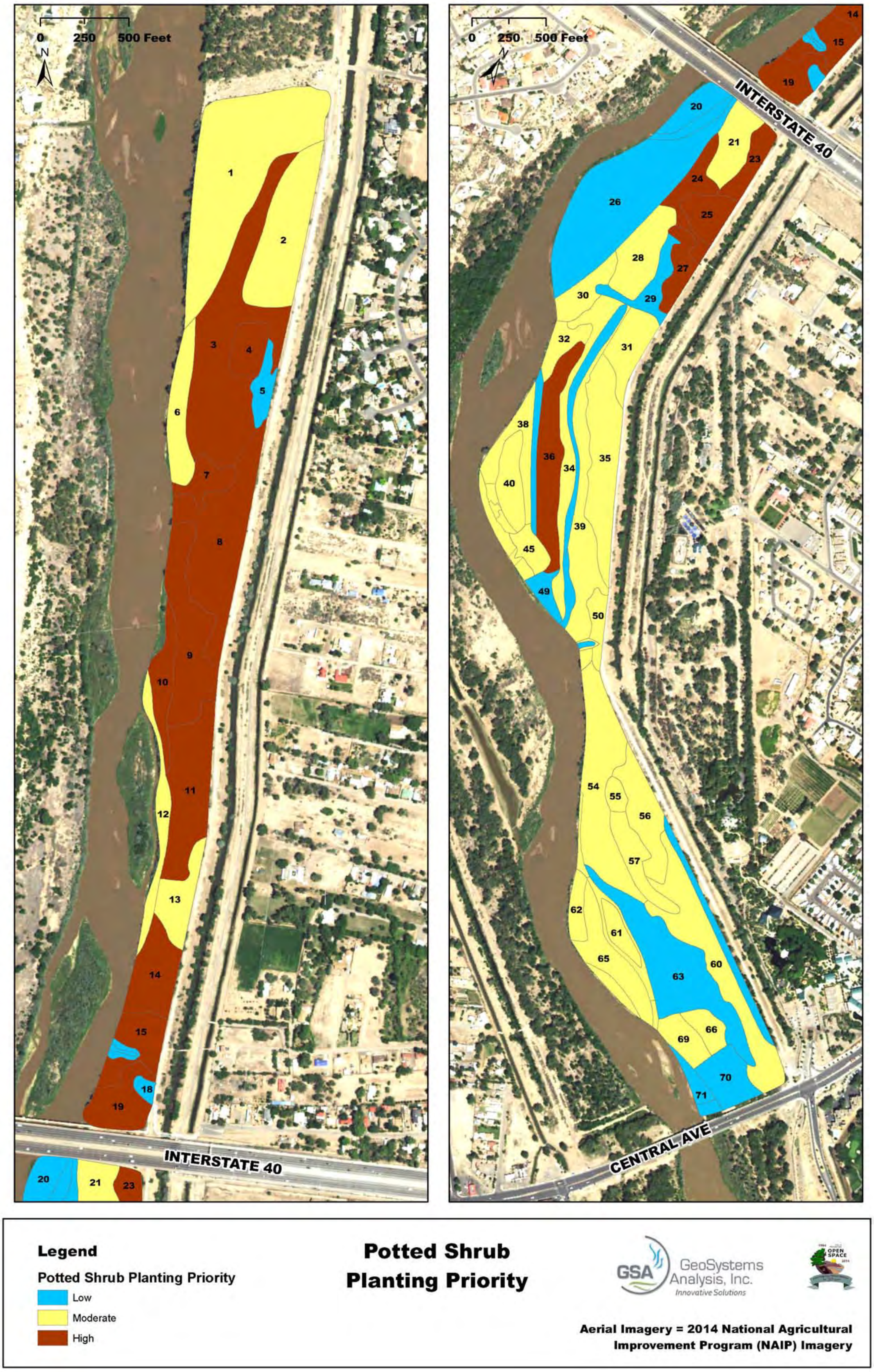

FIGURE 11. SHRUB INSTALLATION PRIORITY MAP

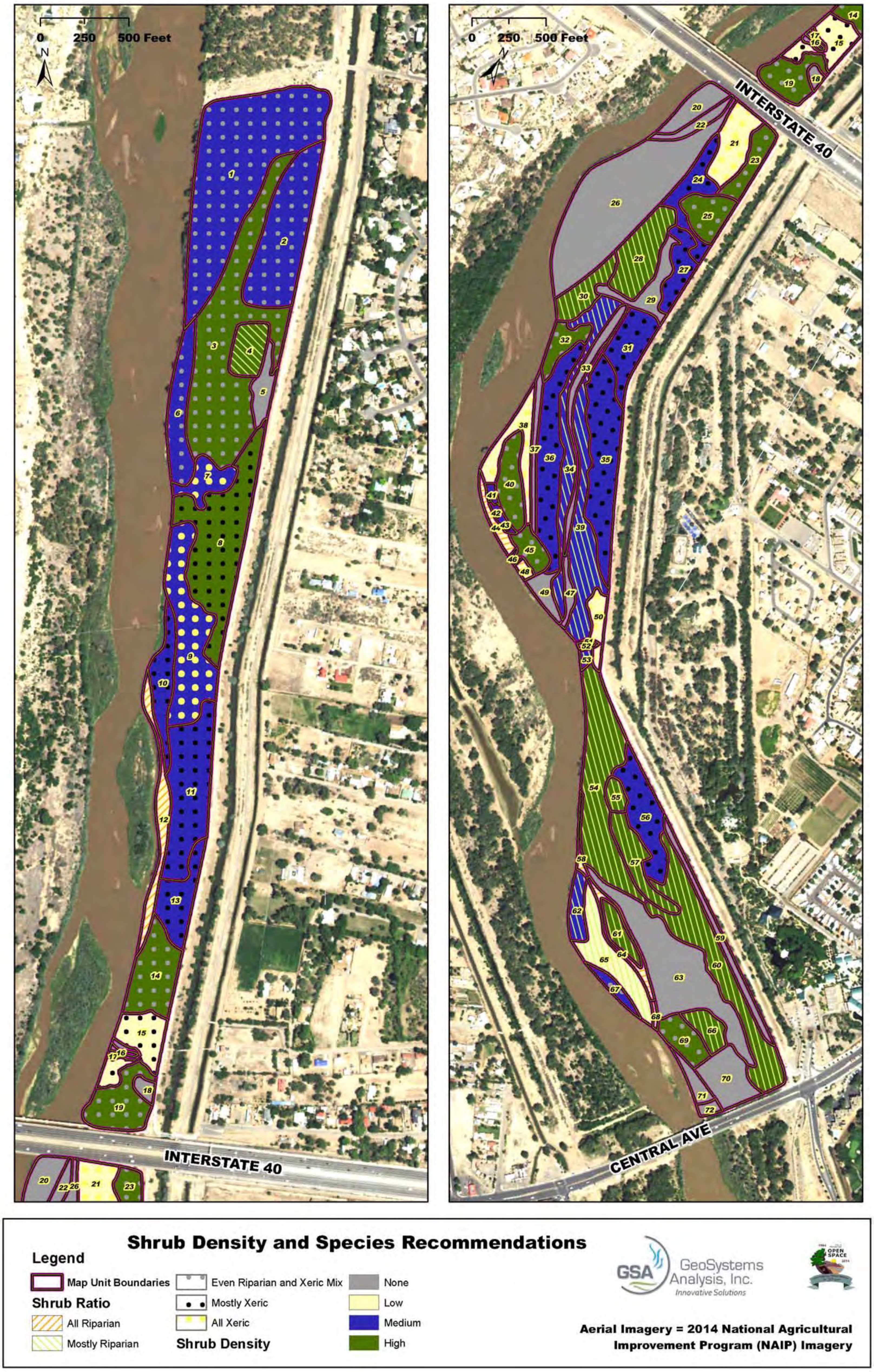

FIGURE 12. RECOMMENDED SHRUB SPECIES MIX AND DENSITY MAP

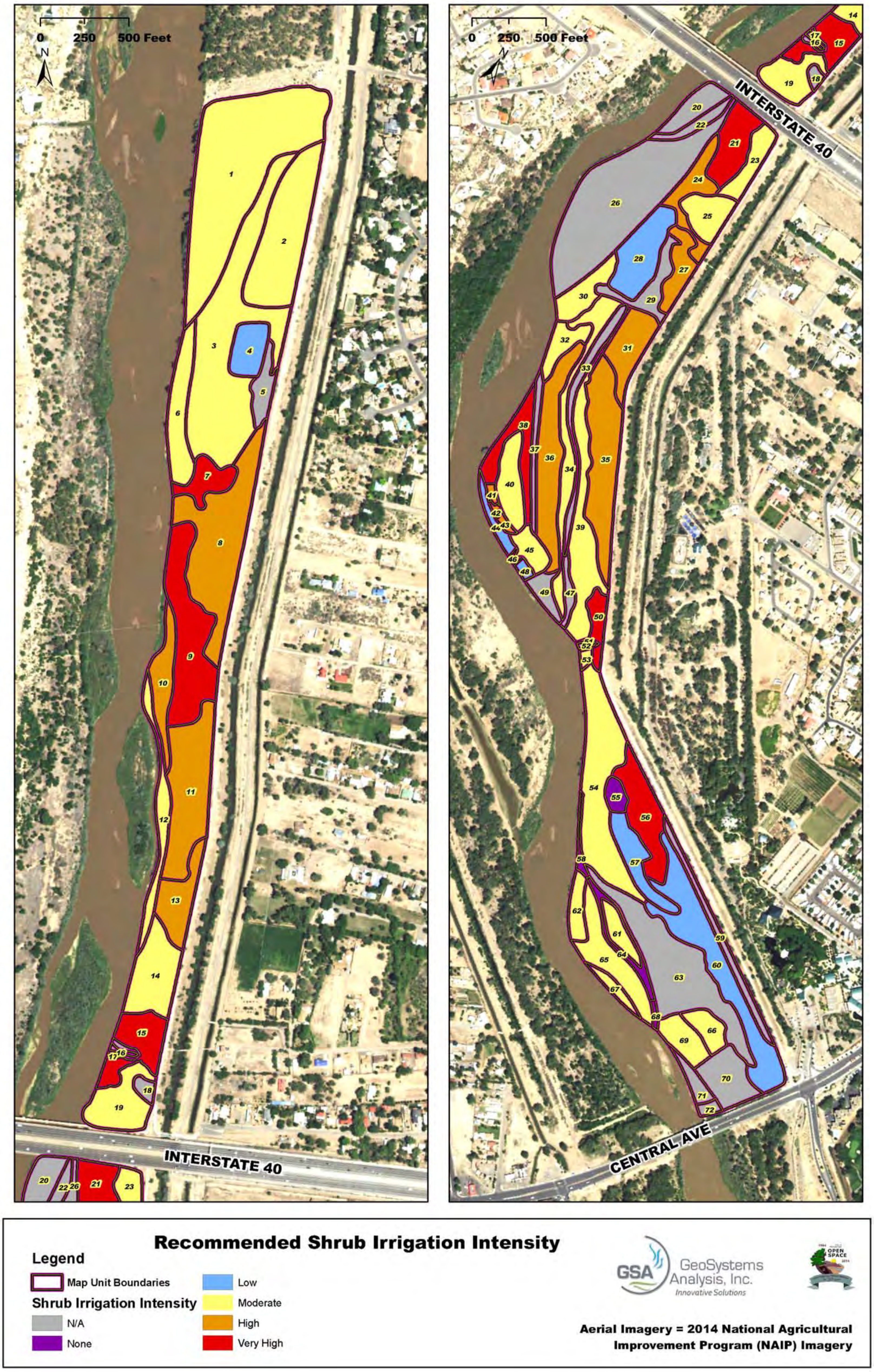

FIGURE 13. RECOMMENDED SHRUB IRRIGATION INTENSITY MAP

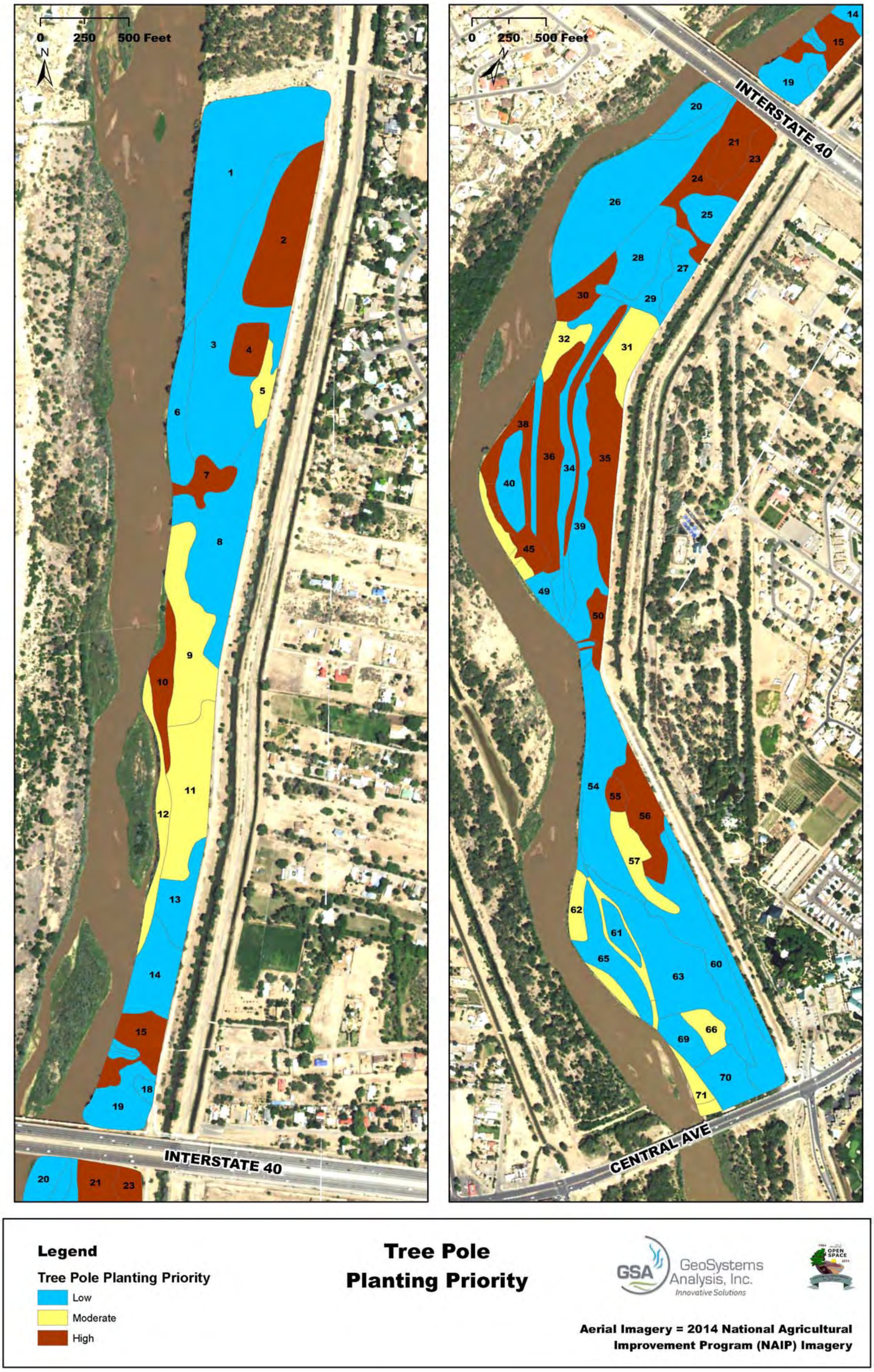

FIGURE 14. TREE INSTALLATION PRIORITY MAP

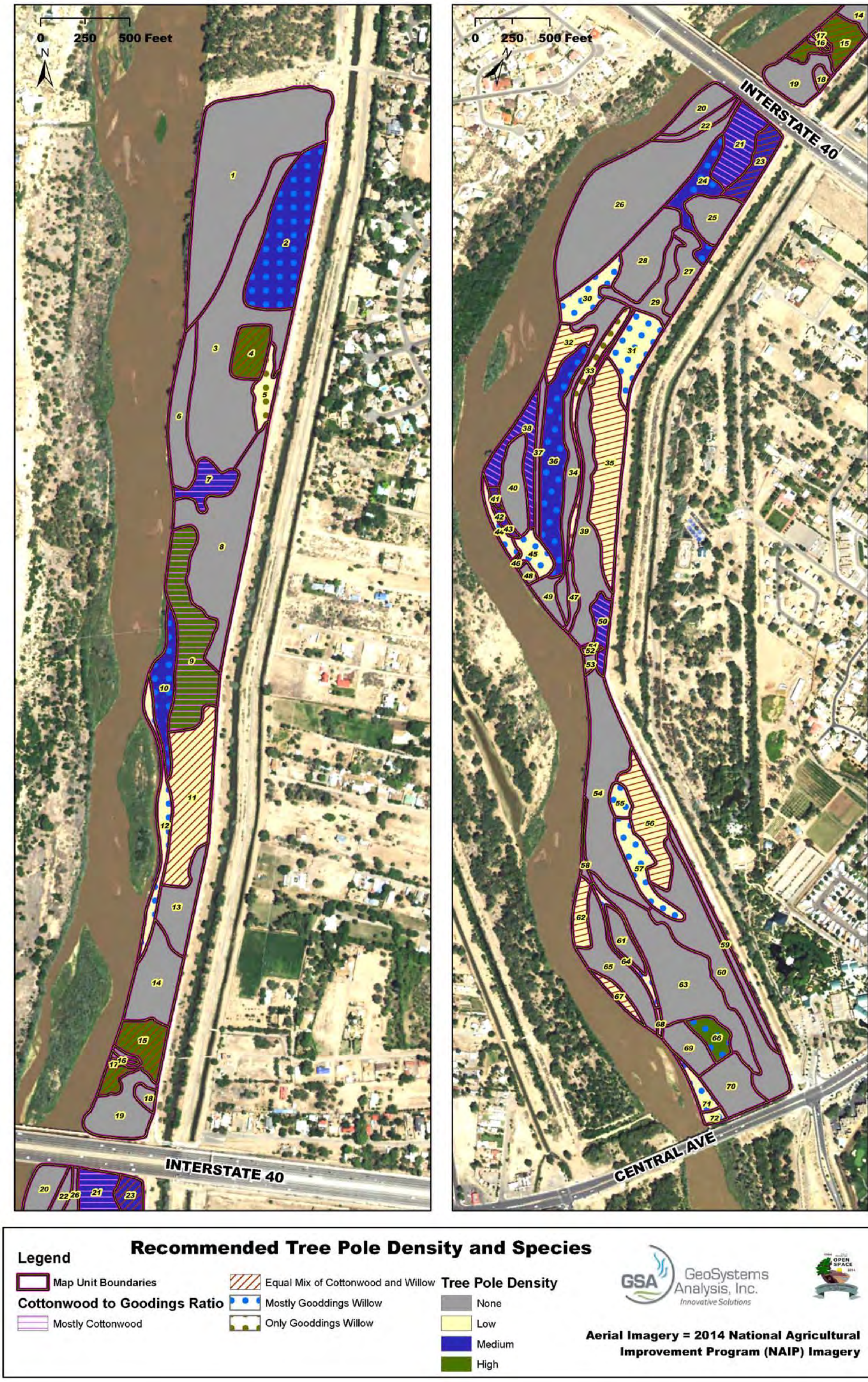

FIGURE 15. TREE POLE DENSITY AND SPECIES MIX MAP

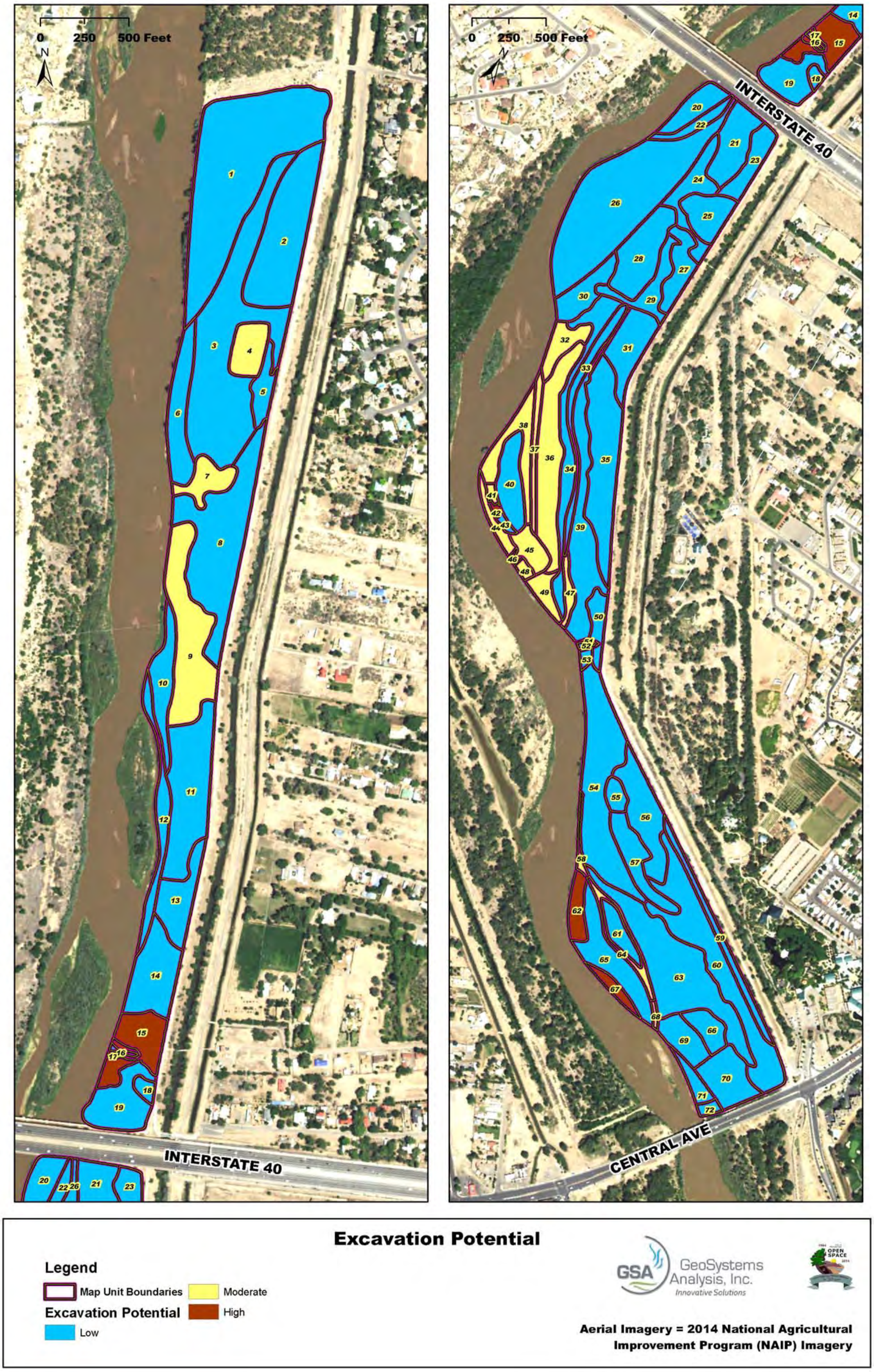

FIGURE 16. EXCAVATION POTENTIAL MAP

SCHEDULE OF MAJOR ACTIVITIES

Major maintenance and management activities recommended in this plan can be organized into regularly scheduled seasonal activities that become part of OSD's annual workflow. A list of the recommended timing for primary activities recommended in this report is included in **Table 18**. No mechanical activity is recommended between April 15 and August 15 in consideration of the Migratory Bird Treaty Act. While some of the management actions listed in the table below can be successful during a broader window, the ideal timing we recommend intends to parse activities into discrete blocks to avoid overwhelming staff resources, particularly between August 15 and April 15, when OSD staff will also be maintaining other sites throughout the city.

TABLE 18. RECOMMENDED SEASONAL ACTIVITY SCHEDULE

Ideal Timing	**Activity**
February 1 - October 15	Irrigate Potted Shrubs – per specific irrigation intensity recommended for individual map units previously in this report
March 15 - September 15	Monitor and Remove Annual Weed Seedlings
May 1 - May 30	Herbicide Treatment – Whitetop (rosette to bolting period)
June 15 - July 15	Seed Grasses
June 15 - September 1	Herbicide Treatment - Ravenna Grass (during peak growing season, if chemical control is preferred over physical removal)
July 15 - September 30	Irrigate Seeding Areas – daily to weekly, as frequently as possible through monsoon season
August 15 - September 15	Foliar Treatment - Tree of Heaven (during growing season, before leaf fall)
August 15 - April 15	Basal Bark or Hack and Squirt Treatment (Initial Treatment) - Tree of Heaven
August 15 - April 15	Cut Stump Treatment - Siberian Elm
October 1 – December 1	Install Potted Shrubs
December 1 - March 15	Install Tree Poles
Year Round	Hand Excavate - Ravenna Grass (if physical removal is preferred over chemical control)

IMPLEMENTATION SEQUENCE

The site was divided into two Management Zones (**Figure 17**) for the purpose of organizing a specific sequence that achieves all of the maintenance, management, and habitat enhancement recommendations within this report over the course of a five-year implementation period (**Table 19-23**). Management Zone 1 (67 acres) includes the northern portion of the site, which is still recovering from the I-40 burn. Overall, that portion of the site requires more intensive maintenance and management. Management Zone 2 (103 acres) is located in the southern portion of the site. While relatively intensive maintenance and management is recommended for Zone 2, most work in Zone 2 follows the highest priority activities in Zone 1.

The implementation sequence aligns with maintenance and management priority classes, methods, and ideal timing of various actions as communicated in previous sections of this report. Steps are organized on a yearly basis. To assist with budgeting and planning, total acreage is listed for each step along with the quantity of shrub or tree material needed for installation. If OSD plans to excavate new overbank habitat than those particular map units should be removed from the acreage and plant quantities tables below.

TABLE 19. YEAR 1 RECOMMENDED PROJECT IMPLEMENTATION SCHEDULE

Recommended Year	Step	Action	Management Zone	Recommended Season	Acres	Quantity of Material Needed
Year 1	1	Initial treatment of annual weeds in all Open/Barren areas, regardless of management zone	All Open/Barren Areas	Spring through Late Summer	21.2	
Year 1	2	Hand seed grasses in Open/Barren areas, regardless of management zone	All Open/Barren Areas	Early Summer	21.2	
Year 1	3	Irrigate a portion of the areas seeded during 2016 and monitor results to guide irrigation practices for future seeding at the site	Zone 1	Early Summer through Late Summer	TBD	
Year 1	4	Initial treatment of all tree of heaven in Management Zone 1	Zone 1	Early Fall	1.4	
Year 1	5	Initial treatment of Siberian elm in high priority elm treatment areas of Management Zone 1	Zone 1	Fall	29.7	
Year 1	6	Install tree poles in Open/Barren areas, regardless of management zone	All Open/Barren Areas	Fall through Winter	21.2	807 Total Trees (345 Gooddings and 459 cottonwood)

TABLE 20. YEAR 2 RECOMMENDED PROJECT IMPLEMENTATION SCHEDULE

Recommended Year	Step	Action	Management Zone	Recommended Season	Acres	Quantity of Material Needed
Year 2	1	Maintain annual weeds in Open/Barren areas that were previously treated and initially treat other high priority annual weed management areas located in Management Zone 1	All Open/Barren Areas and Other Portions of Zone 1	Spring through Late Summer	29.4	
Year 2	2	Seed remaining high priority grass/forb seeding portions of Management Zone 1 that were not seeded during the previous year	Zone 1	Early Summer	20.6	
Year 2	3	Irrigate new seeding areas based on results of irrigation and monitoring from the previous year.	Zone 1	Early Summer through Late Summer	TBD	
Year 2	4	Retreat tree of heaven in Management Zone 1	Zone 1	Early Fall	1.4	
Year 2	5	Retreat Siberian elm in portions of Management Zone 1 that were treated during the previous year (High Priority Zones)	Zone 1	Fall	29.7	
Year 2	6	Initial treatment of Siberian elm in moderate priority elm treatment areas of Management Zone 1	Zone 1	Fall	18.7	
Year 2	7	Plant shrubs in high priority shrub planting areas of Management Zone 1	Zone 1	Fall through Winter	41.2	9,815 Total Shrubs (3,758 riparian and 6,057 xeric)
Year 2	8	Plant poles in high priority pole planting areas of Management Zone 1 that were not planted during the previous year	Zone 1	Fall through Winter	5.4	136 Total Trees (92 Gooddings and 44 cottonwood)
Year 2	9	Irrigate shrubs planted during this season	Zone 1	Spring through Fall	41.2	

TABLE 21. YEAR 3 RECOMMENDED PROJECT IMPLEMENTATION SCHEDULE

Recommended Year	Step	Action	Management Zone	Recommended Season	Acres	Quantity of Material Needed
Year 3	1	Maintain annual weeds in high priority areas in Management Zone 1 and initial treatment on moderate priority weed management areas located in that zone	Zone 1	Spring through Late Summer	54.9	
Year 3	2	Initial annual weed treatment in high priority annual weed management areas that are located in Management Zone 2	Zone 2	Spring through Late Summer	14.5	
Year 3	3	Seed high priority grass/forb seeding portions of Management Zone 2 that were not previously seeded when all Open/Barren areas were seeded during Year 1	Zone 2	Early Summer	13.5	
Year 3	4	Irrigate new seeding areas based on results of irrigation and monitoring from previous years	Zone 2	Early Summer through Late Summer	TBD	
Year 3	5	Retreat tree of heaven in Management Zone 1	Zone 1	Early Fall	1.4	
Year 3	6	Initial treatment of all tree of heaven in Management Zone 2	Zone 2	Early Fall	2	
Year 3	7	Retreat Siberian elm in in portions of Management Zone 1 that were treated during the previous year (Moderate Priority Zones)	Zone 1	Fall	18.7	
Year 3	8	Initial treatment of Siberian elm in high priority elm treatment areas of Management Zone 2	Zone 2	Fall	55.8	
Year 3	9	Plant shrubs in moderate priority shrub planting areas of Management Zone 1	Zone 1	Fall through Winter	24.5	3,357 Total Shrubs (1,575 riparian and 1,781 xeric)
Year 3	10	Plant poles in moderate priority pole planting areas of Management Zone 1 that were not planted during the previous year	Zone 1	Fall through Winter	7	84 Total Trees (52 Gooddings and 32 cottonwood)
Year 3	11	Irrigate shrubs planted during this season	Zone 1	Spring through Fall	24.5	

TABLE 22. YEAR 4 RECOMMENDED PROJECT IMPLEMENTATION SCHEDULE

Recommended Year	**Step**	**Action**	**Management Zone**	**Recommended Season**	**Acres**	**Quantity of Material Needed**
Year 4	1	Manage Ravenna grass in Management Zone 1	Zone 1	Year Round	0.2	
Year 4	2	Maintain annual weeds in high and moderate priority weed management areas throughout the site	Zone 1 and Zone 2	Spring through Late Summer	82.5	
Year 4	3	Seed moderate priority grass/forb seeding portions of Management Zone 1	Zone 1	Early Summer	13.5	
Year 4	4	Irrigate new seeding areas based on results of irrigation and monitoring from previous years	Zone 1	Early Summer through Late Summer	TBD	
Year 4	5	Retreat tree of heaven in Management Zone 2	Zone 2	Early Fall	2	
Year 4	6	Retreat Siberian elm in in portions of Management Zone 2 that were treated during the previous year (High Priority Zones)	Zone 2	Fall	55.8	
Year 4	7	Initial treatment of Siberian elm in moderate priority elm treatment areas of Management Zone 2	Zone 2	Fall	24.8	
Year 4	8	Plant shrubs in high priority shrub planting areas of Management Zone 2	Zone 2	Fall through Winter	6.6	990 Total Shrubs (248 riparian and 742 xeric)
Year 4	9	Plant poles in high priority pole planting areas of Management Zone 2	Zone 2	Fall through Winter	18.9	398 Total Trees (292 Goodings and 106 cottonwood)
Year 4	10	Irrigate shrubs planted during this season	Zone 2	Spring through Fall	6.6	

TABLE 23. YEAR 5 RECOMMENDED PROJECT IMPLEMENTATION SCHEDULE

Recommended Year	Step	Action	Management Zone	Recommended Season	Acres	Quantity of Material Needed
Year 5	1	Manage Ravenna grass in Management Zone 2	Zone 2	Year Round	7.4	
Year 5	2	Maintain annual weeds in high and moderate priority weed management areas throughout the site	Zone 1 and Zone 2	Spring through Late Summer	82.5	
Year 5	3	Manage white top (only known to occur in Management Zone 2)	Zone 2	Late Fall to Early Summer	0.1	
Year 5	4	Seed moderate priority grass/forb seeding portions of Management Zone 2	Zone 2	Early Summer	17.9	
Year 5	5	Irrigate new seeding areas based on results of irrigation and monitoring from previous years	Zone 2	Early Summer through Late Summer	TBD	
Year 5	6	Retreat tree of heaven in Management Zone 2	Zone 2	Early Fall	2	
Year 5	7	Retreat Siberian elm in in portions of Management Zone 2 that were treated during the previous year (Moderate Priority Zones)	Zone 2	Fall	24.8	
Year 5	8	Plant shrubs in moderate priority shrub planting areas of Management Zone 2	Zone 2	Fall through Winter	62.8	13,576 Total Shrubs (8,636 riparian and 4,939 xeric)
Year 5	9	Plant poles in moderate priority pole planting areas of Management Zone 2	Zone 2	Fall through Winter	12	190 Total Trees (137 Gooddings and 53 cottonwood)
Year 5	10	Irrigate shrubs planted during this season	Zone 2	Spring through Fall	62.8	

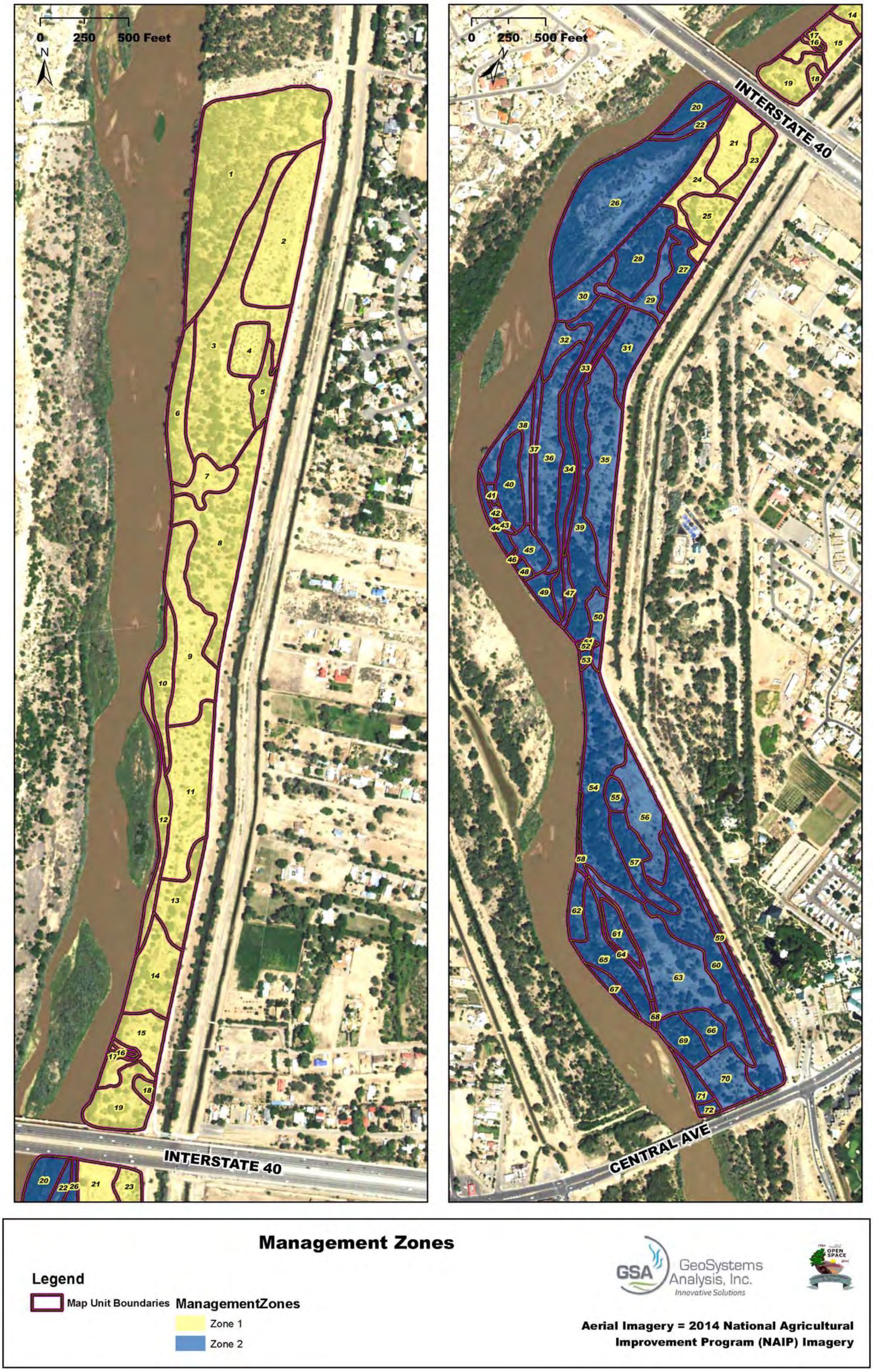

FIGURE 17. MANAGEMENT ZONES MAP

APPENDIX A: Detailed Soil Log