FINAL REPORT

TASK AGREEMENT NO. J8530030115

to

COOPERATIVE AGREEMENT NO. H8530010095

between the

NATIONAL PARK SERVICE

and the

HUMBOLDT STATE UNIVERSITY SPONSORED PROGRAMS FOUNDATION

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ABSTRACT

The purpose of this Task Agreement was to assess the thematic and positional accuracy of a vegetation map compiled previously for the Whiskeytown Unit of the Whiskeytown-Shasta-Trinity National Recreation Area. We sampled the mapped vegetation polygons in the field because United States Geological Survey-National Park Service (USGS-NPS) standards (USGS-NPS Vegetation Mapping Program 1994) recommend field sampling as the most reliable method for determining the true vegetation class for a sampled polygon. The previously compiled vegetation map was used to define 38 strata (the 38 associations-alliances classes of vegetation mapped into individual polygons) and these classes were used to stratify the sampling of mapped polygons. Polygons that were less than 500 meters from a road were selected as the sampling population. Then polygons were selected from a random sample of those polygons until 15 polygons were selected from each class (strata). We sampled 21, differentially corrected, Global Positioning System (GPS) locations at well defined points throughout the study area in order to assess the positional accuracy of the vegetation map compiled previously.

Our field crew sampled 499 usable thematic accuracy assessment plots during the summer and fall of 2004 that were distributed throughout the study area. The point estimate from the sample of 499 plots for the overall thematic accuracy is 61.5 percent for the 38 associations-alliances classes. The one-sided, 90 percent confidence interval is 2.9 percent, assuming a binomial distribution. It can be concluded that with 90 percent certainty the estimated accuracy of the map is equal to or greater than 58.6 percent (61.5 – 2.9). This poor accuracy resulted from confusion between similar associations and sometime between similar alliances.

Three versions of the vegetation map were compiled previously including the 38-class associations-alliances map, a 22-class alliances map and a 17-class mapping units map. The mapping units map contained 13 alliances, three mixed alliances (the mapping units) and a combined formation level class (*Barren-disturbed*). In order to more fully understand the types of errors associated with the mapping at various levels of detail, we analyzed accuracy statistics for all three maps.

The point estimate from the sample of 499 plots for the overall thematic accuracy is 79.8 percent for the alliance level of classification. The one-sided, 90 percent confidence interval is 2.4 percent, assuming a binomial distribution. It can be concluded that with 90 percent certainty the estimated overall accuracy of the map is equal to or greater than 77.4 percent (79.8 – 2.4). The point estimate from the sample of 499 plots for the overall thematic accuracy of the mapping units map is 85.6 percent. The one-sided, 90 percent confidence interval is 2.1 percent, assuming a binomial distribution. It can be concluded that with 90 percent certainty the estimated accuracy of the mapping units map is equal to or greater than 83.5 percent (85.6 – 2.1) exceeding the USGS-NPS standard of 80 percent for thematic accuracy.

The root mean square positional error of the X coordinates (east-west, UTM grid) is 2.4 meters based on 20 reference points. The root mean square positional error of the Y coordinates (north-south, UTM grid) is 1.8 meters.

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INTRODUCTION

The National Park Service and the Humboldt State University Sponsored Programs Foundation signed a cooperative agreement for assistance and collaboration in cultural and natural resource management initiatives (Cooperative Agreement number H8530010095) and further initiated this Task Agreement (number J8530030115). The purpose of this Task Agreement was to assess the accuracy of a previously completed vegetation map of the Whiskeytown Unit of the Whiskeytown-Shasta-Trinity National Recreation Area lands and the surrounding State, County, and Private land within the study area defined for that project (previous Task Agreement Number J8530030078, Fox et al. 2006). All references to the vegetation map in this report refer to that specific vegetation map developed during the previous Task Agreement (J8530030078). The objectives of this effort were to:

1. Install a minimum of three hundred (300) temporary; *relevé* type, thematic accuracy assessment plots using a stratified random sample of mapped polygons throughout the mapped area. Samples were allocated such that the proportion of plots assigned to each mapped vegetation type was consistent with the United State Geological Survey-National Park Service (USGS-NPS) standard (USGS-NPS Vegetation Mapping Program 1994). The standard sampling protocol allowed for the exclusion of sample sites found inappropriate for sampling according due to access constraints.

2. Install a minimum of twenty (20) temporary, differentially corrected, GPS locations at well defined points, for determining the positional accuracy of the vegetation map.

3. Statistically analyze the positional and thematic accuracy assessment data as described in the Accuracy Assessment Procedures of the USGS-NPS Vegetation Mapping Program (USGS-NPS Vegetation Mapping Program 1994).

METHODS

Thematic Accuracy - We completed a modified, stratified, random sampling plan for assessing thematic accuracy that was formulated as part of the previous Task Agreement as the *Sampling Protocol* (Fox, et al. 2006). In order to assess the thematic accuracy of the vegetation map compiled for the Whiskeytown Unit, we decided to sample mapped vegetation polygons in the field. We believe, and the USGS-NPS standards (USGS-NPS Vegetation Mapping Program 1994) recommends, field sampling as the most reliable method for determining the true vegetation class for a sampled polygon. The previously compiled vegetation map was used to define 38 strata (the 38 classes of vegetation mapped into individual polygons, Fox et al. 2006) and these classes were used to stratify the sampling of mapped polygons.

Polygons that were less than 500 meters from a road were selected as the sampling population. Then polygons were selected from a random sample of those polygons until 15 polygons were selected from each class (strata). We used a progressive approach to selecting polygons, first selecting from polygons within 100 meters from any existing road and then when the required number of sampled polygons per strata was not met, expanding to 300 meters from a road and finally to 500 meters. The USGS-NPS Vegetation Mapping Program (1994) standards allow for departure from a purely stratified random sample to allow for access problems. The nature of the landscape in the Whiskeytown Unit demanded that we constrain our sampling to those polygons near existing roads otherwise the field data collection would have taken several summer field seasons and been excessively expensive. For polygons actually intersected by a road, field crews avoided areas in which any direct effects of the road surface, or its cut slope or fill slope, occurred.

The map was not fully completed at the time of sample polygon selection for field measurement and the beginning of field sampling. The field crews did not know the mapped vegetation class of the polygon they sampled and the accuracy assessment samples were analyzed after the map was completely finished.

Since sampling began before the map was finished, we were not completely sure how many of the mapped classes would be abundant (Scenario A, USGS-NPS Vegetation Mapping Program 1994) requiring 30 samples by the USGS-NPS standard and how many would be less abundant requiring 20 samples for Scenario B and C, 5 samples for Scenario D and "visit all" for Scenario E (Table 1, Column 3). Based on the sampling protocol developed previously (Fox, et al. 2006) for a budget of $32,000 and a production rate of 10 sample plots per day, we determined to allocate samples in the same proportion as the standard but with fewer samples per strata (Table 1, Column 4). We anticipated that almost all of the mapped classes would be abundant when the samples were selected and since many factors were probably going to influence how many samples would actually be measured in the field (access, time constraints, road

conditions, etc.) we decided to select 15 potential sample polygons for each of the 38 classes mapped previously.

When the map was completed, after the field sampling for accuracy assessment began, we realized that 29 of the 38 classes defined were abundant (requiring 15 samples by our reduced sampling plan) and nine were less abundant, requiring fewer samples. However, since we were sampling at a rate below the standard of 20 samples (USGS-NPS Vegetation Mapping Program 1994) for these less abundant strata, any sampling above our planned 10 samples in scenarios B and C would still be useful.

Table 1. Number of vegetation types, samples per type and total samples planned to be obtained. The sampling plan assumed a funding level of $32,000 and a production rate of approximately 10 plots per day.

1 Abundance Class of Vegetation Class	2 Number of Classes on the Map	3 No. of samples required per Class	4 No. of sample plots planned per Class	5 Total Sample Plots Planned
Abundant, NPS Scenario A	29	30	15	435
Relatively Abundant, Scenario B	6	20	10	60
Relatively Rare, Scenario C	1	20	10	10
Rare, Scenario D	1	5	3	3
Very Rare, Scenario E	1	Visit all	3	3
TOTAL	38			511

Sampling for thematic accuracy assessment was accomplished using a *relevé* approach such that the field crew entered a polygon according to coordinate location (determined by Global Positioning System navigation) and begin to assess the vegetation within the polygon as they walked to the approximate geographic center of the polygon. The exact position of the crew was not nearly as important as the crew's assessment of the vegetation type characterized by the polygon (that is, assuming they were far enough from the polygon boundary to avoid edge effects). Dominant overstory and understory plant species was recorded by cover class, determined by ocular estimation. Because of minor inclusions that are smaller than the minimum mapping unit (MMU) and variation within polygons defined by the mapping methods, exceptions to the majority vegetation type within a polygon did exist. The field crew determined the best location to characterize the majority of the vegetation within the polygon and labeled the polygon accordingly.

This sample was planned to be proportionally consistent with the USGS-NPS accuracy assessment standard (column 4, Table 1) but short of the number of plots required to fully meet the standard (column 3). In order to fully meet the NPS accuracy assessment standard, we would have needed to sample approximately 1,000 plots as detailed in Table 2. Sampling 1,000 plots would have required approximately 100 days (production rate of 10 plots per day) and cost approximately $61,000. While the larger sample would have likely meet the standard for number of samples completely, it would have

cost twice as much and it may not have been possible to complete the work within one summer's field season, complicating and prolonging the assessment more than is practical in our opinion.

Table 2. Number of vegetation classes by Scenario, required samples per class and total samples to be obtained across the vegetation map if the USGS-NPS Accuracy Assessment Standard (USGS-NPS Vegetation Mapping Program 1994) for quantity of plots was to be met.

Abundance Class of Vegetation Class	Number of Classes in the Map	Required Samples per Class by USGS-NPS Standard	Total Samples Required
Abundant, NPS Scenario A	29	30	870
Relatively Abundant, Scenario B	6	20	120
Relatively Rare, Scenario C	1	20	20
Rare, Scenario D	1	5	5
Very Rare, Scenario E	1	5 polygons, sample all	5
TOTAL	38		1020

Positional Accuracy – We sampled 21, differentially corrected, GPS locations at well defined points throughout the study area in order to assess the positional accuracy of the vegetation map compiled previously (Fox et al. 2006). USGS-NPS standards for positional accuracy assessment (USGS-NPS Vegetation Mapping Program 1994) were used to guide the sampling plan in that we used well defined points that were well distributed on the image that was used as the spatial reference for compiling the vegetation map.

These points were primarily road intersections and bridges or other small features visible on the image and also visible on the ground. We used a Trimble GeoXT CE hand held GPS receiver (Trimble Navigation Ltd. 2006) capable of resolving positions to less than one meter when differentially corrected. We differentially corrected the locations using a base station in Eureka, California because the less distant base station (Redding) was not recording on the day of our data collection, September 17, 2005.

RESULTS AND DISCUSSION

Thematic Accuracy - Our field crew sampled 510 plots during the summer and fall of 2004 (Figure 1). Because the sample was constrained to those polygons within 500 meters from a road, the distribution of sample plots shows a linear pattern, near existing roads. Samples were well distributed throughout the Whiskeytown Unit. Navigation errors produced uncertainty about exactly where vegetation was sampled in eleven (11) of the plots and therefore these were dropped from the analysis, leaving a total of 499 accuracy assessment plots measured and analyzed for this assessment (Table 3).

Table 3. Land area, USGS-NPS Abundance Scenario (USGS-NPS Vegetation Mapping Program 1994) and number of polygons sampled for each of the 38 vegetation classes mapped.

Plant Associations - Alliances	Land Area of all Polygons (hectares)	USGS-NPS Abundance Scenario	Number of Mapped Polygons Sampled
Canyon live oak/whiteleaf manzanita association	3,632.0	A	25
Mixed conifer alliance	3,050.6	A	16
Mixed conifer/shrub tanoak - greenleaf manzanita association	2,543.7	A	23
Ghost pine - canyon live oak/whiteleaf manzanita association	2,412.6	A	20
Knobcone pine - mixed oak/whiteleaf manzanita association	2,377.7	A	30
Ponderosa pine - tanoak - canyon live oak/poisonoak association	1,701.1	A	14
Ponderosa pine - Douglas-fir - canyon live oak association	1,677.1	A	17
Black oak - canyon live oak/toyon - poisonoak association	1,464.6	A	32
Ghost pine - black oak/snowdrop bush - poisonoak association	1,204.7	A	11
Douglas-fir - tanoak/iris association	974.7	A	26
White alder alliance	792.6	A	17
Chamise alliance	610.9	A	15
Canyon live oak - bigleaf maple/needle grass association	564.1	A	11
Douglas-fir - canyon live oak - bigleaf maple/poisonoak association	482.8	A	11
Ghost pine - interior live oak - Brewer oak association	448.1	A	15
Black oak/whiteleaf manzanita association	333.9	A	12
Interior live oak/whiteleaf manzanita association	325.8	A	13
Whiteleaf manzanita - toyon - poisonoak association	304.6	A	16
Shrub canyon live oak - greenleaf manzanita - shrub tanoak association	267.1	A	10
Whiteleaf manzanita - chamise association	262.6	A	16
Canyon live oak/snowdrop bush association	251.2	A	8
Brewer oak - birchleaf mountain-mahogany association	222.6	B	4
Barren	217.0	A	23
Interior live oak/poisonoak association	155.7	A	7
Disturbed	149.8	A	12
Ponderosa pine - black oak/whiteleaf manzanita - poisonoak association	135.6	A	12

Plant Associations - Alliances	Land Area of all Polygons (hectares)	USGS-NPS Abundance Scenario	Number of Mapped Polygons Sampled
Greenleaf manzanita - bush chinquapin/pinemat manzanita association	104.3	A	8
Shrub tanoak/bracken fern association	96.6	B	6
Oregon white oak - black oak/poisonoak association	91.0	A	7
Shrub canyon live oak/rock association	90.2	A	2
Knobcone pine/Lemmon ceanothus association	83.6	A	15
Canyon live oak/poisonoak association	82.5	B	7
Interior live oak/poisonoak/yellow starthistle association	62.4	B	7
Blue oak/redbud association	57.7	B	12
Shrub tanoak/pinemat manzanita association	55.2	B	9
Red fir alliance	49.7	D	3
Tanoak - mountain dogwood/poisonoak association	48.7	C	6
Black oak alliance	6.6	E	1

Our plans to proportionally allocate the sample plots did achieve generally more samples measured for the more abundant classes. However, as shown in Table 3, several abundant classes had fewer than 15 samples measured and some had more than 15 samples. Because of the minimum type size constraint of 0.5 hectares for polygons on the vegetation map (USGS-NPS Vegetation Mapping Program 1994), some polygons were mixed and the field crew would sometimes locate a spot that was not in the class in which that polygon was labeled. In these cases, we evaluated the accuracy of the vegetation class actually occurring at the sampling point rather than considering only the polygon label as recommended by the accuracy assessment standard (USGS-NPS Vegetation Mapping Program 1994).

Since the field crew did not know the mapped class of the polygon being assessed, they had no way of knowing to select a patch of vegetation of the labeled class in a mixed polygon. In general we feel that the sampling plan worked to concentrate samples in the more abundant classes. However, we did "oversample" one class with 32 plots; the Black oak - canyon live oak/toyon - poisonoak association. This small amount of oversampling was to be expected considering the extremely complex vegetation mosaic of the study area.

The cross tabulation of 38 association-alliance classes for ground truth and mapped class is shown in Table 4. The point estimate from the sample of 499 plots for the overall accuracy is 61.5 percent. The one-sided, 90 percent confidence interval is 2.9 percent, assuming a binomial distribution. It can be concluded that with 90 percent certainty the estimated accuracy of the map is equal to or greater than 58.6 percent (61.5 – 2.9). However, this point estimate and conficence interval should be interpreted with caution since the sampling was constrained by distance from an existing road. Statistically speaking, one can only conclude that the polygons within 500 meters from a road were mapped with at least 58.6 percent accuracy at 90 percent confidence. However, reason would dictate that inferences can be made to the population of

mapped ploygons since we know of no bias associated with distance to a road and would have no reason to expect that the map would be less or more accurate at distances greater than 500 meters from a road.

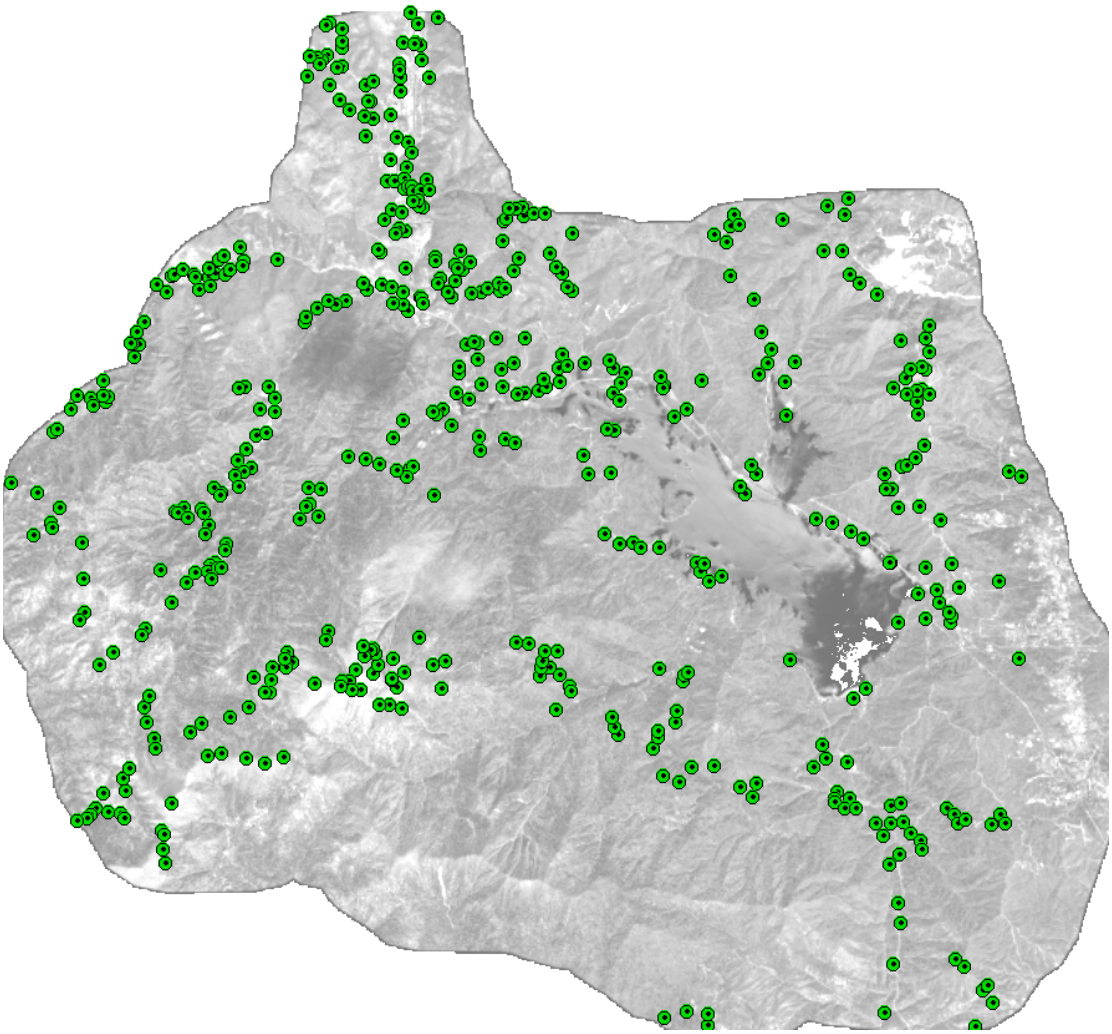

Figure 1. Distribution of accuracy assessment plots throughout the study area.

Table 4. Accuracy matrix for the associations-alliances level of classificaiton.

Association-Alliance Truth	Association-Alliance Mapped																																								
	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	Total	% acc. (omis-sion)
Whiteleaf manzanita - chamise association	1	7	1																		1																			9	78
Whiteleaf manzanita - toyon - poisonoak association	2	5	12																																					17	71
White alder alliance	3			13		1																			1				1				1							17	76
Brewer oak - birchleaf mountain-mahogany association	4				3																								2											5	60
Tanoak - mountain dogwood/poisonoak association	5					5																																		5	100
Shrub tanoak/bracken fern association	6						2	2			1											1																		6	33
Shrub tanoak/pinemat manzanita association	7						2	4														1																		7	57
Red fir alliance	8								2																															2	100
Ponderosa pine - Douglas-fir - canyon live oak association	9									12	8		2													4				1	2		1							30	40
Ponderosa pine - tanoak - canyon live oak/poisonoak association	10									3	2		1																											6	33
Black oak alliance	11											1																		1										2	50
Ponderosa pine - black oak/whiteleaf manzanita - poisonoak association	12									1	1		7														1		1	1						1				13	54
Oregon white oak - black oak/poisonoak association	13													4										1					1								1			7	57
Mixed conifer alliance	14			1					1						14											1							1							18	78
Mixed conifer/shrub tanoak - greenleaf manzanita association	15			2												22																	1							25	88
Knobcone pine/Lemmon ceanothus association	16																6	4							1														1	12	50

Association-Alliance Truth	Association-Alliance Mapped																																								
	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	Total	% acc. (omis-sion)
Knobcone pine - mixed oak/whiteleaf manzanita association	17	3													1		7	20	2	1			3	4	2			1					1		1		1			47	43
Interior live oak/whiteleaf manzanita association	18												1				1		9	1																1				13	69
Interior live oak/poisonoak/yellow starthistle association	19		1																2	5																				8	63
Interior live oak/poisonoak association	20		1																		4																			5	80
Greenleaf manzanita - bush chinquapin/pinemat manzanita association	21						1	2														6												1						10	60
Ghost pine - interior live oak - Brewer oak association	22	1	1							1				1				1					3		2															10	30
Ghost pine - canyon live oak/whiteleaf manzanita association	23												1					3					4	10	1															19	53
Ghost pine - black oak/snowdrop bush - poisonoak association	24																						3	2	4															9	44
Douglas-fir - tanoak/iris association	25																									14	2						1							17	82
Douglas-fir - canyon live oak - bigleaf maple/poisonoak association	26			1							1				1									1		7	7													18	39
Chamise alliance	27																											13												13	100
Canyon live oak/whiteleaf manzanita association	28																										1		9	3										13	69
Canyon live oak/snowdrop bush association	29																												7	2		1								10	20
Shrub canyon live oak/rock association	30																												1					3						4	0
Canyon live oak/poisonoak association	31																						2					1	2			6	3							14	43
Canyon live oak - bigleaf maple/needle grass association	32																																2							2	100

Association-Alliance Truth	Association-Alliance Mapped																																										
	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	Total	% acc. (omis-sion)
Shrub canyon live oak - greenleaf manzanita - shrub tanoak association	33						1	1								1																		6						9	67
Blue oak/redbud association	34																1				1								1						11					14	79
Black oak/whiteleaf manzanita association	35				1									2																						6	7			16	38
Black oak - canyon live oak/toyon - poisonoak association	36										1							1						2												4	23			31	74
Barren	37																	1																				22	2	25	88
Disturbed	38																				1																	1	9	11	82
Column Total		16	16	17	4	6	6	9	3	17	14	1	12	7	16	23	15	30	13	7	7	8	15	20	11	26	11	15	25	8	2	7	11	10	12	12	32	23	12	499	
Percent accuracy relative to errors of commission		44	75	76	75	83	33	44	67	71	14	100	58	57	88	96	40	67	69	71	57	75	20	50	36	54	64	87	36	25	0	86	18	60	92	50	72	96	75	Over all Acc.	61.5 %

Confidence intervals for individual classes vary depending on sample size. The confidence interval becomes very large and statistical inferences become impractical for very small sample sizes. For example the estimated accuracy relative to errors of omission for the Brewer oak - birchleaf mountain-mahogany association (class number 4) is 60 percent (n = 5, probability that the true class is mapped correctly and not omitted) and its accuracy relative to errors of commission is 75 percent (n = 4, page 12, the probability that the mapped class is actually this association and not something else). However since the sample size is so small, the 90 percent confidence interval is 41 percent (n = 4). It can be concluded with 90 percent certainty that the estimated accuracy relative to commission errors of the Brewer oak - birchleaf mountain-mahogany association is equal to or greater than 34 percent (75-41)! Such statements are not useful because the confidence is wide making statistical inference inappropriate.

When the sample size is larger, at least 15, the 90 percent confidence interval is smaller and statistical inference is more informative. For example, the estimated accuracy relative to errors of omission for the Douglas-fir – tanoak/iris association (class number 25) is 82 percent and its accuracy relative to commission errors is 54 percent. The smaller of the two sample sizes is 17 and the confidence interval (omission) is 15 percent. It can be concluded with 90 percent certainty that the estimated accuracy relative to omission errors of the Douglas-fir – tanoak/iris association is equal to or greater than 67 percent (82-15). Now we have a statement that narrows the range at least somewhat so that inference to the population is more useful for understanding the accuracy of the map.

While class accuracies were generally low for the 38 associations-alliances and often below the accuracy standard of 80 percent correct (USGS-NPS Vegetation Mapping Program 1994), the mapping procedure far exceeded the accuracy that would have been expected from random chance alone. With 38 possible classes, the random chance of correct classification would only be 1 in 38 (2.6 percent correct). Also, eight classes exceeded the 80 percent standard relative to errors of commission and nine classes exceeded the 80 percent standard relative to errors of omission.

Since the classification was generalized to the alliance level and an alliance level map produced, we also wished to evaluate class accuracy at the alliance level of classification. The cross tabulation of 22 alliances for ground truth and mapped alliance is shown in Table 5. The point estimate from the sample of 499 plots for the overall accuracy is 79.8 percent for the alliance level of classification. The one-sided, 90 percent confidence interval is 2.4 percent, assuming a binomial distribution. It can be concluded that with 90 percent certainty the estimated overall accuracy of the map is equal to or greater than 77.4 percent (79.8 – 2.4). Point estimates for individual class accuray varried considerably but showed improvement over the 38 more specific classes of the associations-alliances classificaiton. Eleven classes met or exceeded the 80 percent correct standard relative to errors of omission and ten met the standard relative to errors of commission. Again, sample sizes of approximately 15 produce condifence intervals of about 15 percent depending on the accuracies involved for any specific class. Smaller samples produce very large confidence intervals that have little meaning for inferences to the population. However, the point estimate of the sample is a valid, unbiased estimate of map accuracy.

Table 5. Accuracy matrix for the alliance level of classificaiton

Alliance Truth	Alliance Mapped																								
	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Row Total	% Acc. (omission)
Whiteleaf manzanita shrubland	1	25												1										26	96
White alder temp. flooded forest	2		13		1											1			2					17	76
Brewer oak shrubland	3			3															2					5	60
Tanoak forest	4				5																			5	100
Tanoak shrubland	5					10		1							2									13	77
Red fir forest	6						2																	2	100
Ponderosa pine forest	7							37	1								5		4	2				49	76
Black oak forest	8			1				1	41	2			1			2			1					49	84
Oregon white oak woodland	9								1	4						1			1					7	57
Mixed conifer forest	10		1				1				14						1		1					18	78
Mixed conifer shrubland	11		2									22							1					25	88
Knobcone pine woodland	12	3							1		1		37	3		10		1	1		1		1	59	63
Interior live oak woodland	13	2						1	1				1	21										26	81
Greenleaf manzanita shrubland	14					3									6					1				10	60
Ghost pine woodland	15	2						2		1			4			29								38	76
Douglas-fir forest	16		1					1			1					1	30		1					35	86
Chamise shrubland	17																	13						13	100
Canyon live oak forest	18															2	1	1	35					39	90
Canyon live oak shrubland	19					2						1							1	9				13	69
Blue oak woodland	20												1	1					1		11			14	79
Barren	21												1									22	2	25	88
Disturbed	22													1								1	9	11	82
Column Total		32	17	4	6	15	3	43	45	7	16	23	45	27	8	46	37	15	51	12	12	23	12	499	
Percent Acc. Relative to errors of commission		78	76	75	83	67	67	86	91	57	88	96	82	78	75	63	81	87	69	75	92	96	75	Overall Acc. 79.8 percent	

An evaluation of the accuracy matrix in Table 5 shows that several classes were confused with very similar classes. For example class 12, *Knobcone pine – woodland,* was confused with class 15, *Ghost pine – woodland.* Such confusions of very similar types without excessive misclassification into other types encouraged us to define a mixed alliance level of mapping in the previous mapping project that we found useful for the mapping objectives (Fox et al. 2006). We defined three mixed alliances as mapping units in the previous mapping effort:

1. *Deciduous oak forest* = *Black oak forest* + *Oregon white oak woodland*. The *Oregon white oak woodland* had nearly as much cover of black oak (23.9%) as it did Oregon white oak (26.8%). Furthermore, the *Oregon white oak woodland* was often nearby or intermixed with black oak communities.

2. *Mixed pine – mixed oak* = *Ghost pine woodland* + *Knobcone pine woodland*. These alliances had scattered pines over a dense cover of mixed oaks and whiteleaf manzanita. The spectral signature of the manzanita and oaks overwhelmed any contribution of the widely spaced, thin canopies of the pines. These two alliances are physiognomically very similar and ecosystem processes are undoubtedly dominated by the oaks and whiteleaf manzanita. The vegetation classification presents nearly identical relative cover values in the Knobcone pine and Ghost pine woodlands for pines (7.8% versus 8.4%) and for whiteleaf manzanita (22.3% vs. 21.4%). Furthermore, both types had relative covers of mixed oaks and toyon of 32.8% and 52.6%, respectively.

3. *Montane chaparral* = *Canyon live oak shrubland* + *Greenleaf manzanita shrubland* + *Tanoak shrubland*. This mapping unit is found on and around Shasta Bally. The physiognomy of these alliances is essentially identical, all being of similar heights and canopy cover. The dominant shrubs in each alliance have evergreen, sclerophyllous leaves of similar size and shape and the alliances differ only in the relative cover of the predominant species. One area might be dominated by shrub tanoak with lesser amounts of the shrub form of canyon live oak, greenleaf manzanita, or bush chinquapin. Another area, on the other hand, might have more leaf cover of canyon live oak with lesser amounts of the other species. The landscape represents a constant physiognomic form, but with a multidimensional continuum of changing patterns of cover of the predominant evergreen shrub species. Shrubs have the highest relative cover with 78%, with trees having 17%, and herbs with 5%. The dominant shrubs in decreasing order of relative cover are the shrub variety of tanoak (35%), greenleaf manzanita (14%), the shrub form of canyon live oak (10%), bush chinquapin (9%), and pinemat manzanita (6%).

We evaluated classification accuracy relative to three mapping units, 13 alliances and a combined Barren-disturbed class (these formation level classes were functionally very similar as disturbed areas were almost barren having only very sparse grass cover). The cross tabulation of ground truth and mapped class is shown in Table 6.

Table 6. Accuracy matrix for the mapping unit level of classificaiton. Three mixed alliances (the mapping units), 13 alliances and a mixed formation class (*Barren-disturbed*) make up the mapping unit level of classificaiton.

Mapping Unit Truth	Mapping Unit Mapped																			
	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total	% accuracy (omission)
Whiteleaf manzanita shrubland	1	25											1						26	96
White alder temp. flooded forest	2		13		1							1				2			17	76
Brewer oak shrubland	3			3												2			5	60
Tanoak forest	4				5														5	100
Montane Chaparral	5					33		1			1					1			36	92
Red fir forest	6						2												2	100
Ponderosa pine forest	7					2		37	1					5		4			49	76
Dediuous oak forest	8			1				1	48			4				2			56	86
Mixed conifer forest	9		1				1			14				1		1			18	78
Mixed conifer shrubland	10		2								22					1			25	88
Mixed pine - mixed oak	11	5						2	2	1		80	2		1	1	1	1	96	83
Interior live oak woodland	12	2						1	1			1	22						27	81
Douglas-fir forest	13		1					1		1		1		30		1			35	86
Chamise shrubland	14														13				13	100
Canyon live oak forest	15											2		1	1	35			39	90
Blue oak woodland	16											1	1			1	11		14	79
Barren - disturbed	17											1	1					34	36	94
Column Total		32	17	4	6	35	3	43	52	16	23	91	27	37	15	51	12	35	499	

Percent accuracy relative to errors of commission		78	76	75	83	94	67	86	92	88	96	88	81	81	87	69	92	97	Overall Accuracy	85.6 Percent

The point estimate from the sample of 499 plots for the overall accuracy is 85.6 percent. The one-sided, 90 percent confidence interval is 2.1 percent, assuming a binomial distribution. It can be concluded that with 90 percent certainty the estimated accuracy of the map is equal to or greater than 83.5 percent (85.6 – 2.1) exceeding the standard of 80 percent correct for thematic accuracy (USGS-NPS Vegetation Mapping Program 1994).

Point accuracy estimates for twelve classes met or exceeded the 80 percent standard relative to errors of omission and commission. The five remaining classes were mapped with reasonable accuracy, the lowest being 60 percent for class 3 *(Brewer oak shrubland).* Five sampled polygons were truly in the *Brewer oak shrubland* class but two of them were mapped as *Canyon live oak forest.* We feel from general inspection of the image and map that most of the *Brewer oak shrubland* was mapped correctly and this small sample is not characteristic of mapping accuracy for this class. A similar argument can be made for *Red fir forest* which showed low mapping accurcies with respect to errors of commission, with three samples. Accuracy relative to omission errors was 100 percent for *Red fir forest*. General inspection of all of the polygons mapped into the *Red fir forest* class indicate that this class was mapped with high accuracy.

Positional Accuracy – We located 21 positions throughout the Whiskeytown Unit at identifiable points both on the ground and on the satellite image using differential correction of positions determined with a Global Positioning System (GPS) receiver. However, we could not use one location (point 4) acquired at the corner of a fenced area (used for boat storage) because the fence was not installed when the image was acquired by the satellite on July 25, 2003. Therefore we analyzed 20 ground control points (Figure 2).

Differences between The GPS location and the image location were calculated for both X and Y coordinates in the Universal Transverse Mercator (UTM) Projection and coordinate system, North American Datum (NAD) 1983, Geodetic Reference System (GRS) 1980). After plotting the locations of the points as registered by the GPS receiver in a geographic information system, we interpreted the location of each point as it appeared on the image. For example, if the point was a road intersection, we determined where the point was relative to the image of that location based on our field notes and the appearance of the image in that location and placed an image interpreted point at the location of the point (Figure 3). The red rectangle in Figure 3 locates the image position of point number 2, intersection of Hwy. 299 and Whiskey Creek road, SW corner of the triangular safety island. The green triangle locates the position that the GPS field survey indicated was the true location of this point. The difference in location is the positional error of the image for this point. The image is shifted 5.7 meters to the east (X coordinate) and 5.0 meters to the south (Y coordinate) according to measurements made at this point.

Summary statistics for all 20 reference points are shown in Table 7. The mean error in the X coordinate (east-west, UTM grid) is 4.8 meters indicating a possible bias to the east (positive direction). Random errors should have a zero mean. This is a small sample size so conclusions about the entire image are difficult. However, the root mean square error (RMSE) is less than the mean indicating a potential positive bias. The mean error in the Y coordinate (north-south, UTM grid) is -2.8 meters, with a root mean square error of 1.8 meters, indicating a slight bias to the south for the image. Again, inference should be made cautiously because of the small sample size.

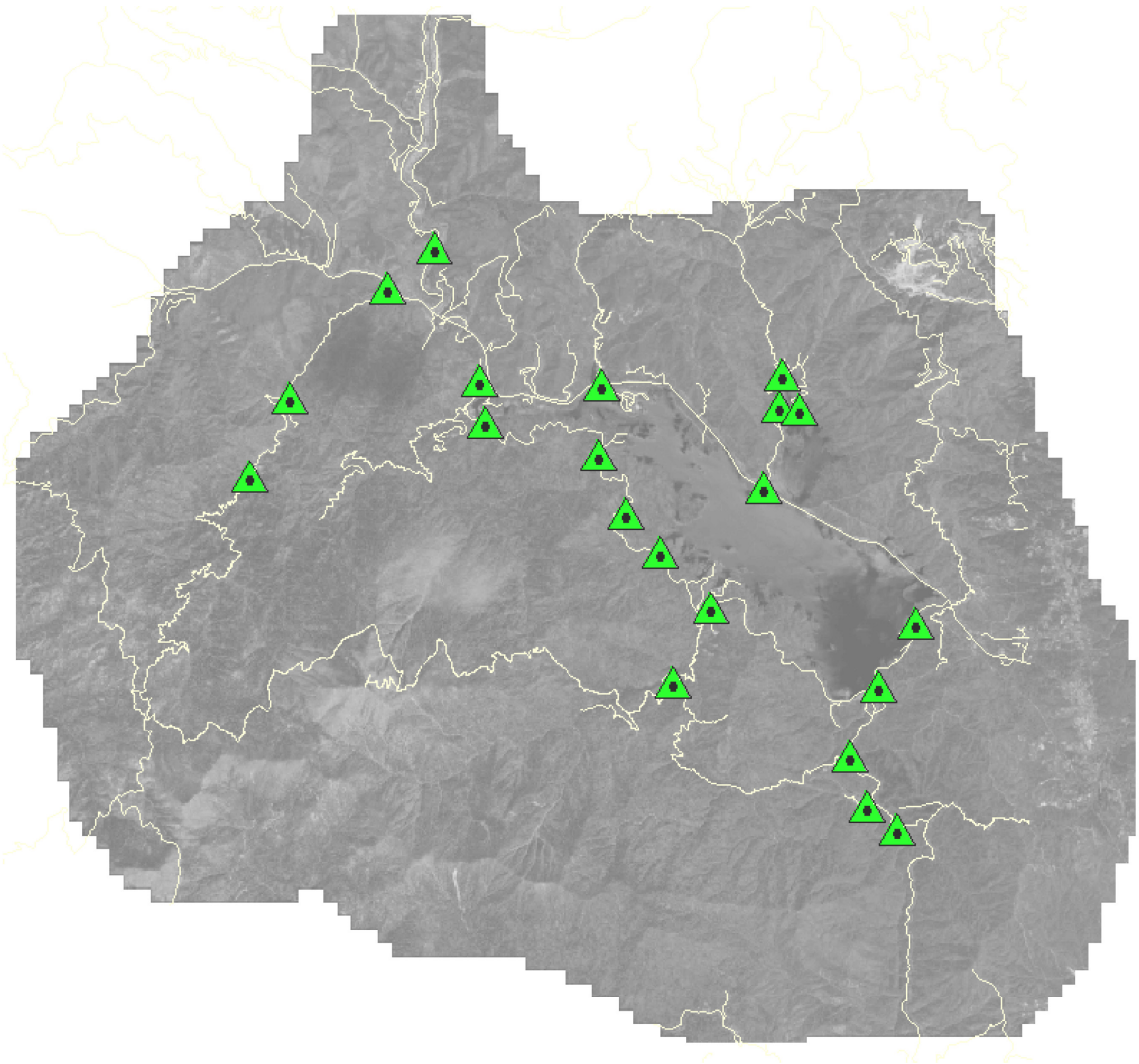

Figure 2. The distribution of 20 positional accuracy assessment locations obtained with a differentially corrected global positioning system (GPS) receiver.

Figure 3. Example of the difference between the image location of point 2 and the actual location of the same point as determined by ground survey. The red rectangle locates the image position of point number 2, intersection of Hwy. 299 and Whiskey Creek road, SW corner of the triangular safety island. Pixels are visible and are 1 meter across. The green triangle locates the position that the field survey (differentially corrected Global Positioning System receiver) indicated was the true location of this point. The difference in location is the positional error of the image for this point. The thin yellow lines are the fairly imprecise, USGS road vectors for this intersection obtained from a 1:100,000 scale topographic map. (Note the semi truck, lower left, that happened to be traveling by on July 25, 2003).

Table 7. Universal Transverse Mercator (UTM) Coordinates (meters) for the twenty reference points collected for positional accuracy assessment. Image coordinates (X_coor_image and Y_coor_image) were measured digitally by computer from the image used to make the vegetation map. Ground coordinates (X_coor_DGPS and Y_coor_DGPS) were acquired in the field with a differentially corrected Global Positioning System (DGPS) receiver. Point ID 4 was not analyzed as reliable image coordinates could not be obtained for that point. The fence corner used as the ground point was not present in 2003 when the image was acquired by the satellite.

ID	Description	X_coor_image	X_coor_DGPS	X_coor_diff	Y_coor_image	Y_coor_DGPS	Y_coor_diff
1	Oak Bottom Sign, east side	534015.4	534008.0	7.4	4500232.4	4500233.7	-1.3
2	Hwy 299, Whiskey Cr. Int. SW corner triangle	537119.6	537113.9	5.7	4498267.1	4498272.1	-5.0
3	Center of west island, whiskey creek parking lot	537420.2	537414.5	5.7	4499811.1	4499815.6	-4.5
5	Center of Intersection	537457.9	537453.2	4.7	4500426.1	4500427.6	-1.5
6	Admin Sign, South Side of Sign	540016.8	540011.9	4.9	4495679.8	4495684.8	-5.0
7	Kennedy Memorial Sign	539311.3	539305.6	5.7	4494501.2	4494505.0	-3.8
8	Horse Camp SE Corner South Bear Box	539672.7	539671.7	1.0	4491776.8	4491780.7	-3.9
9	N.E.E.D. Cmp Brdg, E Side, 2 ft E of Con/asph.	539094.5	539086.2	8.3	4492202.3	4492204.8	-2.5
10	Intersection Peltier Brdg Rd & Paige Bar Rd	538778.0	538772.1	5.9	4493147.8	4493149.9	-2.1
11	Brandy Ck Campgd turnoff at stop sign	536090.4	536088.5	1.9	4495976.4	4495980.6	-4.2
12	Intersec Sheep Camp & Peltier Rd on gate	535380.1	535374.7	5.4	4494574.4	4494578.4	-4.0
13	Gate on S. Shore Turnoff, s end	535126.0	535121.6	4.4	4497054.1	4497057.9	-3.8
14	Culvert Switch Back S. shore Rd, inside of turn	534479.8	534473.4	6.4	4497794.3	4497798.0	-3.7
15	Boulder Ck Xing, lge culvert, dwnst side	533953.8	533952.2	1.6	4498912.5	4498914.3	-1.8
16	Carr Pwr Station at gate	531772.3	531772.4	-0.1	4499537.8	4499536.2	1.6
17	Clear Ck Bdge, east end of bridge	531671.4	531664.2	7.2	4500315.9	4500316.4	-0.5
18	Small side Rd opp side of Fr Gul Rd	530806.4	530798.7	7.7	4502857.6	4502858.5	-0.9
19	Intersection Coggins Ck Rd & Crys Ck Rd	527259.4	527253.1	6.3	4498497.8	4498502.0	-4.2
20	Gravel Pit Old Sorter	528009.4	528004.4	5.0	4499983.0	4499987.1	-4.1
21	Crystal Ck Bridge, W end at con/asph edge	529883.3	529882.4	0.9	4502076.6	4502076.5	0.1
	Mean			4.8			-2.8
	Root Mean Square Error			2.4			1.8

Circular error was not calculated because it assumes random errors in X and Y averaging to zero (USGS-NPS Vegetation Mapping Program 1994). We noticed a fairly large difference between the mean error and zero for both X and Y coordinates (Table 7). Circular error is not required by the USGS-NPS standard and may be inappropriate in this case. In any case, the positional accuracy of the image that was used to make the vegetation map is better than three meters on average and this is to be expected for the 1-meter pixel size of the image. The vegetation boundaries drawn from this image by the classification and mapping software are difficult to see in the field and therefore their positional accuracy could not be addressed directly. USGS-NPS standards (USGS-NPS Vegetation Mapping Program 1994) recognize the difficulty of finding vegetation boundaries in the field and recommend the approach of measuring the positional accuracy of visible reference points on imagery used to make the vegetation map, the procedure that we executed. Since the image resolution was degraded from 1-meter pixels to 2-meter pixels before mapping, we believe a reasonable positional accuracy for the vegetation map derived from this image is approximately five meters in X and Y, based on our sample of 20 reference points.

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