APPENDIX I.1. VERNAL POOL AND OTHER SEASONAL WETLAND MAPPING METHODS

I.1 Methods Used to Map BRCP Vernal Swale Complex and Vernal Pools and the Resolution of Mapping Issues

I.1.1 Introduction

In June 2007, USFWS requested that additional detail be incorporated into the mapping of vernal pool and swale features in the Butte Regional Conservation Plan (BRCP) land cover dataset. Prior mapping prepared by Leidos, Inc. (formerly a part of SAIC) as part of the 2007 *Ecological Baseline Assessment Report*[1] had identified grasslands without vernal pools and grasslands with vernal pools (greater than 1 percent cover) as separate land cover categories. Upon recommendation of the BRCP Stakeholder Committee, BCAG contracted with the Chico Geographic Information Center (GIC) to completely re-map vernal pools and swales individually using similar methods as GIC had used for the South Sacramento County Habitat Conservation Plan.

I.1.2 GIC Mapping Methods

The GIC mapping of the entire vernal pool grassland landscape in the BRCP Plan Area was based on photointerpretation of 2002 color orthorectified aerial photography with 1-meter resolution. This was the only available aerial imagery of the Plan Area taken during the wet season. The aerial imagery was taken by Radman Aerial out of Sacramento, California under contract with BCAG in late February and early March 2002. The 9-inch-by-9-inch film was then scanned and orthorectified by the GIC using standard protocols. Rainfall for the 2001–2002 year was above average prior to January, then approximately average January through February. Additional aerial imagery from different periods was used to assist in the mapping effort, including August 2005 and November 2006 imagery (both 1-meter resolution). These were primarily used to check for any land use changes that might have occurred since 2002. All vernal pool/swale land cover type classifications listed in Table I.1-1, *Minimum Mapping Units for GIC Methods* were determined based on the signature (i.e., color and texture) of a given area on the aerial photograph via the same methods used by GIC staff to develop the South Sacramento County HCP vernal pool/swale mapping, which are described below.

Orthophoto images were brought into ArcView or ArcInfo GIS software by GIC staff. Vernal pool classification types (described below) were then digitized via the same methodology used in the South Sacramento HCP, creating a polygon shapefile (.shp). Using a scale range of 1,000 to 2,500 feet and a range of minimum mapping units (MMU) (see Table I.1-1), polygons were identified, digitized, and placed in one of the following vernal pool categories.

[1] The 2007 *Ecological Baseline Assessment Report* constituted the first draft of Chapter 3, *Ecological Baseline Conditions*.

Table I.1-1. Minimum Mapping Units for GIC Methods

Land Cover Feature	Minimum Mapping Unit (acres)
Vernal Pool	0.002
Vernal Pool Complex	0.032
Vernal Pool Deep	0.008
Vernal Impoundment	0.004
Altered Vernal Pool	0.002
Vernal Swale Complex	0.002
Hummock Complex Wet	0.644
Hummock Complex Dry	0.600

The following vernal pool/swale categories were used by the GIC for the BRCP vernal pool/swale mapping. These categories were selected by BCAG and the GIC because they were the same categories used in the South Sacramento HCP mapping, which USFWS and the Stakeholder Committee indicated to be a preferred methodology. Category descriptions below were taken directly from the GIS metadata developed by the GIC staff who conducted the mapping.

Vernal Pool (VP): This category was comprised of natural seasonal wetlands that are completely dry by the end of summer. Vernal Pool included those pools that exist singly (i.e., not connected to swales), impounding water due to natural topography, slope and soil type and are not inundated by artificial impoundments. These were identified primarily by color and to some degree by shape and texture. These pools usually have a boundary or edge, differentiating them from the less distinct spongy areas.

Vernal Pool Deep (VPD): This category included natural seasonal wetlands that dry by the end of summer as vernal pools described above but are deeper, thus holding more water. Vernal Pool Deep represented pools that exist singly and impound water due to natural topography, slope, and soil type and are not inundated by artificial impoundments. These were described as being typically black to very dark in color. Some pools may have been mapped as deep pools because even though they did not appear dark in color, they were interpreted as having vegetation growing in them. Some pools were not entirely dark in color, giving the impression of being deep in one area and shallower in another area. These pools were mapped as deep if they were at least 50 percent dark.

Vernal Pool Complex (VPC): This category was comprised of clusters of vernal pools that were not identified as part of a vernal swale or hummock complex.

Vernal Impoundment (VI): This category included pools inundated by artificial impoundments such as road grades, low berms or dams that may have experienced some degree of excavation within the impounded area. Vernal Impoundment areas could contain some water by the end of summer but would not be fully inundated. Pools could exist singly or as part of a swale or hummock complex. These were identified by earthen dams, berms or excavation. In some instances polygons may have been called Vernal Impoundment if they were within road berms, railroad berms, fence lines, or other human disturbances that caused water to pool or impound.

Altered Vernal Pool (**AVP**): This category was comprised of vernal pools that have been altered in such a way that the integrity of the pool as a functioning ecosystem may be compromised to some degree. Such alterations include manipulation of the drainage into or out of the pool, discing,

disturbance from recreational vehicles or changes in topography or relief. These pools were defined as those that had not been completely altered to the degree that they no longer functioned as vernal pool ecosystems, although they did appear different from their normal state. Most pools altered by plowing have a jagged or serrated look instead of the natural rounded edges. In some instances the pools may become separated into small fragments. A few pools may have roads through them and may have been identified by corresponding pool portions on each side of the road.

Vernal Swale Complex (VSC): This category included areas with low, meandering channels that tend to be saturated long enough to support vegetative associations that might also be found in small pools with short periods of inundation. Swales often contain natural and/or artificial pools. These were described as being usually lighter in color (due to not holding water) and connected to pools or not. Typically vernal swales are shallow, vegetated and do not have steep banks.

Hummock Complex: This category included areas that support Mima mound relief with site conditions including soil type, topography and slope that provide pool creation opportunities. These complexes generally contain dense Mima mounds on level to moderately level slopes with slow to very slow soil permeability. The low areas between mounds do not stay saturated long enough to be classified as a vernal swale complex. These were mapped as a separate mapping unit. Individual mounds and inter-mounds were not mapped; instead, the general terrain type was mapped separately from other mapping units. Mima mound terrain can be identified by its textured appearance caused by numerous mounds being located within close proximity of one another and their general hummocky signature. Aerial imagery from different seasons was used to best capture this mapping unit. Two categories were established for Mima mound terrain, Hummock Complex Wet and Hummock Complex Dry, which are defined below.

Hummock Complex Wet (HCW): Hummock Complex Wet could contain natural and/or artificial pools. The wetter hummock complexes were identified on aerial photographs by appearances that are similar to swale complexes, but vernal pools are generally few. Areas surrounding the Mima mounds give the appearance of compact swales. The wet hummock complexes, compared to the dry hummock complexes, were identified mainly by color on the aerial photographs. It is assumed that these wet hummock complexes would have a darker color due to a more saturated condition than the Hummock Complex Dry. HCW was mapped most often in areas adjacent to high vernal pool concentrations. Hummock complexes were mostly mapped in both the north and east portions of the County.

Hummock Complex Dry (HCD): Hummock Complex Dry could contain natural and/or artificial pools. The dryer hummock complexes were identified on aerial photographs by the appearance of areas that are similar to swale complexes but generally have few vernal pools. The dry hummock complexes compared to wet hummock complexes were identified by color on the aerial photographs. It is assumed that HCD would have a lighter color due to a less saturated condition than the wet hummock complex.

The GIC final product deliverable to BCAG and Leidos was a single shapefile in the State Plane NAD 83 feet projection delivered in September 2007. Attribute data fields included category (e.g., Vernal Pool, Vernal Pool Deep), category abbreviation (e.g., VP, VPD), square feet, acres and a unique identifier number. Appropriate metadata was also provided. This mapping was reviewed and discussed with the Stakeholder Committee at the August, September, October and November 2007 meetings. On December 12, 2007, a public workshop was held from 2:00 p.m. to 5:00 p.m. specifically to provide the opportunity for public review of the mapping. Large scale maps (40 inches by 60 inches) were developed for the entire mapping area and spread out on the BCAG

Conference Room tables for review. Comments and potential mapping errors were noted by workshop attendees, which were then corrected by the GIC.

Limited field verification was conducted by BCAG and Leidos from Chico to south of Oroville that confirmed the general accuracy of the mapping units.

I.1.3 Leidos' Assessment of GIC Mapping Product

BCAG tasked Leidos with integrating the GIC's vernal pool/swale mapping into the overall land cover GIS dataset that had been developed in 2007 as part of the *Ecological Baseline Assessment Report*. Leidos was also tasked with reviewing the GIC's mapping to ensure consistency in mapping categories and units to ensure its sufficiency for developing the BRCP impact assessment and conservation strategy; inconsistent mapping can lead to skewed calculations of both impacts and conservation acreage.

Leidos' assessment of GIC's vernal pool mapping identified several issues with the classification and mapping results (see *Issues with GIC Mapping* below). Leidos provided proposed solutions to BCAG and the Stakeholder Committee, which were accepted and carried forward as described beginning on page I-7.

I.1.3.1 Issues with GIC Mapping

Within the Vernal Swale Complex category, GIC mapped some swales individually following the swale-upland edge and mapped others as larger complexes that encompassed many swales and inter-swale upland areas as a single polygon. Some polygons were hybrids, mapped at one end along swale-upland boundaries and at the other end as larger complexes that encompassed many swales and inter-swale upland areas within the same polygon. GIC indicated that the vernal swale mapping methodology used in the South Sacramento HCP mapping did not work well in portions of the BRCP Plan Area due to the different geology and more complex vernal swale terrain in Butte County. Where individual tendrils were easily mapped as vernal swales in the South Sacramento HCP plan area, swales in certain areas in Butte County tended to be much more complex "nets" of swale and inter-swale upland areas in which it was impossible to differentiate swales from upland areas.

This hybrid mapping of vernal swales resulted in a substantial inconsistency in the way swales were handled in the GIC dataset (Figure I-1, *Example GIC Vernal Swale Complex Mapping Detail Inconsistencies*). A hybrid vernal swale mapping does not allow for a consistent approach to estimating acres of habitat lost to covered activities or that could be protected through implementation of conservation measures.

In addition to the issues with the vernal swale complex mapping, additional issues were identified by Leidos regarding the hummock feature types. Inconsistencies were observed regarding the hummock feature type boundaries. In many instances the boundaries appeared arbitrary where some regions were mapped while others that appeared identical were left unmapped. Furthermore, the Hummock Complex Dry category occurred on steeper terrain that was not likely to support wetland features. Field verification confirmed this. Additionally, the Hummock Complex Wet category tended to occur as inclusions within vernal swale complexes rather than as separate features.

Several issues were raised concerning the vernal pool (VP, VPD, AVP, and VI) feature categories. First, there were a significant number of pools that were mapped smaller than 0.01 acre. At the mapping scale of 1:1,000 it became difficult to determine why similar features were mapped as vernal pools and others were ignored. This inconsistency led to an overall lack of confidence in the mapped vernal pool features less than 0.01 acre for which a high rate of false positives and false negatives appeared to be present. Several areas that were mapped by Leidos as containing Grasslands with Vernal Pool (less than 1 percent cover) as part of the 2007 *Ecological Baseline Assessment Report* (Chapter 3) did not contain significant GIC mapped Vernal Pool units. Second, there was inconsistent application of mapping rules associated with the Altered Vernal Pool and Vernal Impoundment categories, which was likely due to these two categories being too similar in definition. Third, there were concerns with the validity of the Vernal Pool Deep category. At the mapping scale of 1:1,000, it was difficult to consistently determine relative depths of vernal pool features. Finally, there appeared to be spatial alignment issues when comparing the mapped features with the 2005 NAIP imagery. This was caused by differences in the underlying aerial imagery the mapping was digitized from. The 2002 BCAG aerials were developed in the State Plane zone 2 geographic projection while the 2005 NAIP aerials were developed in the Albers conformal conic projection, resulting in slight spatial shifts when comparing one to the other.

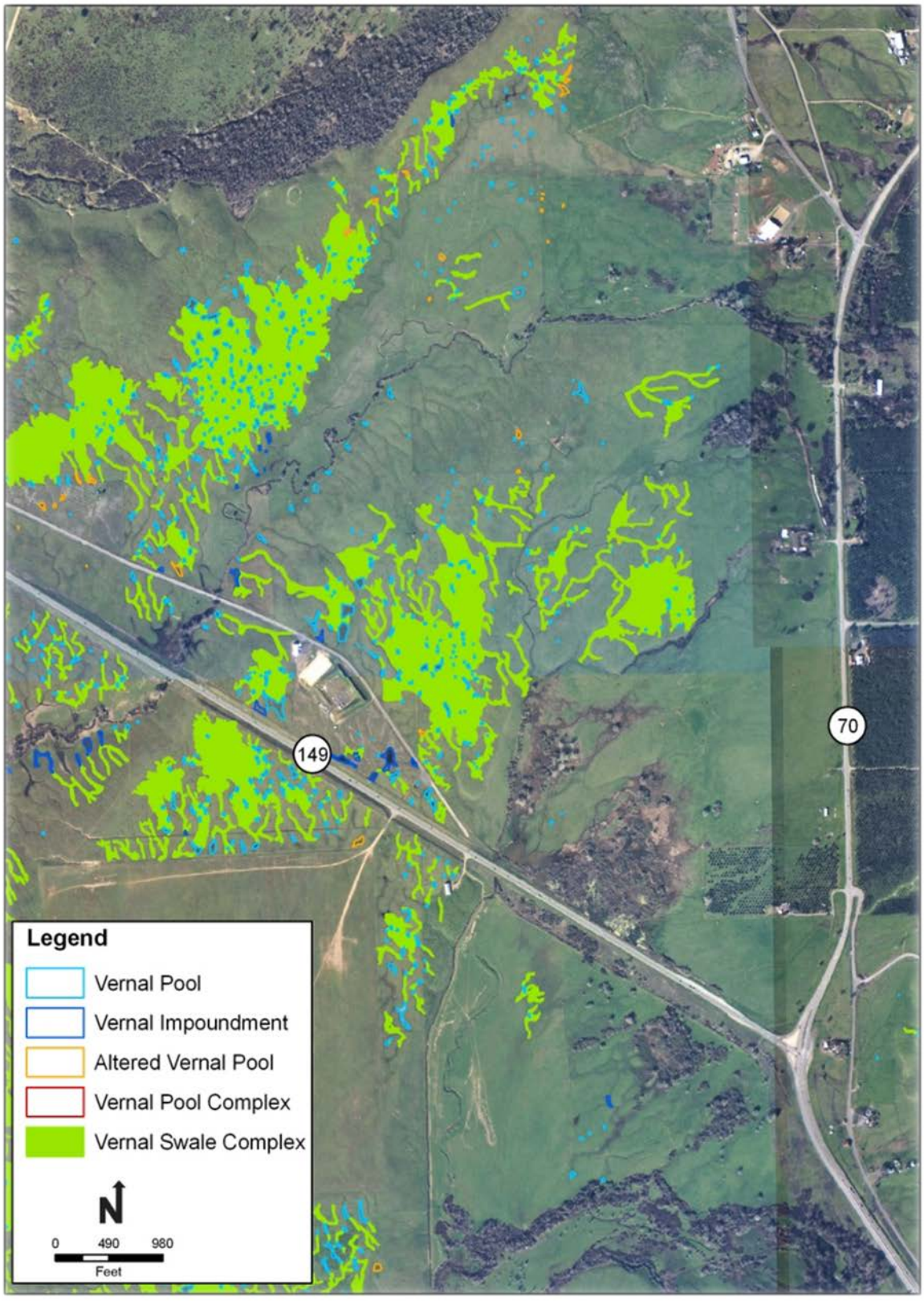

Figure I-1. Example GIC Vernal Swale Complex Mapping Detail Inconsistencies

I.1.3.2 Leidos Changes to GIC Mapping

The following changes to the GIC mapping were recommended by Leidos and accepted by BCAG and the Stakeholder Committee for use in the BRCP land cover dataset. These changes were implemented by Leidos in December 2007.

1. **Vernal Swale Complex.** Leidos used the new Grassland with Vernal Swale Complex (VSC) mapping protocol provided below to refine the GIC Vernal Swale Complex GIS layer to obtain consistent level of detail within the Vernal Swale Complex (VSC) category. Figure I-2, *Revised Mapping of Vernal Swale Complex as Grassland with Vernal Swale Complex (G/VSC)* provides an example of the suggested standardization of the VSC category. The following methodology was suggested in a Leidos methods document and implemented to correct the hybrid nature of the VSC category:

    - Use the National Hydrography Dataset (NHD) hydrography layer (in particular the intermittent streams) to provide divisions among the complexes drawn; the intermittent streams shown in the NHD create general sub-basin boundaries between the VSC polygons drawn, based on the hydrology and geomorphology of these areas. Note: Use the NHD's intermittent streams as general boundaries, but in some cases the 2002/2005 aerials will be needed for a more accurate delineation of streams as the present stream system has modified itself since the NHD was developed.
    - Within the boundaries described above, draw larger polygons around the GIC hybrid VSC polygons using the rules presented below to create larger, more standardized VSC areas following the landscape features (see attached examples for additional guidance) and encompassing the individual swales mapped by the GIC.
    - Use an on-screen resolution of 1:12,000 as the appropriate scale to visually determine VSC units; zoom in if necessary to ensure appropriate separation based on hydrology.
    - Use a maximum of 100 meters between VSC polygons. (If a smaller polygon lies beyond 100 meters of the region in question, leave it out).
    - Use an MMU of 10 acres (i.e., do not encompass VSC polygons smaller than 10 acres if further than 100 meters from a larger polygon). Ten acres was determined by Leidos staff to be the smallest unit that can be interpreted accurately and consistently from the 1-meter aerial imagery.
    - Use the level of complexity of HCW-mapped polygons as a general guideline for these new VSC polygon boundaries.
    - Include HCW polygons in the revised VSC category if they are directly adjacent to the existing VSC category.
    - Note that there are a few instances where an existing swale system straddles a stream; keep these as-is rather than using the NHD layer to separate VSC units.

    After these changes were made by Leidos, BCAG calculated that only 369 out of 33,525 acres of vernal swale complex mapped by the GIC did not get integrated into the new Leidos VSC polygons. Many of these polygons were below the 10-acre MMU.

2. **Vernal Pool, Vernal Pool Deep and Vernal Pool Complex.** After Leidos reviewed the 2002 aerial imagery at a 1:1,000 mapping scale, it was apparent that it was very difficult to accurately

discern pool depth. Furthermore, there were only three instances of the vernal pool complex category mapped by GIC amounting to a total of 0.2 acre. It was proposed that the three categories (VP, VPD, and VPC) all be merged into one category called Vernal Pool. This change is reflected in Figure I-2.

3. **Altered Vernal Pool and Vernal Impoundment.** In light of the inconsistent identification of these features, these two categories (AVP and VI) were merged into one category called Altered Vernal Pool. This change is reflected in Figure I-2. These two categories were not merged into the Vernal Pool category described above because AVP and VI represent pools that have been modified to varying extents from their natural state, and could provide for restoration opportunities in the future.

4. **Hummock Complex Wet and Hummock Complex Dry.** After close review of the mapped HCW features, Leidos concluded that these features were essentially vernal swale complex. Leidos reclassified the HCW features as Vernal Swale Complex. Leidos removed the HCD features altogether, because this feature occurs on steep slopes that would not support vernal pools or vernal swales. This was confirmed by Leidos via field verification.

5. **Vernal Pool and Altered Vernal Pool Alignment Correction.** Because the other land cover type categories mapped in the Plan Area were based on 2005 NAIP aerial imagery, and because the GIC vernal pool/swale mapping was based on 2002 BCAG aerial imagery, spatial alignment issues resulted when overlaying the GIC mapping on the 2005 NAIP imagery. This made the GIC mapping spatially inconsistent with the rest of the BRCP land cover mapping (i.e., the GIC mapping lined up accurately with the pools/swales depicted on the 2002 BCAG aerials, but when overlaid on the 2005 NAIP aerials, the mapping appeared shifted and did not line up with the pools and other features visible in the imagery). To correct the visual alignment issues of the VP and AVP categories, these features were realigned with NAIP 2005 aerial image mosaic. By applying a spatial shift to the entire dataset, this resulted in the BRCP land cover dataset having spatial consistency for all land cover types.

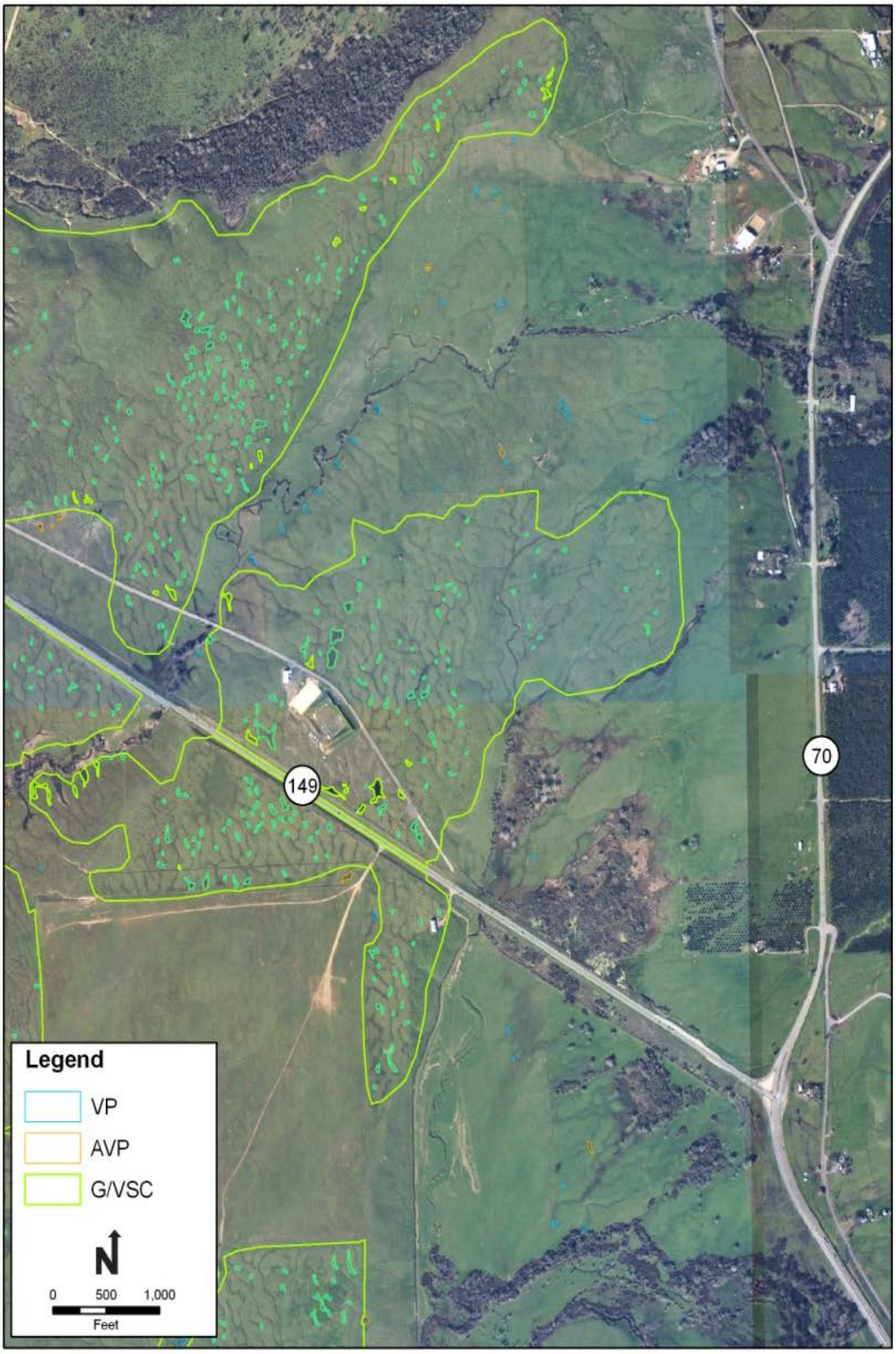

Figure I-2. Revised Mapping of Vernal Swale Complex as Grassland with Vernal Swale Complex (G/VSC)

6. **Minimum Mapping Unit Adjustment for Vernal Pools.** To address the lack of confidence in the accuracy of vernal pool features mapped at small scales (e.g., accuracy below MMU of 0.01 acre), Leidos removed all VP and AVP polygons mapped at less than 0.01 acre from the land cover dataset. While this change resulted in a large number of small pools being removed from the dataset, the total acreage of these pools was small and most of these pools were captured within the vernal swale complex polygons. Vernal pools greater than 0.01 acre are clearly discernable from the imagery and can be mapped with much more consistency.
7. **Occurrence of False Negatives.** Where false negatives arose between mapping of Grasslands with Vernal Pool (GWVP that was part of the *2007 Ecological Baseline Assessment Report*) and GIC vernal mapping product, Leidos reassessed these gaps and digitized additional regions using the 2002 and 2005 imagery. This resulted in a limited number of new vernal pools being added to the dataset.

Information provided in Table I.1-2, *Vernal Feature Mapping Results Comparison* documents the results of the revisions made to the original GIC mapping effort. There was an increase in the generalization of polygons demonstrated by an overall increase in acreage accompanied by a reduction in total number of polygons. Furthermore, the dataset was simplified with the reduction of mapping categories from eight to three.

Table I.1-2. Vernal Feature Mapping Results Comparison

GIC Mapping	Polygons	Acreage
Vernal Pool	15,703	449
Vernal Pool Deep	151	13
Altered Vernal Pool	4,852	192
Vernal Pool Impoundment	651	106
Vernal Pool Complex	3	0.2
Vernal Swale Complex	4,933	12,449
Hummock Wet Complex	77	1,188
Hummock Dry Complex	41	292
Total	**26,411**	**14,689**
Leidos Mapping	**Polygons**	**Acreage**
Vernal Pool	9,703	422
Altered Vernal Pool	3,486	246
Vernal Swale Complex	279	33,525
Total	**13,468**	**34,193**

The results of the revised mapping of vernal wetlands features are provided in Figure I-3, *Final Vernal Wetlands Feature Mapping for BRCP in Relation to USFWS (2005) Vernal Pool Recovery Plan Core Areas*. This dataset provides a uniform and consistent mapping of vernal pool and vernal swale features across the entire Plan Area and a higher confidence in the accuracy of results.

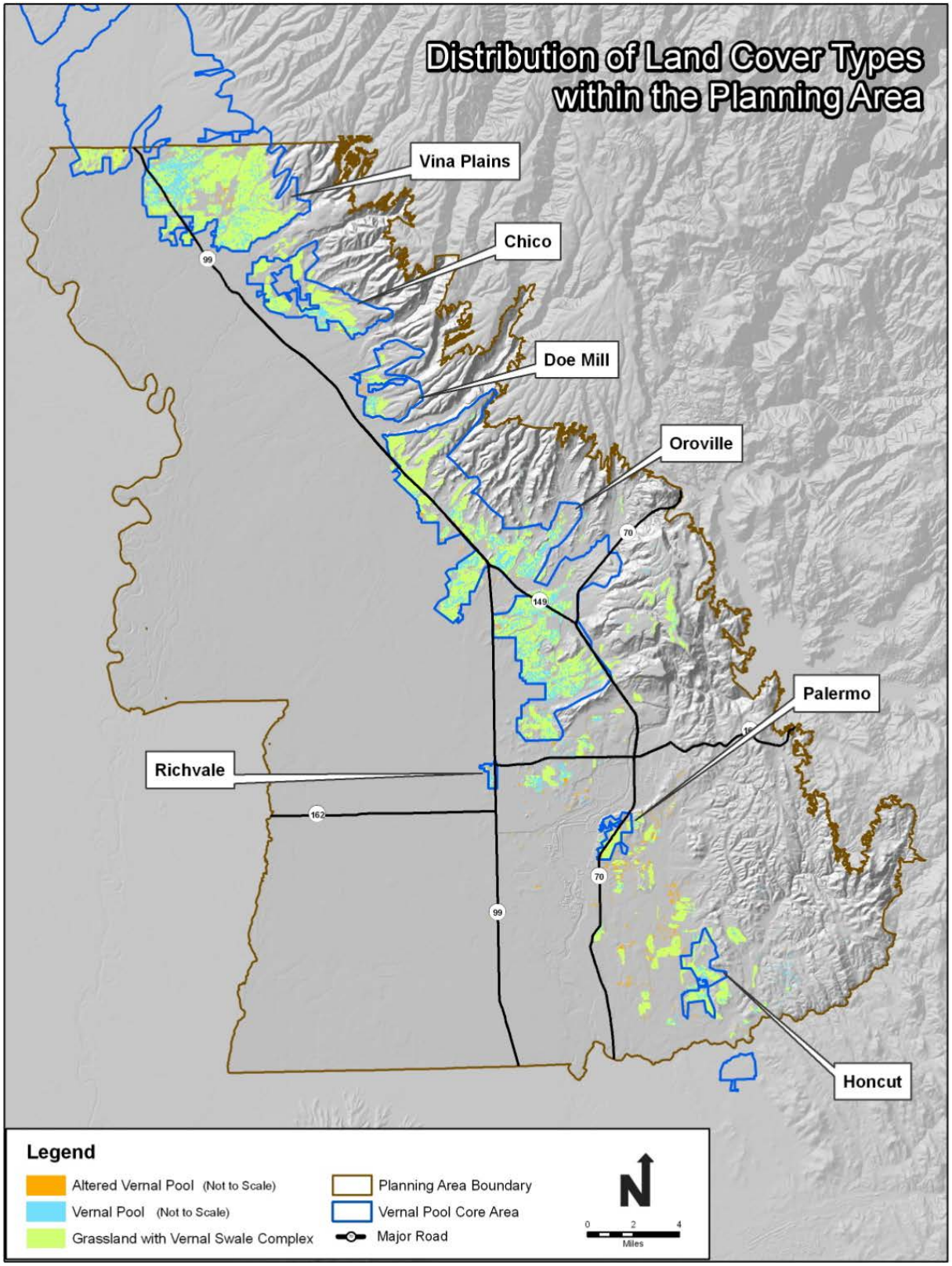

Figure I-3. Final Vernal Wetlands Feature Mapping for BRCP in Relation to USFWS (2005) Vernal Pool Recovery Plan Core Areas

This more consistent, uniform, and accurate land cover data allows for its use in development of species habitat models, analysis of impacts of covered activities, and development and assessment of the conservation strategy for the BRCP. Because the dataset was developed on a large regional scale, it may not be appropriate for use in a project-specific or parcel-level analysis. In these cases, on-the-ground survey data will be needed to more accurately capture the smaller vernal features not captured in this regional-level mapping.