Preliminary Assessment of the Effects of Habitat and Landscape Variables on Vernal Pool Ecosystems

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PRELIMINARY ASSESSMENT OF THE EFFECTS OF HABITAT AND LANDSCAPE VARIABLES ON VERNAL POOL ECOSYSTEMS

1.0 ABSTRACT

The purpose of this study is to provide Placer County with preliminary information regarding the flora and fauna of vernal pool landscapes, as well as to document environmental factors that may influence effective conservation planning for local vernal pool landscapes. Surveys for vernal pool plants and birds, along with preliminary surveys for mammals, amphibians, and pollinating insects, were conducted within 12 vernal pool preserves in western Placer County from March through July 2003. Sites were selected based on access availability rather than by standard random sampling methodologies. Preserve variables such as size, area-to-perimeter ratio, number of vegetation communities, and presence of various anthropogenic influences were documented at each site. We documented 184 plant species in the sampled vernal pools, 102 bird species, and a number of mammals, amphibians and pollinating insects utilizing the vernal pool landscapes in this study. Plant and bird data were compared among preserves, and where significant differences were detected, the diversity was statistically analyzed to detect any relationships among plant and bird diversity and preserve variables. In this study, some significant variation in biodiversity was detected; however, the results indicated that some of the factors that would be expected to have a significant effect on plant and spring bird diversity did not (e.g., preserve size), while other variables did (e.g., preserve area to perimeter ratio, diversity of vegetation communities, and the extent of certain anthropogenic influences like altered hydrology and grazing regime). However, small sample size (number of preserves) and variable survey effort among the different taxa may have biased results, raising the possibility that significant differences or the lack of significant differences are an artifact of these issues rather than actual biological trends. Additional research is needed to more accurately determine the relationships between preserve variables and plant and animal diversity. In the meantime, it is our professional opinion that, prior to acquiring new preserve sites, each possible site should be individually assessed for factors that will promote or hinder the ability of that preserve to meet vernal pool landscape conservation objectives.

2.0 INTRODUCTION

Vernal pools are shallow depressional wetlands, formed when the percolation of rainwater and surface run-off is impeded by the presence of a restrictive, subsurface layer (Barbour and Major 1984). These pools remain inundated throughout late winter and early spring, evaporating slowly as temperatures rise and precipitation diminishes. These pools can range anywhere in size between 2 m^2 to the size of a small lake. As a result of periods of inundation, anaerobic conditions develop within the pools, creating a unique ecosystem that supports only a select group of plants. Approximately 70 plant species observed within California's vernal pools are endemic, or confined, to this state alone (Barbour and Major 1984). This endemism has prompted classification of California vernal pools as a unique ecosystem (Keeley and Zedler 1998) despite the occurrence of vernal pool landscapes throughout other regions in the world. As vernal pools are comprised of largely endemic species, they function as islands within a mosaic of grasslands dominated by non-native plants (Holland and Jain 1988). Typical densities

of vernal pools within a grassland matrix range between 5 and 15%. The "vernal pool landscape" is composed of both wetlands and adjacent uplands.

Despite their biological value, many of California's vernal pools have been destroyed. Since European settlement, Holland (1998) estimated that three million acres of vernal pool landscapes have been destroyed within the Central Valley, Sierra Nevada foothills, and San Francisco Bay regions. As of 1997, fewer than one million acres of vernal pool grasslands remained, many of which were severely fragmented (Holland 1998). The destruction of vernal pool landscapes throughout California has contributed to significant reductions in wetland-dependent plant and animal species populations. At present time, a total of 100 special-status plant and animal species are associated with vernal pool habitat (CDFG 2003).

Currently, pressures from rapid development and growth are impacting Placer County's vernal pools. As vernal pool landscapes continue to diminish, an increased demand for ecologically sound conservation planning has surfaced.

In June of 2000, the Placer County Board of Supervisors requested that the Planning Department initiate preparation of a Natural Community Conservation Plan (NCCP) and a Habitat Conservation Plan (HCP). These plans will serve to: 1) strategize about the conservation of vernal pool communities; and, 2) design and implement resource management objectives. However, successful implementation will require the use of current and locally relevant scientific data.

The purpose of this study is to provide Placer County with detailed information regarding environmental factors that may influence effective conservation planning for local vernal pool landscapes. In particular, the County is investigating the hypothesis that effective conservation of vernal pool/grassland biota requires the protection of larger reserve areas.

Most conservation biologists agree that, in most cases, ecosystems and their resident species are better protected within larger reserves (Meffe et al. 1997). This notion, supporting larger reserves, is based on the Theory of Island Biogeography. The theory states that larger islands support a larger number of species than smaller islands, assuming the water surrounding the island is uninhabitable (MacArthur and Wilson 1967). This theory has been applied to terrestrial landscapes where reserves are the "islands" found within a matrix of altered landscapes. When applying the theory to a terrestrial scenario, the general prediction is that larger reserves are superior to smaller reserves because they can support a greater number of species.

More recent research has suggested that effective reserve design may not rely solely on size, but may also depend on a variety of other factors. Some factors that may change the basic assumption that larger reserves are better-suited include: 1) the natural history of the species present (e.g., small required home ranges); 2) the conditions of the surrounding area (e.g., is the surrounding matrix truly inhospitable); 3) the occurrence of corridors that connect reserves; and, 4) whether the goal of the reserve is to protect something other than overall species richness (e.g., protection of a particular endangered species). Therefore, decisions about appropriate reserve design (e.g., location and size) depend on a number of factors in addition to size and on preservation goals. Specific reserve goals may be to provide for the conservation of

high levels of biological diversity, native habitats, ecosystem processes, and/or stable populations of "target" species (Meffe et al. 1997).

By definition, a "reserve" or a "preserve" is a protected natural area, and is defined in the Convention on Biodiversity as: "a geographically defined area which is designated, regulated, and managed to achieve specific conservation objectives" (Meffe et al. 1997). However, in this area, these study sites are most commonly referred to as "preserves." In general, the terms "reserve" and "preserve" are used interchangeably within the literature. Because the sites used in this study are commonly referred to as "preserves," this is the term that will be used in this report.

Many aspects of vernal pool ecology have been studied, including their floristic composition (Schlishing and Sanders 1982, Jokerst 1990, Barbour et al. 2003), hydrology (Hanes et al 1990, Butterwick 1998, Hanes and Stromberg 1998,), associations with soil formations (Smith 1998), invertebrate fauna (Balfour and Freeman 1996, Alexander 1998, King et al. 1996, Simovich 1998, Eriksen and Belk 1999, Belk and Fugate 2000, Philippi et al. 2001), and associated wildlife (Baker et al. 1992, Morey and Guinn 1992, Silveira 1998, Morey 1998, Balfour and Morey 1999). In terms of overall biodiversity, Vollmar (2002) documents the biodiversity of the eastern Merced County vernal pool landscape and Holland and Jain (1981) studied the variation in individual vernal pool species richness relative to various geographic parameters like pool size, depth, and latitude. The latter study concluded plant "species diversity patterns in California vernal pools were poorly correlated with habitat and geographic parameters." Current research is being conducted that evaluates the effects of grazing regimes on vernal pool flora and invertebrate composition (Marty 2003). To date, however, researchers have not examined the broader hypothesis that larger vernal pool landscapes function more effectively than smaller ones.

2.1 Project Purpose

The purpose of this study was to provide Placer County with preliminary data to facilitate future conservation and management of local vernal pool ecosystems. This pilot study assesses the diversity of various vernal pool plant and animal communities located at 12 western Placer County vernal pool preserves and provides analysis as to whether differences in species diversity or composition are correlated to specific habitat or landscape variables. Placer County may accordingly use these habitat and land landscape variables and considerations to assess the conservation value of new potential preserve sites.

Specifically, this study documents baseline data on different vernal pool reserve variables, including: 1) vernal pool plant species composition, abundance and richness and 2) anthropogenic (human-caused) influences. In addition, we collected preliminary data about insect pollinators, amphibians, birds, and mammals. This study also presents historical data and observations that are relevant to the selection and acquisition of future preserves. Finally, this study recommends topics for future research within vernal pool preserves. Due to sample size restrictions and the inability to have a random sampling protocol in selecting the preserve sites, this study presents only preliminary, pilot study data for western Placer County and may not reflect the conditions of all vernal pool landscapes in this region. The information gathered in this study is meant to be used to guide both future research and new reserve design decisions.

3.0 METHODS

Biologists from ECORP Consulting, Inc. and North Fork Associates conducted all field surveys associated with for this study (Appendix A – Summary of Project Personnel). The initial study plan was presented to the County in response to the Placer County Vernal Pool Ecosystem Assessment - Proposed Scope of Work issued on 5 December 2002. Subsequent consultations related to project goals, study methodologies, and budget constraints occurred with Placer County, the NCCP/HCP Inter-Agency Working Group (IAWG), Dr. Peter Brussard (University of Nevada, Reno), and Jeff Finn (California Department of Fish and Game (CDFG). Development of a final study plan was a collaborative effort between ECORP Consulting, Inc. and the above parties. The investigation was designed to assess a broad range of vernal pool taxa and parameters rather than to focus on a more rigorous study of any one taxonomic group. The final study plan methodology is described below.

3.1 Study Sites

Placer County secured access to twelve study sites. Study site selection was not based on standard sampling protocols such as random sampling but instead on the availability of access and all preserves with access were included in the study. The included study sites, located in western Placer County (Figure 1 – *Study Site Locations*), consisted of vernal pool preserves of various sizes. Whereas each preserve contained vernal pools, the distributions and densities of vernal pools differed greatly within each preserve. Table 1 provides the names of the 12 study sites selected for inclusion in the study along with each site's current land owner/manager.

Table 1. ***Placer County Vernal Pool Ecosystem Study Sites.***

Site	Preserve Name	Preserve Owner/Manager
1	Mahaney Park	City of Roseville
2	Woodcreek Oaks City Preserve	City of Roseville
3	Woodcreek North Preserve	City of Roseville
4	Woodcreek West Preserve	City of Roseville
5	Sun City Roseville	Del Webb Corporation
6	Stanford Ranch Rocklin Vernal Pool Preserve	City of Rocklin
7	Highland Reserve South	City of Roseville
8	Rodeo Grounds Preserve	Del Webb Corporation
9	Sheridan Mitigation Bank	Wildlands, Inc.
10	Aitken Ranch Mitigation Bank	Wildlands, Inc.
11	East Sheridan Vernal Pool Preserve	Wildlands, Inc.
12	Orchard Creek Mitigation Bank	Wildlands, Inc.

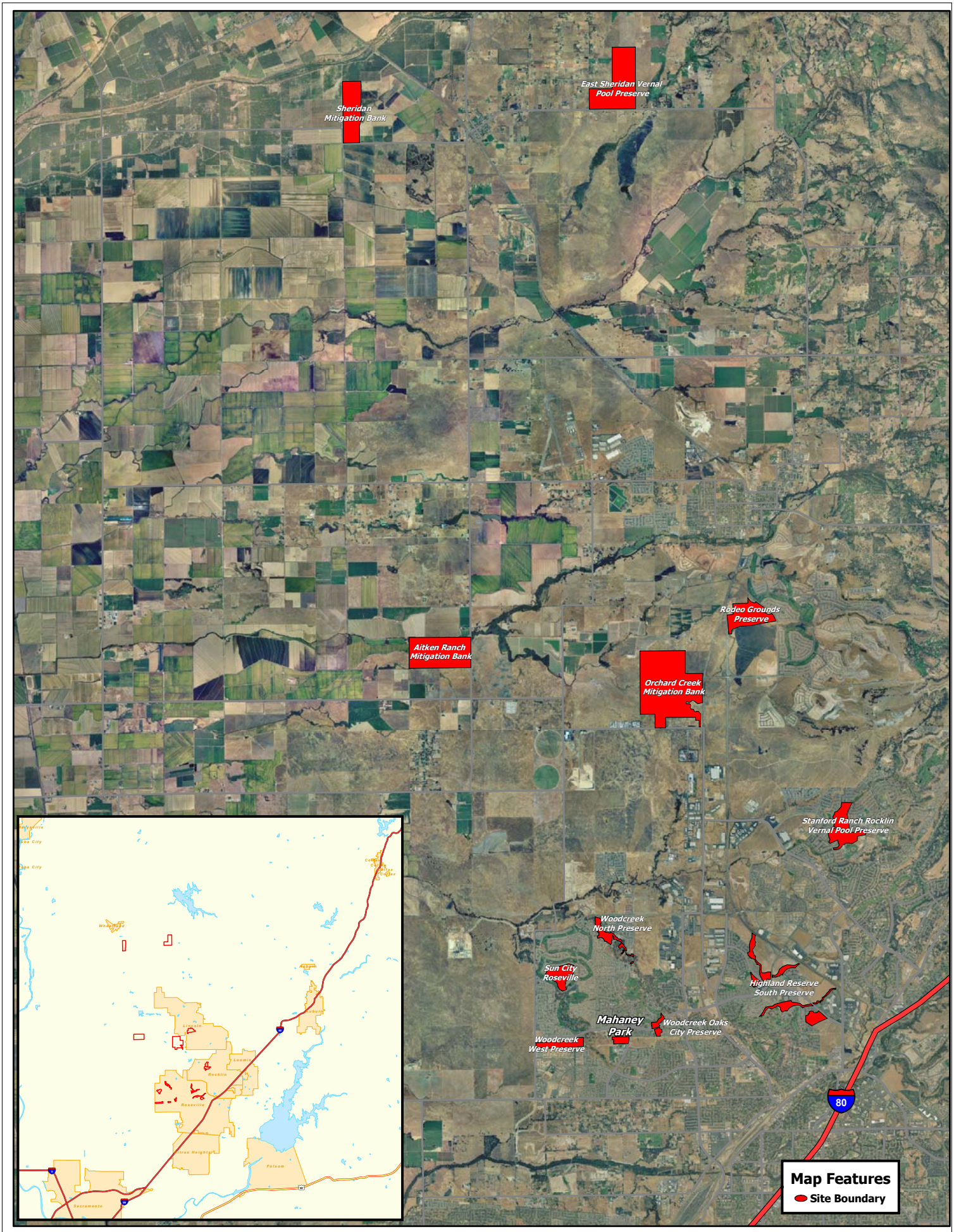

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Figure 1. Study Site Locations

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3.2 Habitat and Landscape Characteristics

For each study site, the following variables were quantified: preserve size (acres), preserve area to perimeter ratio, percent of perimeter with potential (or actual) altered hydrology, total number of vernal pools, and length of linear features. The purpose of quantifying these variables was to create measurable attributes for use when comparing taxa specific results. These variables were assessed using aerial photographs and wetland delineation maps, combined with ECORP staff familiarity with the project areas.

AutoCAD® 2004 was used to calculate preserve acreage and perimeter. All of the City of Roseville's preserve boundaries were obtained from previously existing ECORP AutoCAD files. The preserve boundaries for the remaining eight sites were estimated using November 2002 aerial photographs and hard copy preserve maps (AirPhoto USA 2004).

In addition to measuring the overall perimeter, the adjacent land-uses were assigned to one of eight categories. The sum of these individual perimeter categories equaled the total perimeter for each site. Adjacent land use perimeter categories included developed, currently under construction, road or railroad track, open space, grazing land, fallow/undeveloped field, irrigated pasture, and irrigated parks, schools or parks.

"Developed lands" referred to any sites with residential or commercial development. This included the backyards of single-family residential homes, as well as, parking lots associated with commercial developments or apartment complexes. Sites currently under construction were separated out from those that were fully developed. "Roads" included any paved roadway; gravel or dirt roads were not classified as a perimeter category and the land use beyond the gravel or dirt road was used to assign a category. "Open space" included any adjacent land that is officially designated as open space or is part of a park system that is not irrigated and has been left in its natural state. "Grazing land" referred to lands that were actively grazed during 2003. "Fallow fields" included both larger, fields that could be used for grazing or farming, as well as, smaller parcels that were undeveloped but may be slated for future development. Finally, "irrigated" adjacent land uses were separated into either irrigated pasture or park-like irrigated sites such as schools, golf courses or parks. Figure 2 depicts an example of several of these different adjacent land-use categories.

Finally, the percent of perimeter with potential, and actual, altered hydrology was calculated in order to consolidate these perimeter data. This value is the sum of the linear feet of currently: 1) "developed" perimeter, 2) perimeter under construction, and 3) irrigated perimeter areas, divided by the total preserve perimeter.

The length of linear hydrologic features was approximated using existing AutoCAD files, recent aerial photographs, and wetland delineation maps available for each preserve site. Linear features included all intermittent drainages, creeks, and canals within each site.

Biologists determined the total number of on-site vegetation communities when conducting various taxa-specific field surveys. Vegetation communities were assigned according to the classification system described in "A Guide to Wildlife Habitats of California" (Mayer and Laudenslayer 1988).

FIGURE 2. Sample Adjacent Land Use Designations: Highland Reserve South

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Finally, each preserve was categorized according to the following criteria:

1. Grazed vs. Non-Grazed
2. Urban vs. Rural
3. Natural Vernal Pools Only vs. Natural and Constructed Vernal Pools
4. Outfalls Into Preserve vs. No Outfalls Into Preserve
5. Irrigation Run-Off in Preserve vs. No Irrigation Run-Off in Preserve
6. Perennial Water Features Present vs. No Perennial Water Features
7. Paved Paths Present vs. No Paved Paths
8. Public Access vs. No Public Access
9. Beaver Activity On-Site vs. No Beaver Activity On-Site

3.3 Field Surveys

Field surveys, as described below, included systematic surveys for vernal pool plants and birds, and preliminary (pilot) surveys for amphibians, mammals, and pollinating insects.

3.3.1 Vernal Pool Plants

The goals of the plant species surveys were to: 1) provide baseline data about plant species diversity, composition, and abundance in western Placer County vernal pool landscapes; and, 2) assess the effects of various habitat and landscape variables on plant diversity and composition.

The initial study design proposed using quadrat-method sampling to record data in both vernal pool and upland habitats. Under this scenario, floristic data collection was to be conducted by sampling a subset of the vernal pools within each study site, compiling a comprehensive species list from each sampled pool. However, due to time and financial resource constraints and subsequent consultation with the Inter-Agency Working Group (IAWG) and the Biological Review Committee, an assessment level sampling protocol was deemed to be a more appropriate strategy. A detailed description of the 2003 field sampling protocol follows.

The floristic investigation targeted 500 vernal pools. This number was not arrived at by any statistical methodology; rather, it was based staff knowledge and available funding for the field effort, along with consultation with the IAWG. First, a minimum number of wetland features were selected for sampling per study site (n). Then, to achieve a total sample size of approximately 500 vernal pools, additional vernal pools were subsequently added from each site. The minimum number of vernal pools to sample per site (n=22) was based on the following formula:

$$n = \log(1\text{-confidence level})/\log(1-P)$$

This statistical determination was based upon a thorough evaluation of previously recorded vernal pool floristic data sets (collected through Clean Water Act Section 404 mitigation monitoring compliance), which employed similar protocols and methodologies as used in this study. The probability of a plant species occurring in any particular pool (P) was estimated to be 19-32% (average number of species per pool divided by the total number of species within all the vernal pools). This coarse estimate would be accurate only if we could assume that all plant

species are equally distributed and have equal chances of occurring in each vernal pool. Because both of these assumptions are violated, these approximations provide only preliminary guidance for estimating probability of occurrence, and the estimation of P for this study was lowered to a more conservative value of 10%. Ideally, setting P = 10% will establish a minimum sample that will detect all plant species, with a 90% certainty, that occur in >10% of the vernal pools at any given site. Because the focus of this study is to detect overall biodiversity rather than the presence of rare plants, this limit seemed to be a reasonable target.

Based on this established minimum sample size, 264 features would be sampled among the 12 sample sites. Woodcreek North Preserve was a study site that contained only 15 vernal pool features. Consequently, all 15 features were sampled at this smaller site. Next, to achieve sampling in the desired 500 vernal pools, 243 additional pools were required to be added to the floristic sampling plan. Additional vernal pool sampling units were allocated to the study proportionate to the total number of pools present on each study site. Rather than evenly distributing the additional 243 sample units among all preserve sites, those study sites with a large number of pools received a proportionately larger sample size. For example, Woodcreek West (with 99 pools) had seven additional pools sampled while Orchard Creek (with 672 pools) had 56 additional pools sampled. Because the 243 requisite pools were allocated according to vernal pool density, the sampling effort was not equal between sites. Instead, the design met a definitive, minimum threshold, appropriating the remaining sampling units according to the number of total features at each site.

Prior to any fieldwork, all sampling units (pools) in all preserves were assigned numbers to assist with pool identification. Once each pool was identified, a random number table was used to select those pools that were to be monitored in the study. Map and aerial photo quality varied among sites, resulting in occasional uncertainty as to accurate sampling unit identification. Under these circumstances, field biologists were instructed to make an "educated guess" regarding which pool to sample. Therefore, the assumption of a completely random sample was violated for a small subset of the data (i.e., a subset of Highland Reserve South). Because the goal of the study was to accurately characterize each preserve, rather than analyze different habitat types within the preserve, we do not believe this detail will compromise the validity of the overall data set. As a result, no specific effort was made to stratify the random sampling between created and natural pools or among different soil types. Nevertheless, these data were recorded for each sample unit to enable possible future analysis based on these criteria.

Each pool was sampled once during the 2003 spring flowering season. Sampling began on 31 March 2003 and continued through 28 July 2003 with a majority of data collection occurring in May following several late season storms in April 2003. If, during the initial field visit, a pool was still holding water or had not started to flower, the pool was bypassed and surveyed at a later date. Quantitative data were recorded on a standardized data sheet (sample included in Appendix B). Recorded data included a comprehensive list of all observed plant species in addition to estimated overall cover. Pool cover was estimated by a visual assessment of vegetation, thatch, rock and bare ground area. These four individual category values had to add up to 100%. In addition, each observed species within the pool was assigned a cover class (<5%, 5-25%, 25-50%, 50-75%, 75-100%). These individual species cover classes could exceed 100% since there can be multiple layers of vegetation. Biologists also documented any

individual species that were "locally abundant," meaning that species occurred in distinct, dense patches. A species could only be considered "locally abundant" if it had a minimum cover class of 25% or greater.

Typically, biologists spent no more than twenty minutes identifying and recording species observed within any one pool. For larger pools, this timeframe was often extended; however, twenty minutes was generally sufficient time to observe and record at least 90% of the species within a given pool. Field biologists noted other unique pool characteristics, including observations regarding general pool quality, high rodent activity, altered hydrology, or other unusual circumstances.

Lastly, all vernal pools sampled during the study were mapped using a Trimble™ GPS Pathfinder Pro XR receiver (or similar model) with a TSCe data collector. Most were mapped at the time of plant data collection. A pin flag was placed in those pools that were not immediately mapped, and GPS coordinates for those pools were collected at a later date.

Because a number of biologists from both ECORP Consulting, Inc. and North Fork Associates were contributing to the floristic sampling effort (Appendix A), potential inter-observer bias was a concern. To limit inter-observer bias, all biologists met on 31 March 2003, to review the study's protocol and methodology. One vernal pool was collectively sampled as a group. Afterward, each biologist sampled a second vernal pool separately. Observer data were then compared. This group effort was conducted to calibrate the overall cover and individual cover class estimation values and to minimize inter-observer bias. Additionally, each botanist carried a plastic bag to collect samples of any unknown species for identification purposes.

Each species was classified as either a native or non-native species, consistent with *The Jepson Manual: Higher Plants of California* (Hickman 1993). In addition, each species was then designated as a vernal pool species, a generalist wetland species, or other species. Vernal pool species are those plant species listed in the California Department of Fish and Game's "California Vernal Pool Assessment Preliminary Report" (CDFG 1998) as either vernal pool indicators (VPI) or vernal pool associates (VPA). This report defines vernal pool species and generalist species as follows:

1. Vernal pool indicators (VPI): species that are restricted to vernal pools and are not known from other habitats;
2. Vernal pool associates (VPA): species that regularly occur in vernal pools but are not restricted to them, also occurring in similar wetland habitats;
3. Generalists (GEN): species that are distributed in a number of habitats, both wetland and upland, which can include disturbed places, vernal pools, and pool margins;
4. VPI?: species that is a VPI in certain region(s) only, and can be a VPA or GEN in other regions;
5. VPA?: species that is a VPA in certain region(s) only, and is a GEN in other regions;
6. VPI/VPA: species that is a VPI in some regions and a VPA in other regions, yet not known to be a GEN, in any region.

Those species that corresponded with the last three categories (i.e., 4, 5, or 6) were evaluated by ECORP and North Fork botanists to determine appropriate category placement. Species not

included on the list were considered upland species, unless information in the literature supported a different categorical assignment.

"Dominant species" were those species with an individual cover class of 25% or greater.

Finally, historic plant datasets were available for a subset of the preserves used in this study (Highland Reserve South, Woodcreek West, Woodcreek North, and Woodcreek Oaks). These datasets included both individual pool plant species lists as well as overall summary statistics for various years beginning in 1993. The data collection methods in these older datasets were very similar to the methods used in the current study. This allowed us to conduct a side-by-side comparison of a few "case study" vernal pools, as well as, to show the progression of the diversity of vernal pool plants in a particular preserve over a ten year time-period.

3.3.2 Birds

The goals of the bird surveys were to: 1) provide baseline data about avian diversity, composition, and abundance in western Placer County vernal pool landscapes during spring migration; and, 2) assess the effects of various habitat and landscape variables on avian diversity and composition during spring migration.

Three discrete bird surveys were conducted at each site during spring migration (mid-March through April 2003). To account for potential variability in bird activity at different times of day, biologists conducted each successive survey during a different time period. Each site was surveyed once during the morning (sunrise to 10:00), once during the mid-day (10:00 to 14:00), and once in the afternoon/evening (14:00 to sunset). In general, sites were surveyed in a consistent manner so as to ensure that no other site was surveyed more than any other site at any given time. Due to late access authorization, one site (Rodeo Grounds Preserve) was added to the study after two rounds of surveys had already been completed at some of the other sites. All bird surveys were conducted in weather conditions considered conducive to bird activity. No surveys were conducted during times of low visibility, heavy winds, or rain.

Each survey was conducted by walking throughout the site and recording each bird species detected. Each site was surveyed for a minimum of 30 minutes, but for no longer than four hours. The specific amount of time spent surveying each site depended on the size of the site, and diversity of habitats present. At all sites, biologists attempted to devote enough effort to ensure that most, or all of the species present at the site during the time of the survey were recorded. In general, two biologists surveyed large sites, whereas one biologist surveyed small sites. When two biologists surveyed a site, they worked independently, and each surveyed approximately half of the site.

When possible, information was recorded on microhabitat use and bird behavior of species detected. Extra effort was devoted to recording any signs of bird breeding activity or use of vernal pools. During, or at the end of each survey, each species was scored with one of three relative abundance values. Values depended on the number of individuals detected, and were:

"1" (one individual detected),
"2 to 5" (two to five individuals detected), and
">5" (>5 individuals detected).

After completing all bird surveys, the data were entered into an MS Excel spreadsheet, creating a species list (including relative abundance values) for each site. Then, the species richness at each site was calculated by counting the number of species that had been detected during at least one of the surveys.

Avian guilds

For analysis, two unique groups of guilds were created. The "Habitat" guild group was based on a grouping created by Jones and Stokes (2003). In this study, Jones and Stokes (2003) categorized avian habitat preferences, foraging methods, and morphological and behavioral characteristics to create seven different guilds of species. These guilds were Waterbirds, Waders, Shorebirds, Gulls and Terns, Raptors, Terrestrial Landbirds, and Arboreal Landbirds. Each species detected during surveys was placed into one of the seven "habitat" guilds (see Jones and Stokes [2003] for discussions and definitions of each habitat guild). For species not listed in Jones and Stokes (2003), avian biologists used their local knowledge to determine appropriate guild placement.

The second guild group created was based on species' tendency to occur in urban areas. The three guilds in the "Development" guild group were Urban (occur primarily in urban areas), Wild (occur primarily in non-urban areas), and Neutral (occur in both urban and non-urban areas). ECORP avian biologists placed each species into one of the three guilds using knowledge of species occurrence in the greater Sacramento area.

Like overall species richness, guild species richness numbers can be used to compare different study sites. Guild species richness numbers, however, are not a good indicator of the relative composition of bird species at each site. To gain insight into the relative composition of avian guild species within and among sites, the relative richness of each guild was calculated by dividing the number of species detected in the guild by the total number of bird species detected. For example, 73 bird species were detected at the Sheridan Mitigation Bank site, of which 16 were "Arboreal Landbirds". Thus, the relative composition of Arboreal Landbirds at the Sheridan Mitigation Bank was 16/73, or 22%.

3.3.3 Mammals

Between 5 June and 18 August 2003, two methods were used to sample the mammal community within each of the twelve preserve sites. Nocturnal live traps were set to capture crepuscular and nocturnal rodents and other small mammals and transect surveys were conducted to identify mammal signs (e.g., scat, prints, and burrows) throughout each site. The primary objectives for mammal sampling were to: 1) collect preliminary information on the variety of mammal species using each site; and 2) identify potential relationships between relative abundance or diversity of mammal species and other site variables (e.g. preserve size and area to edge ratio).

Nocturnal Live Trapping

One nocturnal trapping session was conducted at each study site using thirty Sherman box traps (3″ x 3.5″ x 9″) and five Tomahawk traps (18″ x 5″ x 5″). Traps were situated in areas of potentially high rodent activity (i.e., along wildlife trails) and were distributed along transects that meandered through each site. Traps were located both in dried vernal pools and in the surrounding grassland. The traps were set up no earlier than 2 hours before sunset (1800 to 2000 hrs). Each trap was then checked at dawn the following morning, between 0500 and 0700 hrs. A mixture of oats and peanut butter was used as bait, while cotton batting was inserted to serve as bedding/insulation material. The species and sex of the captured mammals were recorded onto standardized data sheets (Appendix B). Representative photographs of the mammals and traps were taken.

Mammal Sign Surveys

Each site was qualitatively surveyed for mammal signs once during the summer of 2003. Meandering transects were walked sufficient to span lengths and widths of each site. Due to time constraints, a minimum of two hours and a maximum of five hours were spent on each site's survey, depending on preserve size. Surveyors slowly walked each transect, recording sign type, and probable species or animal type responsible. Typical wildlife signs observed included scat (feces), tracks (or foot prints), trails through vegetation, burrow entrances, carcasses, visual observations, and audio detections (e.g., animal alarm calls).

3.3.4 Amphibians

The primary objectives for the amphibian surveys were to: 1) provide baseline presence/absence information for locally occurring amphibian species; 2) document the occurrence of amphibian breeding activities at each site; and 3) identify potential relationships between presence/absence and other site variables (e.g., preserve size and area to perimeter ratio).

Surveys were conducted from 26 March through 21 April 2003. Survey efforts were opportunistic and included sampling of a variety of water features within each preserve. Surveys included but were not limited to vernal pool features. Other features sampled included intermittent drainages, seasonal wetlands, emergent marshes, stock ponds, and perennial water features. All features were first visually inspected to detect any occurrence of amphibians or egg masses. After the visual inspection, a dip-net was passed through the water, in an attempt to capture larvae or flush hidden adults. The following quantitative data were recorded on a standardized data sheet at each surveyed feature: sampling unit (pool) number, approximate maximum depth (cm), water temperature (C), and the presence and relative abundance of all adult and larval amphibians and egg masses. Finally, each biologist used a ranking system to provide an estimate of the relative abundance of each amphibian species observed (e.g., not abundant, somewhat abundant, very abundant). The presence of special status invertebrates and other notable aquatic organisms were also recorded. A sample data sheet is included in Appendix B.

3.3.5 Pollinating Insects

Between 13 March and 20 May 2003, surveys were conducted for pollinating insects of vernal pool plants. There were two primary objectives for the pollinating insect surveys: 1) to document the presence of pollinating insect guilds at the preserves and their relative abundance; and, 2) to distinguish variations in pollinating insect guilds and relative abundances among different study sites.

Of the 12 study sites, ten were for sampled for pollinating insects. Mahaney Park and Stanford Ranch Rocklin Vernal Pool preserves were not sampled due to weather induced inappropriate floristic conditions. Within each site, sampling location was largely determined by the presence of vernal pools with high flowering plant diversity. Close coordination with the ECORP botanists ensured that sampling events at these locations were optimized with peak bloom. Initial sampling designs focused on sampling at ten randomly selected vernal pools, as a subset of the pools previously selected for floristic surveys. However, after evaluating conditions at the preserve sites, sampling efforts instead targeted vernal pools with the greatest diversity and abundance of flowering plant taxa at the time of the site visit.

In addition, sampling methods were modified to ensure sufficient sample replicates and ample collection samples of pollinating insects. The originally proposed method involved classifying vernal pools by size (small, medium, or large), and conducting sweep net sampling as follows: one sweep each for upper, middle, and lower sections of small pools, two sweeps each for upper, middle and lower sections of medium pools, and three sweeps each for upper, middle and lower sections of large pools. The modified sampling method involved walking two transects across the longest axis of each pool, while taking one sweep per step with a 15-inch hoop diameter sweep net. Transects were selected such that all dominant flowering plant taxa occurring at each pool were thoroughly sampled. The number of sweeps per pool ranged between 6 and 134 sweeps.

Captured insects were placed in 1-gallon plastic bags labeled with the site name, pool number, and collection date. Samples were stored in a freezer until insect identification occurred. Prior to sampling, time, date, temperature, wind speed, wind direction, and cloud cover data were recorded at each site (see sample datasheet in Appendix B). The unusually cool and rainy period from early April through early May necessitated a "split season" sampling approach. As numerous pools were re-inundated during their peak bloom period, pollinating insect activity was drastically reduced. Sampling at the Aitken Ranch Mitigation Bank was limited to one pool, as all pools were either sparsely populated with flowering plant taxa or inundated above the flowering portions of the plants. Therefore, data from Aitken Ranch are neither disclosed nor discussed in the body of this report.

All insects were identified to family level, with the exception of several closely related and difficult to distinguish families of flies (Diptera): Ephidridae, Lauxaniidae, Chamaemyiidae, Milichiidae, and Chloropidae, which were grouped together as unidentified Diptera. Members of the above families are not reported in the literature as being important pollinators, although they were frequently observed on flowers (mostly *Lasthenia fremontii*) at all sites prior to sweep net sampling, and therefore counted as one of the pollinating guilds (Thorp and Leong 1998, Thorp 1976). Identified insects were sorted by family and preserved in 1-dram vials containing

70% ethanol. Vials were labeled with the following information: site name, pool number, family, number of specimens, county (Placer), collection date, and collector's initials.

3.4 Statistical Analysis

Basic descriptive statistical terminology (e.g., mean, minimum, and maximum) was used when describing and analyzing the data. The data collected for the amphibians, mammals, and insect pollinators was preliminary data and did not include sufficient sampling to warrant further detailed statistical analysis. As for vernal pool plant and bird species data (the dependent variables), several additional statistical tests were implemented to test for significant variation within the datasets and for relationships with the habitat and landscape variables (the independent variables).

3.4.1 Vernal Pool Plants

Individual data sets for each sampling unit (pool) were grouped together to create one inclusive floristic data set per study site for data analysis. In addition to an overall plant species richness value, floristic data for each study site were also separated into subsets such as vernal pool species richness, native species richness, dominant species richness, and abundant species richness. Using SPSS 9.0, these floristic data were then tested for statistically significant differences in species richness values (Chi Square test) and in mean per pool species richness values (ANOVA). To detect statistically significant trends relative to the habitat and landscape variables, Pearson's Correlations and T-tests were used.

3.4.2 Birds

Linear regression analysis was used to examine the relationship between 20 dependent bird parameters and 12 independent landscape variables (Appendix C). Analysis of the relationship between bird and landscape variables began with through forward stepwise regression (Zar 1996). In forward stepwise regression, the variable with the largest F-statistic is added to the model if its contribution is statistically significant. Subsequent variables are then added if their contributions are significant given the inclusion of the previously added variable(s). At this preliminary stage of the analysis, we defined statistical significance as all independent variables with alpha values < 1.0. Once potentially significant contributors to the regression model were detected, the analysis was repeated using complete estimation, eliminating variables with alpha values > 0.05 one at a time. This process continued until all variables in the model had alpha values < 0.05.

3.4.3 Habitat and landscape Characteristics

To determine the correlation between independent variables and to aid in interpretation of the regression results, a Pearson correlation matrix was calculated. Co-linearity of independent variables often causes problems in linear regression and some significant predictors may be excluded from the final model because of their high correlation with other variables. One technique used when multicolinearity exists is to omit some of the highly correlated variables prior to running the regression. In our analysis, we chose not to omit variables from the regression, but instead recognize that highly correlated variables would produce similar F-

statistics if tested independently. By not omitting variables from the model, we were able to find the single best predictor(s) of each dependent variable (albeit not all possible predictors).

4.0 RESULTS

4.1 Habitat and Landscape Characteristics

At each study site, data were collected regarding habitat and landscape characteristics (independent variables), which included both continuous and categorical variables. Continuous data, typically measured using a select device or tool, include any quantifiable values within a given interval. Categorical, or qualitative, data are measured on a nominal scale. Appendix C lists the independent variables used in this study and Appendix D shows the actual landscape and habitat variable values.

4.1.1 Continuous Variables

Table 2 presents summary data for the different continuous variables.

Table 2. ***Summary of Continuous Habitat and Landscape Characteristic Variables***

Variable	Mean	Minimum	Maximum
Preserve Acreage (acres)	177.3	18	708
Area to Perimeter Ratio	438.7	127.6	1093.9
Number of Vernal Pools	262.6	15	672
Length of Linear Features (feet)	7,090.5	0	21,360
Percent of Perimeter with Potential (or Actual) Altered Hydrology	38.6%	0%	67.8%

In this study, Mahaney Park (18 acres) was the smallest preserve and Orchard Creek (708 acres) was the largest preserve (Figure 3). The mean preserve size was 177.3 acres and the median was 130 acres. Because preserve size is a major focus of this study, a majority of the subsequent figures have their data arrange along the x-axis from smallest to largest preserve. This facilitates easy visual comparisons between preserve size and other independent and dependent variable distributions

The area to perimeter ratio is an indication of the amount of interior habitat relative to edge habitat. In general, this ratio increases as the preserve size increases (Figure 4). Because larger preserves have greater area per linear feet of edge, the ratio is large and the interior is farther removed from edge influences. If the ratio is low, then the average distance from interior points to the boundary is small (Meffe et al. 1997). Lower ratios occur within small or elongated preserves with proportionately more perimeter length per unit area of interior area, creating a disproportionately large "edge." In this study, preserve size was positively correlated with

preserve area to perimeter ratio ($r^2 = 0.913$). The one notable exception was the Highland Reserve South Preserve, which is medium, sized (135 acres) but has a lower ratio as a result of its division into long, linear shaped sub-units (Figure 2).

In general, larger preserves would be expected to have more pools and this was generally true in this study with the number of pools being positively correlated with preserve size ($r^2 = 0.730$) (Figure 5). Again, the Highland Reserve South Preserve was the exception with approximately the same number of vernal pools as Orchard Creek Preserve, a preserve five times as large. The key difference between the sites is the size of the individual pools. Highland Reserve South had a large number of small (<0.05 acres) pools, totaling only 7.2 acres. However, at Orchard Creek Preserve, there were a variety of vernal pool sizes, totaling 31.41 acres. There were also sites that had fewer total pools, but relatively large-sized pools (e.g., Sheridan Mitigation Bank). In addition to variable pool size, vernal pools also vary with respect to their density within the surrounding annual grassland matrix. Total vernal pool acreage, and the resulting density, was unavailable at several preserves; therefore, this information was not included in the analyses. Thus, total number of pools, while important, is lacking as a site descriptor because it does not address pool size or density.

The "length of linear features" variable is an all-inclusive category, describing features, such as perennial creeks, ephemeral drainages, or intermittent drainages. In general, the length of linear features in this study was positively correlated to preserve size ($r^2 = 0.772$), however, several exceptions occurred in this study (Figure 6). For example, despite the fact that the Woodcreek North Preserve is less than fifty acres, it had a similar amount of linear water features as the 145-acre Rodeo Grounds Preserve. This is because the entire eastern boundary of Woodcreek North Preserve is Pleasant Grove Creek.

The percent of perimeter with actual or potential altered hydrology was negatively correlated with preserve size ($r^2 = -0.602$). As can be seen in Figure 7, the data regarding this factor fell into two groups: 1) preserves with 42-68% altered hydrology; and, 2) preserves with less than 0-17% altered hydrology. The latter included the four largest preserves (145 acres – 708 acres) Thus, the data indicated that, for the preserves included in this study, larger preserves had fewer incidences of potential altered or potentially altered hydrology edge effects.

Figure 3. Range of Sampled Preserve Sizes (Acres), Western Placer County, California

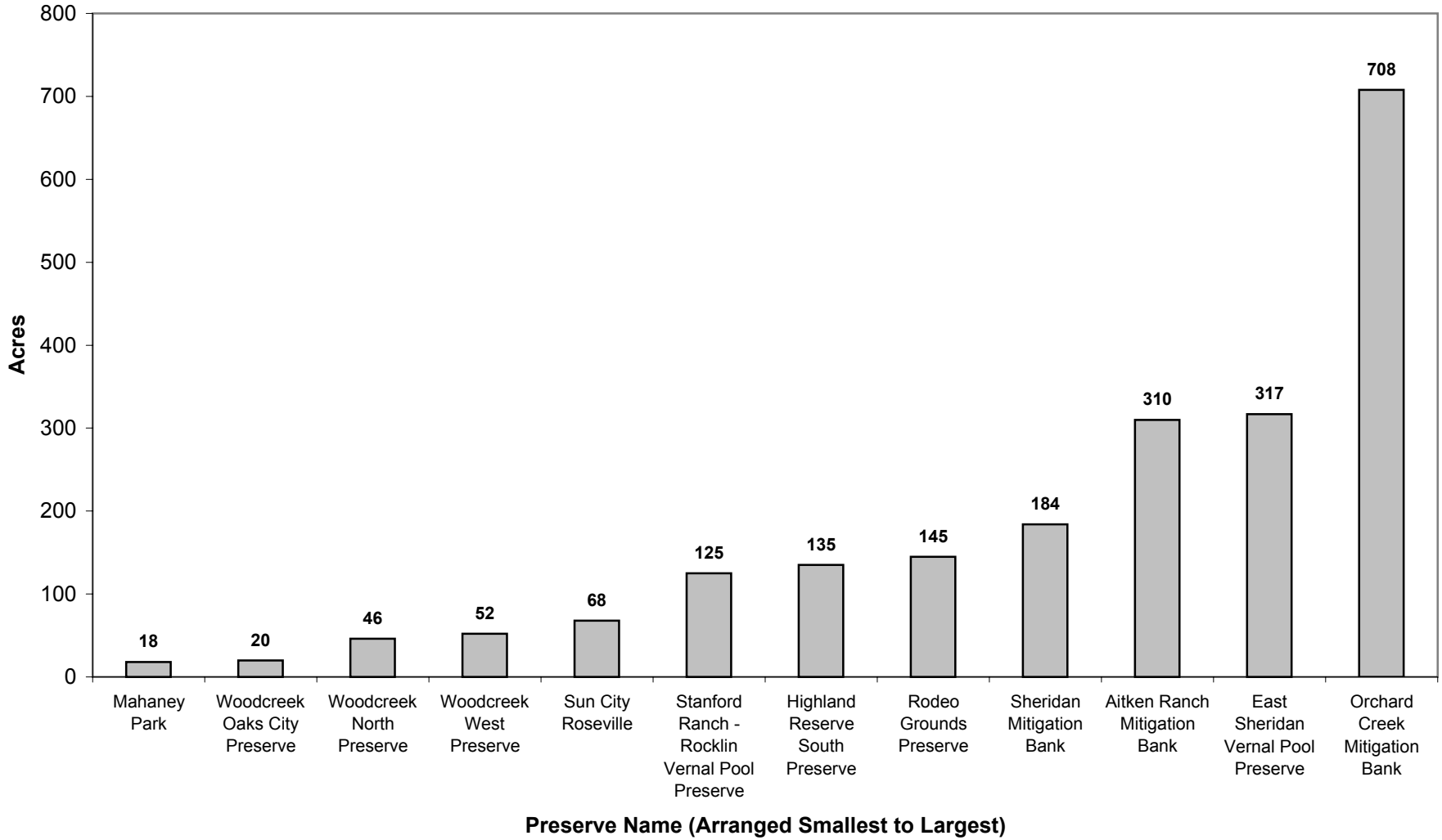


Figure 4. Area to Perimeter Ratios for Sampled Preserves, Western Placer County, Caifornia

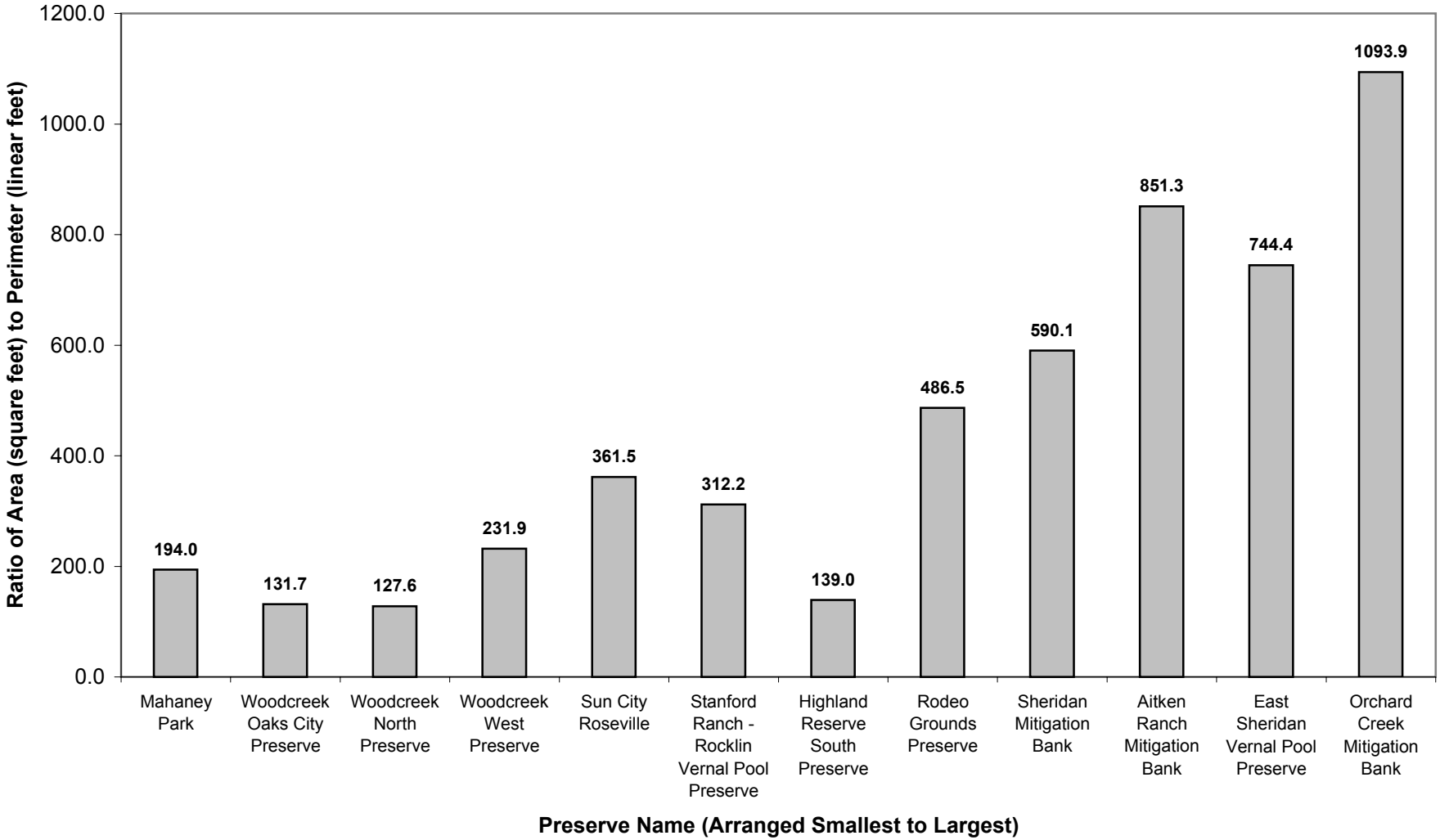


Figure 5. Number of Vernal Pools Per Sampled Preserve, Western Placer County, California

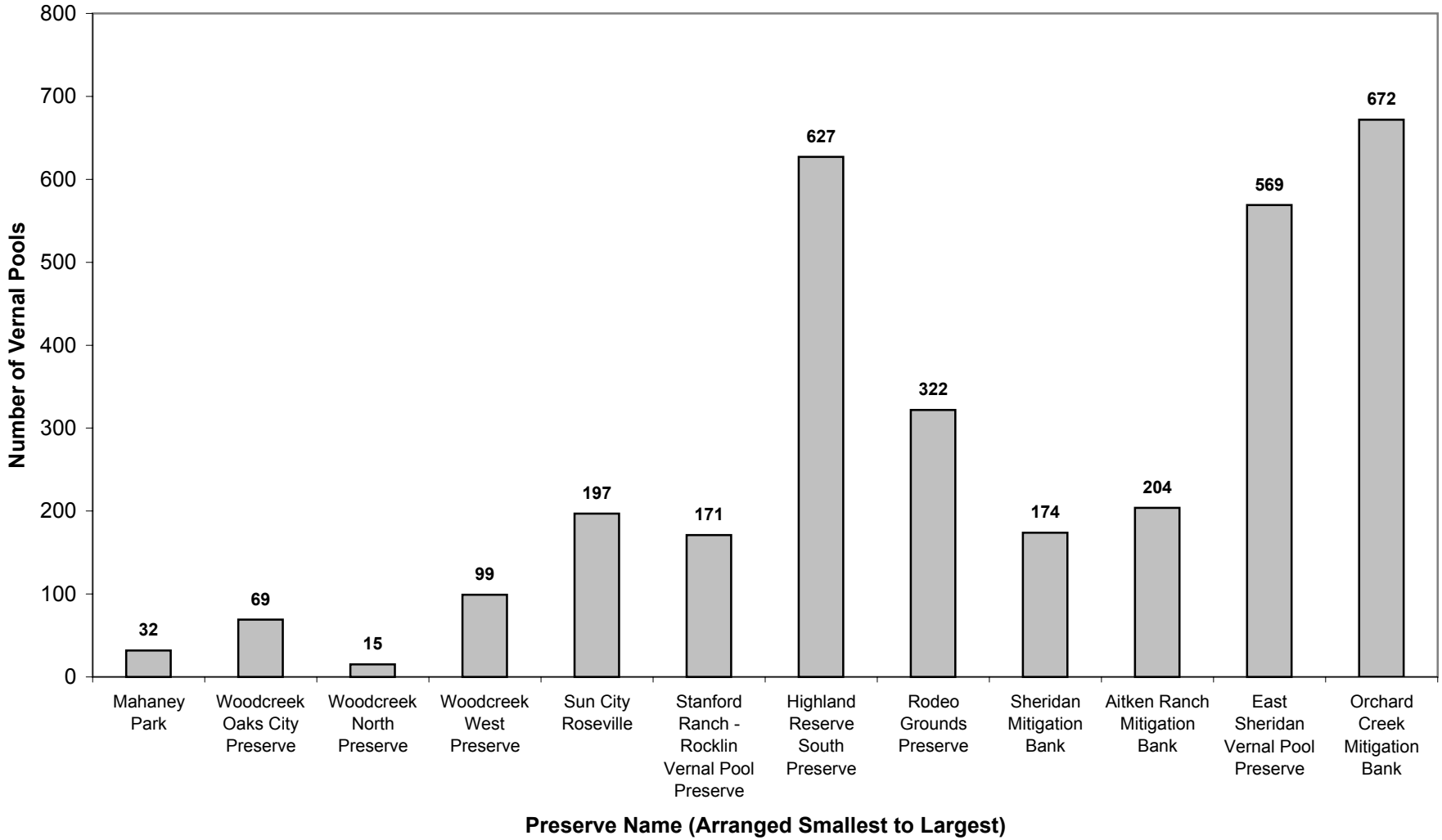


Figure 6. Length of Linear Water Features within Each Sampled Preserve, Western Placer County, California

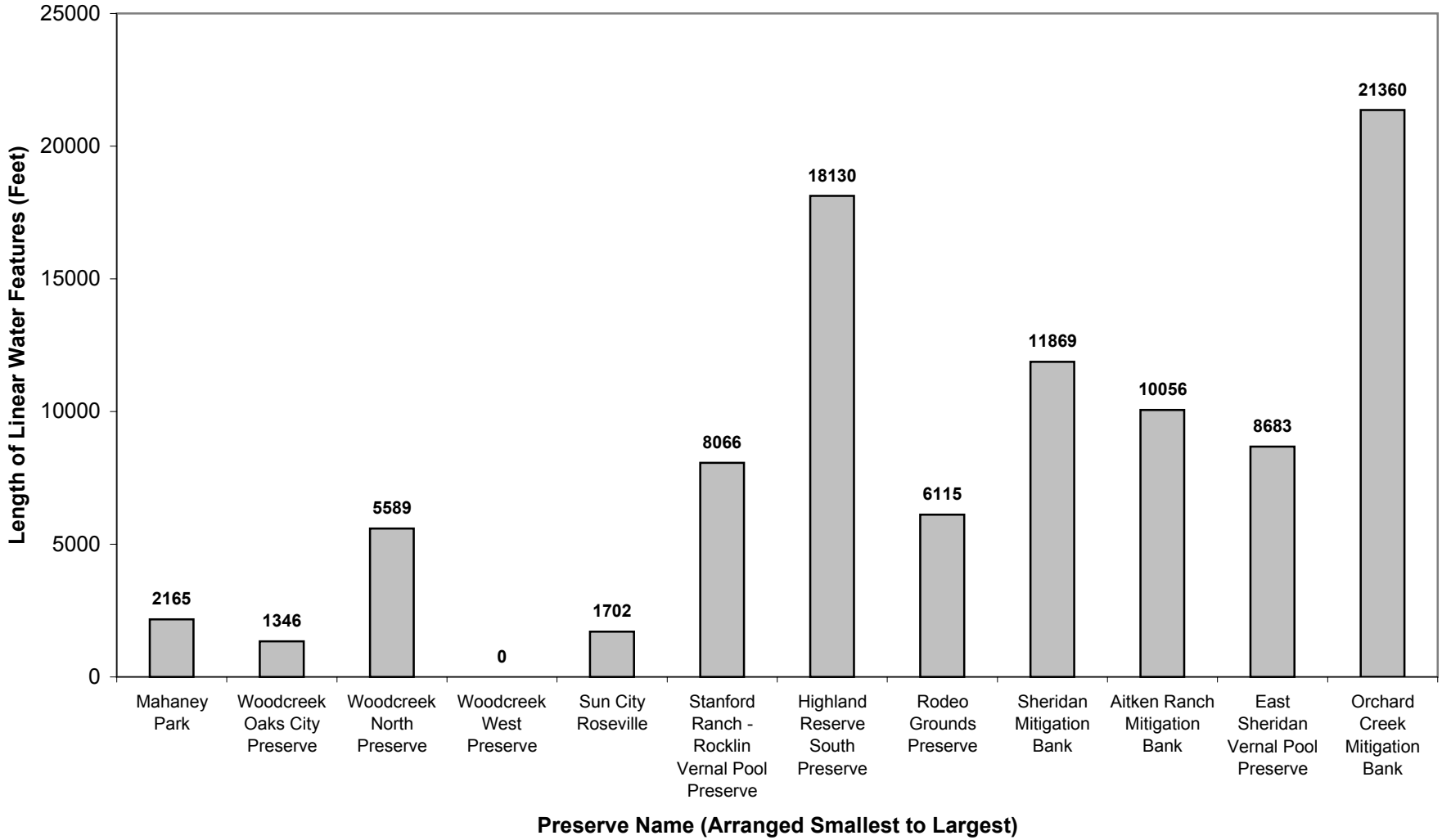
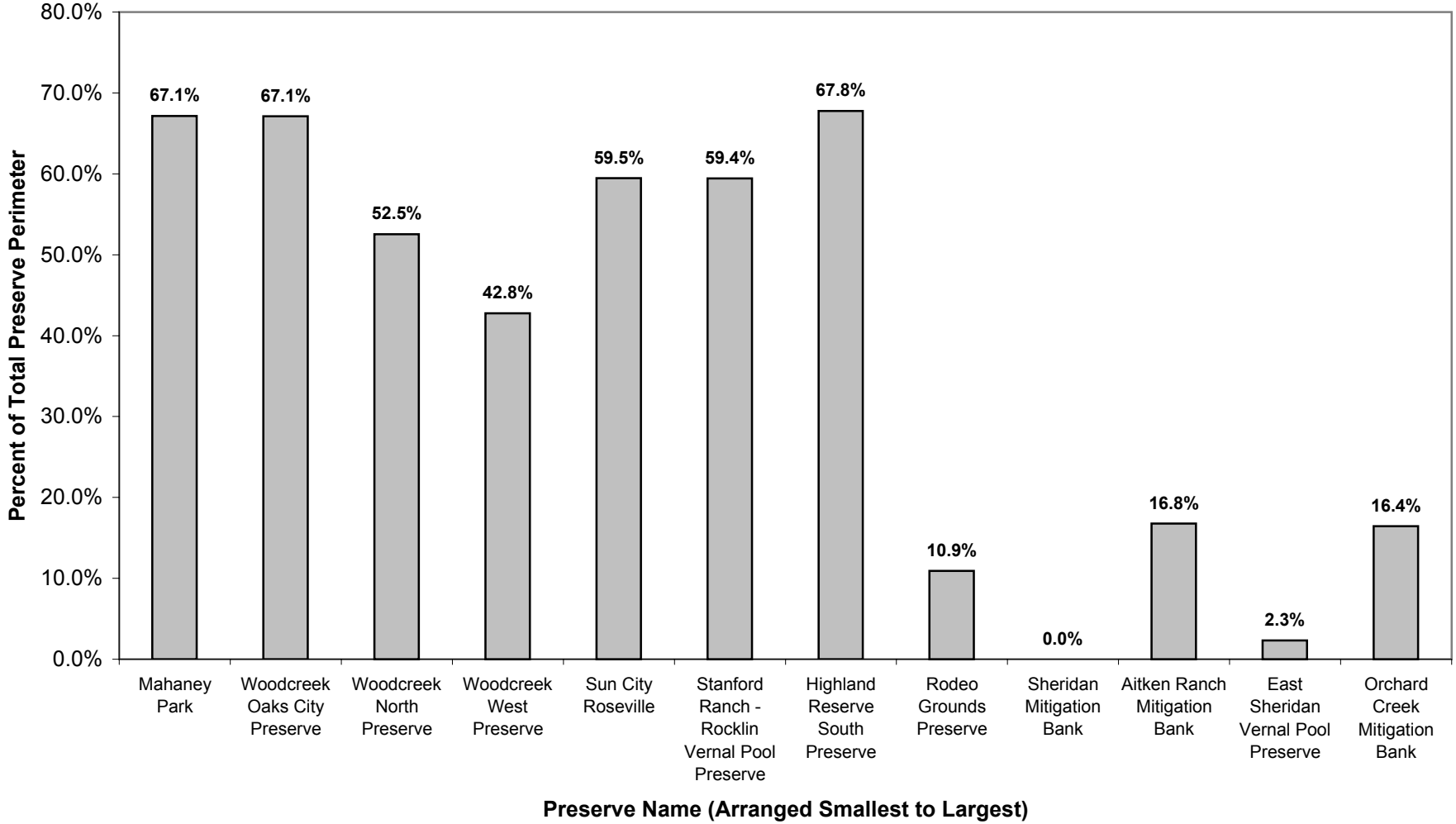


Figure 7. Percent of Preserve Perimeter with Altered or Potentially Altered Hydrology* for Sampled Preserves, Western Placer County, California

***see report text for definition**



4.1.2 Vegetation Communities

Four vegetation communities were documented among the twelve study sites. All twelve sites had vernal pool features intermixed with annual grassland vegetation communities. Three sites had only the vernal pool annual grassland vegetation community. The remaining nine sites contained one or more of the following vegetation communities: blue oak woodland, freshwater emergent wetland, and Valley foothill riparian (Table 3). The blue oak woodland vegetation community was assigned to each site that supported at least one cluster of blue oaks. Those sites with one or two individual oaks were not assigned to this category. The oak woodlands observed on the study sites ranged between widely spaced savannah-type woodlands to densely wooded areas. The freshwater emergent wetland vegetation community was designated to sites containing marsh-like features. These features supported marsh vegetation and associated willows and willow scrub. The Valley foothill riparian vegetation community was assigned only to those sites that supported a mature riparian canopy.

Table 3. ***Summary of Study Site Vegetation Communities Present in Addition to Annual Grassland/Vernal Pool Landscape***

Preserve Name	**Blue Oak Woodland**	**Freshwater Emergent Wetland**	**Valley Foothill Riparian**
Mahaney Park		•	
Woodcreek Oaks City Preserve	•		
Woodcreek North Preserve	•		
Woodcreek West Preserve			
Sun City Roseville	•		
Stanford Ranch Rocklin Vernal Pool Preserve		•	
Highland Reserve South Preserve		•	
Rodeo Grounds Preserve		•	
Sheridan Mitigation Bank		•	•
Aitken Ranch Mitigation Bank		•	•
East Sheridan Mitigation Site			
Orchard Creek Mitigation Bank			

4.1.3 Categorical Variables

Table 4 summarizes the subset of study sites that fall into each of the categorical variable options. Figures 8 – 16 illustrate which study sites correspond to each of the categorical variable options.

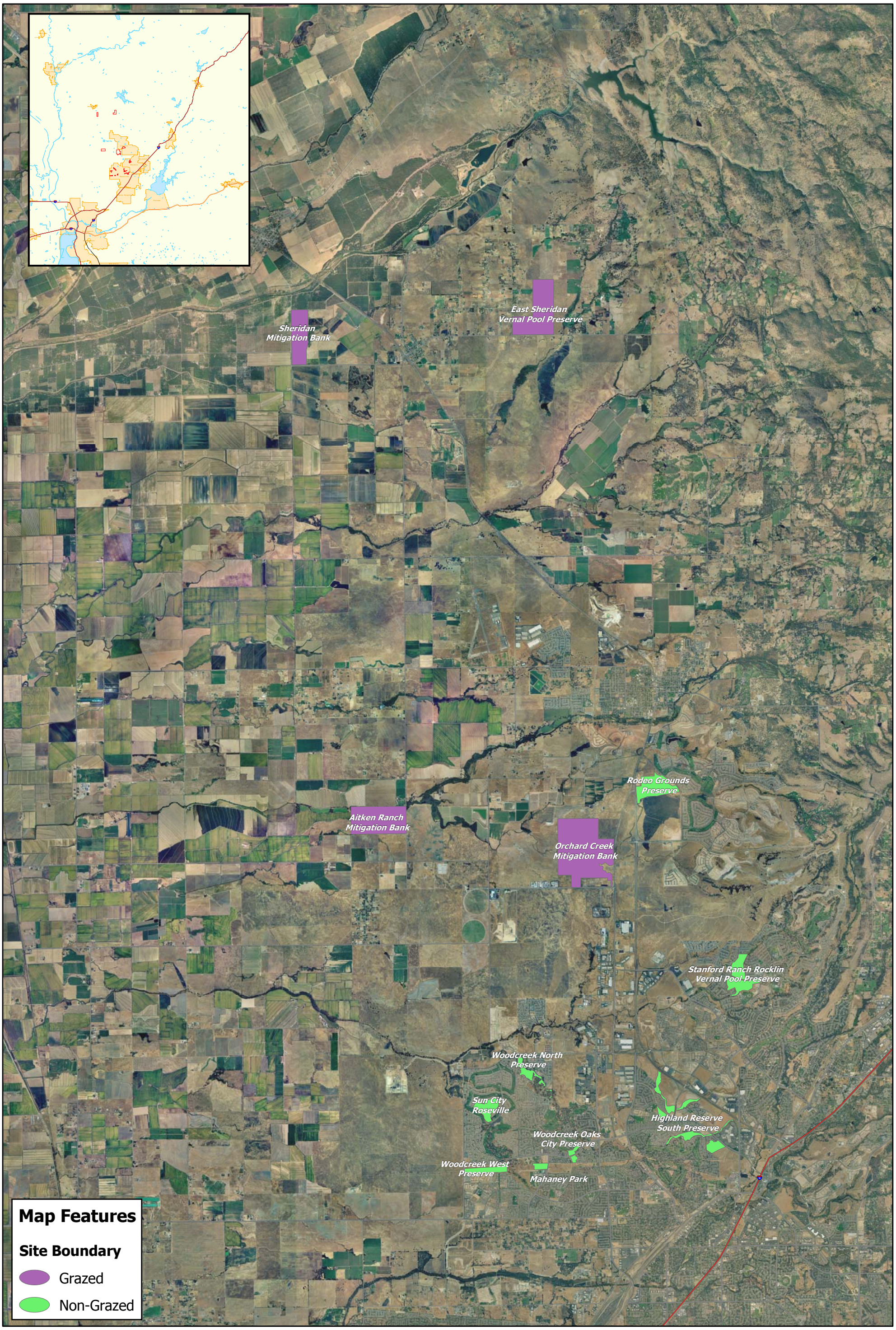
Table 4. ***Summary of Categorical Habitat and Landscape Characteristics***

Grazed **(4)**	Non-Grazed **(8)**
Urban **(7)**	Rural **(5)**
Natural Vernal Pools Only **(3)**	Natural and Constructed Vernal Pools **(9)**
Outfalls Into Preserve **(5)**	No Outfalls Into Preserve **(7)**
Irrigation Run-Off in Preserve **(7)**	No Irrigation Run-Off in Preserve **(5)**
Perennial Water Features Present **(10)**	No Perennial Water Features **(2)**
Paved Paths Present **(5)**	No Paved Paths **(7)**
Public Access **(7)**	No Public Access **(5)**
Beaver Dams Present **(7)**	No Beaver Dams **(5)**

Of the 12 preserves, the four largest vernal pool preserves were being grazed during the course of this study. In addition, the five largest vernal pool preserves occurred within a rural setting. The Rodeo Grounds Preserve was the only "rural" preserve without a prescribed grazing regime. Within western Placer County, most vernal pool preserves include both natural vernal pools and constructed vernal pools. Within this study, nine preserves contained both natural and constructed vernal pools while three preserves contained only natural pools. Preserves containing only natural pools included the two largest preserves (Orchard Creek and East Sheridan Preserves) and the smallest preserve (Mahaney Park). The number and acreage of constructed vernal pools was unavailable for several preserves. Therefore, the ratio of natural to constructed vernal pools was not included in these analyses. Generally, public access, paved trails, and grazing status were inversely related to preserve size. Irrigation run-off was observed within seven sampled preserves, ranging from 18 to 310 acres in size. All but two of the sampled preserves, including the largest and the smallest preserves, had at least one perennial water feature. Beaver activity was observed within seven preserves, again ranging between 18 and 310 acres in size.

4.1.4 Independent Variable Correlations

A number of the independent variables co-vary (Table 5). For example, the decreased occurrence of potential altered hydrology may be related to preserve size or due to its rural setting. The five largest preserves with the lowest potential hydrology edge effects were also the rural preserves. Similarly, public access and paved trails were mainly located within the smaller preserves, within urban settings and without grazing. Data indicate that preserve size, grazing status, urban/rural setting, public access, and paved trails were all variable and interrelated. While there was evidence of corresponding relationships among these variables, they were treated as independent variables.



Map Document: (F:\2003-034_Placer_Co_VP\2004Mar18\Grazed_Non_Grazed.mxd)
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Figure 8. Grazed Versus Non-Grazed

2003-034 Placer VP

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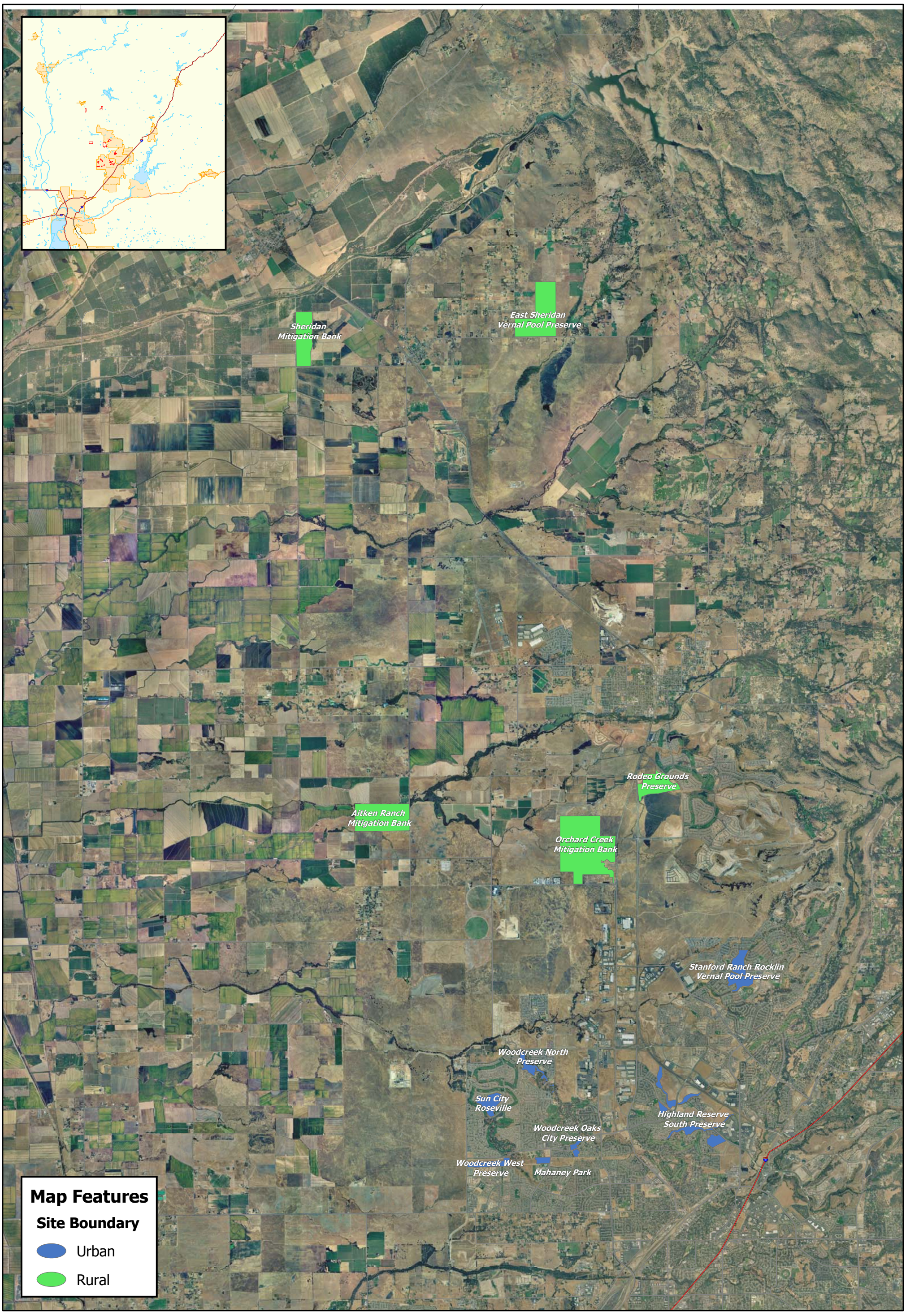

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Figure 9. Urban Preserve vs. Rural Preserve

2003-034 Placer VP

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ECORP Consulting, Inc.
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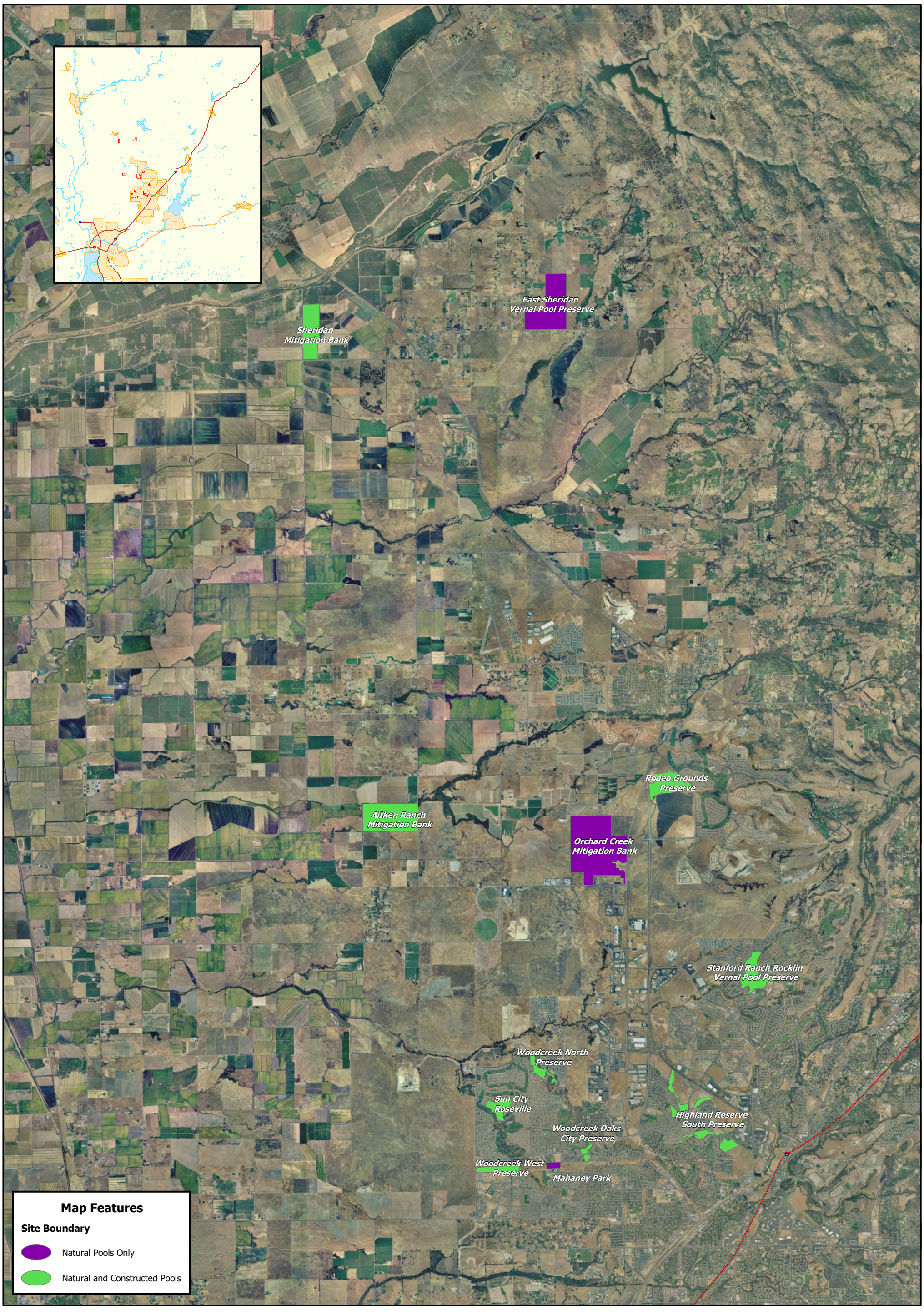

Map Document: (F:\2003-034_Placer_Co_VP\2004Mar18\Natural_Construct.mxd)
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Figure 10. Natural Pools Only vs. Natural and Constructed Pools

2003-034 Placer VP

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ECORP Consulting, Inc.
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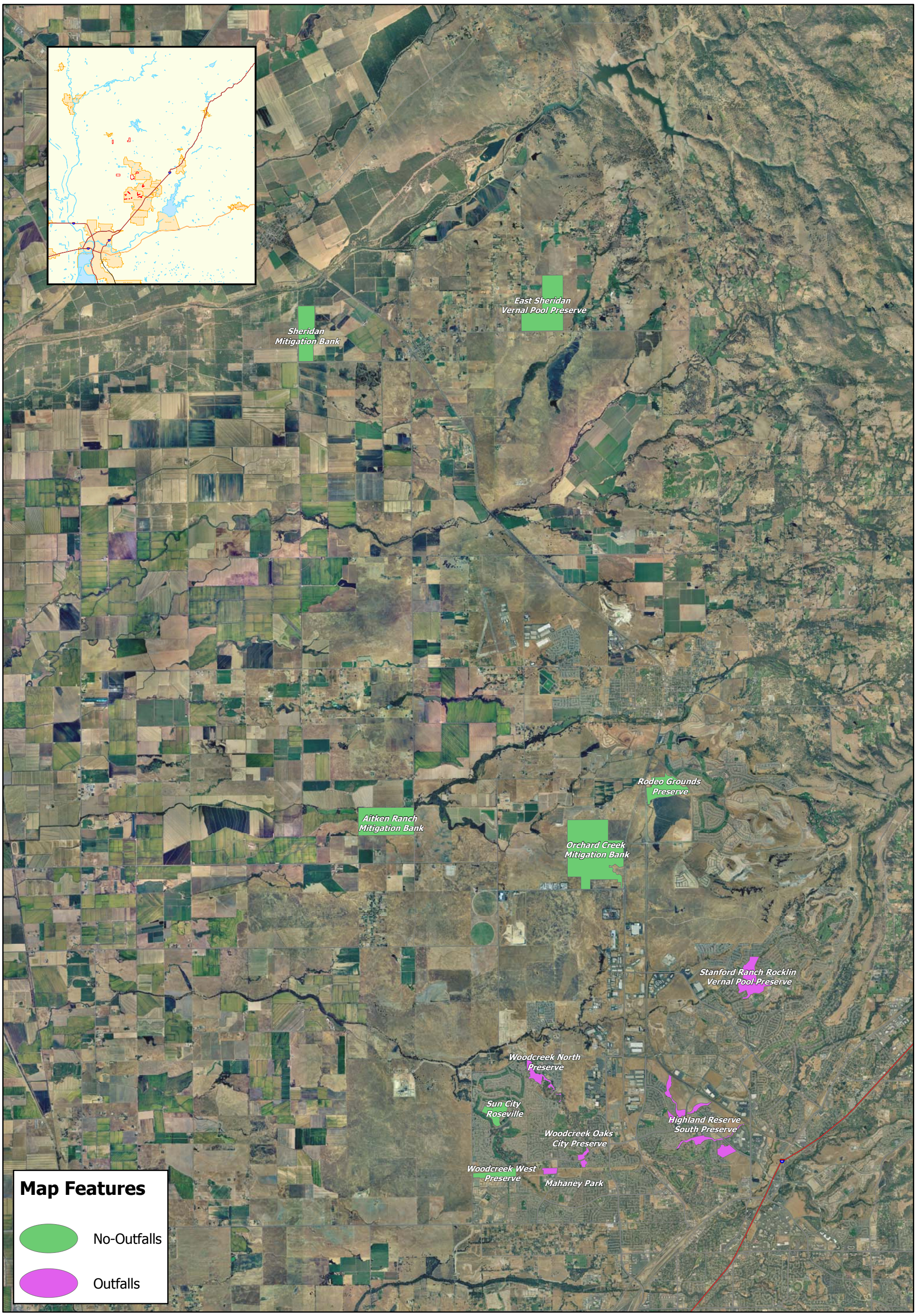

Map Document: (F:\2003-034_Placer_Co_VP\2004Mar18\Outfalls_None.mxd)
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N

0 1 2 3 Miles

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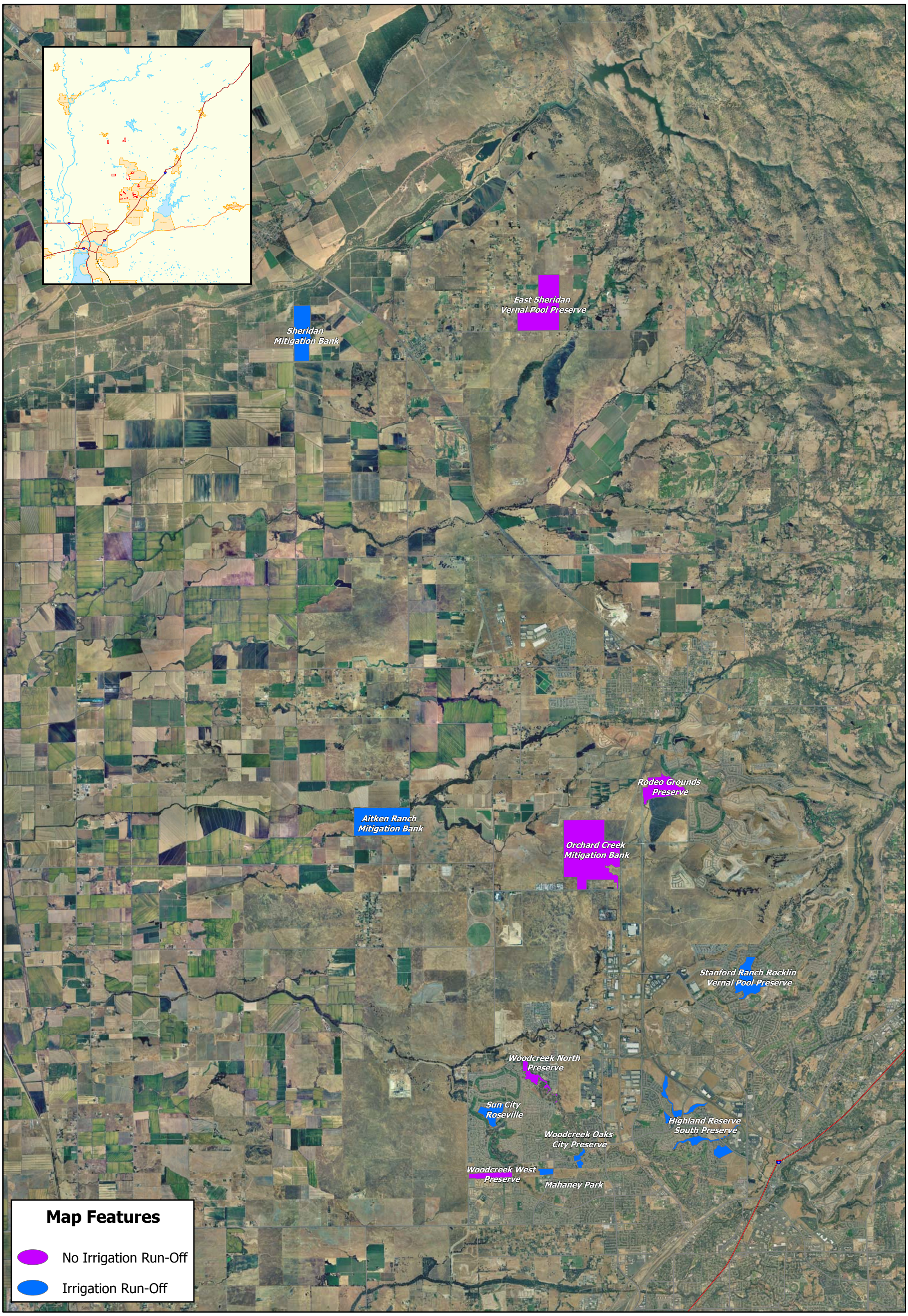
Figure 11. Outfalls Into Preserve vs. No Outfalls into Preserve

2003-034 Placer VP

ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS



Map Document: (F:\2003-034_Placer_Co_VP\2004Mar18\Irrigation_none.mxd)
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Figure 12. Irrigation Run-Off into Preserve vs. No Irrigation Run-Off into Preserve

2003-034 Placer VP

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0 1 2 3 Miles

1:100,000

ECORP Consulting, Inc.
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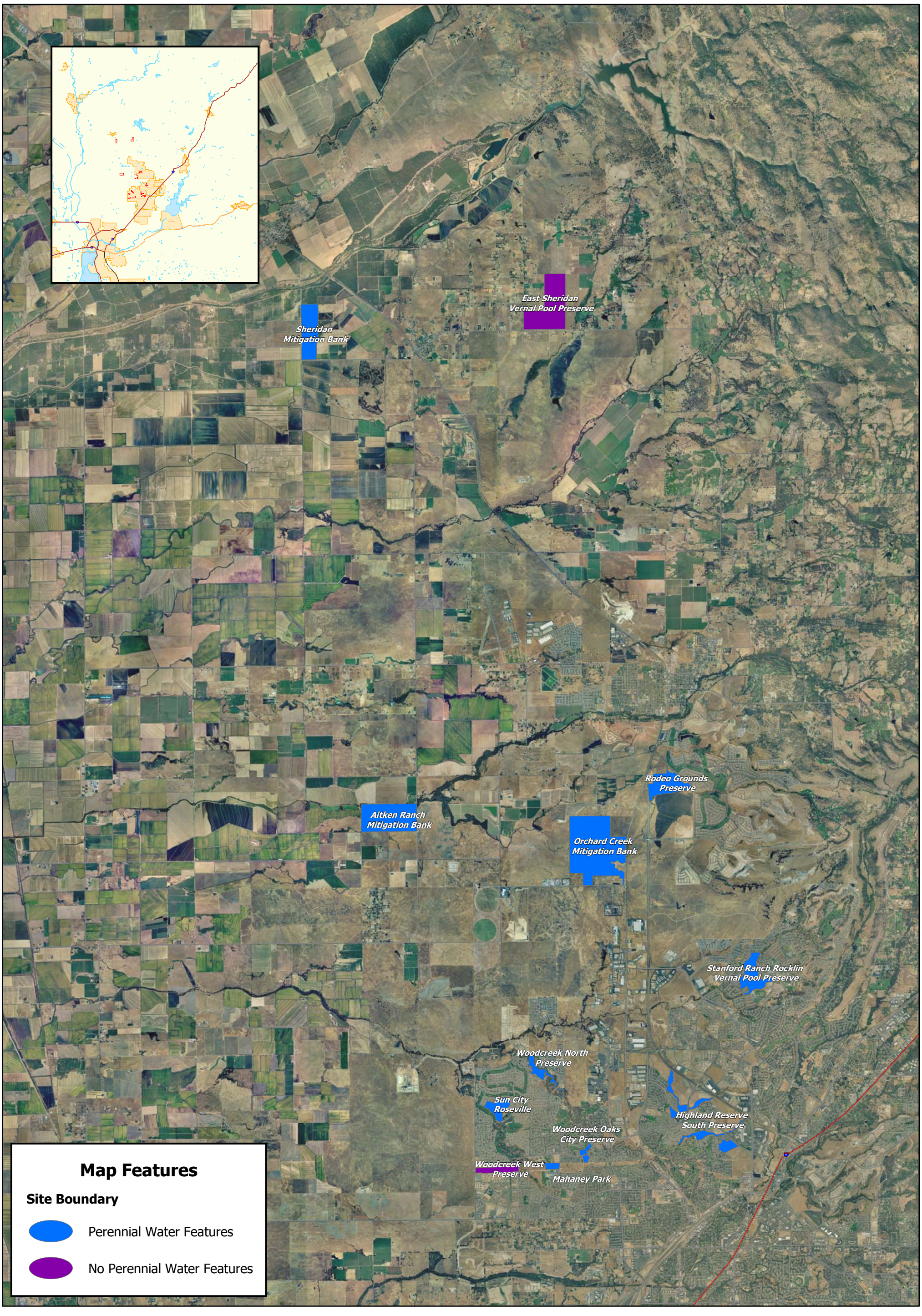

Map Document: (F:\2003-034_Placer_Co_VP\2004Mar18\Perennial_not.mxd)
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N

0 1 2 3 Miles

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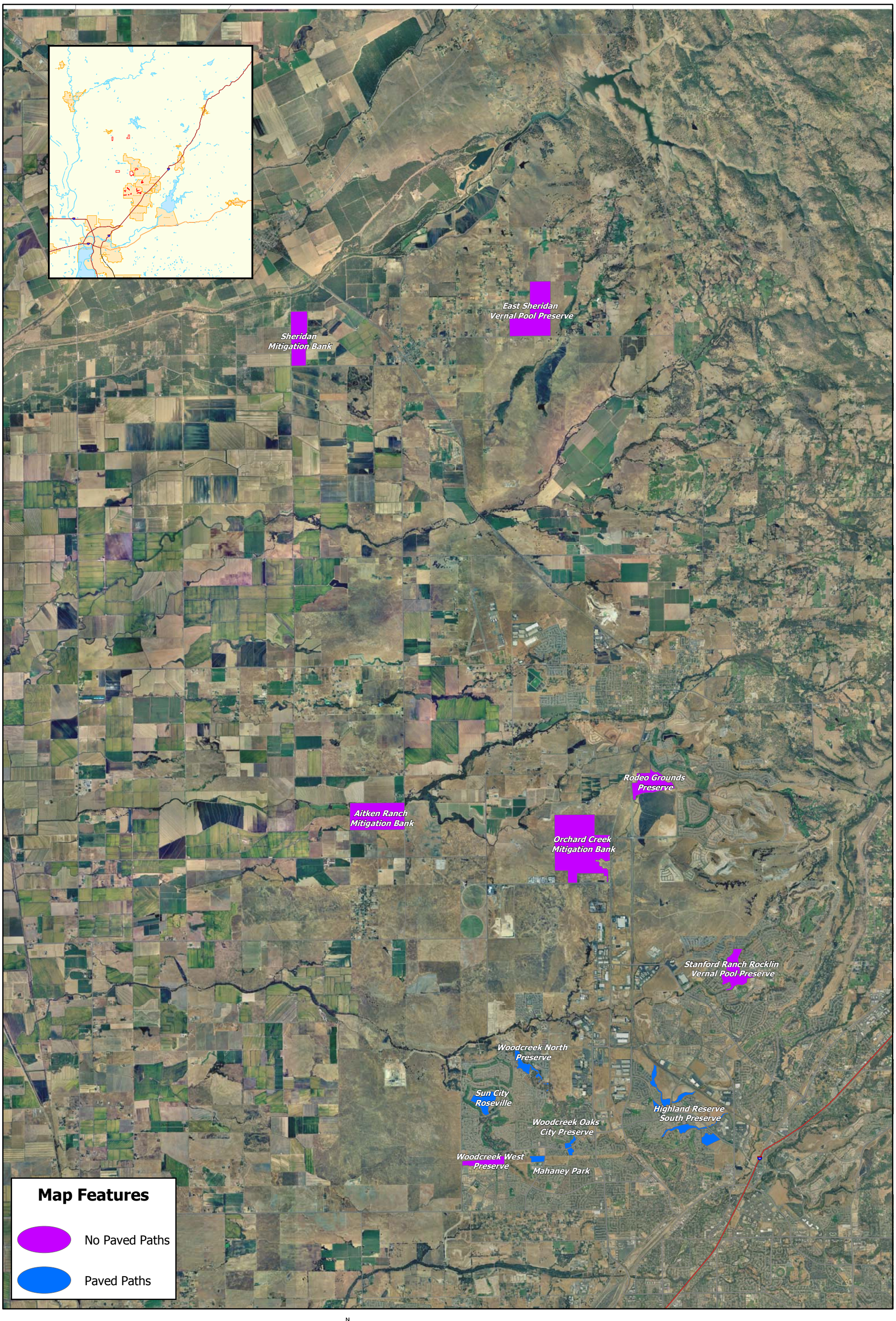
Figure 13. Perennial Water Features vs. No Perennial Water Features

2003-034 Placer VP

ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS



Map Document: (F:\2003-034_Placer_Co_VP\2004Mar18\Paved_not.mxd)
3/18/2004 -- 11:23:27 AM

Figure 14. Paved Paths vs. No Paved Paths

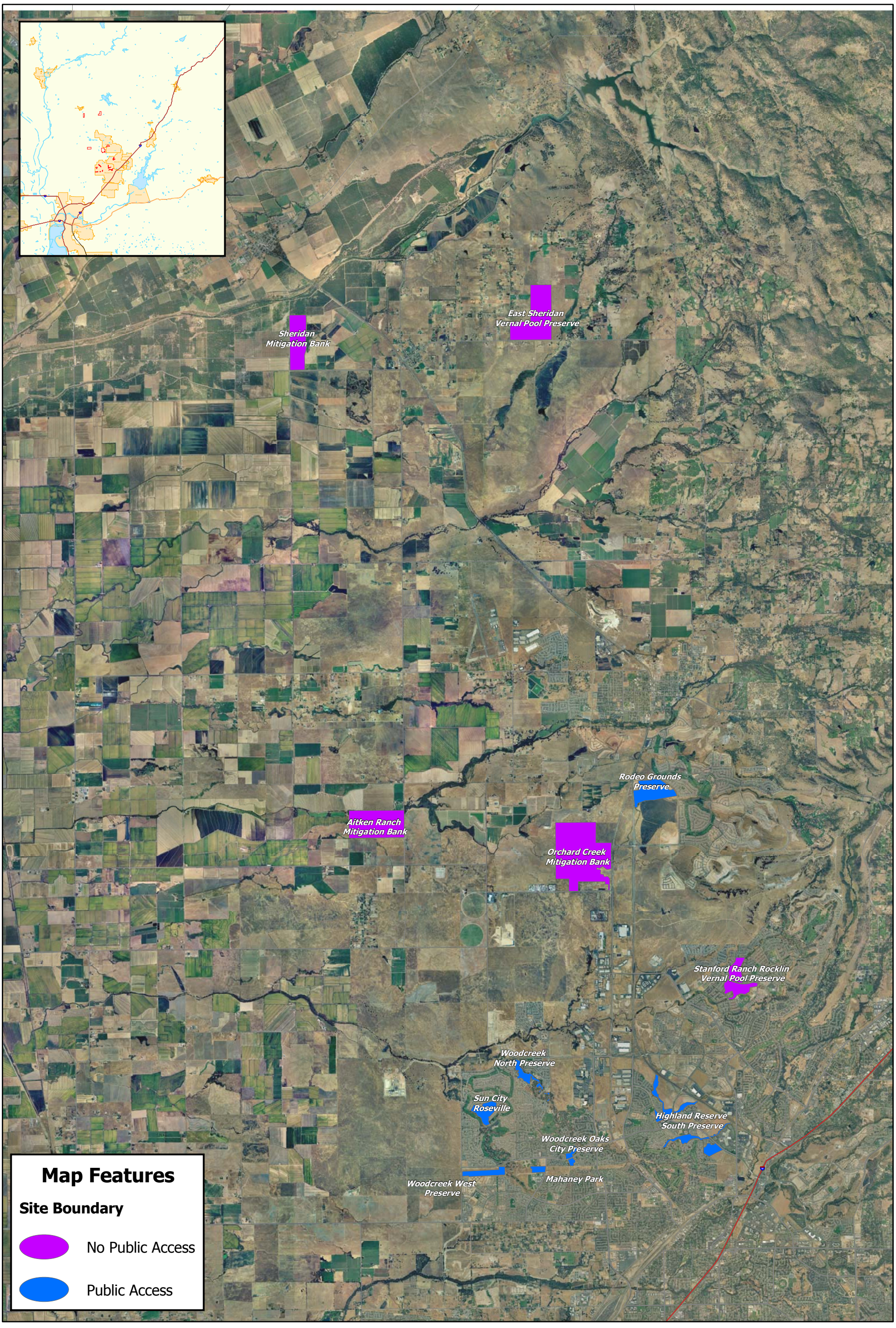
2003-034 Placer VP

N

0 1 2 3 Miles

1:100,000

ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS



Map Document: (F:\2003-034_Placer_Co_VP\2004Mar18\Public_Not.mxd)
5/3/2004 -- 2:45:31 PM

Figure 15. Public Access vs. No Public Access

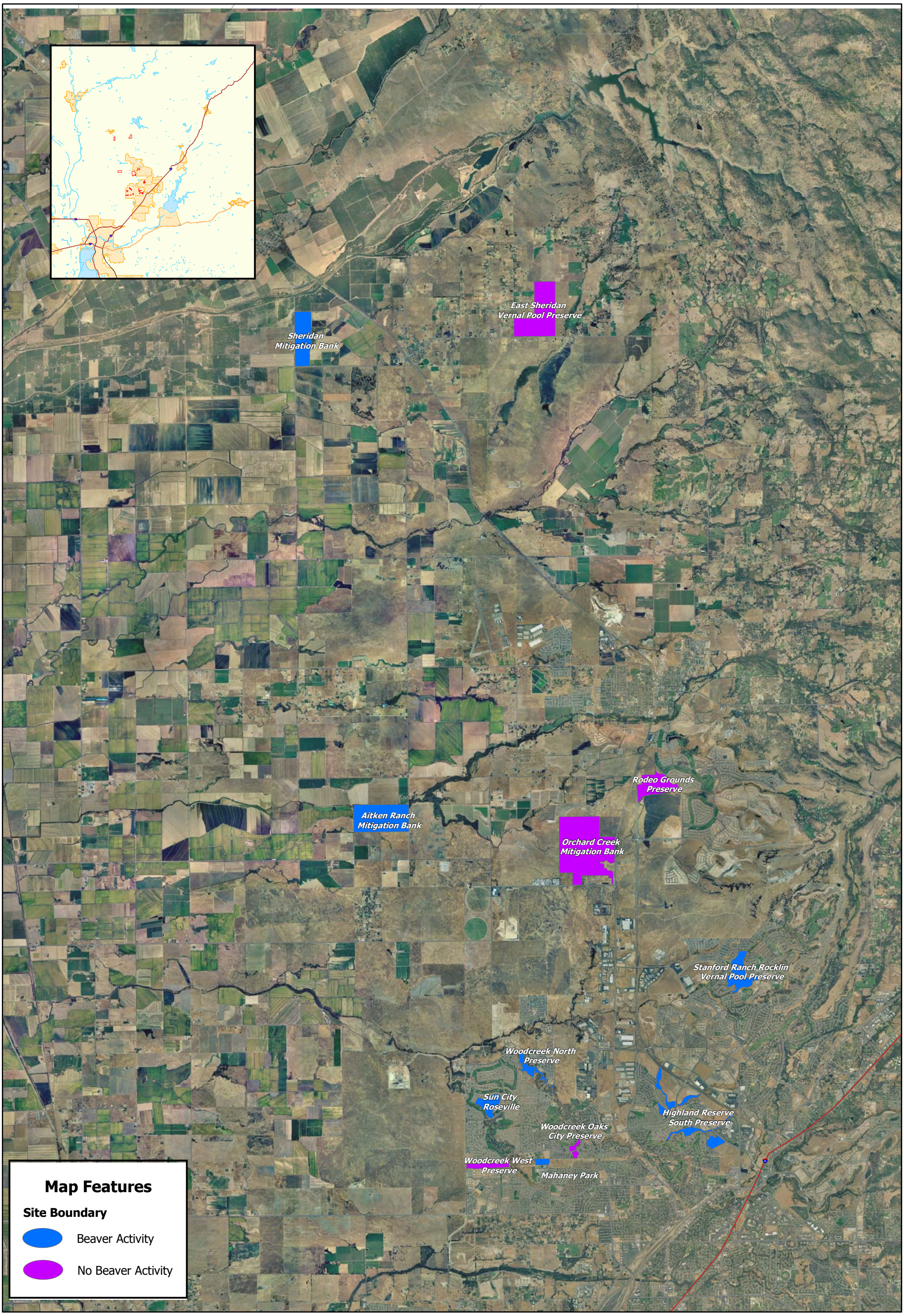
2003-034 Placer VP

N

0 1 2 3 Miles

1:100,000

ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS



Map Document: (F:\2003-034_Placer_Co_VP\2004Mar18\Beaver_Not.mxd)
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Figure 16. Beaver Activity vs. No Beaver Activity

2003-034 Placer VP

N

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Table 5. *Independent Variable Pearson's Correlations*

	Size	Ratio	Grazed	Natural	Urban	Vernal Pools	Vegcomm	Outfalls
Size	1.000							
Ratio	**.913****	1.000						
Grazed	**-.766****	**-.881****	1.000					
Natural	-0.526	-0.45	0.408	1.000				
Urban	**.703***	**.869****	**-.837****	-0.293	1.000			
Vernal Pools	**.730****	0.562	-0.449	-0.417	0.475	1.000		
Vegcomm	-0.283	-0.081	-0.092	0.526	0.11	-0.407	1.000	
Outfalls	-0.491	**-.712****	**.598***	0.098	**-0.714****	-0.301	0.11	1.000
Irrigation	-0.345	-0.271	0.12	0.293	-0.314	-0.275	**.682***	0.371
Perennial	-0.017	-0.072	0.158	0.258	-0.076	-0.143	**.640***	0.378
Lengthlinear	**.772****	.579*	-0.56	-0.254	0.487	**.799****	-0.004	-0.114
Paved	-0.542	**-.685***	**.598***	0.098	**-.714****	-0.282	0.11	**.657***
Public	**-.685***	**-.773****	**.837****	0.293	**-.657***	-0.36	-0.11	0.371
Beaver	-0.321	-0.273	0.12	0.293	-0.314	-0.316	**.682***	0.371
Paltered	**-.602***	**-.794****	**.808****	0.22	**-.952****	-0.373	-0.031	**.789****

	Irrigation	Perennial	Lengthlinear	Paved	Public	Beaver	Paltered
Irrigation	1.000						
Perennial	0.529	1.000					
Lengthlinear	-0.056	0.25	1.000				
Paved	0.371	0.378	-0.282	1.000			
Public	-0.029	0.076	-0.539	**.714****	1.000		
Beaver	**.657***	0.529	0.056	0.371	-0.029	1.000	
Paltered	0.441	0.276	-0.361	**.789****	**.636***	0.346	1.000

BOLD indicates significant correlation (* p<0.05, ** p<0.01)

Description of variables included in Appendix C

4.2 Vernal Pool Plants

4.2.1 Summary Data

To document floristic diversity, 495 vernal pools were sampled over the 12 study sites. This represents a sampling set of approximately 15% of the vernal pools within the 12 study sites. The number of pools and the percentage of pools sampled within each site are presented in Table 6 and depicted in Figure 17.

Table 6. ***Summary of Floristic Sampling Effort***

Preserve Name	Number of Vernal Pools Sampled	Percentage of Total Vernal Pools Sampled
Mahaney Park	25	78.1%
Woodcreek Oaks City Preserve	28	40.6%
Woodcreek North Preserve	15	100.0%
Woodcreek West Preserve	29	29.3%
Sun City Roseville	33	16.8%
Stanford Ranch Rocklin Vernal Pool Preserve	34	19.9%
Highland Reserve South Preserve	72	11.5%
Rodeo Grounds Preserve	35	10.9%
Sheridan Mitigation Bank	37	21.3%
Aitken Ranch Mitigation Bank	39	19.1%
East Sheridan Mitigation Site	70	12.3%
Orchard Creek Mitigation Bank	78	11.6%

A total of 184 different plant species were documented within the sampled vernal pools; however, the actual number of species present within the study sites is somewhere between 161 and 184 species, due to potential duplication of plants identified to genus only (Table 7). Of the 184 species identified, 23 were identified only to genus and may or may not be duplicates. For example, the *Downingia* spp. in the overall species list would have been at a developmental stage in which the species could not be distinguished. This could mean that it was either: a) one of the species identified at various sites (*D. bicornuta, D. cuspidata, D. ornatissima*, or *D. pusilla*); and/or b) a different species of *Downingia*. Because these duplicates occur across all of the preserve site and for ease of analysis, these potential duplicates were included in all the subsequent analyses with a cautionary note that they may cause a slight inflation of the species richness numbers.

The most common plant species found throughout the sample sites included *Plagiobothrys stipitatus* (76% of sampled pools), *Lolium multiflorum* (75% of sampled pools), *Eryngium vaseyi* (74% of sampled pools), *Hordeum marinum* (72% of sampled pools), *Lasthenia fremontii* (70% of sampled pools), and *Lythrum hyssopifolium* (63% of sampled pools). Of these most commonly occurring species, *Lolium multiflorum* and *Hordeum marinum* are considered "generalist" species while the remaining four species are all "vernal indicator" or "vernal pool associate" species. One hundred and eleven (60%) of the plant species documented occurred in less than 5% of the sampled pools. Thus, while 184 species were documented, only 74 occurred regularly.

Figure 17. ***Number of Vernal Pools Floristically Sampled with Total Number of Vernal Pools Present Per Preserve, Western Placer County, California***

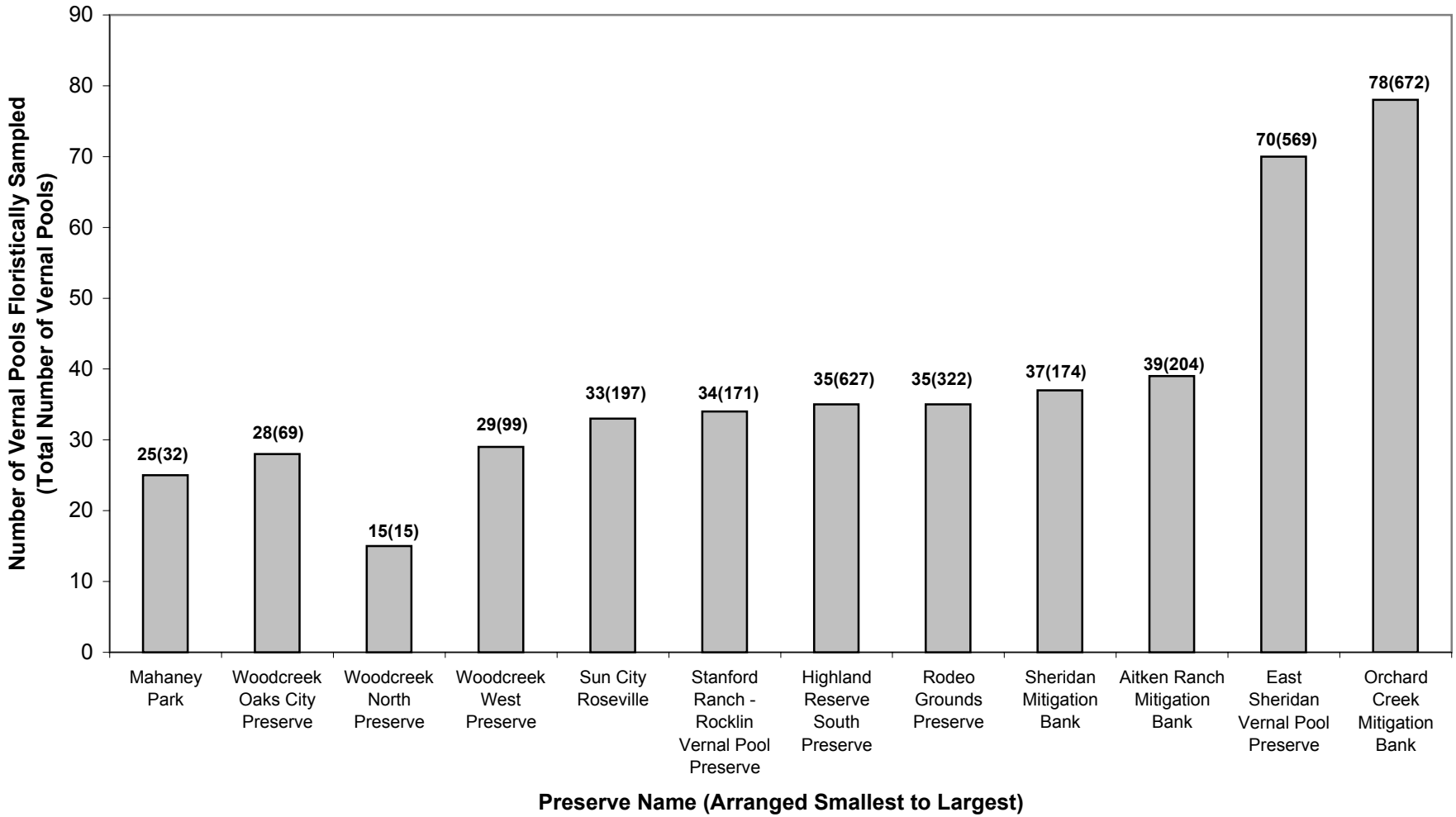

Table 7. ***Overall Plant Species List, Spring 2003***

Scientific Name	Common Name	# of Sampled Pools with this Species	Dominant Species?	Abundant Species?	Native Species?	Vernal Pool Plant Classification
Plagiobothrys stipitatus	Slender popcorn-flower	376		•	•	VPA
Lolium multiflorum	Italian ryegrass	369	•	•		GEN
Eryngium vaseyi	Vasey's coyote-thistle	366	•	•	•	VPA
Hordeum marinum	Mediterranean barley	356	•	•		GEN
Lasthenia fremontii	Fremont's goldfields	345	•	•	•	VPI
Lythrum hyssopifolium	Hyssop loosestrife	314	•			VPA
Ranunculus bonariensis	Butter-cup	285	•	•	•	VPA
Deschampsia danthonioides	Annual hairgrass	284	•	•	•	VPA
Navarretia leucocephala	White-head navarretia	283	•	•	•	VPI
Juncus bufonius	Toad rush	282	•	•	•	VPA
Crassula aquatica	Water pygmy-weed	255	•	•	•	VPA
Trifolium depauperatum	Dwarf sack clover	235	•	•	•	GEN
Psilocarphus brevissimus	Dwarf woolly-heads	223	•	•	•	VPI
Pogogyne zizyphoroides	Sacramento mesamint	216	•		•	VPA
Leontodon taraxacoides	Hairy hawkbit	213	•			
Triteleia hyacinthina	Hyacinth brodiaea	208	•		•	VPA
Eleocharis macrostachya	Creeping spikerush	201	•	•	•	VPI
Downingia ornatissima	Solano downingia	192	•	•	•	VPA
Holocarpha virgata	Sticky tarweed	191	•	•	•	GEN
Briza minor	Little quaking grass	187	•	•		GEN
Bromus hordeaceus	Soft brome	166	•	•		GEN
Juncus capitatus	Capped rush	166	•			VPA
Hypochaeris glabra	Smooth cat's-ear	159	•	•		GEN
Achyrachaena mollis	Blowwives	159	•	•	•	GEN
Callitriche marginata	Winged water-starwort	155	•		•	VPA

Table 7. ***Overall Plant Species List, Spring 2003 cont.***

Scientific Name	Common Name	# of Sampled Pools with this Species	Dominant Species?	Abundant Species?	Native Species?	Vernal Pool Plant Classification
Centunculus minimus	Chaffweed	151	•		•	VPI
Brodiaea spp.	Brodiaea	143	•		•	
Gratiola ebracteata	Bractless hedgehyssop	137	•	•	•	VPA
Downingia bicornuta	Double-horn downingia	125	•	•	•	VPA
Plagiobothrys greenei	Greene's popcorn-flower	122	•	•	•	VPA
Taeniatherum caput-medusae	Medusahead grass	118	•	•		GEN
Trifolium variegatum	White-tip clover	116	•	•	•	VPA
Isoetes spp.	Quillwort	111	•		•	GEN
Rumex crispus	Curly dock	99	•	•		GEN
Lasthenia glaberrima	Smooth goldfields	97	•	•	•	VPA
Hemizonia fitchii	Fitch's spikeweed	97	•		•	GEN
Aira caryophyllea	Hairgrass	93	•			GEN
Polypogon monspeliensis	Annual rabbit-foot grass	92	•	•		VPA
Eleocharis acicularis	Least spikerush	85	•		•	VPA
Geranium dissectum	Cut-leaved geranium	78	•			GEN
Psilocarphus tenellus	Slender woolly-heads	76	•		•	VPI
Medicago polymorpha	Bur clover	75	•	•		
Cicendia quadrangularis	Gentian	72		•	•	GEN
Layia fremontii	Freemont's tidy-tips	71	•		•	GEN
Erodium spp.	Filaree	66	•			
Triphysaria eriantha	Butter and eggs	66			•	GEN
Erodium botrys	Filaree	65	•			GEN
Glyceria sp.	Manna grass	64	•	•	•	GEN
Trifolium hirtum	Rose clover	63	•	•		
Juncus uncialis	Inch-high rush	60			•	VPI
Navarretia intertexta	Needle-leaf navarretia	59	•	•	•	VPA

Table 7. ***Overall Plant Species List, Spring 2003 cont.***

Scientific Name	Common Name	# of Sampled Pools with this Species	Dominant Species?	Abundant Species?	Native Species?	Vernal Pool Plant Classification
Avena spp.	Wild oat	55	•	•		
Eremocarpus setigerus	Turkey mullien	54			•	GEN
Rumex pulcher	Fiddle dock	53	•			GEN
Lupinus bicolor	Bicolored lupine	53			•	
Vulpia bromoides	Six-weeks brome grass	51	•	•		GEN
Alopecurus saccatus	Pacific foxtail	50	•	•	•	VPA
Pilularia americana	American pillwort	47		•	•	VPA
Trifolium dubium	Shamrock	44	•	•		
Vicia spp.	Vetch	42	•			
Vulpia spp.	Fescue	38				
Poa annua	Annual bluegrass	37	•	•		GEN
Limnanthes alba	White foam-meadow	36	•	•	•	VPA
Lilaea scilloides	Flowering quillwort	36	•		•	VPI
Trichostema lanceolatum	Vinegar weed	34	•		•	GEN
Castilleja attenuata	Valley tassels	33		•	•	GEN
Castilleja campestris	Field owl's-clover	32	•		•	VPI
Epilobium spp.	Willow herb	31	•		•	
Veronica peregrina	Purslane speedwell	29	•	•	•	VPA
Lepidium nitidum	Pepper grass	28			•	VPA
Psilocarphus oregonus	Oregon woolly-heads	27	•	•	•	VPI
Epilobium brachycarpum	Panicked willow-herb	27			•	GEN
Lotus corniculatus	Birdsfoot trefoil	26	•			GEN
Triteleia laxa	Ithuriel's spear	26	•		•	
Downingia spp.	Downingia	22	•	•	•	VPA
Blennosperma nanum	Common blennosperma	22			•	VPI
Phalaris lemmonii	Lemon's canary grass	21	•		•	VPA
Lactuca serriola	Prickly lettuce	20	•	•		

Table 7. ***Overall Plant Species List, Spring 2003 cont.***

Scientific Name	Common Name	# of Sampled Pools with this Species	Dominant Species?	Abundant Species?	Native Species?	Vernal Pool Plant Classification
Lolium perenne	Perennial ryegrass	20	•			GEN
Convolvulus arvensis	Bindweed	20	•			GEN
Polygonum arenastrum	Prostrate knotweed	18	•	•		GEN
Bromus diandrus	Ripgut brome	18	•			
Plantago elongata	Coast annual plaintain	18			•	VPA
Cyperus strigosus	Sedge	17	•	•	•	
Cuscuta howelliana	Vernal pool dodder	17			•	VPI
Geranium spp.	Geranium	14	•			GEN
Ranunculus muricatus	Spiny-fruit butter-cup	14				VPA
Cardamine oligosperma	Few-seed bitter-cress	14			•	GEN
Elatine spp.	Waterwort	14			•	VPA
Epilobium cleistogamum	Cleistogamous spike-primrose	14			•	VPA
Plantago lanceolata	English plantain	13				GEN
Sidalcea malvaeflora	Checker mallow	12			•	
Avena fatua	Wild oat	11				
Cyperus spp.	Flatsedge	10	•			
Centaurea solstitalis	Yellow star-thistle	10	•			GEN
Hordeum brachyantherum	Meadow barley	10			•	GEN
Montia fontana	Fountain miner s-lettuce	10			•	VPA
Cynodon dactylon	Bermuda grass	9	•			
Glyceria occidentalis	Manna grass	9	•		•	GEN
Cyperus eragrostis	Tall flatsedge	9			•	GEN
Mentha pulegium	Pennyroyal	8	•	•		VPA
Geranium molle	Hairy geranium	8				GEN
Typha spp.	Cattail	8	•	•	•	
Isoetes orcuttii	Orcutt's quillwort	8			•	VPI
Hordeum murinum	Barley	7	•			GEN
Chenopodium album	White goosefoot	7				

Table 7. ***Overall Plant Species List, Spring 2003 cont.***

Scientific Name	Common Name	# of Sampled Pools with this Species	Dominant Species?	Abundant Species?	Native Species?	Vernal Pool Plant Classification
Vicia sativa	Common vetch	7				
Crassula connata	Sand pygmy-weed	7			•	GEN
Mimulus guttatus	Common large monkey-flower	7			•	VPA
Mimulus tricolor	Tri-color monkey-flower	7			•	VPI
Plantago spp.	Plantain	6	•	•		
Lotus spp.	Bird s foot trefoil	6				
Rumex spp.	Dock	6				
Marsilea vestita	Hairy water fern	6	•	•	•	VPA
Galium spp.	Bedstraw	6	•	•	•	
Brodiaea minor	Dwarf brodiaea	6			•	GEN
Polygonum lapathifolium	Willow Weed	6			•	
Anagallis arvensis	Scarlet pimpernel	5				GEN
Polygonum spp.	Smartweed	5				
Isoetes howellii	Howell's quillwort	5			•	VPI
Juncus spp.	Rush	5			•	
Lotus purshianus	Bird-foot trefoil	5			•	GEN
Navarretia spp.	Navarretia	5			•	
Cerastium glomeratum	Mouse-ear chickweed	4				GEN
Cotula coronopifolia	Brassbuttons	4				GEN
Juncus effusus	Soft rush	4	•	•	•	
Centaurium muehlenbergii	Monterey centaury	4			•	GEN
Pogogyne douglasii	Douglas mesamint	4			•	VPA
Vulpia microstachys	Fescue	4			•	
Wyethia angustifolia	Narrow-leaf Mule Ears	4			•	
Lathyrus spp.	Wild Pea	4		•	•	No
Agrostis spp.	Bentgrass	3	•			VPA
Crypsis schoenoides	Swamp Timothy	3				VPA
Silene gallica		3				GEN

Table 7. ***Overall Plant Species List, Spring 2003 cont.***

Scientific Name	Common Name	# of Sampled Pools with this Species	Dominant Species?	Abundant Species?	Native Species?	Vernal Pool Plant Classification
Trifolium glomeratum	Clover	3				
Trifolium spp.	Clover	3				
Veronica spp.	Speedwell	3				
Vulpia myuros	Rat-tail fescue	3				GEN
Cyperus odoratus	Rusty Flatsedge	3	•		•	
Callitriche heterophylla	Larger water-starwort	3			•	VPA
Downingia cuspidata	Cuspidate downingia	3			•	VPA
Downingia pusilla	Dwarf downingia	3			•	VPA
Epilobium ciliatum	Hairy willow-herb	3			•	
Juncus xiphioides	Iris-leaf rush	3			•	GEN
Limnanthes douglasii	Douglas foam-meadow	3			•	VPA
Myosurus minimus	Tiny mouse-tail	3			•	VPA
Cichorium intybus	Chicory	2	•	•		
Trifolium repens	White clover	2	•			
Bellardia trixago	Bellardia	2				
Filago gallica	Narrow-leaved filago	2				
Spergularia rubra	Purple sandspurry	2				GEN
Stellaria media	Common chickweed	2				GEN
Trifolium subterraneum	Subterranean Clover	2				
Plagiobothrys nothofulvus	Rusty popcorn-flower	2	•		•	GEN
Clarkia spp.	Clarkia	2			•	
Juncus balticus	Baltic rush	2			•	
Plantago erecta	Plantain	2			•	
Rorippa curvisiliqua	Yellow Cress	2			•	GEN
Sidalcea calycosa	Annual checker-mallow	2			•	VPA
Xanthium strumarium	Rough cockle-bur	2			•	GEN
Hypochaeris radicata	Perennial cat's-ear	1	•			

Table 7. ***Overall Plant Species List cont.***

Scientific Name	Common Name	# of Sampled Pools with this Species	Dominant Species?	Abundant Species?	Native Species?	Vernal Pool Plant Classification
Agropyron spp.	Wheatgrass	1				
Carduus pycnocephalus	Italian thistle	1				
Mentha spicata	Spearmint	1				
Phalaris spp.	Canary grass	1				
Rumex acetosella	Sheep sorrel	1				GEN
Secale cereale	Rye	1				
Sonchus asper	Prickly sowthistle	1				
Sonchus oleraceus	Common sowthistle	1				
Vicia villosa	winter vetch	1				
Typha latifolia	Broad-leaf cattail	1	•		•	
Ranunculus aquatilis	White water butter-cup	1	•		•	GEN
Brodiaea elegans	Elegant brodiaea	1			•	
Calandrina ciliata	Red maids	1			•	GEN
Clarkia purpurea	Four-spot clarkia	1			•	
Epilobium densiflorum	Dense-flower spike-primrose	1			•	GEN
Gnaphalium spp.	Cudweed	1			•	
Lepidium latipes	Dwarf pepper-grass	1			•	VPA
Limosella acaulis	Mudwort	1			•	
Minuartia californica	Sandwort	1			•	
Muhlenbergia rigens	Deergrass	1			•	
Salix spp.	Willow	1			•	
Trifolium fucatum	Sack Clover	1			•	
Lathyrus cicera	Wild Pea	1		•	•	No

As described in the methods, because the unit of study is the overall preserve rather than each individual pool, the data from individual pool samples were lumped to create a summary set of floristic summary values that characterized each site. Table 8 provides a list of these preserve summary values and presents their associated descriptive statistics.

Table 8. ***Summary of Floristic Data, Spring 2003***

Variable	Mean	Minimum	Maximum
Total Species Richness	79.9	52	99
Total Native Species Richness	49.0	26	64
Percent Total Native Species	58.3%	37%	66%
Total Vernal Pool Species Richness	34.8	17	47
Percent Vernal Pool Species	42.9%	33%	51%
Dominant Species Richness	13.4	7	21
Percent Dominant Species Richness	16.4%	11.1%	26.6%
Abundant Species Richness	18.3	2	41
Percent Abundant Species Richness	22.8%	3.2%	64.1%
Mean Species Richness Per Pool	19.6	7.7	27.6
Mean Native Species Richness Per Pool	12.9	4.0	19.9
Mean Vernal Pool Species Richness Per Pool	10.8	2.6	17.7

The total species richness within the different preserves ranged from 52 to 99 species (Figure 18). The total species richness varied significantly among the different preserves (X^2=33.00275, df=11, p<0.001). Based on 184 overall plant species documented in the study, each preserve had between 28% and 54% of the total plant species documented. Native species richness and vernal pool species richness numbers (Figure 18) are independent subsets of the total species richness; both of these measures also varied significantly ($X_{\text{native spp}}^2$=34.08163, df=11, p<0.001; $X_{\text{vernal pool spp}}^2$=27.51799, df=11, p<0.005). As shown in Figure 19, the percentage of the overall species in a preserve that were native species ranged from 37% to 66% and the percentage of the overall species in a preserve that were "vernal pool species" ranged from 33% to 51%. These ranges show that, based on species numbers alone, that non-native species and non-vernal pool species make up an average of 39% and 56%, respectively, of the diversity found within a preserve.

Dominant species richness refers to the number of species that had a relative vegetative cover of 25% or greater within one or more pools on-site. Sampled preserves had between 7 and 21 different dominant species, a significant variation (X^2=22.7267, df=11, p<0.025) (Figure 20). With an average of 13.5 dominant species, an average of 15% of the species found in a particular preserve contributed to greater density within one or more of the sampled pools. Of these dominant species, an average of 59% were "vernal pool" species. Starting with the most common, the eight most common dominant species were: *Eryngium vaseyi, Lasthenia fremontii, Plagiobothrys stipitatus, Navarretia leucocephala, Hordeum marinum, Ranunculus bonariensis, Lolium multiflorum,* and *Eleocharis macrostachya*. All of these except, *Hordeum marinum* and *Lolium multiflorum* are "vernal pool indicators" or "vernal pool associates."