Assessment Report of Wetland Mapping Improvements to NOAA's Coastal Change Analysis Program (C-CAP) Land Cover in Western Washington State

The following report provides a summary of several efforts to assess improvements made to the National Oceanic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program (C-CAP) land cover and change data for the coastal area of western Washington state. These improvements were aimed at increasing the level of spatial detail and accuracy with which C-CAP maps wetland categories.

The assessment will be divided into two components. The first is focused on the accuracy of the individual map categories for C-CAP's most recent date (2011), as well as a comparison of these improvements over previously mapped wetlands in 2006. The second component assesses the ability of these moderate-resolution, nationally consistent products to discern changes over an individual five-year period (2006 to 2011) as compared to the ability of higher-resolution products to discern changes over the same period.

This work was funded through a U.S. Environmental Protection Agency (EPA) grant to the Washington State Department of Ecology (Ecology). Mapping work leveraged existing C-CAP land cover data and was conducted by an external contractor (PhotoScience) through NOAA's Coastal Geospatial Services Contract vehicle. Mapping product development oversight and this assessment were performed by staff members of the NOAA Coastal Services Center (the Center).

Accuracy of the Coastal Change Analysis Program 2011 Land Cover

The most basic, and potentially the most important, measure of accuracy related to the use of land cover data is whether or not the current date of classification can be considered accurate as compared to the ground conditions during the time period. To get answers, NOAA designed a point sampling scheme, then interpreted the land cover for each point based on high spatial resolution imagery that coincided with the land cover map date. Through this comparison NOAA is able to report upon the overall accuracy, and specific types of errors, related to the product. This information can be useful in informing map users about the general quality of the data, so they can determine the appropriateness of the map data for specific uses.

In this report we will address the methods for sampling where accuracy assessment points would be selected or located, as well as the actual results of that assessment.

Accuracy Point Sampling Design

Because data were developed with the specific intent of improving the accuracy and reliability of C-CAP's wetland categories, the accuracy assessment differed slightly from NOAA's standard methods. These differences included less restrictive homogeneity criteria for sample point placement and a targeted sampling, or oversampling, of accuracy points within wetland and potentially wet features.

Typically, C-CAP accuracy assessment points are located using a 3 x 3 pixel window, restricting point placement to areas that have agreement in the land cover mapped in six out of nine of these pixels. This procedure is followed so that edge pixels and features smaller than C-CAP's minimum mapping unit (MMU) are not sampled. In the assessment performed for Ecology, points were allowed to be placed whether or not they fit this majority agreement criteria. It was thought that this assessment would better reflect Ecology's desire to assess this product for use in identifying wetland features regardless of size.

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Typically, C-CAP accuracy assessment points are sampled by way of a stratified random sampling method, based on the distribution of each land cover category being assessed. This method is used so that accuracy points are distributed across the land cover types in a manner similar to that in which they exist or are mapped. This process prevents relatively rare categories from having a disproportionate effect on the accuracy results. NOAA typically requires a minimum number of points per category as well, so that the dominant categories do not override results related to the smaller, or rarer, classes. In the assessment performed for Ecology, points related to wetland categories were emphasized and were oversampled in relation to their relative distribution within the landscape. All land covers were also sampled based on the generalized wetland potential rating (a separate map product also developed by NOAA as part of this project). This was done to sample areas that might have a high probability of being wetlands, but which might not have been mapped as such in the final land cover product (i.e., as when sampling design was set up to address potentially missed wetland features). This more wetland-focused assessment will better reflect Ecology's desire to use this product for targeted identification of wetland features (as opposed to more general land cover mapping, in which wetlands might be included).

The resulting distribution of accuracy assessment points can be seen as follows (Table 1). A total of 806 points were sampled. 41 percent of these points (333 points) were sampled from wetland features, even though these features make up only about three percent of the total area mapped in western Washington. 56 percent of the points (448 points) sampled were from upland categories, with particular emphasis in developed and agricultural areas. Three percent of the points (25 points) were sampled directly from water features. Distribution by low, medium, high wetland potential, and a water class can also be seen. As would be expected, most upland points were found within lower wetland potential areas, while most wetland points were located in higher potential categories. The samples obtained outside of these expected ranges were placed in order to sample areas that might have been missed in the wetland classification process.

	Wetland Potential Rating					
Land Cover Class	Low	Medium	High	Water	**Totals**	Percent
Palustrine Forest	3	0	82	1	**86**	10.7%
Palustrine Scrub	1	0	47	0	**48**	6.0%
Palustrine Emergent	8	10	36	7	**61**	7.6%
Estuarine Wetlands	6	0	17	0	**23**	2.9%
Unconsolidated Shore	14	4	43	18	**79**	9.8%
Aquatic Bed	5	0	18	13	**36**	4.5%
WETLAND SUBTOTAL	**37**	**14**	**243**	**39**	**333**	**41.3%**
Developed	41	35	33	0	**109**	13.5%
Agriculture	38	36	36	0	**110**	13.6%
Other Upland	157	37	35	0	**229**	28.4%
UPLAND SUBTOTAL	**236**	**108**	**104**	**0**	**448**	**55.6%**
Water	n/a	n/a	n/a	25	**25**	3.1%
Totals	**273**	**122**	**347**	**39**	**806**	

Table 1. Distribution of accuracy assessment points based on generalized land cover class and wetland potential rating.

Once sampled, these points were then reviewed by NOAA analysts, using the 2011 Landsat data upon which the land cover classification was developed; high resolution National Agriculture Imagery Program (NAIP) imagery; high resolution imagery within Google Earth; National Wetlands Inventory (NWI) maps; and the hydric rating and drainage class as categorized within the Soil Survey Geographic Database (SSURGO) data. The analyst noted the majority land cover category designation for the land cover associated with each point location. This could have included both a primary and fuzzy class designation for areas that might have been mixed due to multiple features within the area, or if the point was located near the edge of two features.

Accuracy Assessment Results

Detailed results of the accuracy assessment performed can be seen as follows (Table 2). The overall accuracy achieved was 81.9 percent. This included all 25 categories of potential land cover classes mapped, and all of the possible combinations of confusion that might be experienced between those categories.

As can be seen, most categories achieved reasonable user's and producer's accuracy numbers. Producer's accuracy represents a measure of the errors of ommission, or items that were missed related to the individual class being mapped. This is referred to as producer's as this what the producer of a map might look at to see how good they were at mapping each category. User's accuracy represents a measure of the errors of commission, or items that were incorrectly mapped as a class they should not be. This referred to as user's accuracy as this is what a user might look at to see how often they might expect that the category they are seeing on the map is correct.

Palustrine Forested Wetlands, for instance, had a producer's accuracy of 88.9 percent and a users' accuracy of 81.8 percent. The primary sources of error were generally associated with the confusion between: 1) forests and scrub or grasses and scrub (though little of this was between wetland and upland features); 2) upland forest stands that were mapped as wetland forest (overcalled wetland forests); 3) confusion between some estuarine emergent, unconsolidated shore, and aquatic bed areas; and 4) areas of both upland and wetland forest being mapped as open space or low intensity development.
Many of these confusions are fairly understandable given the nature of the specific categories involved. Grass/scrub and scrub/forest distinctions can be very subtle at the scale that C-CAP maps (and often at higher resolution). It can be difficult to determine height in imagery taken looking down from above. The Emergent/Unconsolidated Shore/Aquatic Bed distinctions are highly variable and dependent on lower tide imagery (which is not always available via Landsat). Finally, many of the features misclassified as Development are relatively small in size, are within a residential or urban setting, and realistically may be beyond the capability of C-CAP to map, given the scale and minimum mapping unit of our products.

It may be important to note that **if one is only interested in whether an area is wetland, upland, or water, the overall accuracy is 95.0 percent** (i.e., accuracy expected if users are only interested in wetland versus upland categories).

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	18	19	20	21	22	23	25	Total	
2	**11**																					11	100.0%
3		**18**	1				1															20	90.0%
4		1	**36**	4		3		1			1	1	1	1					1			50	72.0%
5			1	**13**	1				1	2	2	1		1								22	59.1%
6				3	**20**	3	1						1									28	71.4%
7				5	2	**75**					2		1	2								87	86.2%
8					2	3	**29**		1		4			1								40	72.5%
9								**4**		1												5	80.0%
10			1					1	**108**		3	2										115	93.9%
11										**15**												15	100.0%
12				1		2	7		4	5	**23**		1	1							1	45	51.1%
13									10	3		**72**	2	1								88	81.8%
14						1	2				1	3	**34**	6		1						48	70.8%
15						1				1	1	2	2	**53**		1						61	86.9%
18			1							1					**16**	6	1			5		30	53.3%
19															1	**67**	1	2		3		74	90.5%
20																	**4**					4	100.0%
21																		**25**				25	100.0%
22																			**3**	1		4	75.0%
23																				**32**		32	100.0%
25																					**2**	2	100.0%
Total	11	19	40	26	25	88	40	6	124	28	37	81	42	66	17	75	6	27	4	41	3	806	
	100.0%	94.7%	90.0%	50.0%	80.0%	85.2%	72.5%	66.7%	87.1%	53.6%	62.2%	88.9%	81.0%	80.3%	94.1%	89.3%	66.7%	92.6%	75.0%	78.0%	66.7%	**660**	**81.9%**

Table 2. Accuracy assessment table for the 2011 Coastal Change Analysis Program (C-CAP) Land Cover. Class categories are noted here along each axis according to the C-CAP class number (see appendix). Accuracy points considered correct can be seen along the grey diagonal. Points located off this diagonal are considered errors of confusion between the corresponding classes. C-CAP map call is located on the Y-axis. Photo-interpreted point classifications are noted along the X-axis.

Improvements in Accuracy of NOAA Coastal Change Analysis Program (C-CAP) 2006 Land Cover

As an additional assessment of accuracy, NOAA staff members focused on comparing the pre-existing 2006 date of C-CAP land cover to the new 2006 classification after the wetland potential and improved wetland mapping methods had been applied. This comparison was done by removing any points that were located in features of change from those used to assess the 2011 data in Table 2. (In taking this step, NOAA staff members assumed that the 2011 interpretation of those locations can be used in direct assessment of the 2006 date.) The results of these two accuracy assessments can be seen below (Tables 3 and 4).

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	18	19	20	21	22	23	25	Total	
2	5															1						6	83.3%
3		9	1				1															11	81.8%
4			16			1				1			1						1			20	80.0%
5				8	1						2		1	1								13	61.5%
6				2	16	1				1			1	1								22	72.7%
7				2	2	58				1	1	2	1	4								71	81.7%
8					1		20				2	1										24	83.3%
9								2				1		1								4	50.0%
10									96		1	18	2	3		1		1	1			123	78.0%
11				1					1	7		6	1				1					17	41.2%
12						3	2			1	15	2	5	5								33	45.5%
13						1				1		15		1								18	83.3%
14												1	11	1								13	84.6%
15						1			2		1	1		29								34	85.3%
18			1												14	1	1			1		18	77.8%
19																31		2	1	3		37	83.8%
20																	2		1			3	66.7%
21														1				24				25	96.0%
22																				1		1	0.0%
23																				25		25	100.0%
25																					2	2	100.0%
Total	5	9	18	13	20	65	23	2	99	12	22	47	23	47	14	34	4	27	4	30	2	405	
	100.0%	100.0%	88.9%	61.5%	80.0%	89.2%	87.0%	100.0%	97.0%	58.3%	68.2%	31.9%	47.8%	61.7%	100.0%	91.2%	50.0%	88.9%	0.0%	83.3%	100.0%		77.88%

Table 3. Accuracy assessment table for the 2006 Coastal Change Analysis Program (C-CAP) land cover prior to wetland classification improvements. Class categories are noted here along each axis according to the C-CAP class number (see appendix). Accuracy points considered correct can be seen along the grey diagonal. Points located off this diagonal are considered errors of confusion between the corresponding classes. C-CAP map call is located on the Y-axis. Photo-interpreted point classifications are noted along the X-axis.

As can be seen by the comparison of these two tables, there were considerable improvements to the overall accuracy of the land cover product as well as marked improvements in several of the individual wetland class accuracies. Overall accuracy went from 77.9% to 87.3%, a jump of almost 10 percentage points. In addition to that overall improvement, the individual user's accuracies associated with C-CAP's freshwater wetland classes (classes 13, 14, and 15) went from an average of 47% accurate up to an average of 84% accurate. This essentially doubled the accuracy of several of these classes and dramatically improved the usefulness of these products for wetland related uses.

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	18	19	20	21	22	23	25	Total	
2	5																					5	100.0%
3		9	1				1															11	81.8%
4			16			1				1			1						1			20	80.0%
5				8	1						2			1								12	66.7%
6				2	17								1									20	85.0%
7				2	1	60					1	1	1	2								68	88.2%
8					1	1	20				2											24	83.3%
9								2														2	100.0%
10									93		1	1		2		1						98	94.9%
11				1						6												7	85.7%
12						1	2			1	16			1								21	76.2%
13						1			2	2		43	1	1			1	1				52	82.7%
14											1	1	21	1								24	87.5%
15						1			1	2		2		34								40	85.0%
18			1												14	1	1			1		18	77.8%
19									1							34		2		3		40	85.0%
20																	2					2	100.0%
21														1				24				25	96.0%
22																			3	1		4	75.0%
23																				25		25	100.0%
25																					2	2	100.0%
Total	5	9	18	13	20	65	23	2	97	12	23	48	25	43	14	36	4	27	4	30	2	454	
	100.0%	100.0%	88.9%	61.5%	85.0%	92.3%	87.0%	100.0%	95.9%	50.0%	69.6%	89.6%	84.0%	79.1%	100.0%	94.4%	50.0%	88.9%	75.0%	83.3%	100.0%		87.31%

Table 4. Accuracy assessment table for the 2006 Coastal Change Analysis Program (C-CAP) land cover after wetland classification improvements. Class categories are noted here along each axis according to the C-CAP class number (see appendix). Accuracy points considered correct can be seen along the grey diagonal. Points located off this diagonal are considered errors of confusion between the corresponding classes. C-CAP map call is located on the Y-axis. Photo-interpreted point classifications are noted along the X-axis.

Accuracy of NOAA Coastal Change Analysis Program (C-CAP) 2006 to 2011 Land Cover Change Analysis

As a separate task under the EPA grant received by Ecology, several high resolution change detection studies were conducted by the Washington Department of Fish and Wildlife (WDFW). These studies were conducted for two time periods of change in the watersheds of several Washington Resource Inventory Areas (WRIAs). One was for the 2006 to 2009 time period and another was for the 2009 to 2011 time period. The combination of these two time periods corresponded to the dates utilized in C-CAP's latest change product (2006 to 2011).

Two WRIAs (3 and 15) benefited from both time periods of analysis, and as such were used to compare areas of change identified within the C-CAP change product for that same time period. Comparison of these two change analysis products were performed in two ways. The first was the most basic, comparing the total area of change (along with general change type) identified watershed-wide. The second was to look at the spatial location of changes identified in each study and compare the areas of agreement or disagreement between the two.

Results were generally encouraging, highlighting that the more moderate resolution C-CAP product fulfilled its role as a screening level analysis for more detailed studies. In the examples that follow, see the specific results relating to each of the two WRIAs.

WRIA 3 – Lower Skagit / Samish Watershed

Total area of change
The WDFW mapped 1.99 square miles of development-related change, 12.57 square miles of forest-related change, and 0.09 square miles of what was termed partial change. When grouped into similar classes of change, C-CAP mapped 2.21 square miles of development-related change and 12.67 square miles of forest-related change (partial change had no C-CAP equivalent). **These groupings resulted in a 98.5% agreement in areas of these change types being reported between the two methods.**

Spatial area of change
The following tables highlight the areas mapped as change in these two products and compare the degree of agreement. Several iterations of this first table will be presented in order to better portray how these two products relate. These iterations might also be useful in explaining the expectations that are reasonable when using moderate resolution products such as C-CAP.

It is important to note that this comparison is not a true accuracy assessment, as the WDFW product has not been assessed for accuracy and is not likely to be 100 percent correct. This is, more of a comparison between products produced at two resolutions, which may be considered a measure of how close the moderate resolution C-CAP products might perform to higher resolution analysis.

Table 5 (below) highlights the agreement and disagreement between the WDFW and C-CAP change products. C-CAP products are shown to agree overall 98.4 percent of the time, although this figure is highly weighted by the large amount of "no change" area (change is typically a rare event). **In a direct comparison, C-CAP picks up 62.6% of the change features identified by WDFW** (it also calls out approximately twice the change of WDFW products).

		WDFW			
C-CAP		Change	Not Change	Total	
	Change	9.17	11.41	20.58	**44.6%**
	Not Change	5.47	1021.92	1027.39	
	Total	14.64	1033.33		
		62.6%			

Table 5. Comparison of C-CAP change to all areas mapped within the WDFW high resolution change analysis.

A review found that there was some discrepancy between the image dates used in each of the analyses above. This discrepancy would directly impact the areas identified within the two products, for the following reasons: C-CAP had several areas of 2005 to 2006 changes that were not included in the WDFW product (2.66 square miles); WDFW included changes that happened after the 2011 date used by C-CAP (0.20 square miles); and NOAA interpreted one area as missed change on WDFW's part (1.34 square miles that would have been considered change by NOAA, but was not considered or captured as

change by WDFW). These areas were removed from the comparison table and the result is highlighted in Table 6, below. The producer's accuracy improved slightly, while the user's accuracy improved by more than 10 percent.

		WDFW			
C-CAP		Change	Not Change	Total	
	Change	9.17	7.40	16.57	**55.3%**
	Not Change	5.27	1026.14	1031.41	
	Total	14.44	1033.54		
		63.5%			

Table 6. Comparison of C-CAP change to areas mapped within the WDFW high resolution change analysis after differences in exact image dates were removed.

After these inconsistencies in dates were adjusted for, NOAA turned its attention to the areas of change that are smaller than what we could reasonably expect based on C-CAP's 30-meter resolution and the minimum mapping unit (MMU) of our change products (~ one acre). NOAA found that there were 1,241 polygons of change in the WDFW product equal in size to one thirty-meter pixel as well as an additional 1,832 polygons less than one acre in size. NOAA decided that these areas should be removed from the comparison, as such smaller features cannot realistically be assumed to be mapped with 30-meter land cover data. This removed a total of 1.32 square miles from the areas where WDFW mapped change and C-CAP did not. It also removed 0.60 square miles of C-CAP change not identified by WDFW, and added some areas to the correctly identified and agreed-upon change category. This brought the producer's accuracy of C-CAP wetland categories up to 69.9 percent. The result can be seen in table 7.

		WDFW			
C-CAP		Change	Not Change	Total	
	Change	9.76	6.81	15.98	**57.4%**
	Not Change	3.95	1027.47	1037.46	
	Total	13.12	1040.32		
		69.9%			

Table 7. Comparison of C-CAP change to areas mapped within the WDFW high resolution change analysis after differences in image dates and features below C-CAP's MMU were removed.

Finally, NOAA's review of the remaining areas of disagreement highlighted several features that were missed or overcalled in C-CAP, as compared to the WDFW data that were made up of small linear rings surrounding agreed-upon change features. This is likely due to the scale (pixel size) and projection differences between the two products. It was thought that eliminating some of these features would provide a more realistic assessment of the moderate resolution data compared to this higher resolution product. A one-pixel buffer surrounding areas of agreed-upon change was used to eliminate areas of disagreement. The result of this analysis can be seen in Table 8, below. This step raised the user's accuracy to 64.1 percent and the producer's accuracy to 77.3 percent.

It is NOAA's assertion that reporting the user's and producer's accuracy is a more reasonable accuracy estimate related to change within this WRIA, given the differences in the two data sets, and that this information should be used to explain the accuracy of the product as well as its limitations in mapping change areas less than one acre in size.

		WDFW			
C-CAP		Change	Not Change	Total	
	Change	9.76	5.47	15.23	**64.1%**
	Not Change	2.88	1029.88	1032.75	
	Total	12.63	1035.35		
		77.3%			

Table 8. Comparison of C-CAP change to areas mapped within the WDFW high resolution change analysis, after differences in image dates, features below C-CAP's MMU, and areas adjacent to agreed change were removed

WRIA 15 – Kitsap Watershed

Total area of change
The WDFW mapped 3.43 square miles of development related change, 10.52 square miles of forest related change, and 0.03 square miles of what was termed partial change. When grouped into similar classes of change, C-CAP mapped 2.52 square miles of development related change and 14.80 square miles of forest related change (partial change had no C-CAP equivalent). **This resulted in an 80.7% agreement in areas of these change types being reported between the two methods.**

Spatial area of change
The following tables highlight the areas mapped as change in these two products and compares their degree of agreement. Several iterations of this first table will be presented in order to better portray how these two products relate, and might be useful in explaining the expectations that are reasonable when using moderate resolution products such as C-CAP.

It is important to note that this comparison is not a true accuracy assessment, as the WDFW product has not been assessed for accuracy and is not likely to be 100% correct. It is, more accurately, a comparison between products produced at two resolutions, and may be thought of as a measure of how close the moderate resolution C-CAP products might perform to higher resolution analysis. Not which is right and which is wrong, necessarily.

Table 9 (below) highlights the agreement or disagreement between the WDFW and C-CAP change products. If the WDFW product is considered "truth," the C-CAP products are shown to agree overall 98.4 percent of the time, though this is highly weighted by the large amount of no change area (change is typically a rare event). Looking at the user's and producer's accuracies may provide more meaningful measures of assessment. **In a direct comparison C-CAP picks up 70.2% of the change features identified by WDFW** (it also calls out twice the change of the WDFW products).

		WDFW			
C-CAP		Change	Not Change	Total	
	Change	9.81	11.04	20.85	**47.1%**
	Not Change	4.17	919.82	923.99	
	Total	13.98	930.86		
		70.2%			

Table 9. Comparison of C-CAP change to all areas mapped within the WDFW high resolution change analysis.

NOAA did not perform the detailed examination of all change areas and image dates used, as was done in WRIA 3, but similar to the analysis that was performed in that WRIA, areas of change that are smaller than what could reasonably expected based on C-CAP's 30 meter resolution and the minimum mapping unit of our change products (~ one acre) were removed from this comparison. It was decided that these areas should be removed from the comparison, as such smaller features cannot realistically be assumed to be mapped with 30 meter land cover data. This removed a total of 1.50 square miles from the areas where WDFW mapped change and C-CAP did not (36 percent of the previous missed change total). It also removed 0.62 square miles of C-CAP change not identified by WDFW, and added some areas to the correctly identified or agreed-upon change category**. This brought the producer's accuracy of C-CAP wetland categories up to 79.3 percent.** The result can be seen in table 10.

		WDFW			
C-CAP		Change	Not Change	Total	
	Change	10.22	10.42	20.64	**49.5%**
	Not Change	2.67	921.54	924.21	
	Total	12.89	931.96		
		79.3%			

Table 10. Comparison of C-CAP change to areas mapped within the WDFW high resolution change analysis after features below C-CAP's MMU were removed.

Finally, NOAA's review of the remaining areas of disagreement highlighted that several of the features that were missed or overcalled in C-CAP, as compared to the WDFW data, were made up of small linear rings surrounding agreed-upon change features. This is likely due to the scale (pixel size) and projection differences between the two products. It was thought that eliminating some of these features would provide a more realistic assessment of the moderate resolution data compared to this higher resolution product. A one-pixel buffer surrounding areas of agreed-upon change was used to eliminate areas of disagreement. The result of this analysis can be seen in table 11 below. **The result raised the producer's accuracy to 86.6 percent.** It should be noted that this level of accuracy exceeds that achieved in WRIA 3, and may actually be an underestimate because there may still be areas where differences in imagery used could have an influence.

It is NOAA's assertion that reporting this user's and producer's accuracy is a more reasonable accuracy estimate related to change within this WRIA, given the differences in the two data sets, and that this

information should be used to explain the accuracy of the product as well as its limitations in mapping change areas less than one acre in size.

		WDFW			
C-CAP		Change	Not Change	Total	
	Change	13.16	8.12	21.28	**61.8%**
	Not Change	2.03	921.54	923.57	
	Total	15.19	929.66		
		86.6%			

Table 11. Comparison of C-CAP change to areas mapped within the WDFW high resolution change analysis after features below C-CAP's MMU and features adjacent to agreed change were removed

Conclusions

The accuracy with which NOAA's Coastal Change Analysis Program (C-CAP) maps wetlands in western Washington state have been dramatically improved over results achieved previously. This demonstrates the power and effectiveness of the ancillary data, and methodology, utilized to institute these improvements. Results achieved are clearly an improvement over the previous C-CAP maps.

In addition to this improvement in classification accuracy, it has also been demonstrated that the C-CAP products perform well in detecting changes, as compared to higher resolution analysis. This is especially true if the user is interested in only the total change or amount of change types over a watershed or county geography. Numbers at this scale are shown to be very close.

While it should certainly be explained to potential users that isolated changes of one acre or less in size are not likely to be picked up through such moderate resolution mapping as C-CAP, it is encouraging that these products did pick up the vast majority of changes that exceeded this one acre minimum mapping unit threshold. Many changes below this threshold would likely need to be field-verified for wetness, regardless of the method used to identify them. As such, NOAA believes that this moderate resolution data is clearly useful for state-scale or regional studies, or as a screening level analysis that could be used to better target more detailed studies. It should also be explained that there will always be some level of false positives identified, but that user review of specific geographies can be used to screen these identified change areas quickly.

Another factor, which may be important for potential users or those interested in updating this analysis at a future date, is that moderate resolution analysis, such as C-CAP regional land cover products, tends to be very cost effective. It costs NOAA less than $2 per square mile to produce its 30 meter land cover. This can be compared to the $100 to $250 per square miles to produce NOAA's higher resolution land cover products. Such full land change mapping products would include wall-to-wall land covers and detailed change analysis (including the specific change from and change to categories). This can be compared to detailed studies, like those performed by WDFW and discussed here, that while they are significantly cheaper than higher resolution land cover mapping, do not include these detailed categories of mapping. Which of these might be of the greatest use and be most cost effective likely depends on the specific use intended for the analysis.

Appendix – Coastal Change Analysis Program (C-CAP) Land Cover Classes

Background (0) – areas within the image file limits but containing no data values
Unclassified (1) – areas in which land cover cannot be determined; these include clouds and deep shadow.

Developed, High Intensity (2) – contains significant land area is covered by concrete, asphalt, and other constructed materials. Vegetation, if present, occupies < 20 percent of the landscape. Constructed materials account for 80 to 100 percent of the total cover. This class includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas with a variety of land uses.
Developed, Medium Intensity (3) – contains areas with a mixture of constructed materials and vegetation or other cover. Constructed materials account for 50 to 79 percent of total area. This class commonly includes multi- and single-family housing areas, especially in suburban neighborhoods, but may include all types of land use.
Developed, Low Intensity (4) – contains areas with a mixture of constructed materials and substantial amounts of vegetation or other cover. Constructed materials account for 21 to 49 percent of total area. This subclass commonly includes single-family housing areas, especially in rural neighborhoods, but may include all types of land use.
Developed, Open Space (5) – contains areas with a mixture of some constructed materials, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes. These areas are maintained by human activity such as fertilization and irrigation, are distinguished by enhanced biomass productivity, and can be recognized through vegetative indices based on spectral characteristics. Constructed surfaces account for less than 20 percent of total land cover.

Cultivated Crops (6) – contains areas intensely managed for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
Pasture/Hay (7) – contains areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle and not tilled. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

Grassland/Herbaceous (8) – contains areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Deciduous Forest (9) – contains areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest (10) – contains areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed Forest (11) – contains areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover. *Both coniferous and broad-leaved evergreens are included in this category.*

Scrub/Shrub (12) – contains areas dominated by shrubs less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.

Palustrine Forested Wetland (13) – includes tidal and nontidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent.
Palustrine Scrub/Shrub Wetland (14) – includes tidal and non tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent. *Species present could be true shrubs, young trees and shrubs, or trees that are small or stunted due to environmental conditions.*
Palustrine Emergent Wetland (Persistent) (15) – includes tidal and nontidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation cover is greater than 80 percent. *Plants generally remain standing until the next growing season.*

Estuarine Forested Wetland (16) – includes tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.
Estuarine Scrub / Shrub Wetland (17) – includes tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.
Estuarine Emergent Wetland (18) – Includes all tidal wetlands dominated by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens). Wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and that are present for most of the growing season in most years. Total vegetation cover is greater than 80 percent. *Perennial plants usually dominate these wetlands.*

Unconsolidated Shore (19) – includes material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Substrates lack vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable.

Barren Land (20) – contains areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earth material. Generally, vegetation accounts for less than 10 percent of total cover.

Open Water (21) – include areas of open water, generally with less than 25 percent cover of vegetation or soil.
Palustrine Aquatic Bed (22) – includes tidal and nontidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is below 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, detached floating mats, and rooted vascular plant assemblages. Total vegetation cover is greater than 80 percent.
Estuarine Aquatic Bed (23) – includes tidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, kelp beds, and rooted vascular plant assemblages. Total vegetation cover is greater than 80 percent.

Tundra (24) – is categorized as a treeless region beyond the latitudinal limit of the boreal forest in pole-ward regions and above the elevation range of the boreal forest in high mountains. In the United States, tundra occurs primarily in Alaska.
Perennial Ice/Snow (25) – includes areas characterized by a perennial cover of ice and/or snow, generally greater than 25 percent of total cover.