Columbia Basin Mapping Zone Documentation:
Mapping Methods and Accuracy

1) Predictor Layer Preparation:

a) Image Standardization:

Standardization from DN values to at-sensor reflectance was performed by EROS Data Center as part of the MRLC Preprocessing Procedure. This procedure uses the method presented by Huang et. al (2001a) to transform Landsat 7 ETM+ imagery (Note, Landsat 5 used for some dates). The equation used for reflectance was as follows:

$$r_{BandN} = (\Pi((DN_{Band} * Gain_{Band} + Bias_{BandN}) * D2) / (E_{BandN}(E_{BandN}(SINq))$$

r_{BandN} = Reflectance for Band N
DN = Digital Number for Band N
D = Normalized Earth-Sun Distance
E_{BandN} = Solar Irradiance for Band N
q = Solar Elevation
Gain $_{BandN}$ = Provided within header file, and band specific
Bias $_{BandN}$ = Provided within header file, and band specific

b) Image Dates and Mosaic:

Images were mosaicked using ERDAS Imagine 8.7 Mosaic Tool with "no cutline" for *type*, and the "Overlay" option for *overlap function*.

Image dates and scenes were as follows:

Path/Row	Spring Sat	Spring Julian Date	Spring Calender	Spring Overlay Order	Summer Sat	Summer Julian Date	Summer Calender	Summer Overlay Order	Fall Sat	Fall Julian Date	Fall Calender	Fall Overlay Order
42029	7	01115	4/25/2001	11	7	99206	7/25/1999	11	7	00257	9/13/2000	11
43028	7	02093	4/3/2002	7	7	02205	7/24/2002	7	7	00280	10/6/2000	7
44028	7	01081	3/22/2001	1	7	02196	7/15/2002	1	7	01273	9/30/2001	1
43029	7	00120	4/29/2000	6	7	02205	7/24/2002	6	7	00264	9/20/2000	6
44029	5	02124	5/4/2002	4	7	02164	6/13/2002	4	7	01273	9/30/2001	4
45029	7	00086	3/26/2000	12	7	99211	7/30/1999	12	7	00278	10/4/2000	12
42028	7	01115	4/25/2001	13	7	02230	8/18/2002	13	7	99254	9/11/1999	13
45028	5	01080	3/21/2001	9	7	00198	7/16/2000	9	7	00278	10/4/2000	9
42027	7	01115	4/25/2001	14	7	02230	8/18/2002	10	7	00257	9/13/2000	10
43027	7	00216	8/3/2000	10	7	02221	8/9/2002	14	7	99277	10/4/1999	14
44026	5	03159	6/8/2003	3	7	02196	7/15/2002	3	7	01273	9/30/2001	3
44027	7	02164	6/13/2002	2	7	02196	7/15/2002	2	7	00271	9/27/2000	2
45026	5	01080	3/21/2001	5	7	00198	7/16/2000	5	7	99291	10/18/1999	5
45027	7	00086	3/26/2000	8	7	00198	7/16/2000	8	7	00278	10/4/2000	8

c) Image Derived Datasets:
Normalized Difference Vegetation Index (NDVI): This dataset was provided by the EROS Data Center as part of the MRLC processing output.

Tasseled cap: Brightness, Greenness & Wetness band transformations were provided by the EROS Data Center as part of the MRLC processing output. This transformation followed the methods of Huang et. al 2001b.

Shrub Cover: Overall percent of shrub cover was described following Jennings et. al 2004. Overlap in the top three occurring shrubs strata where addressed by the following:

$$C_i = \left(1 - \prod_{j=1}^{n} (1 - \%\,\mathrm{cov}\ j / 100)\right) * 100$$

where C_i is the percent cover of stratum i for species or growth form j in stratum i.

Fractional Vegetation: The percent of ground covered by photosynthetic vegetation was estimated by the equation of Carlson and Ripley (1997). Reference values used in the equation were identified by examination of NDVI histograms and locating known sites of bare soil and irrigated agricultural fields. The equation is N* = (SQRT ((NDVI - NDVImin)/(NDVImax - NDVImin))) * 100, where NDVImin is the NDVI value for bare soil pixels in the scene, and NDVImax is the NDVI value for fully vegetated pixels in the scene. Fractional vegetation is related to calculations of impervious surface (Imp. Surface = 100 - fractional vegetation). The output is an integer layer with values between 0 and 100.

cb_summer_fv = (SQRT((cb_ndvi_summer - 0.07) / (0.9 - 0.07))) * 100
Image Texture: The texture of the image is

d) DEM Derived Datasets:
Thirty-meter digital elevation models were obtained from the EROS Data Center, National Elevation Database (NED, 1999). DEMs were converted from floating point grids to integer grids and mosaicked for the region, then clipped to the mapping area.

Slope: A slope layer was created using the ARC/INFO SLOPE command. Values represent slope in degrees.

Topographic Relative Moisture Index: A TRMI grid (values ranging from 0-28) was created using an Arc/INFO AML obtained from the Southwest Regional GAP Project created by G. Manis (Manis et. al 2001). The TRMI model is based on the methods defined by Haplin, P. N. 1999, and Parker, A. J. 1982.

Landform: A 10 class landform grid was created using an Arc/INFO AML obtained from the Southwest Regional GAP Project created by G. Manis (Manis et. al 2001). This product was derived from the topographic relative moisture index.

For modeling purposes all arcinfo grids were converted to ERDAS Imagine .img files.

2) Samples:

a) Sample Collection Methods:

Samples were collected in a variety of ways. Originally, it was thought that most, if not all, of the sampling would be derived from field collected information polygons

delineated over imagery in the field by field crews. Classification trees, however, require substantial amounts of training data so that additional information had to be acquired. All samples were assigned a label corresponding to an Ecological System (Comer et. al 2003). On the ground data was collected as polygons delineated over imagery in the field by ORNHIC and USGS field crews. A listing of the number of ground points by source is provided below. On screen digitizing was done using ETM imagery as a backdrop.

Source Sites

Map Region	Shrub Sample (2003)	Nevada ReGap	Bureau of Land Mangement			US Forest Service								Screen Digitized
	Training		Burns	Lakeview	Vale	Freemont NF	Gifford Pinchot NF	Malheur NF	Mt Hood NF	Ochoco NF	Umatilla NF	Wallowa NF	Winema NF	
Columbia Basin	664						289		8093		2574	3668		244

3) Cover Types:

a) Classification Tree Modeled Cover Types:

Thirty-six cover types were modeled in this zone. All forest and barren types were modeled and later reclassified into single classes in the overall Tree modeling.

The following cover types were modeled using the See5 Classification Tree:

Ecological System	Total	Code
Annual/Biannual Farmland	336	280
Invassive Annual Grasses	73	308
Bare Ground	107	301
Columbia Basin Foothill and Canyon Dry Grassland	629	137
Columbia Plateau Scabland Shrubland	122	44
Coumbia Basin Palouse Prairie Grassland	39	141
Columbia Plateau Low Sagebrush Steppe	93	154
Inter-Mountain Basins Big Sagebrush Shrubland - ssp. wyoming	81	54
Inter-Mountain Basins Big Sagebrush Shrubland - ssp. Tridentata	41	149
Inter-Mountain Basins Big Sagebrush Steppe - ssp. wyoming	145	78
Inter-Mountain Basins Big Sagebrush Steppe - ssp. Tridentata	43	150
Inter-Mountain Basins Mixed Salt Desert Scrub	6	65
Inter-Mountain Basins Montane Sagebrush Shrubland	62	71
Inter-Mountain Basins Semi-Desert Grassland	9	90
Inter-Mountain Basins Semi-Desert Shrub-Steppe	360	79
Mediterranean California Alkali Marsh	2	161
North Pacific Avalanche Chute Shrubland	112	168
North Pacific Dry--Mesic Silver Fir-Western Hemlock-Douglas-Fir	6661	178
North Pacific Montane Grassland	797	134
East Cascades Oak-Pine Forest and Woodland	763	146
Northern Rocky Mountain Lower Montane Riparian Woodland and	12	151
Northern Rocky Mountain Subalpine Dry Grassland	2	192
Northern Rocky Mountain Ponderosa Pine Woodland and Savann	2623	146
Open Water	39	211
Agriculture-Pasture	11	281
Recently Logged	51	310
Rocky Mountain Alpine Bedrock and Scree	83	2
Rocky Mountain Alpine Dwarf-Shrubland	1	43
Rocky Mountain Aspen Forest and Woodland	3	23
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Wood	1639	28
Rocky Mountain Lodgepole Pine Forest	94	31
Rocky Mountain Lower Montane Foothills Shrubland	155	47
Rocky Mountain Subalpine-Montane Riparian Woodland	7	151
Temperate Pacific Freshwater Emergent Marsh	2	199
Temperate Pacific Montane Wet Meadow	47	103
Urban	38	222

b) Non Tree modeled Cover Types:
Screen digitized over ETM:

Agriculture-Irrigated and Non-Irrigated (280) were supplemented and modified using the Washington Department of Agriculture's boundaries which represent all farms, orchards and pasture lands in the state. It was not possible to use the data tables supplied with the boundaries did not differentiate between different land use types. To determine actual agricultural fields from other land cover types the fractal dimension was calculated for all polygons in the data table. All values of less than 0.97 (simple geometric shapes) and with area greater 5 ha were burned into the tree model as agriculture.

Recently Burned (302) areas were developed from Fires in Western North America by visually comparing the shapefile to the ETM imagery and selecting those fire scars visible on the imagery and those fires that occurred after the image date. Source of shapefile: USGS Snake River Field Station, 2004, http://sagemap.wr.usgs.gov

All Columbia Plateau Palouse Prairie Grassland (141) was modified to Columbia Plateau Foothills and Canyon Dry Grassland (137) following evaluation of the modified tree model by WA Heritage ecologists. The consensus was the extents of Palouse Grasslands were too extensive and the areas mapped were better represented by the latter type.

Intermountain Basins Juniper Savannah (75) was modified from the modeled extent along the eastern foothills of the Cascades, and was limited within the map zone to the southern Umatilla Basin. All juniper extents north of the Umatilla Basin, with the exception of the Juniper Dunes, were converted to Northern Rocky Mountain Ponderosa Pine Woodland and Savanna.

Interstates and highways were buffered by 30m to develop a transportation mask.

c) Cover Types Modified with a Post-Classification model:
(see section 5c for details)

Ecological System	Action
Agriculture - Irrigated and Non-Irrigated	Modified with agricultural boundaries
Columbia Basin Foothill and Canyon Dry Grassland	Modified regionally with type 90
Columbia Plateau Scabland Shrubland	Cutlines adjusted
Great Basin Xeric Mixed Sagebrush Shrubland	Shrub Cover applied to split for steppe vs shrubland
Inter-Mountain Basins Big Sagebrush Shrubland	Shrub Cover applied to split for steppe vs shrubland
Inter-Mountain Basins Big Sagebrush Shrubland - ssp. tridintata	Shrub Cover applied to split for steppe vs shrubland
Inter-Mountain Basins Big Sagebrush Steppe	Shrub Cover applied to split for steppe vs shrubland
Inter-Mountain Basins Big Sagebrush Steppe - ssp. tridintata	Shrub Cover applied to split for steppe vs shrubland
Inter-Mountain Basins Montane Sagebrush Shrubland	Shrub Cover applied to split for steppe vs shrubland
Inter-Mountain Basins Montane Sagebrush Steppe	Shrub Cover applied to split for steppe vs shrubland
Inter-Mountain Basins Semi-Desert Shrub-Steppe	Shrub Cover applied to split for steppe vs shrubland
Inter-Mountain Basins Semi-Desert Grassland	Modified regionally with type 137
Inter-Mountain Basins Juniper Savanna	Modified along E. Cascades Foothills to 146
Open Water	Terrain modified to remove from slopes
Conifer Forests	All classfied forest type converted to Conifer Forest (242)
Recently Burned	Updated from LandFire boundaries

4) Summary of Predictor Layers Used:

a) Multi band predictors:
ETM bands 1-5 & 7 for fall
ETM bands 1-5 & 7 for spring
ETM bands 1-5 & 7 for summer

b) Single Band Predictors:

Fall Tasseled Cap brightness band
Fall Tasseled Cap greenness band
Fall Tasseled Cap wetness band
Summer Tasseled Cap brightness band
Summer Tasseled Cap greenness band

Summer Tasseled Cap wetness band
Spring Tasseled Cap brightness band
Spring Tasseled Cap greenness band
Spring Tasseled Cap wetness band

Tree model Shrub Cover Percentage (integer) **

Continuous (integer) slope
Continuous (integer) elevation
Categorical 10 class landform (from DEM)
Topographic Relative Moisture Index (from DEM)
** Post Classification

5) Modeling Methods:

a) See5 Classification Tree Modeling:
Sub-Sampling: Pseudo-replication within each sample polygon was conducted in order to increase the number of samples used by the classification algorithm. While this use of non-independent data is not ideal for classification tree modeling, it has been found to improve classification accuracies, particularly when there are limited amounts of training data. 30 random points were placed within each polygon using the Arcview tool Hawth's Tool. The points were converted to pixels while ensuring that the resulting pixels (the new grid) aligned with the raster predictor layers. The resulting sub-sampled pixels would often be less than 30 per sample polygon, if random points fell within the same pixel.

Training and Validation Sites: Twenty percent of the all sample polygons were withheld for validation using the Feature Select extension in ArcView. With the remaining 80%, 30 sub-samples were randomly generated within each sample polygon. This was done by first randomly generating points within each polygon using the Random Points extension in Hawth's Tool for ArcVGIS, later converted to *.img files. Individual points were converted to *.img files (each to be considered a separate observation for the See5 classifier) and were `drilled' through predictor layers using the Sampling tool from CART Module for Imagine (EarthSatellite Corp. 2003), producing two important files for See5: the *.names and *.data files.

See5 Classification Tree: See5 (Release 2.01) data mining software (Rulequest 2004) was used for generating classification trees. Boosting was employed using 20 trials.

The following briefly describes the files used by the See5 Program (Rulequest 2004).

*.names file: Identifies the dependent variable *.img file and the predictor *.img files created from the CART Module Sampling tool. Required by See5 software.
*.data file: Contains the training cases from which See5 extracts rules. This is also produced from the CART Module Sampling tool, by `drilling' the dependent variable pixels through the specified predictor images. Required by See5 Software.

*.set file: Produced from See5 software. This file contains the settings for the classification tree run. For example the third value `15' indicates the number of boosts used for boosting.

*.tree file: Produced from the See5 software. This file contains the classification tree in `tree' format. This along with the *.data and *.names file are required by the CART Module Classifier tool to spatially apply the tree.

*.out file: Output file generated by See5 and displayed when See5 classification tree model has completed the final run. This file provides a visual representation of the classification tree that is somewhat easier to interpret than the *.tree file.

As a result of spatially applying the classification tree using the CART Module's Classifier an *.img file, which is the spatial application of the tree's rules was created.

b) Shrub Cover: Sampling protocols followed by project teams (section 2a) required the collection of a visual estimate of percent coverage of individual shrub strata. Following similar methodology used in trial regions of SW-ReGap (Huang et. al 2003, Jennings et. al 2004) a overall percent shrub cover was estimated for each training site (80%/20% training/validation). The total percent coverage is represented as a continuous surface at each site, and was reclassified to five categorical types following guidelines suggested by LandFire.

Category	Range %
Very High	> 45%
High	36-45%
Moderate	26-35%
Steppe	11-25%
Grassland	<10%

Tree model Validation: Twenty percent of the sample polygons were randomly selected and withheld from Tree modeling. The preliminary Tree models were run as described in section 5a using the remaining 80% of the training site data. The 20% withheld samples were used to assess the predictive capability of the Tree modeled map via the kappa_stats.avx extension for ArcView by intersecting the reference polygons with the Tree modeled land cover map. This extension considers the site correctly mapped when the majority of pixels within the reference polygon agree with the reference label. Output from kappa_stat.avx includes the kappa statistic and an error matrix indicating errors of omission and commission.

c) Post Classification, Recoding and Other Modeling Steps: Post-classification modeling was done to map classes where there were not enough training data to map using the full Tree model, to differentiate between ecological systems that have similar characteristics, use ancillary data sets, or correct problems found during qualitative review. The processes are listed in the order in which they were implemented.

Post-Classification Tree modeling
Shrub Coverage: Unique combinations of all shrub dominated ecological systems and the independent shrub cover were modified to represent a Shrub -> Steppe -> Grassland type based upon the ecoregion of occurrence.

Ecological System	Shrub Cover				
	Very High	High	Moderate	Steppe	Grassland
Great Basin Xeric Mixed Sagebrush Shrubland	Shrubland	Shrubland	Shurbland	Steppe	Steppe
Inter-Mountain Basins Big Sagebrush Shrubland	Shrubland	Shrubland	Shurbland	Steppe	Steppe
Inter-Mountain Basins Big Sagebrush Shrubland - ssp. tridintata	Shrubland	Shrubland	Shurbland	Steppe	Grassland
Inter-Mountain Basins Big Sagebrush Steppe	Shrubland	Shrubland	Steppe	Steppe	Grassland
Inter-Mountain Basins Big Sagebrush Steppe - ssp. tridintata	Shrubland	Shrubland	Steppe	Steppe	Grassland
Inter-Mountain Basins Montane Sagebrush Shrubland	Shrubland	Shrubland	Shurbland	Steppe	Grassland
Inter-Mountain Basins Montane Sagebrush Steppe	Shrubland	Shrubland	Steppe	Steppe	Grassland
Inter-Mountain Basins Semi-Desert Shrub-Steppe	Shrubland	Shrubland	Steppe	Steppe	Grassland

Corrections
A visual examination of the 100% Tree model was done using ETM imagery.

Grasslands and Scablands
Columbia Plateau Scabland Shrubland was affected in several areas by image artifacts propagated when the regional mosaic was completed. Errors generally were comprised of ridgeline scablands ending abruptly at image boundaries. Ridgelines from the Landform data layers were used to correct and extend the scabland type.

Inter-Mountain Basins Semi-Desert Grassland and *Columbia Basin Foothill and Canyon Dry Grassland*. The region of primary conflict occurred in the South-East portion of the map zone where the former occurs; the majority of the map zone is considered the latter. The complex interactions of grassland types in the region required that ORNHIC and WANHP ecologist to identity multiple boundaries in which a series of "if then" statements where used to switch between the two grassland types and correct for tree model errors.

Open Water
Water was over-mapped throughout the canyon regions of the mapping area. Primary areas of error were due to shadows in the deep canyons in which the available image dates did not penetrate the full spatial extent of the canyon wall. Canyon terrain models were used to remove shadow-water conflicts. Groups of misclassified pixels were replaced using a focal majority routine which used the surrounding pixels as representative values.

Forest
Conifer Forest (242) is a composite type composed of all individual ecological systems present within the map zone.

Recent Fires
The recent fires layer was applied as a mask over the landcover map superseding all underlying ecological systems with the Recently Burned (302) land cover type

Transportation
Following the lead of the SWGAP project, Interstates and Highways were applied to the final product. The transportation layer, recoded as Developed Medium (223), was applied as a mask over the landcover map using a conditional statement. See 3b for development

c) Generalizing to MMU and Map Completion:
Once the Tree model and the post-classification steps were employed, the map was generalized using the Clump tool in ERDAS Imagine 8.7. The parameter of 4 connected neighbors was used in the clumping process. Isolated pixels that fell under the specified 1-acre (5 pixels) minimum mapping unit (MMU) were removed using the Eliminate tool. Following the Clump & Eliminate step, the non-Tree modeled classes were then "burned in" to the final map using the Overlay function.

6) Accuracy Assessment

Accuracy statistics were calculated using the 20% withheld samples on the preliminary Tree model. These statistics include an error matrix, kappa statistics and breakdown of user's/producer's accuracy and error.

Error Matrix

ERROR MATRIX: Reference Data in Columns/Classification Data in Rows	Mediterranean Califoria Dry_Mesic Chaparral	Intermountain Basins Big Sagebrush Shurbland - ssp. wyoming	Exotics	Columbia Plateau Low Sagebrush Steppe	Inter-Mountain Basins Mixed Salt Desert Scrub	Inter-Mountain Basins Montane Sagebrush Shrubland	Columbia Basin Palouse Prairie	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	Colmbia Plateau Scabland Shrubland	Inter-Mountain Basins Semi-Desert Grassland	Inter-Mountain Basins Semi-Desert Shrub Steppe	Columbia Basin Foothill and Canyon Dry Grassland	Total	User's Accuracy
Mediterranean Califoria Dry_Mesic Chaparral	5	0	0	0	0	0	0	0	0	0	0	0	5	100%
Intermountain Basins Big Sagebrush Shurbland - ssp. wyoming	0	83	7	0	0	1	5	0	6	1	9	2	114	90%
Exotics	0	3	42	0	0	0	4	0	0	0	0	0	49	86%
Columbia Plateau Low Sagebrush Steppe	0	0	0	10	0	0	0	0	0	0	0	0	10	100%
Inter-Mountain Basins Mixed Salt Desert Scrub	0	0	0	0	5	0	0	0	0	0	0	0	5	100%
Inter-Mountain Basins Montane Sagebrush Shrubland	0	0	1	0	0	48	1	0	0	0	0	0	50	92%
Columbia Basin Palouse Prairie	0	0	0	0	0	0	30	0	0	0	0	0	30	100%
Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	0	1	0	0	0	1	0	5	0	0	0	0	7	71%
Colmbia Plateau Scabland Shrubland	0	0	0	0	0	0	0	0	90	0	0	0	90	100%
Inter-Mountain Basins Semi-Desert Grassland	0	0	0	0	0	0	0	0	0	9	0	0	9	100%
Inter-Mountain Basins Semi-Desert Shrub Steppe	0	0	0	0	0	0	0	0	0	0	16	0	16	100%
Columbia Basin Foothill and Canyon Dry Grassland	0	0	0	0	0	0	0	0	0	0	0	8	8	100%
Total	5	87	50	10	5	50	40	5	96	10	25	10	393	
Producer's Accuracy	100%	99%	84%	100%	100%	96%	75%	100%	94%	90%	64%	80%		89%

User's/Producer's Accuracy and Omission/Commission Error

Ecological Systems	Producer Accurancy	User Accuracy	Secificity	Predictive Power	Omission Error	Commission Error
Mediterranean Califoria Dry_Mesic Chaparral	1	1	1	1	0	0
Intermountain Basins Big Sagebrush Shurbland - ssp. wyoming	0.9860627	0.89557	0.893548	0.9857651	0.013937	0.106452
Exotics	0.84	0.857143	0.987203	0.9854015	0.16	0.012797
Columbia Plateau Low Sagebrush Steppe	1	1	1	1	0	0
Inter-Mountain Basins Mixed Salt Desert Scrub	1	1	1	1	0	0
Inter-Mountain Basins Montane Sagebrush Shrubland	0.96	0.923077	0.992687	0.9963303	0.04	0.007313
Columbia Basin Palouse Prairie	0.75	1	1	0.9823633	0.25	0
Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	1	0.714286	0.996622	1	0	0.003378
Colmbia Plateau Scabland Shrubland	0.9375	1	1	0.9881657	0.0625	0
Inter-Mountain Basins Semi-Desert Grassland	0.9	1	1	0.9982993	0.1	0
Inter-Mountain Basins Semi-Desert Shrub Steppe	0.64	1	1	0.9845095	0.36	0
Columbia Basin Foothill and Canyon Dry Grassland	0.8	1	1	0.9966044	0.2	0

Overall Statistics:

Overall Accuracy: (551 / 597) = 0.922948074
Overall Misclassification Rate: (46 / 597) = 0.077051926
Overall Sensitivity: 0.922948074
Overall Specificity: 0.993579006
Overall Omission Error: 0.077051926
Overall Commission Error: 0.006420994

Kappa Statistics

KHAT = 0.890184
VARIANCE = 000241141
Z = 57.293
P = 0.00000000

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