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# Copper River Delta Existing Vegetation Map Project

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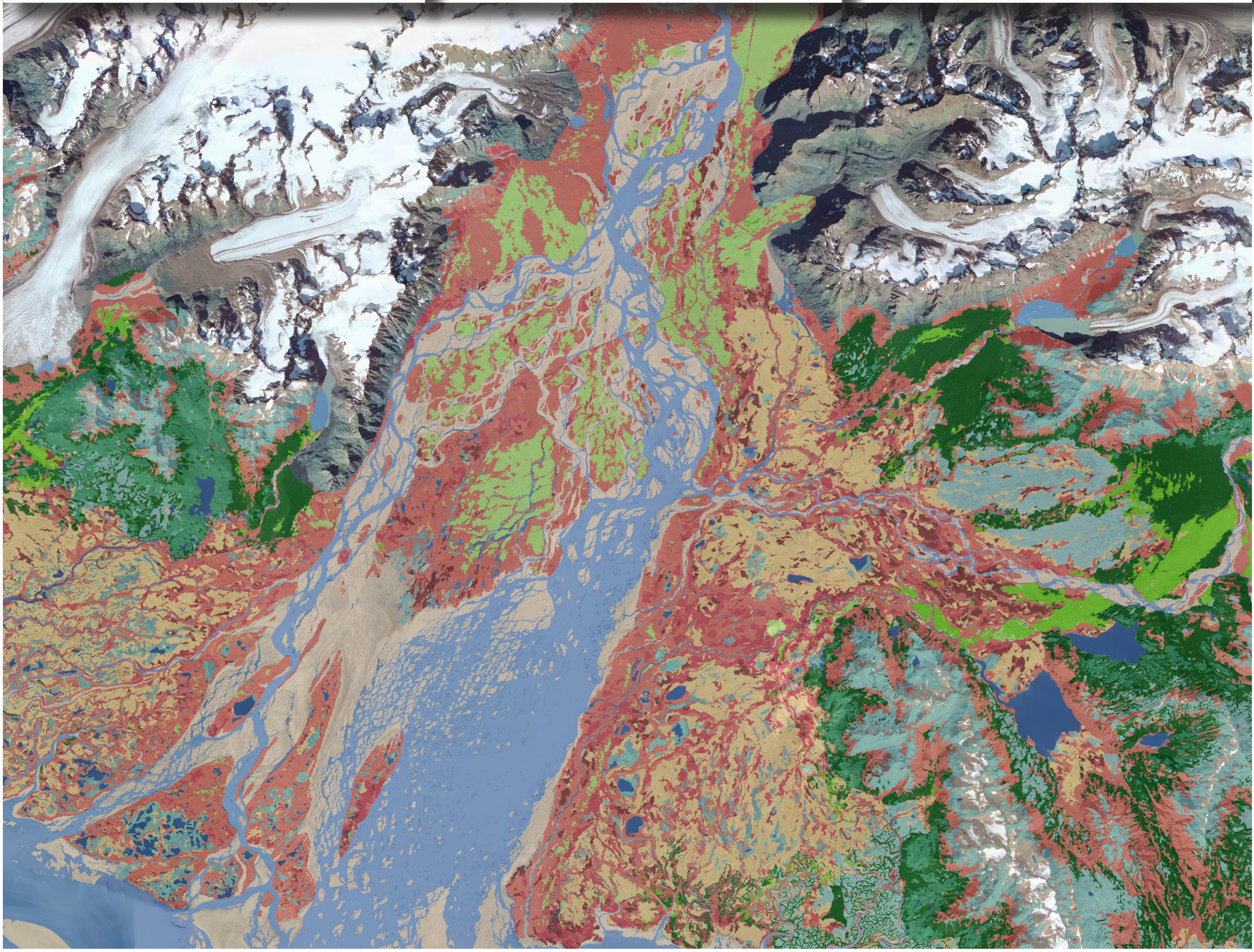

Abstract

An existing vegetation map was prepared in a collaborative effort between the Chugach National Forest, Alaska Regional Office (Region 10), Ducks Unlimited, and the Remote Sensing Applications Center (RSAC). This map was designed to be consistent with the standards established in the Existing Vegetation Classification and Technical Guide (Nelson and others, in press) and to provide baseline information to support project planning and management of the Copper River Delta. The final map comprises 15 land cover types, including 11 vegetation classes and 4 non-vegetated classes. Geospatial data, including remotely sensed imagery, a digital surface model, and ancillary data were assembled. A semi-automated image segmentation process was used to develop the modeling units (mapping polygons), which represented relatively homogeneous areas of land cover to be classified. Land cover class determinations were made for field visited reference sites and subsequently used to develop predictive random forest classification models. Photo interpretation was then used to evaluate individual map models and manually edit interim maps. This process utilized various Forest Service Enterprise software packages and the most contemporary mapping methods. Once the final map was produced, an accuracy assessment was conducted to reveal individual class confusion and provide additional insight into the reliability of the final map for resource applications. Overall accuracy of the final vegetation map was 82 percent.

## Keywords

Copper River Delta, Chugach National Forest, Alaska, vegetation map, classification

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## Acknowledgements

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# Table of Contents

# Introduction

Maps of existing vegetation support resource managers by informing project-level planning efforts with vegetation data that can be used in numerous applications. Land managers of the Copper River Delta require vegetation maps for monitoring and evaluating wildlife habitat used by moose, dusky Canada geese, trumpeter swans, and other species of interest. In addition, vegetation maps are needed for other applications, including land management planning, ecosystem assessment, inventory, silviculture, rare and sensitive species monitoring, invasive species modeling, recreation management, and climate change analyses.

Authority and funding for the Copper River Delta Mapping Project was provided by the Chugach National Forest and the Alaska Regional Office. The Remote Sensing Applications Center (RSAC) produced an existing vegetation map using the most contemporary mapping methods and current data available. The final map product will provide project managers with a vegetation map, at a scale and accuracy previously unachieved, to inform planning and decisions pertinent to the Copper River Delta.

# Project Area

The Copper River Delta project area is located in Southcentral Alaska and encompasses over 1.1 million acres of the Chugach National Forest (figure 1). Elevation of the project area ranges from sea level to over 3,000 ft. The delta contains coastal rain forest, verdant wetlands, and snowcapped peaks. This landscape, being at the interface of marine and terrestrial environments, provides critical habitat for migratory birds along the Pacific Flyway, large mammals such as moose and bear, and numerous anadromous fisheries.

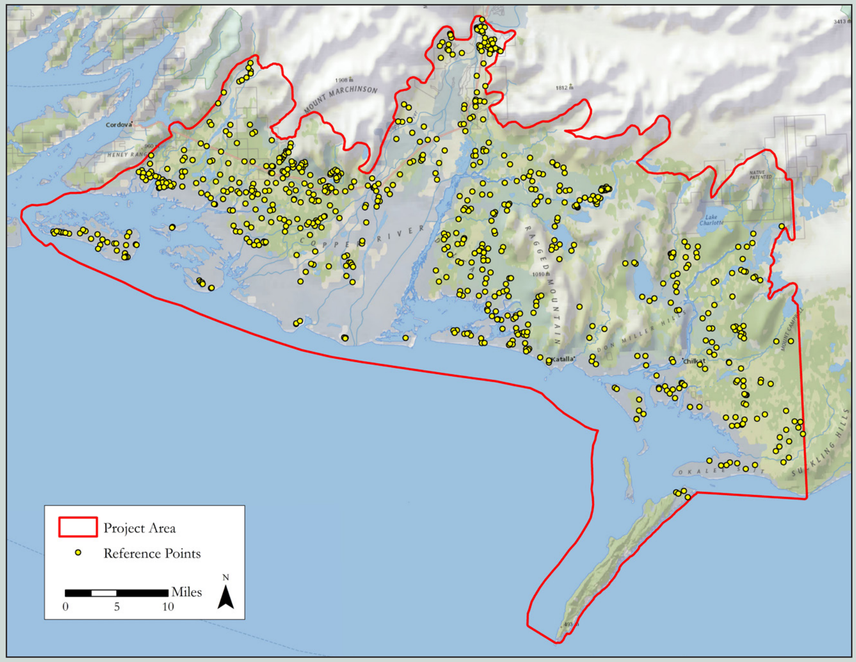


**Figure 1—Copper River Delta mapping project area and the locations of the field-collected reference sites.**

# Methods

The mapping phases for this project included geospatial data acquisition, image segmentation, reference data collection, classification, draft map review and revision, final map development, and accuracy assessment. Topographic and ancillary data were used in conjunction with imagery to develop the modeling units (mapping polygons) and the classification models that ultimately produced the final land cover map.

## Geospatial Data Acquisition

This project involved assembling remotely sensed imagery from multiple sensors. Each image sensor has a unique set of qualities that, along with the imaging geometry, determines the spectral, spatial, and radiometric resolutions of the data that is collected. Expert knowledge determined the appropriate data layers to be used at each stage of the mapping process to ensure the highest quality of interim products. For example, the 60 cm resource imagery lacked the spectral integrity for modeling purposes, but was instrumental in the generation of the mapping polygons and for reviewing draft maps.

Kayak Island was processed separately from the rest of the project area, hereinafter referred to as the 'mainland', because the abundance and availability of cloud-free imagery was disparate between the two regions. The data available for Kayak Island included Quickbird 2 and Landsat 5 Thematic Mapper (TM) imagery, while the remaining project area utilized Level 1A SPOT 5 imagery (from the Statewide Digital Mapping Initiative project, University of Alaska, Fairbanks), Landsat 5 TM satellite imagery, and high resolution (60 cm) aerial imagery. Multiple sources of imagery were used to maximize the range of data used in the computational models to capitalize on the unique information strengths afforded the different sensors.

Utilization of imagery acquired throughout the growing season also captured the phenological variations in vegetation to better distinguish between vegetation types.

The SPOT and Landsat imagery was processed to remove clouds which obscure ground objects. Multiple images from each sensor were mosaicked together to patch areas of cloud or aggregate adjacent image swaths to cover the entire study area. Spectral indices such as the Normalized Difference Vegetation Index (NDVI), the Tasseled Cap transformation, and Principle Component Analysis (PCA) were produced from the mosaicked images.

Elevation data for the entire study area was derived from a 20 m digital surface model (DSM) acquired by the SPOT 5 High Resolution Stereoscopic (HRS) imaging instrument. Topographic derivatives including slope, aspect, heat load, and hillshade were produced. These biophysical variables depict environmental parameters that can help distinguish land cover types in the mapping process.

All data layers were co-registered and projected to UTM, NAD83, Zone 6 North. The data were resampled to 5 m to maintain consistency in spatial resolution accross all data layers. A complete list of geospatial data used in the project can be found in table 1.

## Image Segmentation

The goal of image segmentation is to develop homogenous mapping polygons to serve as the elemental modeling entities for the classification process. A multi-resolution image segmentation was performed using a combination of raw spectral bands, spectral derivatives, and DSM elevation data in the Trimble eCognition software suite (figure 2).

Most polygons for the mainland were derived using 60 cm resource imagery. SPOT 5 imagery was used to segment areas of the mainland obscured by clouds. A combination of Quickbird 2 and Landsat 5 TM imagery was used to segment Kayak Island. The 60 cm resource imagery and the Quickbird 2

**Table 1—List of spectral, topographic and ancillary data layers used in the mapping process**

| Spectral Data | Data Source |
|---|---|
| Resource Imagery: Blue, Green, Red, Near Infrared (NIR) | 60 cm Resource Imagery (Aug-Sep 2010) |
| SPOT 5 Pansharpened Bands: Blue, Green, Red, NIR | 5 m Pansharpened SPOT 5 Imagery (June 2009-Aug 2011) |
| SPOT 5 Derivatives: NDVI, Principle Components 1 & 2, Tasseled Cap Transformation | |
| Landsat 5 Raw Bands: Blue, Green, Red, NIR, NIR2, Middle Infrared (MIR) | 30 m Landsat 5 TM Image (Path 65/Row18–09/02/2010) |
| Landsat 5 Derivatives: NDVI, Principle Components 1 &2, Tasseled Cap Transformation | |
| Quickbird 2 Raw Bands: Blue, Green, Red, NIR | 2.4 m Quickbird 2 Imagery (08/27/2005) |
| Quickbird 2 Derivatives: NDVI, Principle Components 1 &2 | |
| **Topographic Data** | **Data Source** |
| Elevation<br>Aspect (8-direction)<br>Aspect (Cosine Transformation)<br>Aspect (Sin Transformation)<br>Slope (Degrees)<br>Focal Division<br>Heatload<br>Hillshade<br>Slope Position<br>Solar Index | 20 m Digital Surface Model |
| **Ancillary Data** | **Data Source** |
| Geology | 10 m Geology Data |
| Ecological Unit Inventory | 10 m Ecological Unit Inventory Data |

Note: The image acquisition dates are shown in parentheses.

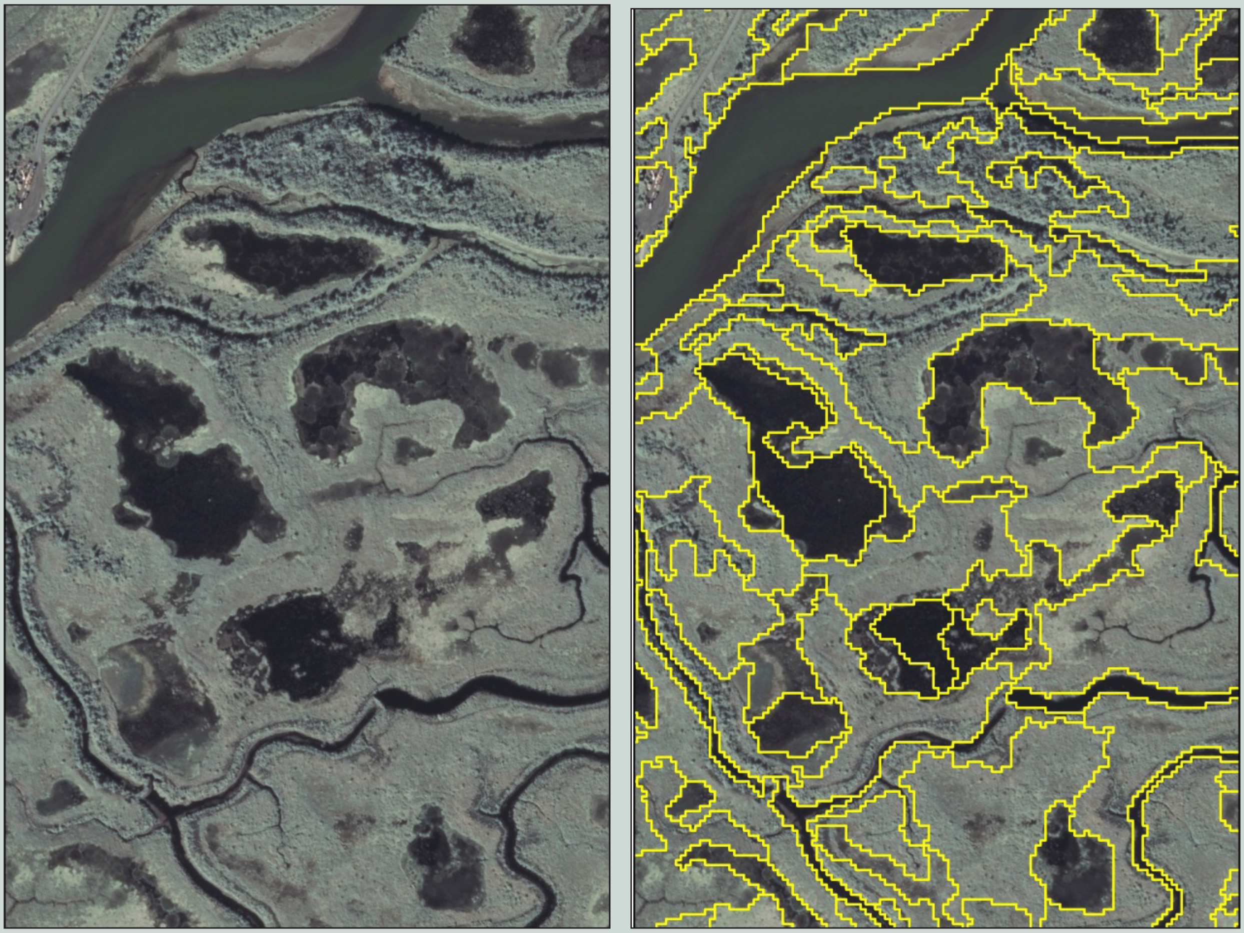

**Figure 2—Example of the segments generated using Trimble eCognition software. This is a snapshot of the 60 cm resource imagery from a Copper River access point on Alaganik Slough *(left)* and overlaid with segments *(right).***

imagery were resampled to 5 m to make data processing more efficient and avoid over-segmenting the complex Copper River Delta landscape.

A quarter-acre filter was used to limit the polygon size to ≥ 0.25 acres. This step eliminated segments too small to accurately model. Most segments were less than 5 acres in size and the median segment size was 1.85 acres. Many segments in the Gulf of Alaska and the Copper River were merged to create a single water polygon that encompassed most of the water within the Copper River Delta project boundary. This dramatically decreased the total number of segments and lessened computer processing times without losing meaningful delineations.

## Reference Data Collection

Vegetation data was collected for preselected reference sites by the Chugach National Forest, Alaska Regional Office, RSAC, and Ducks Unlimited. A total of 479 sites were visited on the ground or observed up close from a helicopter during the summer of 2010. These sites were located in relatively homogenous areas based on an unsupervised spectral stratification of the SPOT 5 imagery using the ISODATA clustering algorithm. Each reference site was a single segment that was evaluated to determine the land cover label.

An ocular estimate of absolute canopy cover was collected for individual plant species contained within each reference site. These estimates were made from a 'birds-eye' perspective to mimic the perspective of a remote sensing instrument from above, discounting vegetation that is overtopped. Total absolute cover for each site equaled 100 percent. Field information was recorded (see appendix A) and a dominance type was determined using a dichotomous key (see appendix B). The dichotomous key, developed specifically for the Copper River Delta mapping project, contained discrete decision rules based on absolute and relative cover percentages that determined a mutually exclusive dominance type. Only mapping polygons containing >10 percent vegetation cover were considered vegetated and assigned a vegetation dominance type. Those reference sites containing less than 10 percent vegetation cover were assigned a non-vegetated land cover class. Because of accessibility and time constraints, limited field data collection occurred on Kayak Island.

Additional sites were photo interpreted to supplement the reference dataset. The photo interpreted sites were assigned a land cover type without specific species canopy cover information. These sites were placed in areas that had limited field access, such as Kayak Island, or in land cover classes that lacked sufficient samples.

All reference data were reviewed for accuracy and quality using the 60 cm resource imagery . Ultimately, several dominance types were merged or eliminated due to their limited occurrence on the landscape (table 2).

## Classification

Random forest was used to assign land cover classes to the mapping polygons. Random forest is an ensemble classifier that uses the plurality of class predictions from a multitude of decision trees for class assignment (Breiman, 2001; Cutler and others 2007).

Initially, a separability analysis was performed to indicate which classes were most distinguishable. This informed a mapping hierarchy that grouped classes based on data similarity (figure 3). The most discernible classes were mapped first, while classes that were more difficult to separate were grouped together and subsequently modeled further down the hierarchy.

The model outputs were iteratively evaluated using photo interpretation at each stage of the hierarchy to avoid unnecessary confusion that would reduce map accuracy. This enabled editing at grosser levels to reduce confusion and improve overall accuracy. The first level of the mapping hierarchy separated vegetation from the non-vegetated classes (snow/ice, sparse/unvegetated, and water). Vegetation was subsequently further divided until all

**Table 2—List of the final map classes and the associated dominance types**

| Dominance Type (DT) | Determination | Final Map Classes |
|---|---|---|
| Western Hemlock<br>Mountain Hemlock | MERGED<br>MERGED | Western Hemlock |
| Sitka Spruce | OK | Sitka Spruce |
| Sitka Spruce – Dwarf Tree | OUT | |
| Black Cottonwood | OK | Black Cottonwood |
| Sitka Spruce – Black Cottonwood | OK | Sitka Spruce – Black Cottonwood |
| Sitka Alder | OK | Sitka Alder |
| Willow | OK | Willow |
| Sitka Alder – Willow Mix | OK | Sitka Alder – Willow Mix |
| Sweetgale | OK | Sweetgale |
| Crowberry | OUT | |
| Dry Graminoid | OK | Dry Graminoid |
| Wet Graminoid<br>Mesic Graminoid<br>Wet Forb<br>Mesic Forb | MERGED<br>MERGED<br>MERGED<br>MERGED | Mesic Wet Herbaceous |
| Dry Forb | OUT | |
| Aquatic Herbaceous | OK | Aquatic Herbaceous |
| Sparse/Unvegetated | OK | Sparse/Unvegetated |
| Water | OK | Water |
| Snow/Ice | OK | Snow/Ice |
| Developed | OK | Developed |

Note: Dominance types were determined to be ‘OK’, ‘OUT’, or ‘MERGED’. Dominance types determined to be: ‘OK’ were unchanged and represented by a single map class; ‘OUT’ were not mapped and their corresponding reference sites were not used in the classification; or ‘MERGED’ were combined into a single map class. The unclassified dominance types found in the dichotomous key were excluded from this list because they were eliminated from the final map class list and did not commonly occur.

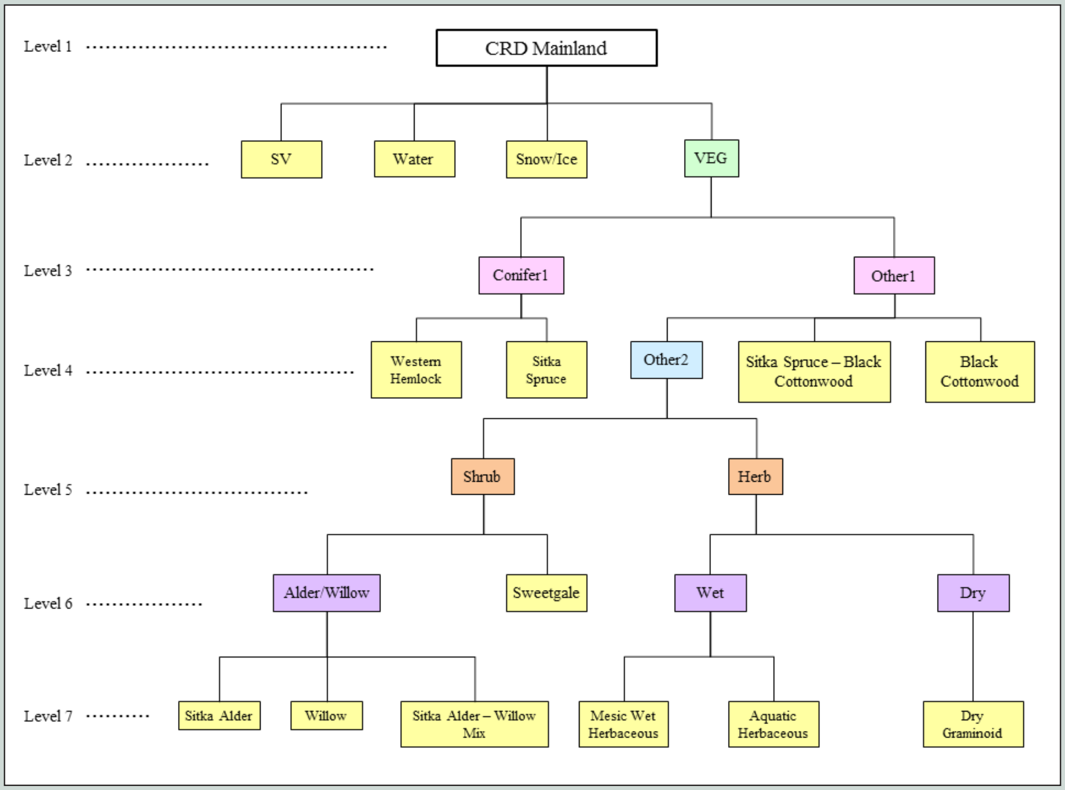


**Figure 3—Illustration of the mapping hierarchy that was used for the Copper River Delta mainland modeling process, excluding the developed class. Note that final map classes are shown in yellow boxes.**

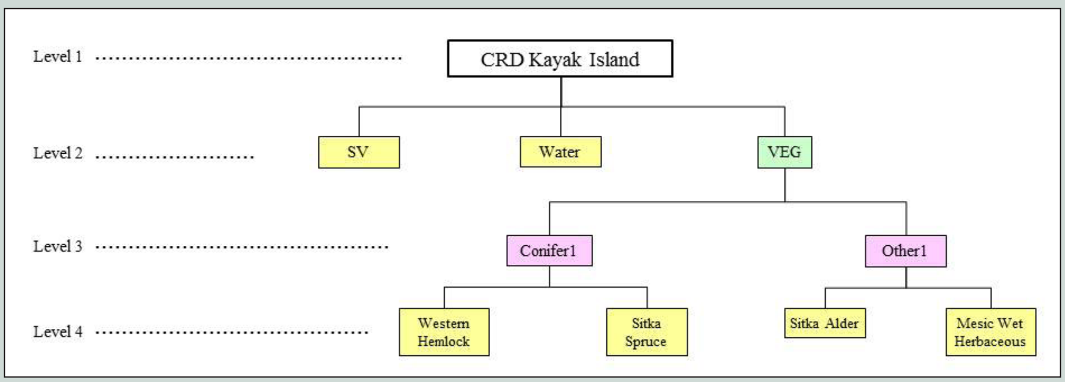


**Figure 4—Illustration of the mapping hierarchy that was used for the Copper River Delta Kayak Island modeling process. Note that final map classes are shown in yellow boxes. Fewer dominance types were found on Kayak Island, therefore the classification hierarchy was comparatively simpler than the mainland.**

classes were mapped. Additional reference sites were added at each hierarchical level to improve modeling results by both increasing the spatial distribution and total amount of training data.

The process of rerunning random forest models at each level of the mapping hierarchy optimized results. This iterative method of model improvement was especially important at higher levels of the modeling hierarchy. By mapping the broad vegetation classes first, obvious lifeform errors could be corrected early in the modeling process since misclassification at higher levels of the hierarchy persist throughout the classification. The developed class was added to the map manually since the project area contained little permanent infrastructure.

Kayak Island was modeled separately from the rest of the Copper River Delta (figure 4). This was done because the data available to each area were disparate and because Kayak Island lacked the vegetation diversity found elsewhere in the project area.

The draft version of the Copper River Delta land cover map was developed by aggregating the classification results from the interim hierarchical map outputs.

## Draft Map Review and Revision

A draft map was provided to local and regional experts for review. This was an opportunity for resource specialists to assess the map and provide critical feedback. Once comments were received, suggested changes were incorporated into the map. Areas of misclassification were either corrected by remodeling with additional reference sites or by incorporating manual edits directly into the map.

## Final Map Production

Once recommended changes and manual edits were incorporated, the final land cover map was assembled. The final map contained 15 land cover classes: 4 forest, 4 shrub, 3 herbaceous, and 4 non-vegetated classes (figure 5). Of the total 1,179,356 acres, (table 3) 32 percent was mapped as water and 69 percent was mapped as land. Of the mapped land area, 28 percent was forest, 41 percent shrubland, 16 percent herbaceous, and 15 percent was mapped as other, which included sparse/unvegetated, snow/ice, and developed areas.

# Accuracy Assessment

An accuracy assessment was conducted to validate the final map and reveal details of individual class confusion. Photo interpretation was used to collect the accuracy assessment data. A stratified random sample, using the draft land cover map, was performed to select 452 accuracy assessment sites (figure 6). This ensured that an adequate number of samples (32 per class) were collected in each map class. This however did not guarantee a balanced sample because sites were selected from a draft version of the map, which was edited further before being finalized. In addition, the developed class was not evaluated because of its limited spatial extent and the snow/ice class was merged with the sparse/unvegetated class for accuracy assessment purposes only.

A caveat exists when using photo interpreted data for validation purposes because there is an increased level of uncertainty associated with these data as compared to using data that has been ground verified. Given that the accuracy assessment protocol treats these data as truth, inherent error in photo interpretation must be considered when evaluating the results.

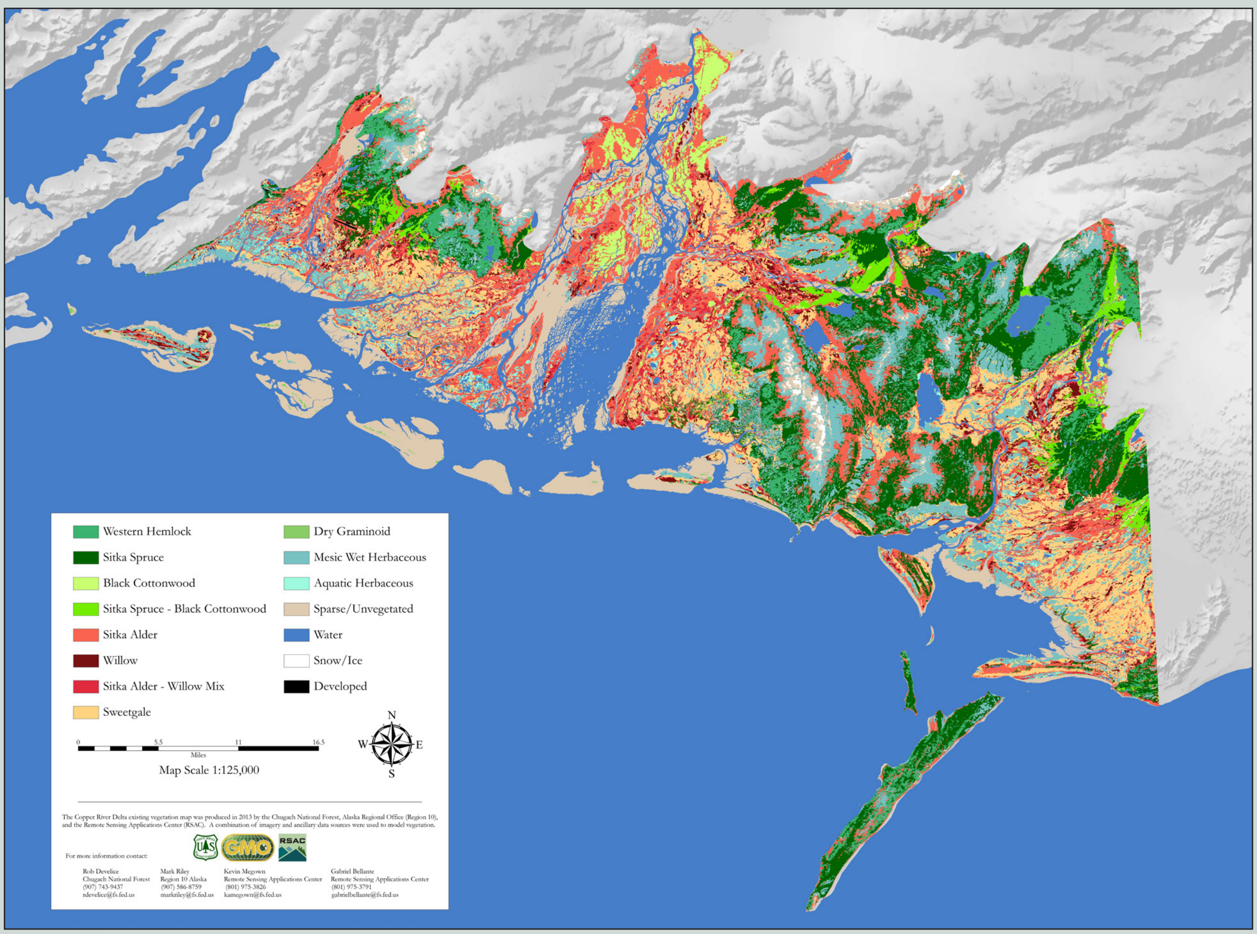


**Figure 5—Final Copper River Delta vegetation map.**

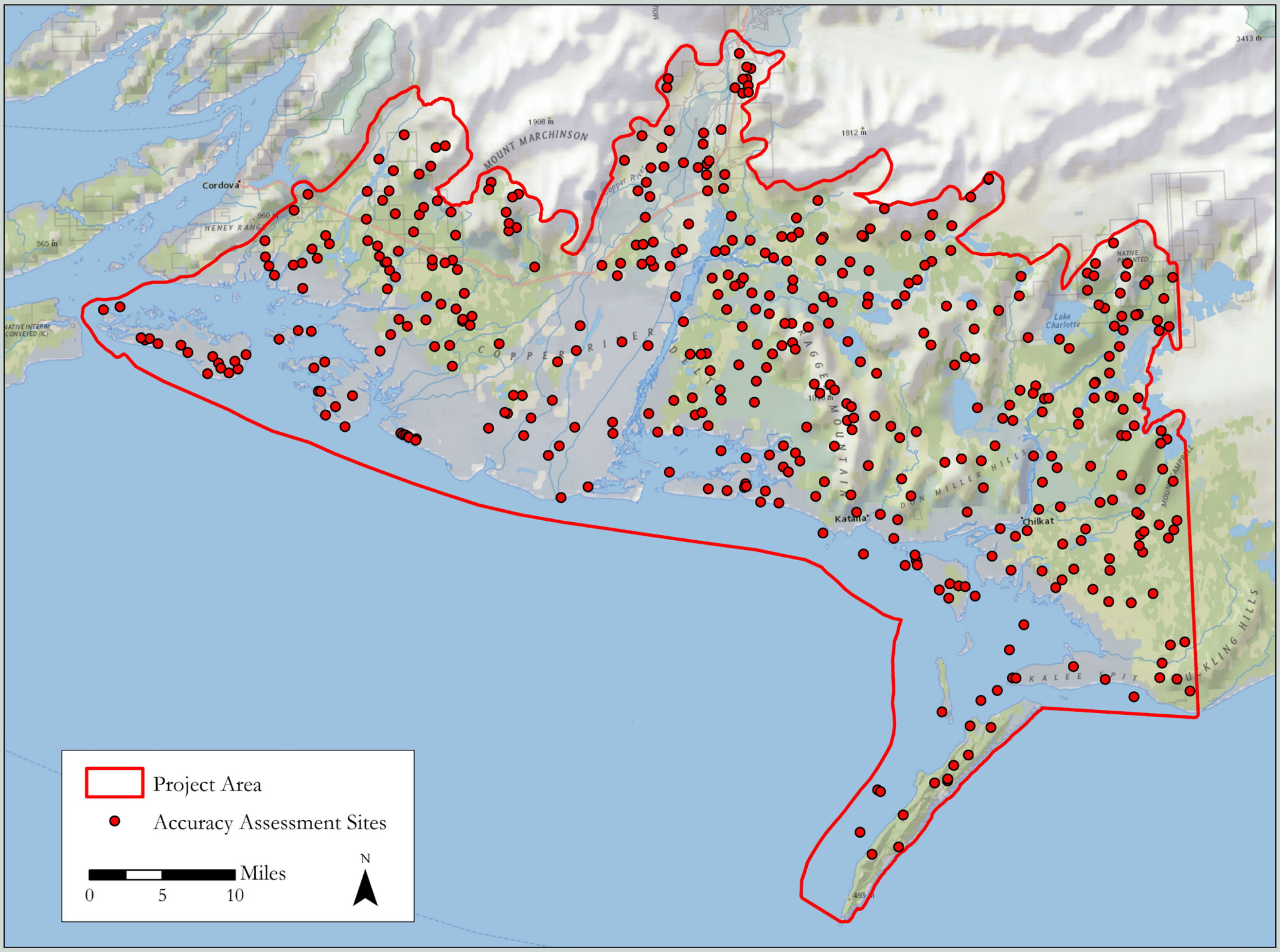


**Figure 6—Copper River Delta mapping project area and the locations of the accuracy assessment sites.**

**Table 3—Total acreages for the different land cover type classes mapped for the Copper River Delta**

| Lifeform | Area (ac) | % Area | % Land Area | Map Class | Area (ac) | % Area | % Land Area |
|---|---|---|---|---|---|---|---|
| Forest | 222,395 | 19% | 28% | Western Hemlock | 48,572 | 4.12% | 6.08% |
| | | | | Sitka Spruce | 129,969 | 11.02% | 16.28% |
| | | | | Black Cottonwood | 23,149 | 1.96% | 2.90% |
| | | | | Sitka Spruce - Black Cottonwood | 20,705 | 1.76% | 2.59% |
| Shrub | 323,190 | 27% | 41% | Sitka Alder | 174,395 | 14.79% | 21.84% |
| | | | | Willow | 20,578 | 1.74% | 2.58% |
| | | | | Sitka Alder - Willow Mix | 21,759 | 1.84% | 2.73% |
| | | | | Sweetgale | 106,458 | 9.03% | 13.33% |
| Herbaceous | 129,281 | 11% | 16% | Dry Graminoid | 1,201 | 0.10% | 0.15% |
| | | | | Mesic Wet Herbaceous | 115,653 | 9.81% | 14.49% |
| | | | | Aquatic Herbaceous | 12,427 | 1.05% | 1.56% |
| Other | 504,490 | 43% | 15% | Sparse/Unvegetated | 119,704 | 10.15% | 14.99% |
| | | | | Water | 380,953 | 32.30% | N/A |
| | | | | Snow/Ice | 3,467 | 0.29% | 0.43% |
| | | | | Developed | 366 | 0.03% | 0.05% |
| Total | 1,179,356 | 100% | 100% | Total | 1,179,356 | 100.00% | 100.00% |

## Procedures

Each accuracy assessment site was assigned a map class using the dichotomous key (appendix B). The dichotomous key contained discrete rules that distinguished map classes by using specific cover thresholds. Determining a land cover type was sometimes difficult, especially when the vegetation cover approached the thresholds that distinguish one class from another. To address this issue an optional field was included that allowed photo interpreters to make a second map class call if necessary. The second call was used in conjunction with the primary class designation to produce a 'fuzzy' accuracy assessment which considered both the first and second calls correct.

The water class required additional processing because during the segmentation a single polygon containing much of the water class was produced. This segment was very large and included a portion of the Gulf of Alaska and the Copper River. The random sites that fell within this area were buffered out 100 m to provide a reasonable area to assess. Otherwise, all other accuracy assessment sites were evaluated using the original mapping polygons.

Once photo interpretation of the accuracy assessment sites was completed, the sites were intersected with the final Copper River Delta map to obtain the associated map class labels. The map labels for the accuracy assessment sites were then cross-referenced with the photo interpretation calls to produce the error matrices (tables 4, 5 and 6).

## Results

Overall accuracy for the final Copper River Delta map product was 82 percent for the 1st call error matrix (table 4) and 87 percent for the fuzzy error matrix (table 5). The map achieved a 91 percent overall accuracy at the lifeform level using the 1st call assessment data (table 6). Of the 452 accuracy assessment sites, the photo interpreters made second calls on 112 of them. Only 24 of these sites contributed to improving the accuracy of the map when using the fuzzy method, meaning that the second call agreed with the map while the primary call disagreed.

The overall accuracy measures the proportion of sites classified correctly to the total number of sites assessed multiplied by an area-weight factor. Individual class accuracies can also be computed. There are two ways to analyze individual class accuracy: 1) producer's accuracy, which is the proportion of sites correctly mapped for that class to the total number of sites of that class as determined by the reference data, i.e. the column total; and 2) user's accuracy, which is the proportion of sites correctly mapped for that class to the total number of sites assigned that particular class, i.e. the row total (Congalton 1991).

Producer's accuracy provides a measure of omission error that describes the probability that an area on the ground is mapped correctly. User's accuracy provides a measure of commission error that describes the probability that a mapped class actually represents what is on the ground. For example, the western hemlock class has a high producer's accuracy (88 percent), but has a low user's accuracy (45 percent). This indicates that western hemlock was over-mapped, mainly because areas of sitka spruce were being mapped as western hemlock (table 4). Studying the error matrices can provide insight not only into the reliability of an individual map class but also into how and where confusion occurs.

Classes with low accuracies may still provide important spatial information regarding vegetation assemblages of interest. Correct interpretation of the error matrices allows a user to apply expert knowledge of known plant associations in order to discriminate between errors caused by completely erroneous classifications and those that were logical confusions. For example, a site misclassified as willow when the reference data indicate it was sweetgale, does not mean that the site does not contain willow. Local ecology informs us that willow is commonly found to mix with sweetgale. Therefore, depending on the user's needs, there may be valuable information contained within those classes that have low accuracy. These confusions are common when you apply discrete decision rules, like that of the dichotomous key, to a continuous landscape that contains transition zones and coexistence of species found in different map classes. Therefore, although critical thinking may be necessary to tease out meaningful information, individual class accuracy numbers do not tell the whole story.

Overall map accuracy is dependent on the distribution of the accuracy assessment sites. Since a stratified sampling design was implemented to adequately sample each cover type the distribution of assessment sites did not correspond to the relative proportions of the cover types found across the study area. This meant that overall accuracy could be disproportionately influenced by rarer class accuracies because each class had approximately the same number of observations. To account for this, overall area-weighted accuracies were calculated by taking the proportion of correctly classified accuracy assessment sites for each class (the individual class user's accuracies) and multiplying them by the proportion of the total area that class occupies on the final map (the area weight factor) (table 7 and 8). The overall area-weighted accuracies were 82 percent and 87 percent for the first call and the fuzzy assessments, respectively. Although there are caveats associated with each accuracy measure, this method accounts for the relative proportions of the individual classes on the final map.

Table 4—Error matrix for the final Copper River Delta map when using the first call only

| | First Call Accuracy Assessment | Reference Data | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Western Hemlock | Sitka Spruce | Black Cottonwood | Sitka Spruce–Black Cottonwood | Sitka Alder | Willow | Sitka Alder–Willow Mix | Sweetgale | Dry Graminoid | Mesic Wet Herbaceous | Aquatic Herbaceous | Sparse/ Unvegetated | Water | Row Total | User's Accuracy |
| Map Data | Western Hemlock | **14** | 15 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 45% |
| | Sitka Spruce | 1 | **37** | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42 | 88% |
| | Black Cottonwood | 0 | 0 | **30** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 31 | 97% |
| | Sitka Spruce–Black Cottonwood | 0 | 11 | 0 | **13** | 8 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 33 | 39% |
| | Sitka Alder | 0 | 1 | 0 | 0 | **25** | 1 | 4 | 3 | 0 | 1 | 0 | 0 | 0 | 35 | 71% |
| | Willow | 0 | 0 | 0 | 0 | 2 | **9** | 0 | 8 | 0 | 7 | 0 | 0 | 0 | 26 | 35% |
| | Sitka Alder–Willow Mix | 0 | 1 | 0 | 0 | 6 | 0 | **16** | 7 | 0 | 0 | 0 | 0 | 0 | 30 | 53% |
| | Sweetgale | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **38** | 0 | 3 | 0 | 0 | 0 | 42 | 90% |
| | Dry Graminoid | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | **29** | 1 | 0 | 0 | 0 | 31 | 94% |
| | Mesic Wet Herbaceous | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | **30** | 0 | 1 | 0 | 38 | 79% |
| | Aquatic Herbaceous | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | **21** | 0 | 0 | 25 | 83% |
| | Sparse/ Unvegetated | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 3 | 0 | **48** | 0 | 53 | 91% |
| | Water | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | **32** | 35 | 91% |
| | Column Total | 16 | 65 | 32 | 16 | 44 | 12 | 22 | 59 | 33 | 48 | 24 | 49 | 32 | 452 | |
| | Producer's Accuracy | 88% | 57% | 94% | 81% | 57% | 75% | 73% | 64% | 88% | 63% | 87% | 98% | 100% | | |
| | Overall Area-Weighted Accuracy | 82% | | | | | | | | | | | | | | |

**Table 5—Error matrix for the final Copper River Delta map when using the first and second call (when available)**

| | Fuzzy Accuracy Assessment | Reference Data | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Western Hemlock | Sitka Spruce | Black Cottonwood | Sitka Spruce-Black Cottonwood | Sitka Alder | Willow | Sitka Alder-Willow Mix | Sweetgale | Dry Graminoid | Mesic Wet Herbaceous | Aquatic Herbaceous | Sparse/ Unvegetated | Water | Row Total | User's Accuracy |
| Map Data | Western Hemlock | **17** | 12 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 55% |
| | Sitka Spruce | 0 | **39** | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42 | 93% |
| | Black Cottonwood | 0 | 0 | **30** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 31 | 97% |
| | Sitka Spruce–Black Cottonwood | 0 | 7 | 0 | **18** | 7 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 33 | 55% |
| | Sitka Alder | 0 | 1 | 0 | 0 | **28** | 1 | 2 | 2 | 0 | 1 | 0 | 0 | 0 | 35 | 80% |
| | Willow | 0 | 0 | 0 | 0 | 2 | **12** | 0 | 6 | 0 | 6 | 0 | 0 | 0 | 26 | 46% |
| | Sitka Alder–Willow Mix | 0 | 1 | 0 | 0 | 4 | 0 | **18** | 7 | 0 | 0 | 0 | 0 | 0 | 30 | 60% |
| | Sweetgale | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **38** | 0 | 3 | 0 | 0 | 0 | 42 | 90% |
| | Dry Graminoid | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | **30** | 0 | 0 | 0 | 0 | 31 | 97% |
| | Mesic Wet Herbaceous | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 3 | **31** | 0 | 1 | 0 | 38 | 82% |
| | Aquatic Herbaceous | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | **22** | 0 | 0 | 25 | 88% |
| | Sparse/ Unvegetated | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | **50** | 0 | 53 | 94% |
| | Water | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | **33** | 35 | 94% |
| | Column Total | 18 | 60 | 32 | 21 | 43 | 15 | 22 | 55 | 34 | 44 | 24 | 51 | 33 | 452 | |
| | Producer's Accuracy | 94% | 65% | 94% | 86% | 65% | 80% | 82% | 69% | 88% | 70% | 91% | 98% | 100% | | |
| | Overall Area-Weighted Accuracy | 87% | | | | | | | | | | | | | | |

**Table 6—Error matrix, at the lifeform level, for the final Copper River Delta map when using the first call only**

| First Call Map Group Accuracy Assessment | Reference Data | | | | | | |
|---|---|---|---|---|---|---|---|
| | Forest | Shrub | Herb | Other | Row Total | User's Accuracy | Area Weight Factor |
| Forest | **126** | 11 | 0 | 0 | 137 | 92% | .1886<br>17.35 |
| Shrub | 2 | **120** | 11 | 0 | 133 | 90% | .2740<br>24.72 |
| Herb | 1 | 5 | **87** | 1 | 94 | 92% | .1096<br>10.14 |
| Other | 0 | 1 | 7 | **80** | 88 | 91% | .4274<br>38.85 |
| Column Total | 129 | 137 | 105 | 81 | 452 | | |
| Producer's Accuracy | 98% | 88% | 83% | 99% | | | |
| Overall Area-Weighted Accuracy | 91% | | | | | | |

## Conclusion

The final Copper River Delta land cover map has an overall accuracy of 82 percent. Due to the level of class complexity and the accuracies achieved, the information depicted on the Copper River Delta map exceeds that of the National Land Cover Dataset (NLCD) and Landfire products. Additionally, the map's precision and finer spatial resolution exceeds prior mapping efforts.

Although this map achieved relatively high accuracies, there were data limitations and other factors that made this project challenging. Low sun angles, even in summer, in northern latitudes increase shadows and limits the amount of light energy reflected from earth objects for detection by remote sensors. The climate of Southcentral Alaska makes obtaining cloud-free imagery difficult, especially when data acquisition has seasonal constraints and imaging sensors have infrequent revisit schedules. Additionally, full-coverage, cloud-free, high resolution data (10 m or finer) is extremely challenging to obtain because these sensors have a relatively narrow swath width. Even though this product utilized 30 m Landsat data, a more resolute product was achieved because of the concomitant usage of higher resolution data (e.g. 60 cm resource imagery and 5 m pansharpened SPOT 5 data) and rigorous manual editing.

This final map product provides a reasonable depiction of existing vegetation within the Copper River Delta for the 2009–2010 timeframe that can be used to assist resource specialists and land managers in project-level planning. This product was made possible through a collaborative team effort that took dedicated work over a span of several years and developed methods that would contribute to a more efficient workflow for future mapping efforts for the Chugach National Forest. Upon completion of the final map, Interferometric Synthetic Aperture Radar (IfSAR) data was obtained for the complete Copper River Delta project area. Future work may include investigations using the 5 m IfSAR data to develop a canopy height model that could be useful to resource managers.

**Table 7— Individual area weighted class contributions to overall map accuracy using the first call assessment**

| First Call | | | |
|---|---|---|---|
| Map Class | Area Weight Factor | User's Accuracy | Weighted User's Accuracy Contribution |
| Western Hemlock | 0.0412 | 45% | 0.019 |
| Sitka Spruce | 0.1102 | 88% | 0.097 |
| Black Cottonwood | 0.0196 | 97% | 0.019 |
| Sitka Spruce - Black Cottonwood | 0.0176 | 39% | 0.007 |
| Sitka Alder | 0.1479 | 71% | 0.106 |
| Willow | 0.0174 | 35% | 0.006 |
| Sitka Alder - Willow Mix | 0.0184 | 53% | 0.010 |
| Sweetgale | 0.0903 | 90% | 0.082 |
| Dry Graminoid | 0.0010 | 94% | 0.001 |
| Mesic Wet Herbaceous | 0.0981 | 79% | 0.077 |
| Aquatic Herbaceous | 0.0105 | 83% | 0.009 |
| Sparse/Unvegetated | 0.1044 | 91% | 0.095 |
| Water | 0.3230 | 91% | 0.295 |
| Overall Area-Weighted Accuracies | | | 0.821*100 = 82% |

**Table 8— Individual area weighted class contributions to overall map accuracy using the fuzzy assessment**

| Fuzzy | | | |
|---|---|---|---|
| Map Class | Area Weight Factor | User's Accuracy | Weighted User's Accuracy Contribution |
| Western Hemlock | 0.0412 | 55% | 0.023 |
| Sitka Spruce | 0.1102 | 93% | 0.102 |
| Black Cottonwood | 0.0196 | 97% | 0.019 |
| Sitka Spruce - Black Cottonwood | 0.0176 | 55% | 0.010 |
| Sitka Alder | 0.1479 | 80% | 0.118 |
| Willow | 0.0174 | 46% | 0.008 |
| Sitka Alder - Willow Mix | 0.0184 | 60% | 0.011 |
| Sweetgale | 0.0903 | 90% | 0.082 |
| Dry Graminoid | 0.0010 | 97% | 0.001 |
| Mesic Wet Herbaceous | 0.0981 | 82% | 0.080 |
| Aquatic Herbaceous | 0.0105 | 88% | 0.009 |
| Sparse/Unvegetated | 0.1044 | 94% | 0.098 |
| Water | 0.3230 | 94% | 0.305 |
| Overall Area-Weighted Accuracies | | | 0.866*100 = 87% |

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# Appendix A: Landcover Mapping Field Form

Field form that was used during 2010 field campaign in which reference sites were either collected on the ground or from a helicopeter.

Rev 8/15/200 7

**Copper River Delta Landcover Mapping Field Form**

| | | | | |
|---|---|---|---|---|
| ___-___-__-_________ Site Number | ___ /___ Nav. / Veg. | Obs. Date: /_ _/ | 1 2 3 4 Obs. Level | Obs.T ime:_____ :_____ Hr Min |
| Photo ______ -______________ __ Session Photo# s | Datum:________ LAT (GPS) __________ .__________ Decimal Degrees | | LONG (GPS) __________ .__________ Decimal Degrees | |

%Slope :______ Aspect: _________ Landcover Class: ___________________________

NOTES: ___________________________________________________________________________
(disturbance, wildlife, human activity, storm lines, mosaic/pattern, peat, permafrost, other interesting observations)

____________ ____________________________________________________________________

| %Cov | Height | **TREES subtotal % cover** |
|---|---|---|
| | | Picea sitchensis |
| | | Tsuga heterophylla / mert. |
| | | Chamaecyparis nootkatensis |
| | | Thuja plicata |
| | | Pinus contorta |
| | | Populus balsamifera |
| | | Alnus Rubra |
| | | |

| %Cov | Height | **SHRUB subtotal % cover** |
|---|---|---|
| | | Alnus spp . |
| | | Rubus spectabilis / parviflorus |
| | | Oplopanax horridus |
| | | Sambucus racemosa |
| | | Menziesia ferruginea |
| | | Vaccinium spp. |
| | | Salix spp. |
| | | Cladothamnus pyroliflorus |
| | | Rosa nutkana |
| | | Myrica gale |
| | | Andromeda polifolia |
| | | Cornus stolonifera |
| | | |
| | | |

**HERBACEOUS**

| %Cov | **FORB subtotal % cover** |
|---|---|
| | Epilobium angustifolium |
| | Equisetum spp. |
| | Atherium filix -femina |
| | Fern spp. |
| | Lysichiton americanus |
| | |
| | |
| | |
| | |

**HERBACEOUS (conÕ)**

| %Cov | **Graminoids** |
|---|---|
| | **Wet Graminoids subtotal % cover** |
| | Carex lyngbyei |
| | Carex spp. |
| | Eleocharis spp. |
| | |
| | |
| | |
| | **Mesic/Dry Graminoids subtotal %** |
| | Calamagrostis canadensis |
| | Leymus mollis |
| | Carex spp. |
| | Grass spp. |
| | |
| | |

| %Cov | **AQUATIC / OTHER subtotal % cover** |
|---|---|
| | Equisetum palustre/fluviatile |
| | Myriophyllum spp. |
| | Menyanthes trifoliata |
| | Nuphar polysepalum |
| | Potentilla palustris |
| | |
| | **Non-vascular Subtotal % Cover** |
| | Moss ÐSphagnum / Other |
| | Lichen |

| %Cov | **NON-VEGETATED subtotal % cover** | |
|---|---|---|
| | Clear/Turbid Water | (circle one) |
| | Mud/Silt/Sand | (circle one) |
| | Gravel/Rock | (circle one) |
| | Litter | |
| | | |

| | |
|---|---|
| | **GRAND TOTAL % COVER** |

# Appendix B: Key to Identify Vegetation Dominance

Dichotomous key used to classify the dominance type of terrestrial polygons. Note that the Snow/Ice class was an added class to the map after field data collection and the Developed class was manually edited in, therefore the dichotomous key did not include them.

**Dichotomous Key to Copper River Delta Dominance Types v. 7/13/10**[1]

**Instructions**

1. Use this key for identifying vegetation dominance types on the Copper River Delta.

2. Locate a representative portion of the site in question. The vegetation and environment within the site should be relatively homogeneous.

3. Estimate the canopy cover for all indicators. The indicators are those species, species groups, taxonomic aggregates, or life form groups used in the key.

4. While in the plot, use the key literally to identify the community type. Start with the "Key to Life Form Groups," couplet number 1.

**Key to Life Form Groups**

1. Dwarf trees, typically less than 25 feet tall, with a cover of at least 10 percent and peat soils present; **caution:** seedling and sapling trees are not dwarf trees . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **Sitka Spruce dwarf tree d.t.**

   *Picea sitchensis/Sphagnum* (Sitka spruce/peat moss) c.t.

1. Dwarf trees with a cover of less than 10 percent and peat soils absent . . . . . . . . . . . . . . . . . . 2

2. Tree species with a combined cover of at least 25 percent or *Populus trichocarpa* (black cottonwood) with a cover of at least 10 percent. . . . . . . . . . . . . . . . . . **Tree Dominance Types**

2. Trees with a cover of less than 25 percent and *Populus trichocarpa* (black cottonwood) with a cover of less than 10 percent. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .3

3. Erect or decumbent shrubs with a combined cover of at least 25 percent . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **Shrub Dominance Types**

3. Erect or decumbent shrubs with a combined cover of less than 25 percent . . . . . . . . . . . . . . . 4

4. Herbaceous species with a combined cover of at least 15 percent . . . . . . . . . . . . . . . . . . . . . . . .

1 Derived from Boggs (2000, see his "Key to Community Types") as described in the Copper River Delta vegetation mapping study plan (v. 3.26.09, see Table 2 of that document) and as summarized in the classification key to dominance types (v. 4/14/10). Two alternatives leading to the Sitka Alder and the Willow dominance types are included (one derived from Boggs 2000—the other from interest in splitting-out a Mixed Sitka Alder-Willow dominance type.

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**Herbaceous Dominance Types**

4. Herbaceous species absent or present with a combined cover of less than 15 percent . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **Sparse/Unvegetated d.t.**

    *Mudflats, Sand dunes, or Beaches, Rock, Gravel, Snow/Ice, Bare Ground*

**Key to Tree Dominance Types**

Trees species with a combined cover of at least 25 percent or *Populus trichocarpa* (black cottonwood) with a cover of at least 10 percent.

1. *Tsuga heterophylla* (western hemlock) with at least 50 percent of the total tree cover . . . . . . . . .. . . . . . . . . . . .. . . . . . . . . . . .. . . . . . . . . . . .. . . . . . . . . . . .. . . . . . . . **Western Hemlock d.t.**

    *Tsuga heterophylla/Echinopanax horridum* (western hemlock/devil's club) c.t.

    *Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry) c.t.

    *Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum* (western hemlock/tall blueberry-devil's club) c.t.

    *Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum* (western hemlock/tall blueberry/yellow skunk cabbage) c.t.

    Unclassified *Tsuga heterophylla* (western hemlock) communities

1. *Tsuga heterophylla* (western hemlock) with less than 50 percent of the total tree cover. . . .. . . 2

2. *Picea sitchensis* (Sitka spruce) with at least 50 percent of the total tree cover . . . . . . . . . . . . . . . . . . . . . . . . . . .. . . . . . . . . . . .. . . . . . . . . . . .. . . . . . . . . . . .. . . . . . . . . . . . . . **Sitka Spruce d.t.**

    *Picea sitchensis/*bryophyte (Sitka spruce/bryophyte) c.t.

    *Picea sitchensis/Alnus crispa* (Sitka spruce/Sitka alder) c.t.

    *Picea sitchensis/Echinopanax horridum* (Sitka spruce/devil's club) c.t.

    *Picea sitchensis/Rubus spectabilis* (Sitka spruce/salmonberry) c.t.

    *Picea sitchensis/Vaccinium ovalifolium* (Sitka spruce/tall blueberry) c.t.

    *Picea sitchensis/Vaccinium ovalifolium-Echinopanax horridum* (Sitka spruce/tall blueberry-devil's club) c.t.

    *Picea sitchensis/Vaccinium ovalifolium/Lysichiton americanum* (Sitka spruce/tall blueberry/yellow skunk-cabbage) c.t.

    Unclassified *Picea sitchensis* (Sitka spruce) communities

2. *Picea sitchensis* (Sitka spruce) with less than 50 percent of the total tree cover . . . . . . . . . . . 3

3. *Populus trichocarpa* (black cottonwood) with at least 50 percent of the total tree cover . . . . .4

3. *Populus trichocarpa* (black cottonwood) with less than 50 percent of the total tree cover; *Tsuga mertensiana* (mountain hemlock) the dominant tree species . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **Unclassified Mountain Hemlock d.t.**

4. *Picea sitchensis* (Sitka spruce) with at least 10 percent cover . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**Sitka Spruce-Black Cottonwood d.t.**

    *Populus trichocarpa-Picea sitchensis* (black cottonwood-Sitka spruce) c.t.

4. *Picea sitchensis* (Sitka spruce) with less than 10 percent cover . . . . . . .**Black Cottonwood d.t.**

    *Populus trichocarpa/*young (black cottonwood/young) c.t.

    *Populus trichocarpa/Alnus crispa* (black cottonwood/Sitka alder) c.t.

    *Populus trichocarpa/Aruncus sylvester* (black cottonwood/goatsbeard) c.t.

    Unclassified *Populus trichocarpa* (black cottonwood) communities

**Key to Shrub Dominance Types**

Erect or decumbent shrubs with a combined cover of at least 25 percent.

1. *Alnus crispa* subsp. *sinuata* (Sitka alder) with at least 25 percent cover or *Salix* (willow) species (excluding prostrate willows less than 1 foot tall), individually or combined, with at least 25 percent cover . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2

1. *Alnus crispa* subsp. *sinuata* (Sitka alder) with less than 25 percent cover and *Salix* (willow) species (excluding prostrate willows less than 1 foot tall), individually or combined, with less than 25 percent cover . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .3

2. *Alnus crispa* subsp. *sinuata* (Sitka alder) with greater than 75 percent of the combined cover of Sitka alder and *Salix* (willow) species (excluding prostrate willows less than 1 foot tall) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**Sitka Alder d.t.**

2. *Salix* (willow) species (excluding prostrate willows less than 1 foot tall) with greater than 75 percent of the combined cover of willow and *Alnus crispa* subsp. *sinuata* (Sitka alder) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**Willow d.t.**

2. Not as above . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **Mixed Sitka Alder-Willow d.t.**

3. *Myrica gale* (sweetgale) with at least 25 percent cover . . . . . . . . . . . . . . . . . . . . **Sweetgale d.t.**

    *Myrica gale/Carex livida* (sweetgale/pale sedge) c.t.

    *Myrica gale/Carex lyngbyaei* (sweetgale/Lyngby's sedge) c.t.

*Myrica gale/Carex pluriflora* (sweetgale/several-flowered sedge) c.t.

*Myrica gale/Carex sitchensis* (sweetgale/Sitka sedge) c.t.

*Myrica gale/Empetrum nigrum* (sweetgale/crowberry) c.t.

*Myrica gale/Epilobium angustifolium* (sweetgale/fireweed) c.t.

*Myrica gale/Equisetum variegatum* (sweetgale/northern horsetail) c.t.

Unclassified Myrica gale (sweetgale) communities

3. *Myrica gale* (sweetgale) with less than 25 percent cover . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4

4. Dwarf ericaceous shrubs (*Empetrum nigrum* [crowberry], *Vaccinium uliginosum* [bog blueberry], *Andromeda polifolia* [bog rosemary], *Vaccinium vitis-idaea* [mountain cranberry], *Oxycoccus microcarpus* [cranberry]), individually or combined, with at least 25 percent cover; typically on peat soils. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**Crowberry d.t.**

   *Empetrum nigrum-Carex pluriflora* (crowberry-several flowered sedge) c.t.

   *Vaccinium uliginosum/Empetrum nigrum* (bog blueberry/crowberry) c.t.

   Unclassified Dwarf Shrub communities

4. Dwarf ericaceous shrubs (*Empetrum nigrum* [crowberry], *Vaccinium uliginosum* [bog blueberry], *Andromeda polifolia* [bog rosemary], *Vaccinium vitis-idaea* [mountain cranberry], *Oxycoccus microcarpus* [cranberry]), individually or combined, with less than 25 percent cover . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . ***Unclassified Shrub d.t.***

**Key to Herbaceous Dominance Types**

1. Emergent or terrestrial herbaceous vegetation with at least 15 percent cover . . . . . . . . . . . . . 2

1. Emergent or terrestrial vegetation with less than 15 percent cover; aquatic vegetation, submerged or floating in water, with at least 15 percent cover . . . . . . . . . . .**Aquatic Herb d.t.**

   *Callitriche hermaphroditica* (water starwort) c.t.

   *Callitriche heterophylla* (different-leaved water starwort) c.t.

   *Callitriche verna* (spring water starwort) c.t.

   *Chara* (chara) species c.t.

   *Myriophyllum spicatum* (spiked water milfoil) c.t.

   *Nuphar polysepalum* (lily-pad) c.t.

   *Potamogeton filiformis* (slender-leaved pondweed) c.t.

   *Potamogeton gramineus* (grass-leaved pondweed) c.t.

   *Potamogeton natans* (pondweed) c.t.

*Potamogeton pectinatus* (fennel-leaved pondweed) c.t.

*Potamogeton perfoliatus* (pondweed) c.t.

*Ranunculus trichophyllus* (white water crowfoot) c.t.

*Subularia aquatica* (awlwort) c.t.

*Utricularia vulgaris* (bladderwort) c.t.

*Zannichellia palustris* (horned pondweed) c.t.

Unclassified aquatic herb communities

2. Individual graminoid species with the greatest canopy cover, or *Carex* (sedge) species and *Lathyrus palustris* (vetchling) codominating the site . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3

2. Individual graminoid species without the greatest canopy cover, and *Carex* (sedge) species and *Lathyrus palustris* (vetchling) not codominating the site . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 6

3. Wet site species (sedge [*Carex*], spike rush [*Eleocharis*], pendant grass [*Arctophila fulva*], cottongrass [*Eriophorum*], alkaligrass [*Puccinellia*], etc.) with the greatest canopy cover or *Carex* (sedge) species and *Lathyrus palustris* (vetchling) codominating the site . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **Wet Graminoid d.t.**

*Arctophila fulva* (pendent grass) c.t.

*Carex chordorrhiza* (creeping sedge) c.t.

*Carex glareosa* c.t.

*Carex limosa* (livid sedge) c.t.

*Carex lyngbyaei* (Lyngby's sedge) c.t.

*Carex lyngbyaei-Lathyrus palustris* (Lyngby's sedge-vetchling) c.t.

*Carex lyngbyaei*-mixed herb (Lyngby's sedge-mixed herb) c.t.

*Carex lyngbyaei-Ranunculus cymbalaria* (Lyngby's sedge-seaside buttercup) c.t.

*Carex pluriflora-Carex lyngbyaei* (several-flowered sedge-Lyngby's sedge) c.t.

*Carex rostrata* (beaked sedge) c.t.

*Carex saxatilis* (russet sedge) c.t.

*Carex sitchensis* (Sitka sedge) c.t.

*Carex sitchensis/Sphagnum* (Sitka sedge/peat moss) c.t.

*Eleocharis palustris* (common spike-rush) c.t.

*Eriophorum angustifolium* (tall cottongrass) c.t.

*Eriophorum russeolum* (russett cottongrass) c.t.

*Glyceria pauciflora* c.t.

*Juncus alpinus* (northern rush) c.t.

*Juncus arcticus* c.t.

*Puccinellia nutkaensis* (dwarf alkaligrass) c.t.

Unclassified wet graminoid communities

3. Wet site species (sedge [*Carex*], spike rush [*Eleocharis*], pendant grass [*Arctophila fulva*], cottongrass [*Eriophorum*], alkaligrass [*Puccinellia*], etc.) without the greatest canopy cover and *Carex* (sedge) species and *Lathyrus palustris* (vetchling) not codominating the site . . . . .4

4. *Calamagrostis canadensis* (bluejoint) with at least 25 percent cover, and with the greatest cover in the tallest layer . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**Mesic Graminoid d.t.**

   *Calamagrostis canadensis* (bluejoint) c.t.

   *Calamagrostis canadensis/Lathyrus palustris* (bluejoint/vetchling) c.t.

   *Calamagrostis canadensis/Potentilla palustris* (bluejoint/marsh fivefinger) c.t.

   *Hierochloe odorata* (vanilla grass) c.t.

   Unclassified mesic graminoid communities

4. *Calamagrostis canadensis* (bluejoint) with less than 25 percent cover, or without the greatest cover in the tallest layer . . . . . . 5

5. *Deschampsia caespitosa* (tufted hairgrass) or *Deschampsia beringensis* (Bering hairgrass), individually or combined, or *Elymus arenarius* (beach rye) with the greatest cover . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**Dry Graminoid d.t.**

   *Deschampsia beringensis* (Bering hairgrass) c.t.

   *Elymus arenarius* (beach rye) c.t.

   *Elymus arenarius/Achillea borealis* (beach rye/yarrow) c.t.

   *Poa eminens* (large flower speargrass) c.t.

5. *Deschampsia caespitosa* (tufted hairgrass) or *Deschampsia beringensis* (Bering hairgrass), individually or combined, or *Elymus arenarius* (beach rye) without the greatest cover . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . ***Unclassified Graminoid d.t.***

6. Wet site species (bur reed [*Sparganium*], marestail [*Hippuris*], swamp horsetail [*Equisetum fluviatile*], marsh fivefinger [*Potentilla palustris*], buckbean [*Menyanthes trifoliata*], Pacific silverweed [*Potentilla egedii*], etc.) with the greatest cover . . . . . . . . . . . . . . . . **Wet Forb d.t.**

    *Equisetum fluviatile* (swamp horsetail) c.t.

    *Equisetum palustre* (marsh horsetail) c.t.

    *Hippuris vulgaris* (common marestail) c.t.

    *Hippuris tetraphylla* (four-leaf marestail) c.t.

    *Honckenya peploides* (seabeach sandwort) c.t.

    *Lysimachia thyrsiflora* (tufted loosestrife) c.t.

    *Menyanthes trifoliata* (buckbean) c.t.

    *Potentilla egedii* (Pacific silverweed) c.t.

    *Potentilla palustris* (marsh fivefinger) c.t.

    *Ranunculus cymbalaria* (seaside buttercup) c.t.

    *Sparganium* species (bur reed) c.t.

    *Triglochin maritimum* (seaside arrow-grass) c.t.

    *Triglochin palustre* (marsh arrow-grass) c.t.

    Unclassified wet forb communities

6. Wet site species (bur reed [*Sparganium*], marestail [*Hippuris*], swamp horsetail [*Equisetum fluviatile*], marsh fivefinger [*Potentilla palustris*], buckbean [*Menyanthes trifoliata*], Pacific silverweed [*Potentilla egedii*], etc.) without the greatest cover . . . . . . . . . . . . . . . . . . . . . . . . 7

7. Dry site species (horsetail [*Equisetum variegatum*], beach pea [*Lathyrus maritimus*], etc.) with the greatest cover . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **Dry Forb d.t.**

    *Epilobium latifolium* (river beauty) c.t.

    *Equisetum variegatum* (horsetail) c.t.

    *Lathyrus maritimus* (beach pea) c.t.

    Unclassified dry forb communities

7. Dry site species (horsetail [*Equisetum variegatum*], beach pea [*Lathyrus maritimus*], etc.) without the greatest cover . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 8

8. Mesic site species (beach strawberry [*Fragaria chiloensis*], nootka lupine [*Lupinus nootkatensis*], fireweed [*Epilobium angustifolium*], etc.) with the greatest cover . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**Mesic Forb d.t.**

*Athyrium filix-femina* (lady-fern) c.t.

*Epilobium adenocaulon* (northern willow-herb) c.t.

*Epilobium angustifolium* (fireweed) c.t.

*Equisetum arvense* (horsetail) c.t.

*Fauria crista-galli* (deer cabbage) c.t.

*Fragaria chiloensis* (beach strawberry) c.t.

*Hedysarum alpinum* (alpine sweet-vetch) c.t.

*Iris setosa* (wild iris) c.t.

*Lupinus nootkatensis* (nootka lupine) c.t.

8. Mesic site species (beach strawberry [*Fragaria chiloensis*], nootka lupine [*Lupinus nootkatensis*], fireweed [*Epilobium angustifolium*], etc.) without the greatest cover . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .***Unclassified Forb d.t.***

Key to Alternative Sitka Alder and Willow Dominance Types

Sitka Alder and Willow dominance type alternative A

1. *Alnus crispa* subsp. *sinuata* (Sitka alder) with at least 25 percent cover, and with a greater cover than the combined cover of all *Salix* (willow) species (excluding prostrate willows less than 1 foot tall) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**Sitka Alder d.t.**

*Alnus crispa/Calamagrostis canadensis* (Sitka alder/bluejoint) c.t.

*Alnus crispa/Equisetum arvense* (Sitka alder/meadow horsetail) c.t.

*Alnus crispa/Rubus spectabilis* (Sitka alder/salmonberry) c.t.

*Alnus crispa/Salix* (Sitka alder/willow) c.t.

*Rubus spectabilis-Echinopanax horridum* (salmonberry-devil's club) c.t.

Unclassified *Alnus crispa* (Sitka alder) communities

1. *Alnus crispa* subsp. *sinuata* (Sitka alder) with less than 25 percent cover, or with less cover than the combined cover of all *Salix* (willow) species (excluding prostrate willows less than 1 foot tall) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .2

2. *Salix* (willow) species, individually or combined, with at least 25 percent cover . . .**Willow d.t.**

*Salix alaxensis* (feltleaf willow) c.t.

*Salix arctica/Carex lyngbyaei* (arctic willow-Lyngby's sedge) c.t.

*Salix barclayi/Carex pluriflora* (Barclay willow/several-flowered sedge) c.t.

*Salix barclayi/Carex sitchensis* (Barclay willow/Sitka sedge) c.t.

*Salix barclayi/Equisetum variegatum* (Barclay willow/northern horsetail) c.t.

*Salix barclayi/Lupinus nootkatensis* (Barclay willow/nootka lupine) c.t.

*Salix barclayi/*mixed herb (Barclay willow/mixed herb) c.t.

*Salix commutata* (undergreen willow) c.t.

*Salix hookeriana* (Hooker willow) c.t.

*Salix setchelliana* (setchell willow) c.t.

*Salix sitchensis* (Sitka willow) c.t.

Unclassified *Salix* (willow) communities

2. *Salix* (willow) species, individually or combined, with less than 25 percent cover . . . . . . . . . .3