California's Great Valley Vernal Pool Habitat Status and Loss: Rephotorevised 2005

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ABSTRACT

Aerial photograph interpretation was used to map the extent of vernal pool habitat in the Great Valley for 2005, and was compared to maps prepared previously for the 1976–1995 period and for 1997. The primary causes of vernal pool habitat loss were also obtained from aerial photograph interpretation. Approximately 1,030,000 acres of vernal pool habitat were documented in the Great Valley for the 1976–1995 period. In 2005, about 895,000 acres remained; a reduction of roughly 135,000 acres. The amount of loss was not distributed evenly across the Great Valley. For example, Mariposa County has not lost any vernal pool habitat since 1976, but at the opposite extreme, Merced County has lost 24,000 acres (or 8 percent) and Placer County 17,000 acres (or 35 percent) of the vernal pool habitat found during initial mapping (in 1987 and 1994, respectively). Counties in the central and western portions of the Great Valley (Colusa, Glenn, Sutter, and Yolo) have also seen high losses, ranging from 40 to 75 percent. Eighty one percent of the total habitat loss between the initial mapping period and 2005 (110,000 acres) was lost due to agricultural land conversions. Establishment of orchards and vineyards represents the largest category of land conversion, or almost 30 percent, which corresponds to an proximately 40,000 acres loss of vernal pool habitat. Most of this loss was concentrated in the southern Sacramento Valley and northern San Joaquin Valley. Urban development accounted for 26,000 acres (19 percent) of total habitat loss. Most urban development caused habitat loss (two-thirds of the total) was concentrated in Placer and Sacramento Counties with relatively small amounts of loss scattered in other parts of the Great Valley.

INTRODUCTION

Vernal pools are ephemeral wetland ecosystems with a specialized biota that includes numerous localized plant and animal species. Typically, they form within shallow depressions in grasslands that are underlain by an impervious soil layer. Beginning in the winter, the pools fill with rain water and then slowly dry out through evaporation in the spring. At the time of initial Spanish exploration in the late 1700s, about half of the area of the Great Valley was likely characterized by vernal pool landscapes (Holland and Hollander 2007). The approximately 7 million acres of vernal pool landscapes present at that time have been much reduced, first by agricultural development and mineral extraction, and more recently by urban expansion. The most recent estimate of remaining vernal pool habitat (i.e., vernal pool wetlands and the surrounding grassland matrix within which vernal pools typically occur) was about 967,600 acres in 1997 (Holland 1998b), an 87 percent reduction in the original habitat acreage. Habitat loss, combined with the intrinsically localized distributions of many vernal pool taxa, has lead to several species of plants and animals being listed by the State of California or federal government as Threatened or Endangered (Table 1). Many more species are considered to be Rare by the California Native Plant Society (2009).

Great Valley vernal pool habitat was initially mapped from aerial photographs over the period from 1976 to 1995 (Holland 1998a). Subsequently, this map was updated in 1997 based on aerial photography for the entire Great Valley, and the loss of habitat over that period was assessed (Holland 1998b). The objectives of the current study were to update the 1997 vernal pool habitat map to 2005 conditions, to evaluate changes to vernal pool habitat distribution, and, for the first time, to identify those land uses to which vernal pool habitat was converted.

MATERIALS AND METHODS

PREVIOUS MAPPING METHODS

1976 to 1995 Map (Baseline)

The first digital map of Great Valley vernal pool habitat (Holland 1998a) documented 1,033,000 acres of remaining habitat. This baseline map was based on air photos taken over the period from 1976 to 1995, with the majority taken between 1982 and 1992 (Holland 1998a). The photos were vertically oriented, 35 mm, true-color slides that covered about 1 x 1.4 miles, with 20 percent front- and side-lap, taken from a specially equipped aircraft that flew at constant height above the ground. The slides were taken as part of a program in the California Department of Water Resources that maps the origin, distribution, and use of agricultural water throughout cultivated California, by mapping crop types in California counties on an approximately 7-year rotation. Every slide in every flight line was visually examined for the characteristic signatures[1] of vernal pools. When habitat was encountered, it was mapped onto paper 7.5' USGS topographic map sheets. Each sheet was digitized on an ArcINFO workstation upon completion. The density of vernal pools within each polygon was subjectively scored as either low, medium, or high and areas of disturbed habitat (e.g., areas of cultivation where extant habitat was still evident) were differentiated from areas of undisturbed habitat. Examples of low, medium, and high density vernal pool habitats are shown in Figures 1 and 2. Over an 18 month period, more than 40,000 slides (covering all or part of 345 7.5' USGS topographic map sheets) were examined in an approximately 18,000,000 acre study area that stretched from Shasta Dam south to the Tehachapi Mountains and west to include several North Bay counties.

1997 Map

In 1997, the California Department of Conservation Farmland Mapping and Monitoring Program sponsored a U2 flight covering the entire Great Valley. The resultant images were 9x9 inch false-color infrared transparencies at 1:130,000 scale. About 1,500 images were required to cover the valley. These images, in combination with readily available black-and-white SPOT satellite imagery, were used to update the baseline map to 1997 conditions. Individual vernal pools were not visible at the mapped scale of the U2 and SPOT images, but changes in land use were readily apparent. Hundreds of vernal pool habitat polygons were converted to other uses. Hundreds more were reduced in size or split into two or more fragments. Polygon boundaries were modified to 1997 conditions. This revised map (Holland 1998b) allowed the first calculation of the rate at which vernal pool habitats in California's Great Valley were vanishing.

The calculation of habitat loss was complicated because the baseline photos were taken county-by-county over several decades. Two counties were mapped from photos just two years old (i.e., 1995 photos). Two other counties were mapped from 1976 photos. Thus, it was possible to calculate annual habitat loss rates for each county, but not for the entire Great Valley. This map (Holland 1998b) has been publicly available for nearly a decade and was the starting point for the present study.

MAPPING METHODS FOR 2005

In 2005, the National Agricultural Imaging Program (NAIP) — administered by the USDA's Farm Service Agency—produced imagery for each of California's counties. The NAIP images are 1-meter pixel true color orthophoto mosaics that can be displayed using Geographic Information Systems over a large range of scales without loss of image quality. Working systematically from north to south, all polygons from the 1997 map (Holland 1998b) were examined in relation to the NAIP imagery. Vernal pool habitat was scored using the same

[1] The photos were taken during peak irrigation demand during the mid summer. During this season, the grassland has completely dried and formerly living annual plants now stand as dead straw. Vernal pools appear as irregularly dendritic features within the tawny matrix of dried annual grassland. See Figures 1 and 2.

methods as employed in the related previous studies. Polygon boundaries were adjusted to 2005 conditions. Due to the enhanced resolution provided by the NAIP imagery, it was possible to add a code indicating the current land use for every polygon, something that was not possible in previous studies. Figure 3 shows several polygons in relation to landscape in Shasta County, California.

Once the 1997 polygons were updated to 2005 conditions and attributed, the map and accompanying attribution underwent an extensive third-party quality assurance and quality control review. The review included attribute checking of random samples of polygons, checking attributes of known areas, assessment and correction of map topology, and comparing of check sums of acreages between years. Each mapped polygon was inspected against the NAIP imagery (and sometimes against other public-domain geospatial datasets if interpretation of a feature or attribute class was unclear). This review did not look outside the mapped polygons to see if additional habitat had been missed in the original mapping efforts. The purpose of the review was to confirm that each polygon was correctly attributed as extant or extirpated and the correct land conversion code was assigned. Overall polygon boundaries were not changed or adjusted, except in the cases of overlapping polygons. Overlapping polygons were adjusted so that the overlap acreage would not be calculated twice. As necessary, polygons were clipped to accurately portray existing land use. This was especially necessary in some of the largest polygons where portions had been converted to agricultural residential land use (e.g., “ranchettes” or “hobby farms”). A total of 222 additional polygons were created. Once all polygons had been reviewed and reattributed as necessary, new areas and acreages were calculated for each polygon.

As a final step, the shapefile was thoroughly checked for topological errors (i.e., minute mapping errors such as edges of adjacent polygons not completely overlapping). Any topological errors were discovered and corrected. The resulting attribute table was exported out of ArcGIS into Microsoft Excel. Excel was used to summarize the data, compute various data cross-tabulations, and display results graphically.

RESULTS

The final 2005 vernal pool habitat map is presented in Figure 4. Figure 5 summarizes the acreage of extant vernal pool habitat, by density class, for each of the three mapping periods. The acreage of habitat loss is also shown for the 1997 map and 2005 update. Tables 2 and 3 list the amount of habitat lost for each mapping period, by county, as well as the rate of habitat loss. Figure 6 summarizes the various land use changes that have resulted in vernal pool habitat loss and lists those counties where the majority of vernal pool habitat has been lost for each land use conversion. Table 4 displays these same data in detail.

Some of the most significant results are described below.

There were 1,033,000 acres of extant vernal pool habitat in the (1976–1995) baseline map. By 1997, the acreage of extant habitat had been reduced to 995,000 acres, and many previously contiguous areas of habitat had been fragmented. By 2005 there were 896,000 acres of extant habitat with additional fragmentation of the habitat that remained. Therefore, a total of 137,000 acres, or roughly 13 percent, of vernal pool habitat has been lost since the baseline map was prepared (Table 2).

About 4 percent of the habitat extant in the original mapping had been eliminated by 1997, an additional 9 percent was lost between 1997 and 2005. This is over 1 percent per year of the extant habitat in the baseline habitat map (Table 2).

While a large amount of habitat has been lost, the amount of loss is not distributed evenly across the study area. For example, Mariposa County has not lost any vernal pool habitat since the baseline mapping year (1976). Merced and Placer Counties occupy the opposite extreme. Merced County lost 6,100 acres between 1986 and 1997, or 552 acres/year. Placer County lost 10,440 acres between 1994 and 1997, or 3,480 acres/year. These two

counties account for almost one-half (46 percent) of the habitat loss documented in 1997. Large acreages of habitat loss continued in these two counties between 1997 and 2005. Merced County lost an additional 18,000 acres of habitat during this period, and Placer County lost 6,600 acres of habitat. In all, these two counties have lost 8 percent and 35 percent, respectively, of their baseline vernal pool habitat acreage. While the percentage of loss in Merced County is only 8 percent of the baseline habitat, this represents a loss of almost 24,000 acres, greatly exceeding the total acreage of loss in any other county during the assessment periods. Areas in the central and western portions of the valley (Colusa, Glenn, Sutter, and Yolo) have experienced dramatic declines in the total proportional of vernal pool habitat, as have Sonoma, Napa, and Marin counties outside the Great Valley in the North Bay Area (Table 2).

Similar to the amount of habitat loss, the rate of habitat loss varies greatly across the study area. Habitat loss rates, in terms of acreage per year, have accelerated markedly in Madera, Stanislaus, Butte, Fresno, Merced, Kings, Kern, Sacramento, San Joaquin, and Sutter counties between 1997 and 2005 relative to the baseline year and 1997. Marked decelerations in habitat loss are evident in Glenn, Placer, and Solano counties. When habitat losses are viewed in terms of the percentage of baseline habitat lost per year slightly different, but equally compelling trends are observed. Six counties (Colusa, Glenn, Napa, Placer, Sutter, and Yolo) have lost more than 3 percent of their baseline habitat *per year*, since the baseline mapping year. For these counties this represents a time span of anywhere from 10 years (Yolo County) to 18 years (Napa County). In some cases the rate of habitat loss is roughly even throughout this period (Colusa and Yolo Counties, both averaging nearly 5 percent of baseline habitat lost per year) while in other cases the rate of loss is declining (Glenn and Placer counties) or increasing (Sutter and Napa counties) (Table 3).

Various forms of agricultural land use conversion plainly exceed urbanization as a source of vernal pool habitat loss. Eighty one percent of the total habitat loss between the baseline year and 2005 was lost due to agricultural land conversions (Table 4 and Figure 6).

Orchards, vineyards, and, less frequently, eucalyptus plantations (for pulp) represent the single largest cause of vernal pool habitat conversion. Almost 30 percent of the total observed vernal pool habitat loss (approximately 40,000 acres) could be attributed to this land conversion. Much of the loss (nearly two-thirds of the total) was concentrated in the northern San Joaquin Valley counties of Merced, Stanislaus, and San Joaquin. Much of the remaining loss occurred in Madera, Glenn, and Colusa counties (Table 4 and Figure 6).

The amount of vernal pool habitat loss attributable to other types of agricultural land conversion (agricultural residential, bare agricultural land, irrigated pasture, and other agricultural activities) was roughly equivalent, ranging from 10 percent to 15 percent of the total habitat loss. With the exception of agricultural residential development, which is most common in the northeastern Sacramento Valley, these activities have been concentrated in the San Joaquin Valley (Table 4 and Figure 6).

Land conversions tied to population growth and urban development accounted for almost 26,000 acres or 19 percent of habitat loss. Most urban habitat loss (two-thirds of the total) was concentrated in Placer and Sacramento Counties (Table 4 and Figure 6).

DISCUSSION

Over 13 percent of the extant vernal pool habitat found in the baseline mapping effort (Holland 1998a) has been eliminated as of 2005. Agricultural conversions (e.g., rangeland being converted to orchards or vineyards) are far and away the primary drivers of vernal pool habitat loss across the Great Valley. The vast majority of these habitat conversions occur outside the normal regulatory processes that apply to urban, commercial, infrastructure, and industrial development (AECOM 2009) and are, therefore, largely unmitigated. In other words, little to no vernal pool habitat is being created or preserved to compensate for this loss, resulting in an overall net loss of vernal pool habitat functions and services. Urbanization exceeds agricultural development as the primary cause of vernal pool habitat loss only in Placer County.

The rate of habitat loss increased sharply between 1997 and 2005, relative to rates of loss prior to 1997. And, while much vernal pool habitat still remains in many counties (despite significant losses), widespread loss of habitat was observed on the western side of the Northern Sacramento Valley, an area that did not have extensive areas of vernal pool habitat initially. If the current rate of annual habitat loss were to continue, vernal pool habitats (with the exception of vernal pool habitat preserves) would be completely eliminated from the Great Valley by 2087.

Given changes in GIS technology since the baseline maps were prepared, a brief discussion of the limitations of the mapping methodology used to prepare the current and historic maps is appropriate. The original maps were sketched by hand from a display screen at about 1: 10,400 scale onto 1: 24,000 scale topographic sheets, and later digitized by a technician using ArcINFO at a dedicated workstation and a digitizing tablet. The 1997 update was drawn by hand on 130,000-scale base maps. These base maps were edited by a technician on-screen using ArcView 3.2. The 2005 update was done entirely on-screen using ArcGIS version 9.2. With this technology, one may zoom in or out, overlay maps of topography, geology, or soils, or compare the photomosaic with other imagery from other dates. The 1997 methods were more accurate than the baseline mapping methods, and the 2005 methods were again more accurate than the 1997 methods.

Because the 2005 NAIP imagery afforded vastly superior image quality to the color aerial photography slides and satellite imagery used to prepare the baseline map and 1997 update, a variety of initial mapping errors were evident. For example, it was not uncommon to find polygons originally mapped from baseline imagery whose boundaries only approximated the detail visible in the 2005 images. There were also instances where habitat that was obviously extant in 2005 was not mapped in the initial baseline map, and, conversely, there were obvious areas of non-habitat that had been lumped with adjacent areas of extant habitat to create a single polygon.

Unfortunately, it would be very time consuming, and likely impossible, to quantify the acres of vernal pool habitat affected by these mapping errors, which are equally likely in both directions. Even if the accuracy of specific acreage estimates for extant and extirpated habitat are somewhat uncertain, the relative amount of loss between the baseline mapping year and 2005 is a valid estimate of the net loss of vernal pool habitat during this period. The clear conclusion is that significant vernal pool habitat loss is occurring throughout the Great Valley and that, despite the attention devoted to urban development, various forms of agricultural development have resulted in over four times more vernal pool habitat loss than urbanization.

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REFERENCES

California Native Plant Society. 2009. Inventory of Rare and Endangered Plants. Available on-line at: http://cnps.site.aplus.net/cgi-bin/inv/inventory.cgi.

AECOM. 2009. U. S. Army Corps of Engineers Permitting and Mitigation of Central Valley Vernal Pool Impacts, 2000–2006. Prepared for Placer Land Trust. Sacramento, CA.

Holland, Robert F. 1998a. Great Valley Vernal Pool Distribution, Photorevised 1996. Pp. 71–75 in Witham, C. W., E. T. Bauder, D. Belk, W. R. Ferren Jr., and R. Ornduff (Editors) *Ecology, Conservation, and Management of Vernal Pool Ecosystems – Proceedings from a 1996 Conference.* California Native Plant Society, Sacramento, CA.

———. 1998b. Changes in Great Valley Vernal Pool Distribution from 1989 to 1997. California. Department of Fish and Game. Natural Heritage Division. Consultant report. 18 pp. Available on-line at: ww.dfg.ca.gov/biogeodata/wetlands/pdfs/Holland_ChangesInGreatValleyVernalPoolDistribution.pdf.

Holland, R. F. and A. D. Hollander. 2007. Hogwallow biogeography before gracias. *In* Schlising, R. A. and D. G. Alexander (eds.) *Vernal pool landscapes*. Studies from the herbarium, Number 14. California State University, Chico. Pp. 29–50.

Table 1
Great Valley Vernal Pool Species That Are Listed As Threatened or Endangered by the U.S. Fish and Wildlife Service or the California Department of Fish and Game

Scientific Name	Common Name
Ambystoma californiense	California tiger salamander
Elaphrus viridis	Delta green ground beetle
Branchinecta longiantenna	longhorn fairy shrimp
Branchinecta conservatio	Conservancy fairy shrimp
Branchinecta lynchi	vernal pool fairy shrimp
Lepidurus packardi	vernal pool tadpole shrimp
Neostapfia colusana	Colusa grass
Orcuttia inaequalis	San Joaquin Valley Orcutt grass
Orcuttia pilosa	hairy Orcutt grass
Orcuttia viscida	Sacramento Orcutt grass
Orcuttia tenuis	slender Orcutt grass
Tuctoria mucronata	Solano grass
Tuctoria greenei	Greene's tuctoria
Castilleja campestris ssp. *succulenta*	succulent owl's clover
Chamaesyce hooveri	Hoover's spurge
Limnanthes floccosa ssp. *californica*	Butte County meadowfoam
Lasthenia conjugens	Contra Costa goldfields

Source: Data provided by EDAW in 2009

Table 2 Acreage of Vernal Pool Habitat Loss, by County										
County	Baseline Year	Mapped Extant			Total Acres Lost			Total Percent Lost		
		Baseline	1997	2005	Base–97	97–05	Base–05	Base–97	97–05	Base–05
Alameda	1986	2,751	2,402	2,006	348	396	745	12.7%	14.4%	27.1%
Amador	1983	4,242	4,242	3,846	0	396	396	0.0%	9.3%	9.3%
Butte	1994	59,166	58,714	53,540	452	5,174	5,626	0.8%	8.7%	9.5%
Calaveras	1983	6,419	6,419	5,917	0	502	502	0.0%	7.8%	7.8%
Colusa	1993	5,703	4,410	2,110	1,293	2,300	3,593	22.7%	40.3%	63.0%
Contra Costa	1985	3,150	3,150	3,131	0	19	19	0.0%	0.6%	0.6%
El Dorado	1983	1,274	1,274	1,018	0	256	256	0.0%	20.1%	20.1%
Fresno	1994	27,690	27,539	25,490	151	2,048	2,199	0.5%	7.4%	7.9%
Glenn	1993	10,803	8,113	6,553	2,690	1,560	4,250	24.9%	14.4%	39.3%
Kern	1990	9,543	9,455	8,681	88	774	862	0.9%	8.1%	9.0%
Kings	1991	11,951	11,662	9,676	289	1,986	2,275	2.4%	16.6%	19.0%
Lake	1995	2,541	2,541	2,410	0	131	131	0.0%	5.2%	5.2%
Madera	1987	94,054	90,357	79,706	3,697	10,651	14,348	3.9%	11.3%	15.3%
Marin	1986	260	260	162	0	98	98	0.0%	37.7%	37.7%
Mariposa	1976	6,553	6,553	6,553	0	0	0	0.0%	0.0%	0.0%
Merced	1987	285,215	279,142	261,180	6,073	17,962	24,035	2.1%	6.2%	8.4%
Napa	1987	1,207	994	165	213	829	1,042	17.6%	68.7%	86.3%
Placer	1994	48,298	37,858	31,185	10,440	6,673	17,113	21.6%	13.8%	35.4%
Sacramento	1993	53,757	53,583	47,159	174	6,424	6,598	0.3%	12.0%	12.3%
San Joaquin	1988	37,976	36,527	29,615	1,449	6,912	8,361	3.8%	18.2%	22.0%
Shasta	1995	24,034	23,937	23,019	97	918	1,015	0.4%	3.8%	4.2%
Solano	1994	38,897	37,334	35,400	1,563	1,934	3,497	4.0%	5.0%	9.0%
Sonoma	1986	4,466	3,925	2,464	541	1,461	2,002	12.1%	32.7%	44.8%
Stanislaus	1988	92,346	91,025	78,254	1,321	12,771	14,092	1.4%	13.8%	15.3%
Sutter	1990	1,444	1,374	700	70	674	744	4.8%	46.7%	51.5%
Tehama	1994	137,902	134,641	126,860	3,261	7,781	11,042	2.4%	5.6%	8.0%
Tulare	1993	38,223	36,442	30,969	1,781	5,473	7,254	4.7%	14.3%	19.0%
Tuolumne	1976	4,164	4,164	4,080	0	84	84	0.0%	2.0%	2.0%
Yolo	1989	3,617	2,640	901	977	1,739	2,716	27.0%	48.1%	75.1%
Yuba	1995	14,337	14,061	13,034	276	1,027	1,303	1.9%	7.2%	9.1%
Totals		**1,031,983**	**994,738**	**895,787**	**37,245**	**98,951**	**136,196**	**3.6%**	**9.6%**	**13.2%**
Map Error		**928**				**928**	**928**			
Net Loss						**99,879**	**137,124**		**9.7%**	**13.3%**

Table 3 Rate of Vernal Pool Habitat Loss, by County							
County	Baseline Year	Acres Lost Per Year			Percent Lost Per Year		
		Base–97	97–05	Base–05	Base–97	97–05	Base–05
Alameda	1986	32	50	39	1.2%	1.8%	1.4%
Amador	1983	0	50	18	0.0%	1.2%	0.4%
Butte	1994	151	647	511	0.3%	1.1%	0.9%
Calaveras	1983	0	63	23	0.0%	1.0%	0.4%
Colusa	1993	323	288	299	5.7%	5.0%	5.3%
Contra Costa	1985	0	2	1	0.0%	0.1%	0.0%
El Dorado	1983	0	32	12	0.0%	2.5%	0.9%
Fresno	1994	50	256	200	0.2%	0.9%	0.7%
Glenn	1993	673	195	354	6.2%	1.8%	3.3%
Kern	1990	13	97	57	0.1%	1.0%	0.6%
Kings	1991	48	248	162	0.4%	2.1%	1.4%
Lake	1995	0	16	13	0.0%	0.6%	0.5%
Madera	1987	370	1,331	797	0.4%	1.4%	0.8%
Marin	1986	0	12	5	0.0%	4.7%	2.0%
Mariposa	1976	0	0	0	0.0%	0.0%	0.0%
Merced	1987	607	2,245	1,335	0.2%	0.8%	0.5%
Napa	1987	21	104	58	1.8%	8.6%	4.8%
Placer	1994	3,480	834	1,556	7.2%	1.7%	3.2%
Sacramento	1993	43	803	550	0.1%	1.5%	1.0%
San Joaquin	1988	161	864	492	0.4%	2.3%	1.3%
Shasta	1995	49	115	102	0.2%	0.5%	0.4%
Solano	1994	521	242	318	1.3%	0.6%	0.8%
Sonoma	1986	49	183	105	1.1%	4.1%	2.4%
Stanislaus	1988	147	1,596	829	0.2%	1.7%	0.9%
Sutter	1990	10	84	50	0.7%	5.8%	3.4%
Tehama	1994	1,087	972	1,004	0.8%	0.7%	0.7%
Tulare	1993	445	684	605	1.2%	1.8%	1.6%
Tuolumne	1976	0	11	3	0.0%	0.3%	0.1%
Yolo	1989	122	217	170	3.4%	6.0%	4.7%
Yuba	1995	138	128	130	1.0%	0.9%	0.9%

Table 4
Amount of Vernal Pool Habitat Loss[1] by Type of Land Conversion and County

County	Urban, Commercial, Industrial		Agricultural Residential		Orchards, Vineyards, & Eucalyptus		Bare, Plowed Agricultural Land		Alfalfa & Pasture		Other Agricultural	
	Acres	Percent of Conversion	Acres	Percent of Conversion	Acres	Percent of Conversion	Acres	Percent of Conversion	Acres	Percent of Conversion	Acres	Percent of Conversion
Alameda	389	1.5%	0	0.0%	151	0.4%	0	0.0%	135	0.9%	69	0.3%
Amador	21	0.1%	69	0.4%	29	0.1%	0	0.0%	121	0.8%	0	0.0%
Butte	1,127	4.3%	2,946	16.8%	936	2.4%	464	2.6%	26	0.2%	368	1.7%
Calaveras	51	0.2%	335	1.9%	2	0.0%	98	0.6%	0	0.0%	16	0.1%
Colusa	22	0.1%	10	0.1%	1,150	2.9%	615	3.5%	432	2.8%	1,364	6.4%
Contra Costa	0	0.0%	0	0.0%	0	0.0%	26	0.1%	0	0.0%	0	0.0%
El Dorado	101	0.4%	155	0.9%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Fresno	61	0.2%	1,010	5.8%	207	0.5%	366	2.1%	0	0.0%	554	2.6%
Glenn	0	0.0%	54	0.3%	2,643	6.7%	851	4.8%	87	0.6%	615	2.9%
Kern	124	0.5%	293	1.7%	0	0.0%	92	0.5%	0	0.0%	198	0.9%
Kings	372	1.4%	11	0.1%	0	0.0%	798	4.5%	901	5.9%	193	0.9%
Lake	0	0.0%	27	0.2%	22	0.1%	0	0.0%	82	0.5%	0	0.0%
Madera	103	0.4%	2,913	16.6%	3,386	8.6%	473	2.7%	3,453	22.7%	4,018	19.0%
Marin	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	97	0.5%
Merced	1,404	5.4%	63	0.4%	11,105	28.1%	3,684	20.8%	3,636	23.9%	3,961	18.7%
Napa	895	3.4%	31	0.2%	0	0.0%	0	0.0%	0	0.0%	213	1.0%
Placer	15,368	59.2%	172	1.0%	103	0.3%	426	2.4%	188	1.2%	1,363	6.4%
Sacramento	3,267	12.6%	416	2.4%	2,193	5.6%	420	2.4%	69	0.5%	387	1.8%
San Joaquin	60	0.2%	1,137	6.5%	4,503	11.4%	1,654	9.3%	506	3.3%	860	4.1%
Shasta	175	0.7%	722	4.1%	7	0.0%	0	0.0%	36	0.2%	76	0.4%
Solano	743	2.9%	132	0.8%	0	0.0%	1,068	6.0%	217	1.4%	1,335	6.3%
Sonoma	500	1.9%	44	0.2%	822	2.1%	62	0.3%	202	1.3%	373	1.8%
Stanislaus	19	0.1%	1,116	6.4%	9,202	23.3%	2,379	13.4%	489	3.2%	944	4.5%
Sutter	22	0.1%	181	1.0%	14	0.0%	132	0.8%	0	0.0%	341	1.6%
Tehama	325	1.3%	5,286	30.1%	2,570	6.5%	448	2.5%	1,443	9.5%	861	4.1%
Tulare	15	0.1%	326	1.9%	314	0.8%	2,589	14.6%	3,123	20.5%	1,032	4.9%
Tuolumne	39	0.2%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	44	0.2%
Yolo	626	2.4%	0	0.0%	132	0.3%	924	5.2%	0	0.0%	1,034	4.9%
Yuba	136	0.5%	94	0.5%	0	0.0%	125	0.7%	74	0.5%	873	4.1%
Totals	**25,965**	**100.0%**	**17,542**	**100.0%**	**39,491**	**100.0%**	**17,696**	**100.0%**	**15,228**	**100.0%**	**21,190**	**100.0%**

Note: 1. Vernal pool habitat loss represents the difference between the acreage for 2005 and the 1976–1995 period.

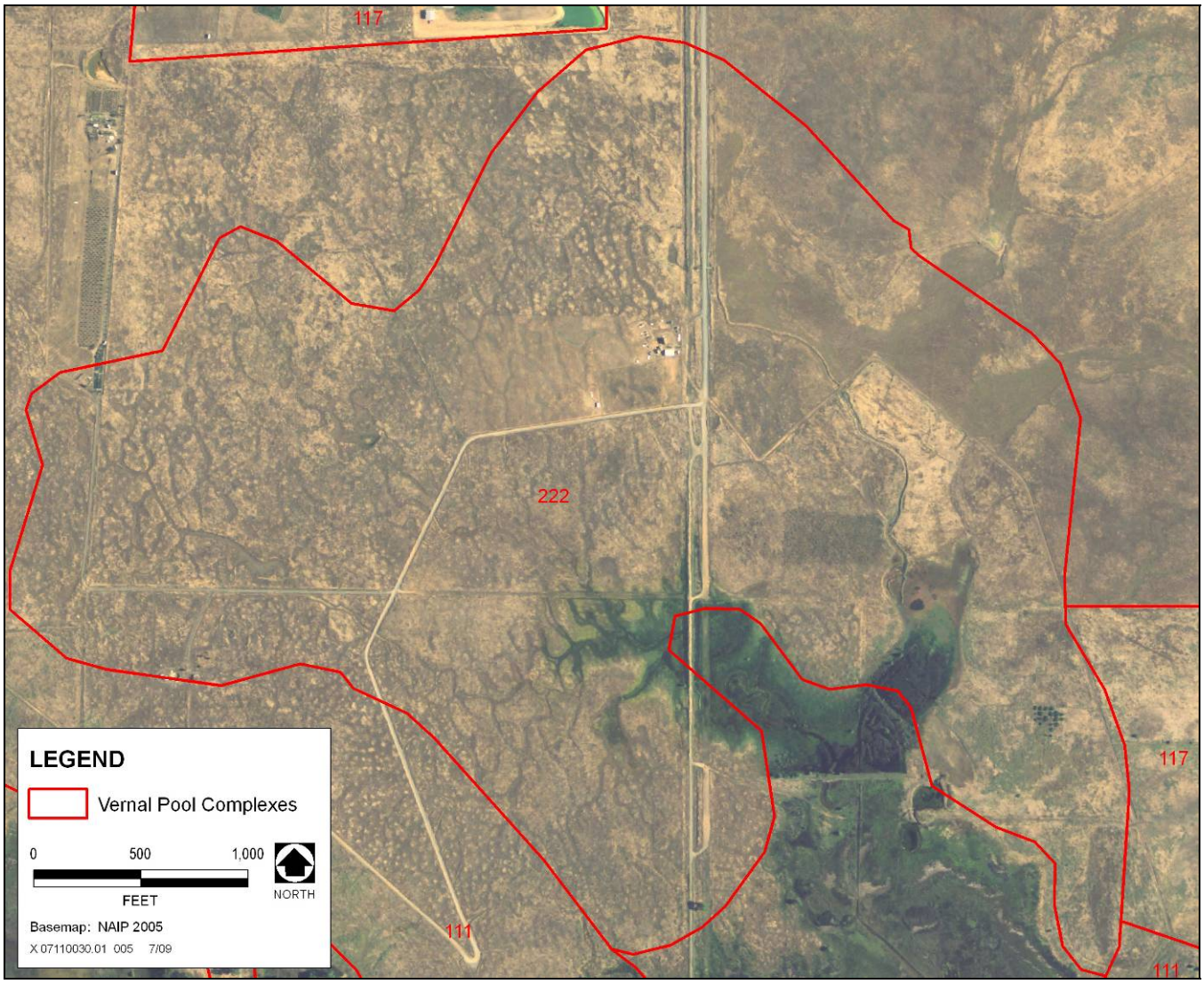


Figure 1. Example Image from Thermalito Afterbay, Butte County

Note: Red numbers indicate habitat scores in the original mapping, 1997, and 2005. Low density habitat (ones) nearly surrounds an area of moderate density habitat (twos). Two areas of low density habitat were converted to agricultural residential (sevens) between 1997 and 2005.

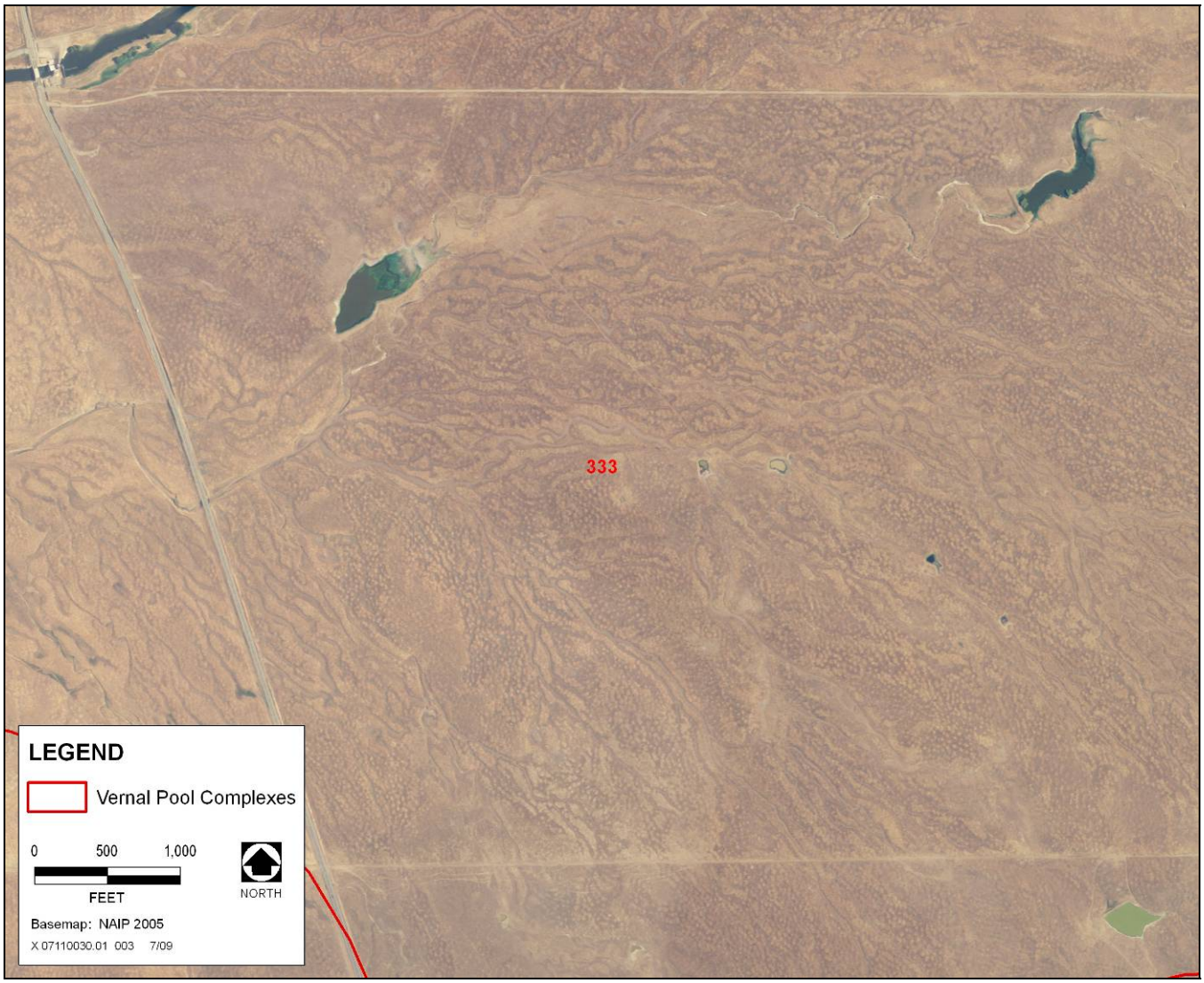


Figure 2. Example Image of High Density Habitat near Snelling, Merced County

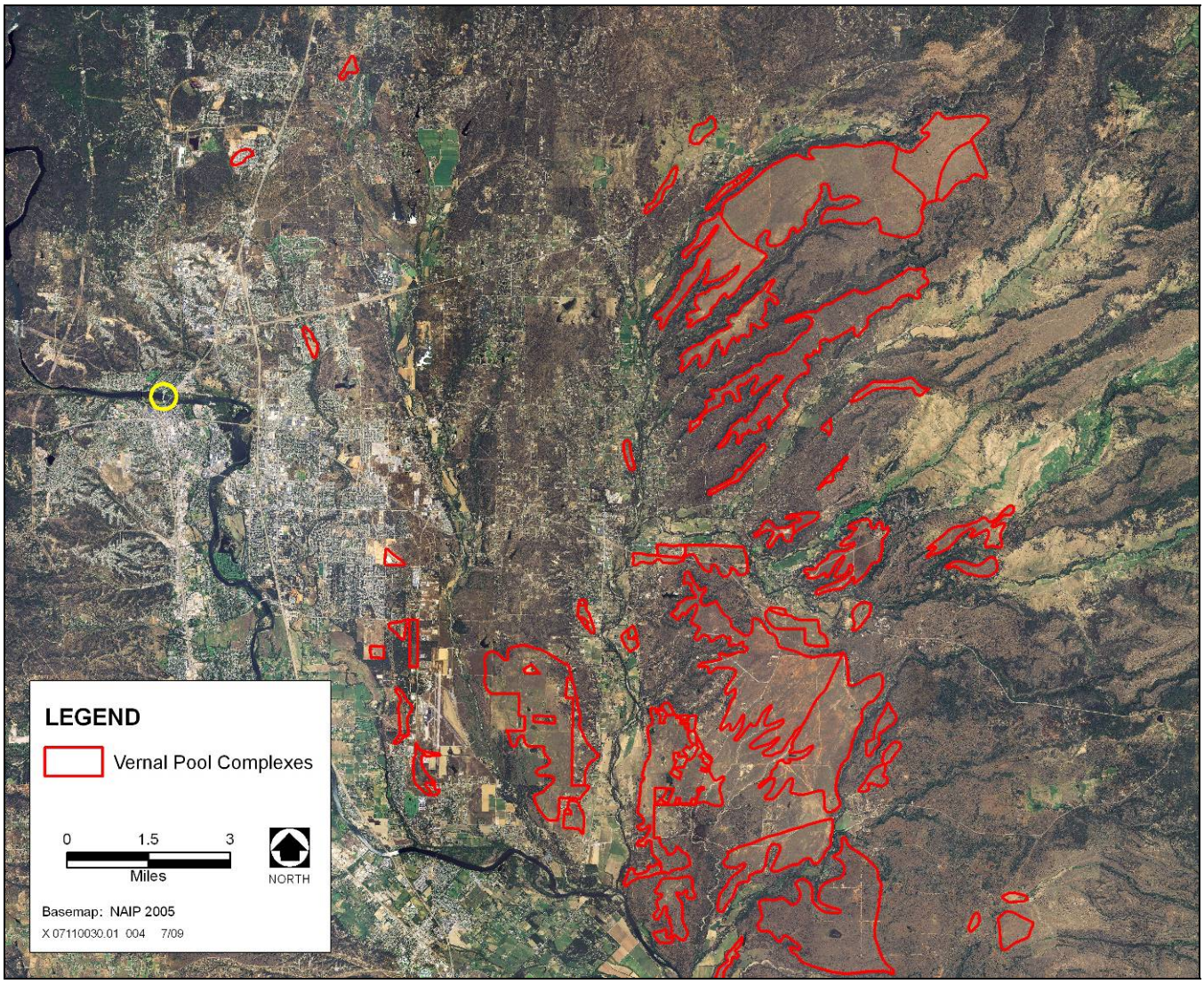


Figure 3. Example Image from Shasta County Showing Several Habitat Polygons in Relation to Landforms

Note: The city of Redding is in the lower left; the 20 foot wide Sundial Bridge over Sacramento River is visible inside the yellow circle. The major north-south road is Interstate 5. The polygon west of the interstate was urbanized after 1997.

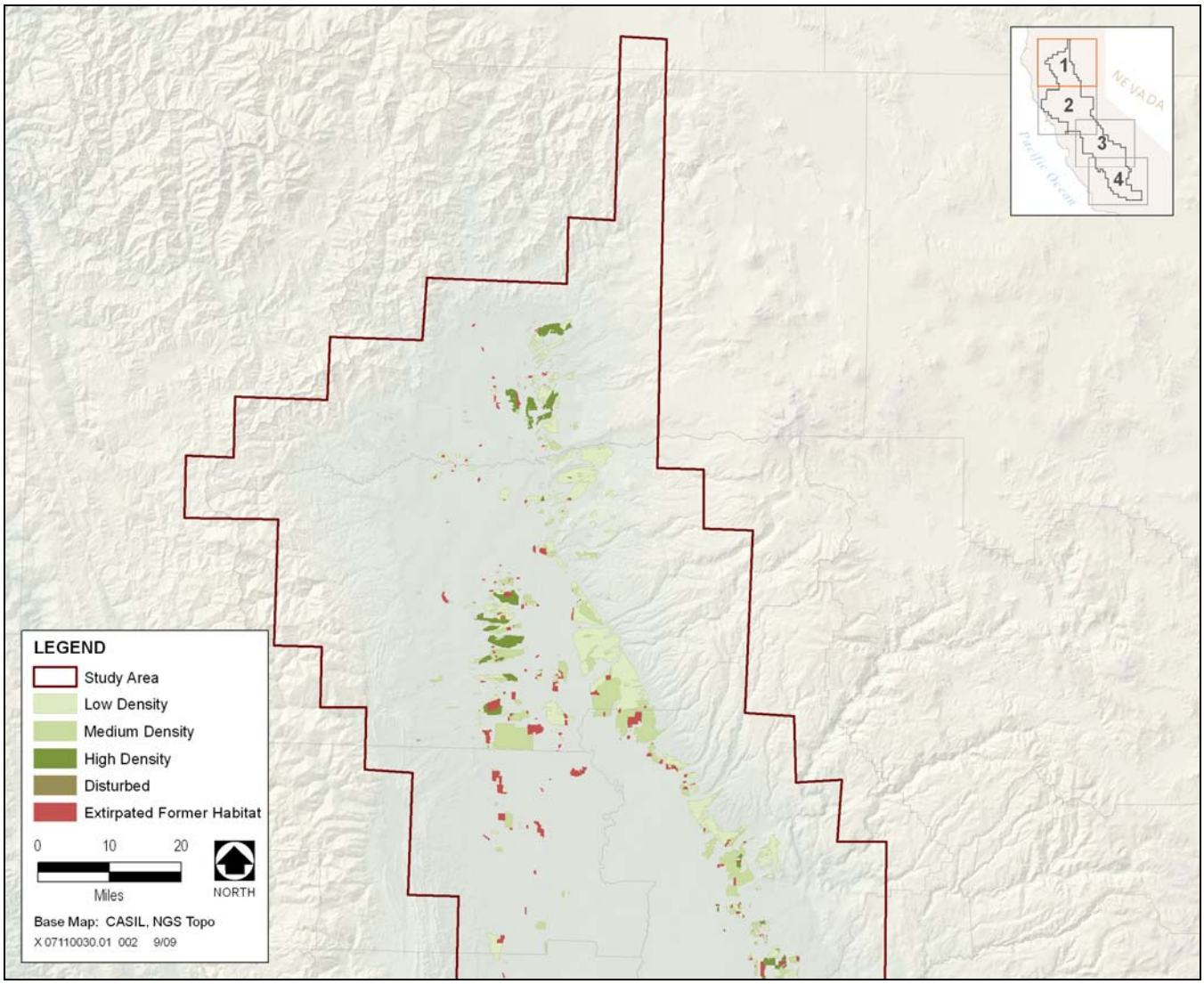


Figure 4a. Distribution of Vernal Pools in the Northern Sacramento Valley as of Summer 2005

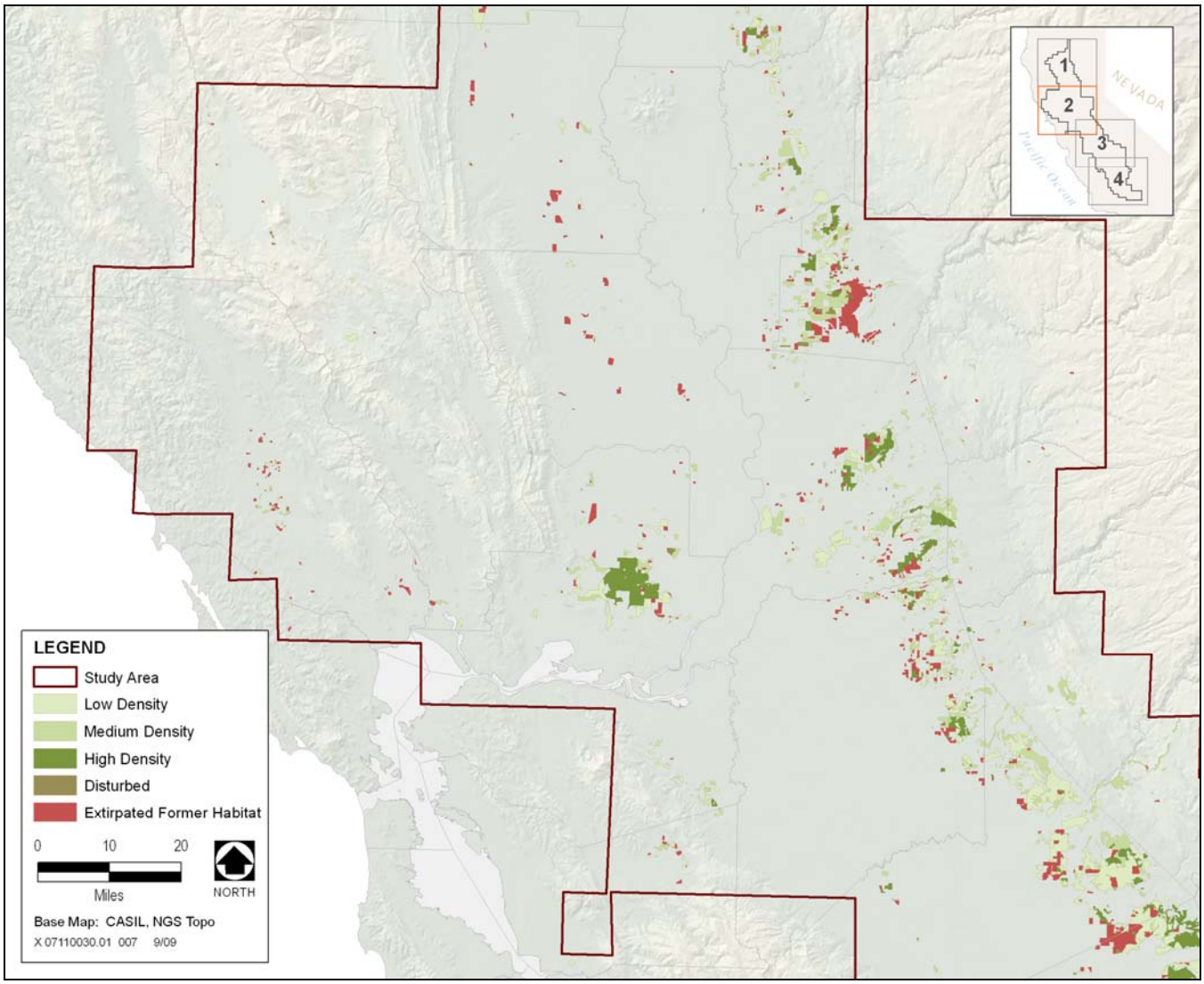


Figure 4b. Distribution of Vernal Pools in the Southern Sacramento and Northern San Joaquin Valleys as of Summer 2005.

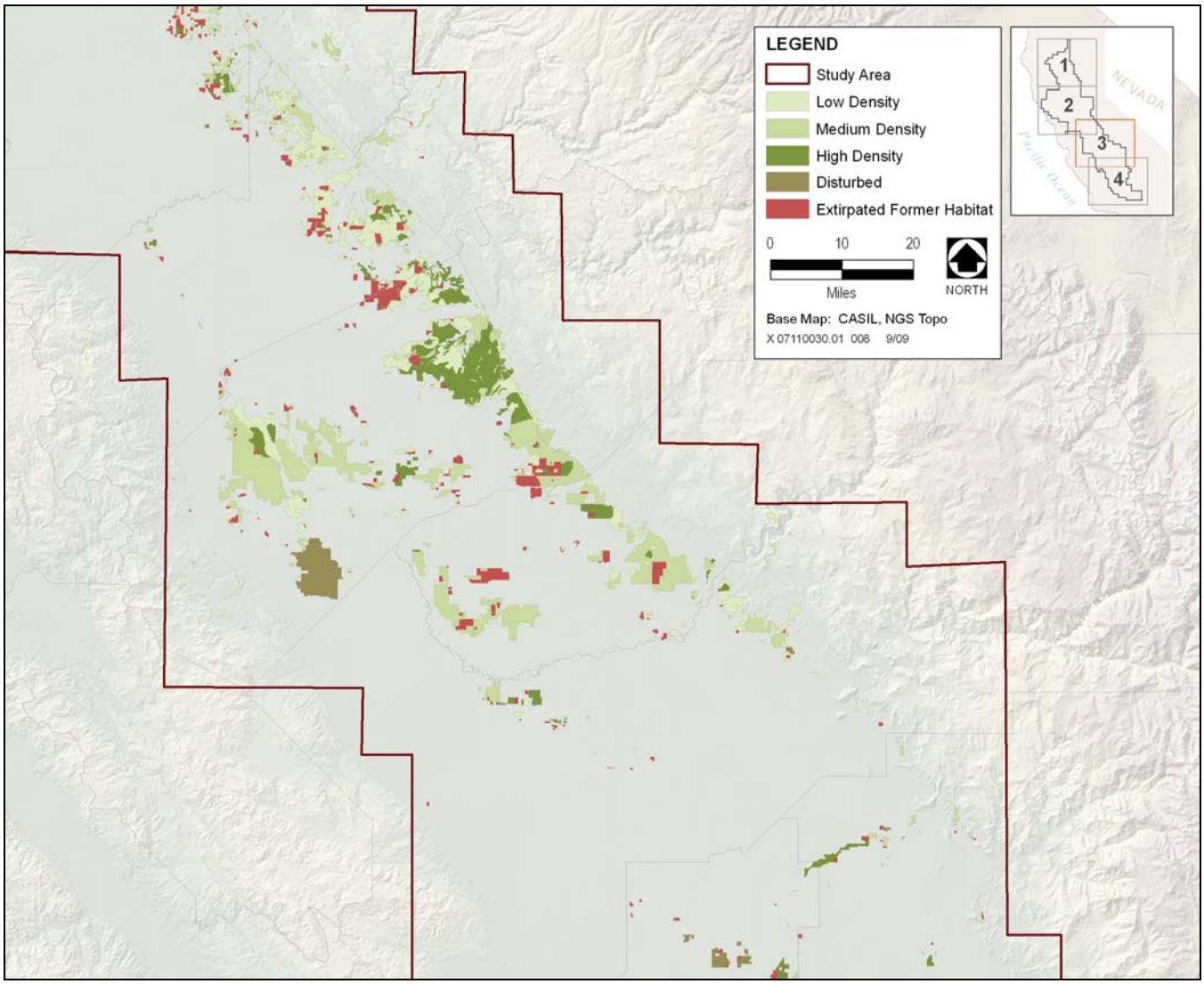


Figure 4c. Distribution of Vernal Pools in the San Joaquin Valley as of Summer 2005.

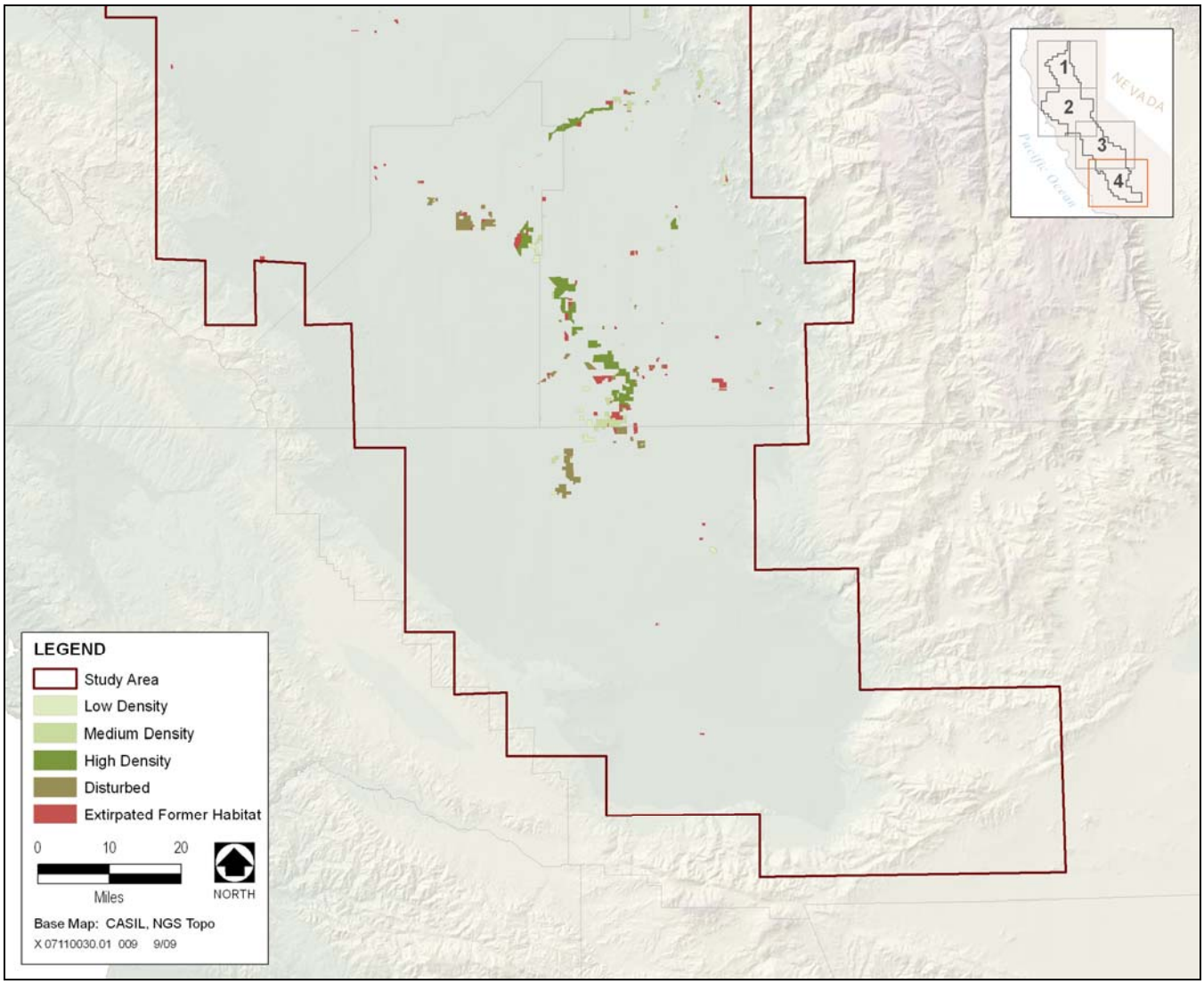
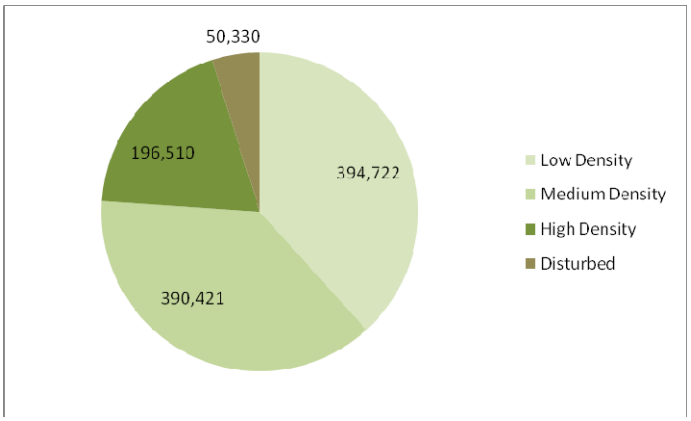
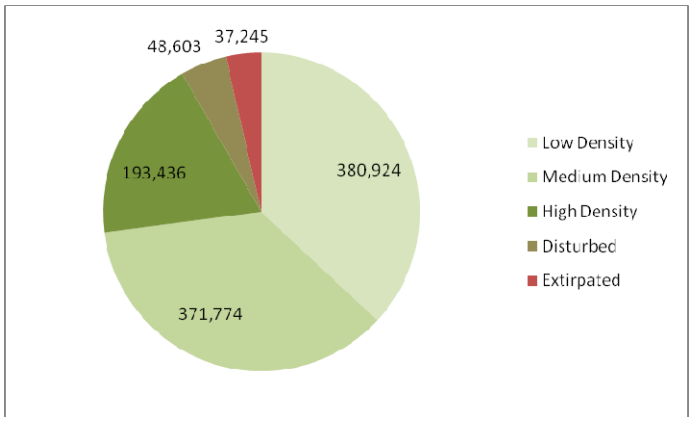


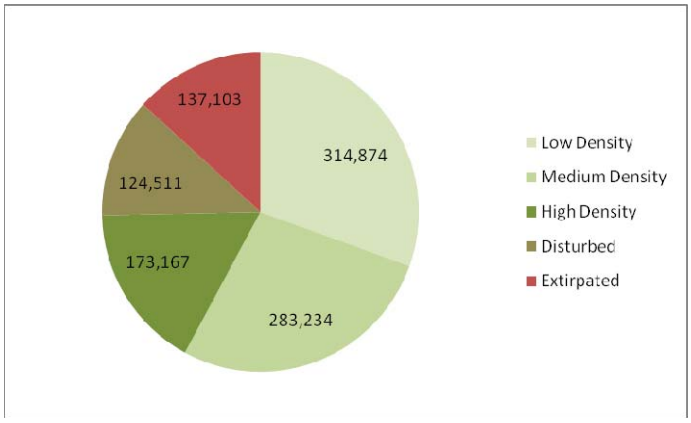
Figure 4d. Distribution of Vernal Pools in the Tulare Basin as of Summer 2005.



Baseline



1997



2005

Habitat Category	Baseline[1]	1997	2005
Low Density	394,722	380,924	314,874
Medium Density	390,421	371,774	283,234
High Density	196,510	193,436	173,167
Disturbed	50,330	48,603	124,511
Extirpated	-	37,245	137,103
TOTAL ACREAGE	1,031,982	1,031,982	1,032,889
% Baseline Habitat Lost		3.61%	13.27%

Note: 1. Baseline represents the period of 1976 to 1995.

Figure 5. Total Existing and Lost Great Valley Vernal Pool Habitat (in acres)

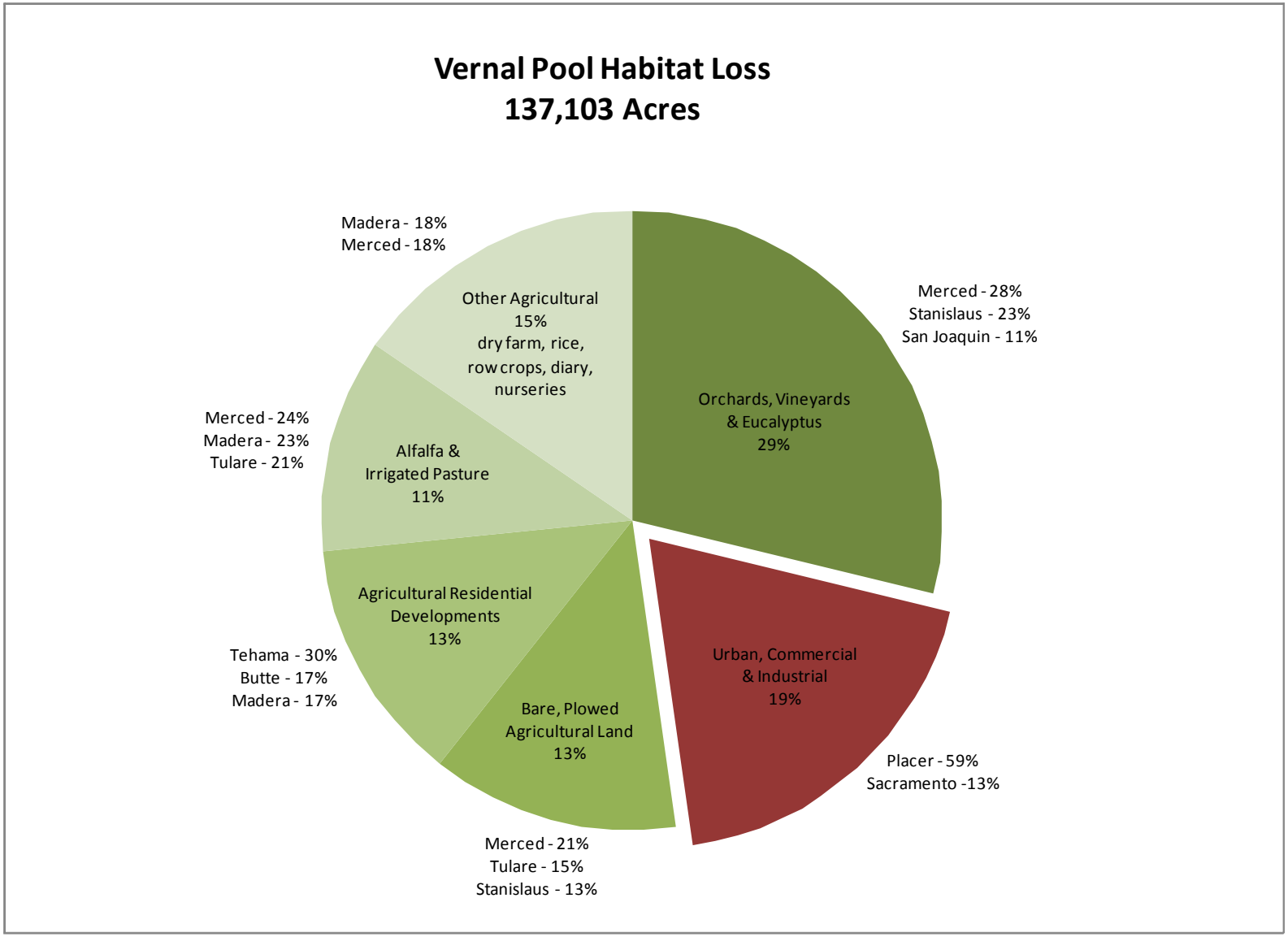


Figure 6. Great Valley Vernal Pool Habitat Loss by Land Use Conversion (percent of baseline) – Counties with Significant Acreages of Loss Highlighted

Note: Percentages for counties indicate the contribution of the county to the Central Valley-wide loss for the category, for example, 59% of all vernal pool loss due to Urban, Commercial and Industrial development occurred in Placer County.