U.S. Fish & Wildlife Service

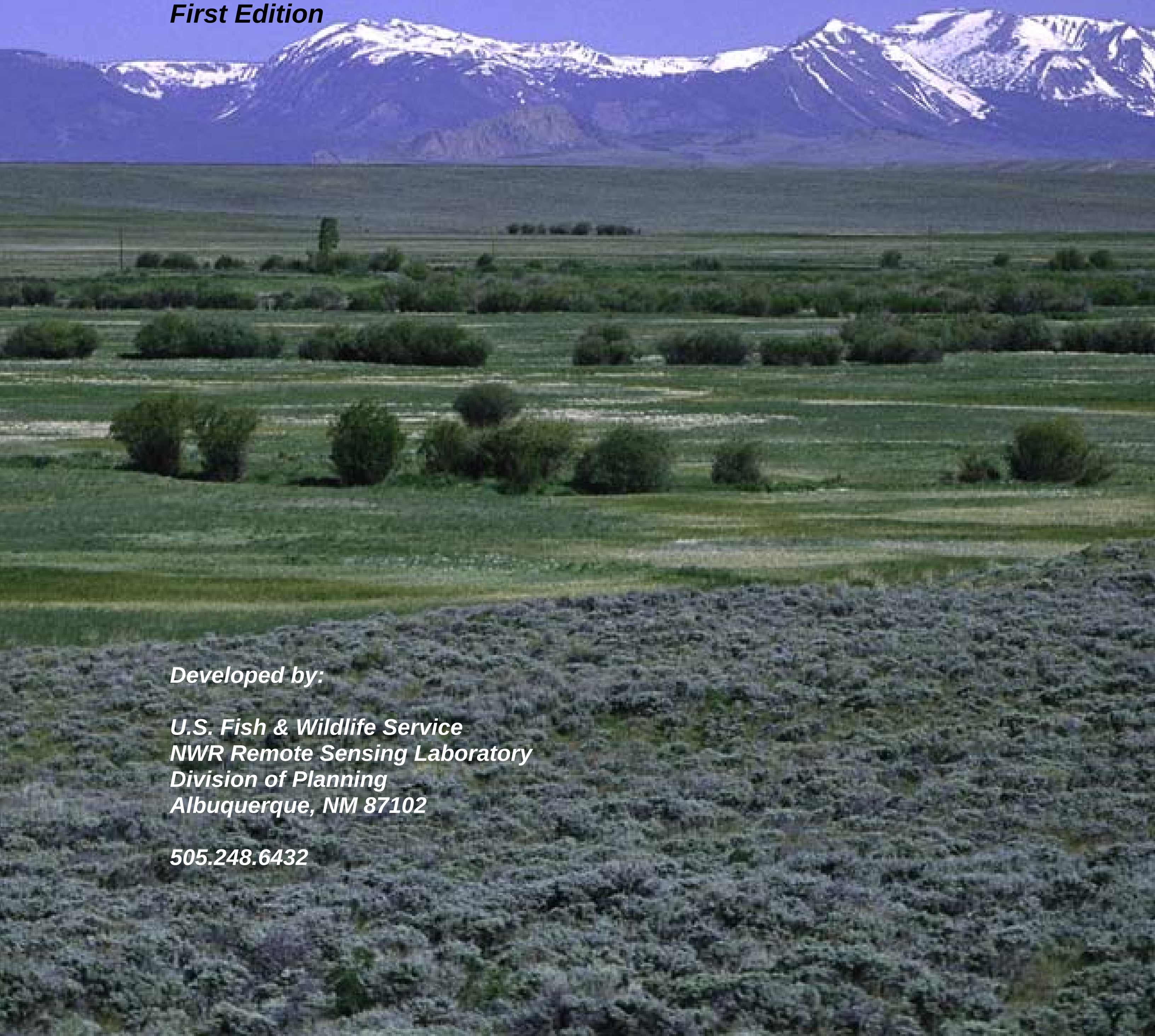
Spatial Inventory and Monitoring on National Wildlife Refuges

Southwest Region
National Wildlife Refuge System
NWR Remote Sensing Lab, Division of Planning

TECHNICAL MANUAL

Vegetation/Habitat Mapping: *NWR Spatial Vegetation Inventory and Monitoring Handbook*

First Edition



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1.1 Purpose

Spatial inventory and monitoring of vegetation, land cover and wildlife habitat on National Wildlife Refuges (NWR) plays an important roll in the management of our natural resources. Within the Southwest Region (R2) the NWR Remote Sensing Lab has been tasked with developing spatial habitat inventory and monitoring methods and producing these data for all NWRs throughout the region. This document describes the sampling, field data collection, remote sensing (RS) and geographic information system (GIS) applications, methods and tools used to complete this process.

The methods described in this document may be applied to vegetation/landcover/habitat mapping, historical land use and change detection analysis. It is important to note that this document goes into some detail outlining the methods used to generate spatial vegetation and habitat inventory and monitoring. It is written under the assumption that staff using these protocols have a developed background in field data collection, general landscape ecology, remote sensing sciences and GIS applications.

1.2 Overview

The procedures in this document are organized to follow the general work flow used by the Lab to produce inventory and monitoring projects. Each chapter and sub chapter outlines the type of data and software required to complete the procedure. The protocols and software used for procedures outlined in this document do not represent the only available means necessary to complete the outlined task (**Figure 1.2.1**). The Lab is testing new field data collection procedures and software that show promise in simplifying the processes outlined in this document. Please contact the Lab for updates and questions related to application of these methods.

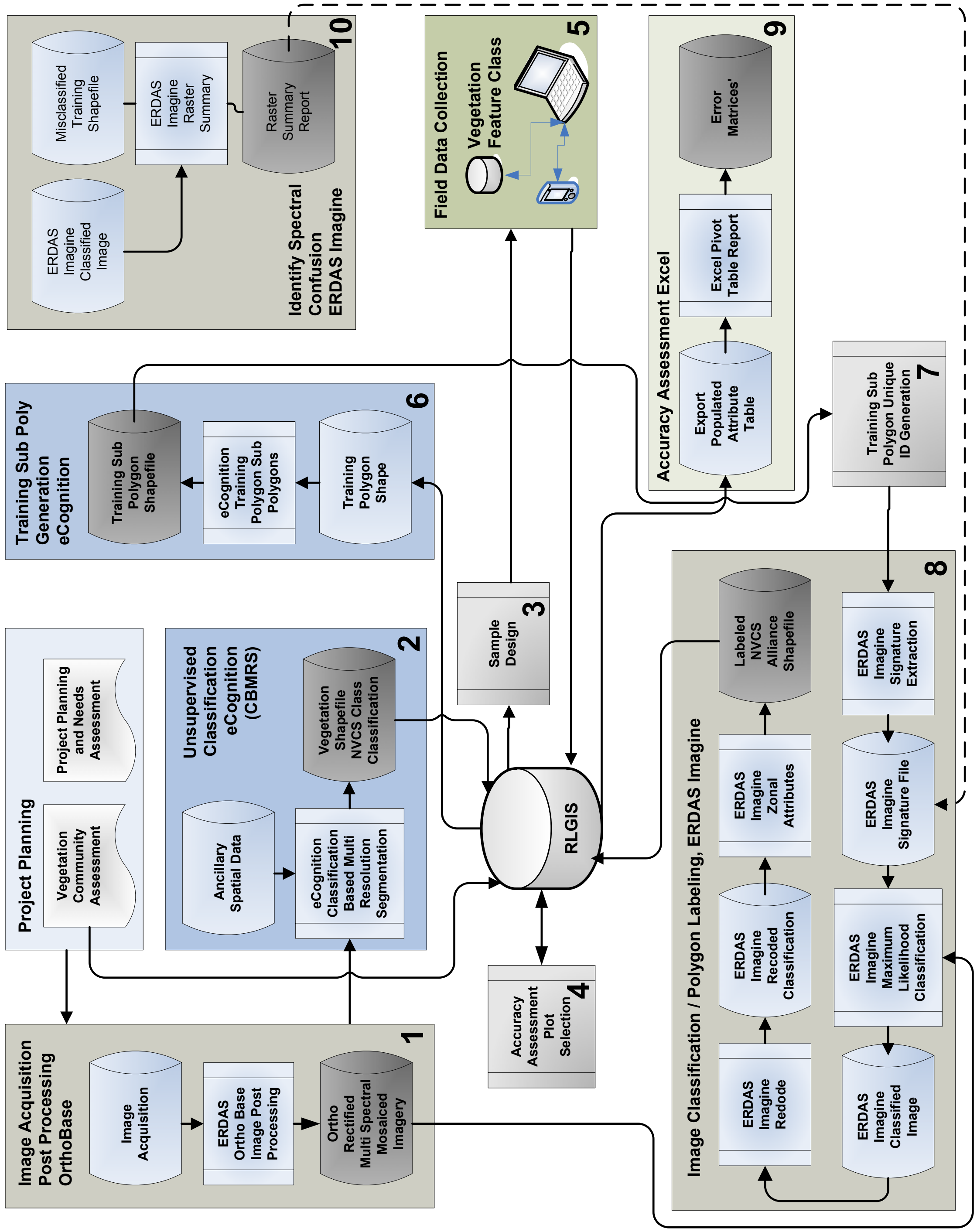

Figure 1.2.1. Vegetation Inventory Work Flow Diagram

The outline below defines the general workflow and process for spatial inventory and monitoring data production on NWRs used by the Lab (**Figure 2.1.1**). The process is broken up into three phases: Planning, Production and Deliverables. All the processes associated with this workflow are completed internally by the NWR Remote Sensing Lab. It is important to note that the outline is a general workflow and is often altered to meet specific project needs.

Time Line

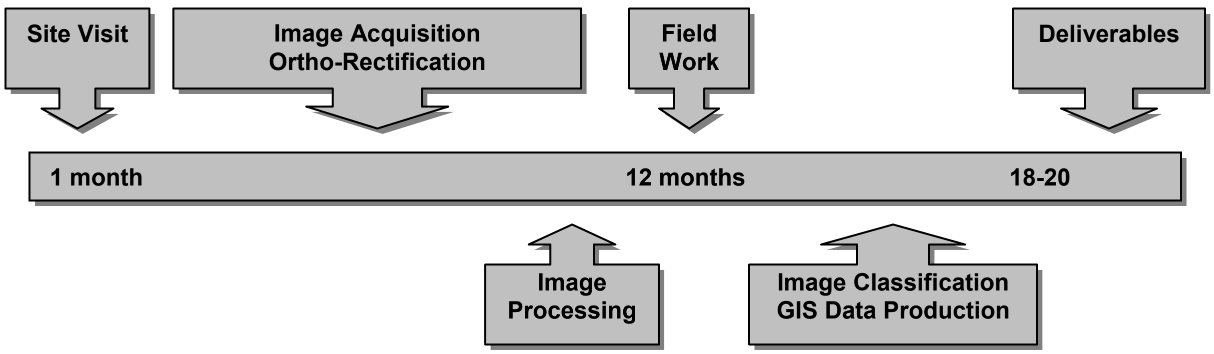

Figure 2.1.1. Timeline depicts general workflow and procedures used to produce inventory and monitoring data on a NWR in Region 2. Please note that the timeline depicts a general workflow and does not take into account specific environmental and project variables that can affect the process.

Project Planning

Site Visit
The individual NWR is contacted and a site visit conducted to assess scope of the project and to identify any special data needs or analysis. At that time a meeting is held with refuge staff to give an overview of the data production process and to address access, equipment and staffing concerns that can affect the workflow of the project.

Land Cover Assessment
During the site visit a list of vegetative classes, existing on the NWR, is generated. This is done through field recon, usually in cooperation with local or regional plant experts. Vegetation classes are defined to the Alliance or Association level of the National Vegetation Classification Standard (NVCS). (For more information on NVCS go to: http://www.fgdc.gov/standards/status/sub2_1.html). The use of NVCS may not be completely applicable to the needs of all National Wildlife Refuges and may be supplemented with other classification systems in addition to NVCS when appropriate.

Data Mining
Before data production begins a data mining exercise is completed. Federal, state and local land management agencies, as well as universities are contacted and informed of the Lab's activities. Any data they may have relative to baseline data generation efforts on the NWR are requested to eliminate duplication of efforts and to explore cost and data sharing when appropriate.

Imagery Acquisition
Once the scope of the project is defined, imagery are acquired appropriate in spatial, spectral, and temporal resolution (In most cases a minimum of two image sets are needed: historic and contemporary). Given the size of most NWRs and the level information being generated, ortho-rectified multi spectral digital airborne imagery is used. To produce these data an image

acquisition flight is first scheduled with the Regional NWR Aviation Management Group or contractor. Resource imagery are collected at the spatial and temporal resolution requested. Once collected, the digital imagery are delivered to the NWR Remote Sensing Lab where they are ortho-rectified, color balanced and mosaiced to a spatial resolution of 1-meter. The ortho-rectification process is also completed using historic digitally scanned print photography. When the type or scale of the analysis is appropriate, Landsat ETM/TM, SPOT or IRS (pan) imagery may be applied.

Data Production

Abiotic Feature Delineation

Once the image acquisition and image post processing is complete, data production begins. Generation of abiotic features into a GIS is completed first. If these data already exist within RLGIS (Refuge Lands GIS) this process can be skipped. These data usually delineate agricultural field boundaries, roads, ecotones etc… If these data have not been developed C-size plots of the NWR are produced, using the digital imagery as a background, are sent to the NWR. Refuge staff delineate specific features on the maps before returning them to the Remote Sensing Lab to be digitized and attributed. This process is iterative and requires a steady dialog between the NWR and Remote Sensing Lab staff. When it is possible GIS staff on the NWR may complete these tasks. Features not readily distinguishable through a photo interpretation process can be colleted using RLGIS, ArcPad and field data loggers/GPS equipment.

Image Processing

To generate vegetative polygons, automated image processing techniques are applied to the acquired imagery. These polygons are correlated to specific land-cover (vegetation types) found on the imagery.

Sample Sets

Based on the information gathered from the initial site visit a statistically appropriate sampling design is used to select a number of polygons for ground-truthing. The ground-truthing data provide information necessary for the image classification and accuracy assessment process used in the generation of the vegetation/landcover/habitat data (map).

Fieldwork

Fieldwork is conducted to collect the vegetation data selected for sampling. ArcPad and field data loggers/GPS equipment are used to navigate to specific polygons on the NWR. Polygons are qualitatively assessed to the Alliance or Association level of the NVCS.

Image Classification

Ground-truth data collected in the field are uploaded into RLGIS and utilized in image classification procedures. Image classification is completed through an integration of multivariate and knowledge based image classification techniques, photo interpretation and application of ancillary data. A portion of the ground-truth data is withheld from the classification process and used to generate error matrices to assess the overall and individual class accuracy of the vegetation/landcover/habitat classification.

Final Data Production

Federal Geographic Data Committee (FGDC) compliant metadata is produced for all spatial data, once production is complete. Data are formatted and stored within RLGIS.

Deliverables

Final Site Visit
Final site visit is conducted to present the data generated to the NWR staff. Time is taken to upgrade or install appropriate GIS software and conduct a 2-3 day RLGIS training and to demonstrate data applications.

3.0 RLGIS and Vegetation Inventory and Monitoring

3.1 What is RLGIS *(Refuge Lands GIS)*?

The vegetation/landcover/habitat model described in this document has been incorporated into a larger spatial inventory; monitoring and management geodatabase (GDB) called RLGIS (Refuge Lands GIS). RLGIS was created to meet inventory, monitoring and analysis needs at the field station level within a structure that supports GIS applications. The model was based on programs and databases already developed, bringing together the Region 1 and Region 2 Geodatabase Models with the existing RLGIS model managed by the HAPET office in Region 6. The thrust of the RLGIS effort has included review and involvement from all Regions of the Service. The development of RLGIS standards and guidelines have been carried out to support spatial inventory and monitoring, targeting refuge program needs at the field station level.

The entire RLGIS Model consists of 3 individual geodatabases. Each of the 3 GDBs encompass a number of feature classes that fall within broad category of similarity. The names of these GDBs are intuitive relative to the content of their feature classes: **Features, Units and Monitoring Geodatabase; Landcover and Habitat Geodatabase and Resource Management Geodatabase**. The feature classes used to inventory and monitor vegetation/landcover/habitat data are stored under the Landcover and Habitat Geodatabase **(Figure 3.1.1).** The feature class name is ***vegetation***.

Developing vegetation/landcover/habitat data within RLGIS provides users with a database template and standards. It makes available and incorporates the use of ArcPad and the checkin-checkout procedure inherent to ArcGIS. Refuges may apply only the vegetation portion of RLGIS without incorporating other aspects off the model. However the Lab does encourage its use as a whole in tangent with the vegetation model. Many of the data collection procedures outlined for the vegetation model are directly applicable to other feature classes in RLGIS.

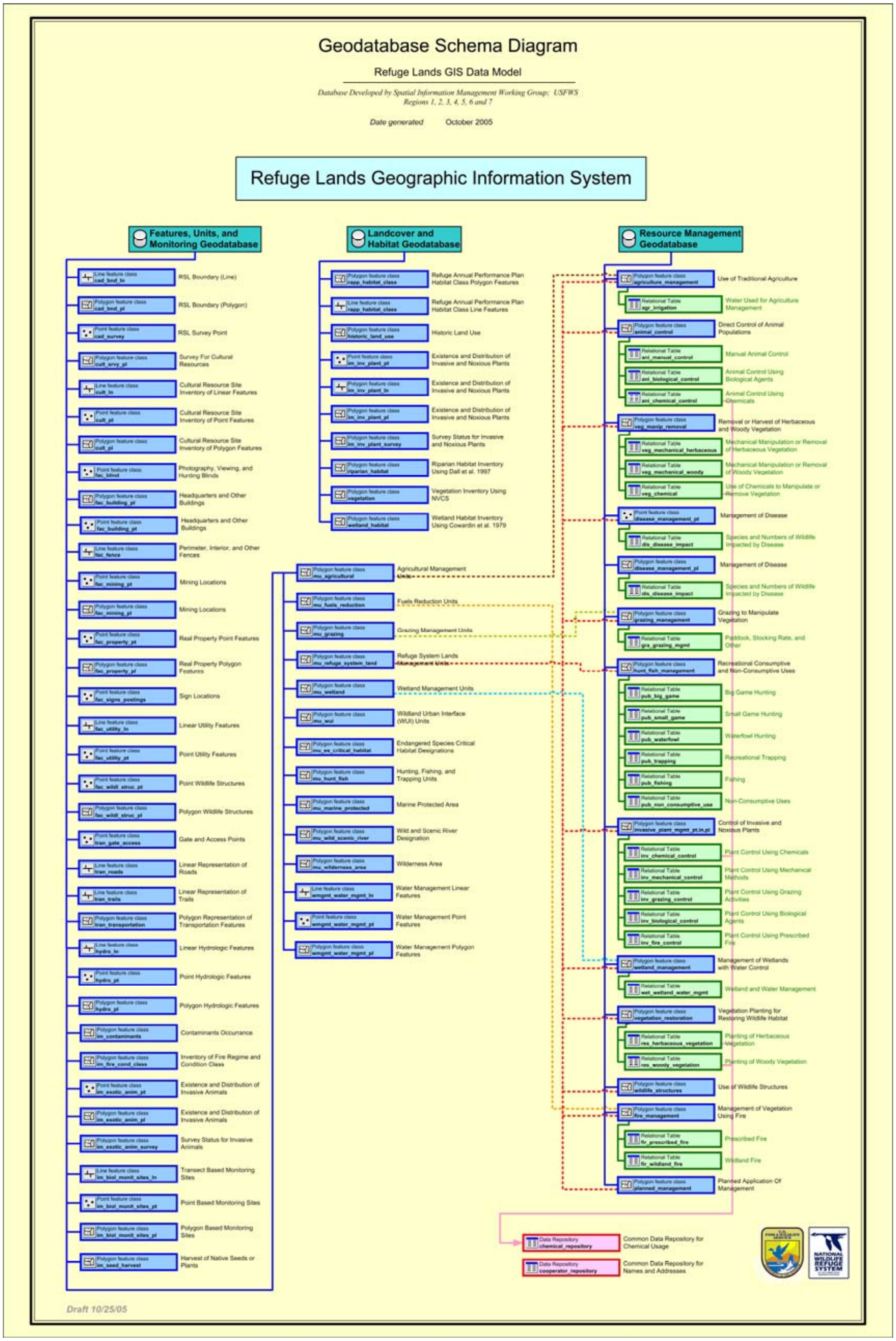

Figure 3.1.1. RLGIS data structure

3.2 Projection

Projection:	Geographic (latitude/longitude)
Units:	Decimal Degrees
Spheroid:	GRS 1980
Datum:	North American Datum 1983 (NAD83)

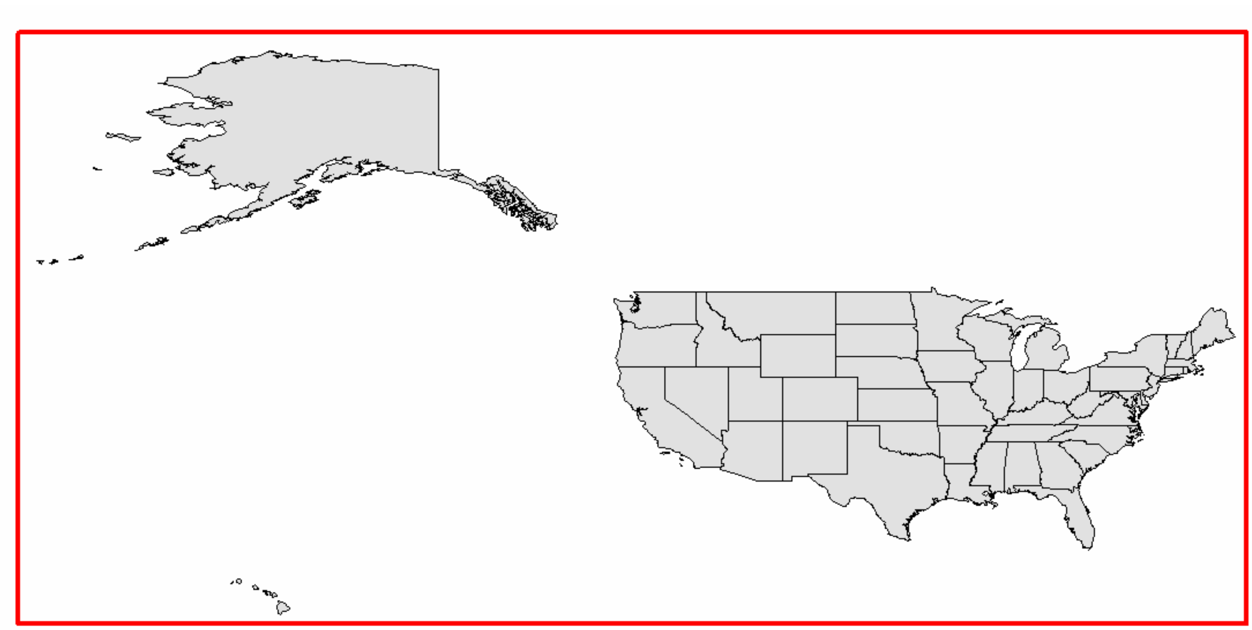

Figure 3.2.1. Feature dataset XY domain extent inherent to RLGIS.

Specific Spatial Reference Properties for the bounding coordinates are:

MinX:	-180	MaxX:	-65
MinY:	18	MaxY:	73

3.3 Positional Accuracy

The spatial databases will have a horizontal positional accuracy that meets National Map Accuracy Standards at the 1:24,000 scale. This means that each well-defined object in the spatial database will be within 1/50 of an inch of its actual location on a 1:24000 scale map or 40 feet (12.2 meters) on the ground.

3.4 File Formats

Vector and raster file formats fall within the compatibility of common software packages used by the Service. In some circumstances alternative file formats may be required when dealing with third party data sources.

Vector: ESRI Geodatabase

Raster: ERDAS Imagine *.img, Tiff (projected) *.tif, Mr. Sid *.sid

Metadata is produced to FGDC standards and provided in *.xtml format within ArcCatalog.

3. Taxonomy

The naming of organisms is a complex task and national standards must be used to ensure that common and scientific names are consistent and meet the highest scientific standards. The **Integrated Taxonomic Information System (ITIS)** is an on-line, scientifically credible, list of biological names focusing on the biota of North America. As part of the RLGIS structure all organism names within this data model will be derived from ITIS.

3.6 File Naming Conventions

Within RLGIS the vegetation/landcover/habitat model used to produce and store the data described in this document is under the Landcover and Habitat Geodatabase. The names of these feature class used is: ***vegetation***.

3.7 Metadata

All vector and raster data produced by the NWR Remote Sensing Lab and produced by the field are required to have accompanying metadata meeting the Federal Geographic Data Commission (FGDC) standards. Metadata associated with vector data are produced using the metadata generation functionality in ArcCatalog. Metadata for raster data should also be developed using this functionality. Because the metadata associated with raster data is external to the raster file, the name used to label metadata for raster files should be identical to the file it is describing, but with the appropriate file extension (*.xtml).

3.8 RLGIS Vegetation Feature Class data structure

Vegetation Feature Class Data Fields[1]:

1. Name: lit*
   Alias: station literal
   Type: text
   Length: 8
   Definition: USFWS 3 character literal of the National Wildlife Refuge or 2 character literal plus wmd for Wetland Management District lands.
   Domain name: 3 letter literal

2. Name: orgcode*
   Alias: organization code
   Type: long integer
   Definition: USFWS 5 character numeric organizational code assigned to NWR
   Domain name: organizational code

3. Name: cmplx_name
   Alias: complex or wmd name
   Type: text
   Length: 50
   Definition: Name of complex or wetland management district the unit is associated with
   Domain name: complex/wmd name

4. Name: orgname*
   Alias: organization name
   Type: text
   Length: 50
   Definition: Official name of the National Wildlife Refuge if applicable.
   Domain name: organizational name

5. Name: dvsn_name
   Alias: division or district name
   Type: text
   Length: 50
   Definition: Division or District name if applicable
   Domain name: complex/wmd name

6. Name: unit_name
   Alias: unit name
   Type: text
   Length: 50
   Definition: Name of the individual WPA, WMA, etc in a Wetland Management District if applicable.
   Domain name: name
   Domain description: Identifies names of the individual WPAs if applicable.

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[1] Please refer to most current RLGIS data dictionary or model for changes to database structure
*** USFWS adopted national standard.**

7. Name: subunit_name
   Alias: subunit name
   Type: text
   Length: 50
   Definition: name of the subunit

8. Name: rsl_type
   Alias: rsl type
   Type: text
   Length: 8
   Definition: Identifies type of refuge lands; i.e. waterfowl production area (WPA), wildlife development area (WDA), etc…
   Domain name: rsl type

9. Name: stateabbr*
   Alias: state
   Type: text
   Length: 8
   Definition: Two letter postal abbreviation of the state the feature lies within.
   Domain name: state

10. Name: region*
    Alias: fws region
    Type: long integer
    Definition: Identifies the number of the region that the REFUGE LAND unit is located in.
    Domain name: region

11. Name: origin
    Type: text
    Length: 40
    Definition: Identifies source of data
    Domain name: origin

12. Name: poly_id
    Alias: poly id number
    Type: long integer
    Precision: 0
    Definition: Unique numeric identifier assigned to each polygon. The numbering system is integer based beginning with 1 and following sequentially.

13. Name: rec_date
    Alias: recording date
    Type: date
    Definition: Identifies date the data was collected or recorded on field data sheet.

14. Name: system
    Type: text
    Length: 20
    Definition: The top division of the classification hierarchy separates vegetated communities from those of unvegetated deep-water habitats.
    Domain name: nvcs – system

15. Name: nvcs_class
Alias: nvcs class
Type: text
Length: 8
Definition: The physiognomic level Class is based on the structure of the vegetation. This is determined by the height and relative percentage of cover of the existing tree, shrub, dwarf shrub, and herbaceous strata. This level has eight mutually exclusive classes
Domain name: nvcs – class

CLASS	DEFINITION
I. FOREST	Trees with their crowns overlapping (generally forming 60 – 100% cover)
II. WOODLAND	Open stands of trees with crowns not usually touching (generally forming 25 – 60% cover) Canopy tree cover may be less than 25% in cases when the cover of each of the other life forms present (i.e. shrub, dwarf-shrub, herb, nonvascular) is less than 25% and tree cover exceeds the cover of other life forms
III. SHRUBLAND	Shrubs generally greater than 0.5 m tall with individuals or clumps not touching to overlapping (generally forming > 25% canopy cover – tree cover generally <25%) Shrub cover may be less than 25% in cases when the cover of each of the other life forms present (i.e. tree, dwarf-shrub, herb, nonvascular) is less than 25% and shrub cover exceeds the cover of the other life forms
IV. DWARF-SHRUBLAND	Low growing shrubs usually under 0.5 m tall. Individuals or clumps not touching to overlapping (dwarf-shrubs generally forming >25% cover – trees and shrubs generally <25% cover) dwarf-shrub cover may be less than 25% in cases when the cover of each of the other life forms present (i.e. tree, shrub, herb, nonvascular) is less than 25% and dwarf-shrub cover exceeds the cover of the other life forms.
V. HERBACEOUS VEGETATION	Herbs (graminoids, forbs and ferns) dominant (generally forming at least 25% canopy cover). Trees shrubs and dwarf-shrubs generally with less than 25% cover. Herbaceous canopy cover may be less than 25% in cases when the cover of each of the the other life forms present (i.e. tree, shrub, dwarf-shrub, nonvascular) 'is less than 25% and herbaceous cover exceeds the cover of the other life forms.
VI. NONVASCULAR VEGETATION	Nonvascular cover (bryophytes, lichens and algae) dominant (generally forming at least 25% cover). Trees, shrubs, dwarf-shrubs and herbs generally with less than 25% cover. Nonvascular cover may be less than 25% in cases when the cover of each of the other life forms present (tree, shrub, dwarf-shrub, and herb) is less than 25% and non-vascular cover exceeds the cover of the other life forms. Crustose lichen-dominated areas should be placed in the Sparsely Vegetated class.
VII. SPARSE VEGETATION	Vegetation is scattered or nearly absent; total vegetation cover, excluding crustose lichens (which can sometimes have greater then 10% cover) is generally 1%- 10%
NON-VEGETATED	<1% Vegetation cover

16. Name: height
    Alias: height class
    Type: text
    Length: 8
    Definition: Height of the dominant strata height class
    Domain name: nvcs – height class

17. Name: nvcs_subcl
    Alias: nvcs subclass
    Type: text
    Length: 8
    Definition: The physiognomic level Subclass is determined by the predominant leaf phenology of classes defined by a tree, shrub, or dwarf shrub strata (evergreen, deciduous, mixed evergreen-deciduous), the average vegetation height for types defined by the herbaceous stratum (tall, medium-tall, short), and particle size of the substrate for sparsely vegetated and nonvascular communities (e.g. consolidated rocks, gravel/cobble, sand accumulations, mud flats).
    Domain name: nvcs – subclass

18. Name: nvcs_group
    Alias: nvcs group
    Type: text
    Length: 8
    Definition: The units for the physiognomic level Group are based largely on a combination of climate, leaf morphology, and leaf phenology. In addition to climate and leaf characteristics, the groups for the sparse woody classes (i.e., sparse woodland, sparse shrubland, and sparse dwarf shrubland) are defined by the dominant lower stratum.
    Domain name: nvcs – group (Domain customized for individual stations or local area).

19. Name: nvcs_subgr
    Alias: nvcs subgroup
    Type: text
    Length: 8
    Definition: The physiognomic level Subgroup represents an ecological grouping of vegetation units based on relative human impact (natural/semi-natural or cultural)
    Domain name: nvcs – subgroup

20. Name: nvcs_form
    Alias: nvcs formation
    Type: text
    Length: 20
    Definition: The physiognomic level Formation represents an ecological grouping of vegetation units based on broadly defined environmental factors such as elevation and hydrologic regime, and additional structural factors such as crown shape, and height.
    Domain name: nvcs – formation

21. Name: nvcs_alli
    Alias: nvcs_alliance
    Type: text
    Length: 20
    Definition: Identifies all known floristic level Alliances present in RLGIS through NVCS code. Code is assigned through a domain table to define the link between the coded value and the Alliance name. The Alliance level of the NVCS can be defined as the following: The Alliance is a physiognomically uniform group of plant associations sharing one or more diagnostic species (dominant, differential, indicator, or character), which, as

a rule, are found in the uppermost strata of the vegetation (see Mueller-Dombois and Ellenberg 1974). The Alliance is roughly equivalent to the “cover type” of the Society of American Foresters (Eyre 1980), although it is not restricted to describing forest cover. The Alliance may be finer in detail than a cover type when the dominant species extend over large geographic areas and varied environmental conditions. The Alliance is also similar in concept to the “Series.” Alliances, however, are described by the diagnostic species for all existing vegetation types, whereas series are restricted to climax types and are described by the primary dominant species (see Pfister and Arno 1980).
Domain name: nvcs - alliance

22. Name: nvcs_asso
    Alias: nvcs_association
    Type: text
    Length: 20
    Definition: Identifies all known floristic level Associations present in RSL through NVCS code. Code is assigned through a domain table to define the link between the coded value and the Association name. The Association level of the NVCS can be defined as the following: An Association is a physiognomic uniform group of vegetation stands that share one or more diagnostic (dominant, differential, indicator, or character) overstory and understory species. These elements occur as repeatable patterns of assemblages across the landscape, and are generally found under similar habitat conditions.
    Domain name: nvcs - association

23. Name: fld_alli
    Alias: field alliance
    Type: text
    Length: 20
    Definition: Identifies NVCS data collected in the field to be used in image classification/photo interpretation and accuracy assessment sites. (Please note that this field must only be populated if a formal accuracy assessment is being conducted.)
    Domain name: nvcs - alliance

24. Name: fld_asso
    Alias: field association
    Type: text
    Length: 20
    Definition: Identifies NVCS data collected in the field to be used in image classification/photo interpretation and accuracy assessment sites. (Please note that this field must only be populated if a formal accuracy assessment is being conducted.)
    Domain name: nvcs - association

25. Name: train_acc
    Alias: training/accuracy
    Type: long integer
    Precision: 0
    Definition: Identifies if field data collected and assigned to a polygon is to be used as training data (Data used in automated image classification or to train the eye of a photo interpreter to label other polygons not visited in the field) or accuracy assessment (Data not used in the training process and held in reserve to assess the accuracy of the image classification) field data or no field data. (Please note that this field must only be populated if a formal accuracy assessment is being conducted.)
    Domain name: vegetation data type

26. Name: other_veg1
    Alias: non-associated 1
    Type: text
    Length: 50
    Definition: Identifies individual plant species not listed as obligates in the NVCS Alliance or Association. Relative to vegetation mapping the non-associated species with the highest occurrence should be listed in the first of the non-associated vegetation fields with additional listing to follow sequentially based upon their level of occurrence within the polygon.
    Domain name: plant – scientific

27. Name: cover_1
    Alias: percent cover 1
    Type: text
    Length: 8
    Definition: Identifies class of canopy or ground cover estimated as a percent of the area (polygon) containing non associated plant species.
    Domain name: vegetation percent cover

28. Name: other_veg2
    Alias: non-associated 2
    Type: text
    Length: 50
    Definition: Identifies individual plant species not listed as obligates in the NVCS Alliance or Association. Relative to vegetation mapping the non-associated species with the highest occurrence should be listed in the first of the non-associated vegetation fields with additional listing to follow sequentially based upon their level of occurrence within the polygon.
    Domain name: plant – scientific

29. Name: cover_2
    Alias: percent cover 2
    Type: text
    Length: 8
    Definition: Identifies class of canopy or ground cover estimated as a percent of the area (polygon) containing non associated plant species.
    Domain name: vegetation percent cover

30. Name: other_veg3
    Alias: non-associated 3
    Type: text
    Length: 50
    Definition: Identifies individual plant species not listed as obligates in the NVCS Alliance or Association. Relative to vegetation mapping the non-associated species with the highest occurrence should be listed in the first of the non-associated vegetation fields with additional listing to follow sequentially based upon their level of occurrence within the polygon.
    Domain name: plant – scientific

31. Name: cover_3
    Alias: percent cover 3
    Type: text
    Length: 8
    Definition: Identifies class of canopy or ground cover estimated as a percent of the area (polygon) containing non associated plant species.
    Domain name: vegetation percent cover

32. Name: other_veg4
    Alias: non-associated 4
    Type: text
    Length: 50
    Definition: Identifies individual plant species not listed as obligates in the NVCS Alliance or Association. Relative to vegetation mapping the non-associated species with the highest occurrence should be listed in the first of the non-associated vegetation fields with additional listing to follow sequentially based upon their level of occurrence within the polygon.
    Domain name: plant – scientific

33. Name: cover_4
    Alias: percent cover 4
    Type: text
    Length: 8
    Definition: Identifies class of canopy or ground cover estimated as a percent of the area (polygon) containing non associated plant species.
    Domain name: vegetation percent cover

34. Name: other_veg5
    Alias: non-associated 5
    Type: text
    Length: 50
    Definition: Identifies individual plant species not listed as obligates in the NVCS Alliance or Association. Relative to vegetation mapping the non-associated species with the highest occurrence should be listed in the first of the non-associated vegetation fields with additional listing to follow sequentially based upon their level of occurrence within the polygon.
    Domain name: plant – scientific

35. Name: cover_5
    Alias: percent cover 5
    Type: text
    Length: 8
    Definition: Identifies class of canopy or ground cover estimated as a percent of the area (polygon) containing non associated plant species.
    Domain name: vegetation percent cover

36. Name: acres
    Type: double
    Precision: 16
    Scale: 2
    Definition: Area of vegetation polygon in acres.

37. Name: class_1
    Alias: class 1
    Type: text
    Length:50
    Definition: placeholder for alternative vegetation classifications to enable crosswalk.

38. Name: class_2
    Alias: class 2
    Type: text
    Length:50
    Definition: placeholder for alternative vegetation classifications to enable crosswalk.

39. Name: class_3
    Alias: class 3
    Type: text
    Length:50
    Definition: placeholder for alternative vegetation classifications to enable crosswalk.

40. Name: comments
    Type: text
    Length: 255
    Definition: Describes any additional information important to the associated record that is not contained within the existing fields.

4.1 National Vegetation Classification System (NVCS)

The National Vegetation Classification System (NVCS) is a hierarchical classification system made up of physiognomic and floristic levels that can be applied to all terrestrial vegetation as well to wetland rooted vascular plants (**Figure 4.1.1**).

	SYSTEM
	CLASS
	SUBCLASS
	GROUP
	SUBGROUP
Physiognomic levels	FORMATION
Floristic levels	ALLIANCE
	ASSOCIATION

Figure 4.1.1. NVCS classification hierarchy.

The NVCS represents existing vegetation rather than climax or potential vegetation. The USFWS has adopted the use of the NVCS as a standard for mapping vegetation and related land cover types. Federal Geographic Data Committee (FGDC) also requires its use to the Formation level of the classification when federal funds are expended. For a full definition of the classification hierarchy go to:

http://www.fgdc.gov/standards/status/sub2_1.html

The use of NVCS may not be completely applicable to the needs of all refuge lands and may be supplemented with other classification systems in addition to NVCS when appropriate. The data structure within the vegetation feature class contains place holders for additional classifications to be attached to vegetation/landcover/habitat polygons. Most commonly NVCS is cross walked to the Cowardin Wetland Habitat Classification or an Omart Anderson riparian structure classification.

4.2 Mapping vegetation not described by NVCS

In many parts of the country the NVCS classification schema at the floristic levels are incomplete. In addition the majority of the schema completed encompass only natural plant communities and not disturbed or invasive plant communities. This shortfall impacts a large number of refuges which contain some area of disturbed or invasive plant communities. These areas are often important to inventory for monitoring and management purposes.

For cases when the NVCS classification schema does not exist or it is inappropriate in the description of the vegetation or management needs of the refuge being mapped, schema may be created to meet these needs. Care must be taken creating new classification schema to ensure the classification remains mutually exclusive as well as exhaustive. New classification schema should be described in a fashion similar to NVCS. Coding of the new classes should follow the example bellow:

Example: bda-01 *Prosopus pubsesnce / Sporalbolis Aroidies* Woodland Association – Community found in flood plain primarily on west side of the Rio Grande adjacent or within intermediately flooded areas. Other associated species include; *Distichlis spicata, Hordeum jubatum, Lycium berlandieri* and *Panicum obtusum*.

Use the refuge literal '-'and a 2 integer value for the code. Use a '0' as a place holder for single digit integers.

4.3 Developing a comprehensive report of vegetation communities

There are a number of sources available to begin the development of vegetation community reports (alliance and association list). The first step in development of these data are understanding the ecological communities on the refuge. This can be done through field reconnaissance and through consultation with local experts. Once a general understanding of the existing plant communities are obtained a comprehensive report of existing alliances and associations can be developed. This report should act as a road map and guide to describing plant communities in detail (**See Appendix I:*Vegetation Communities of Bosque del Apache NWR***).

The most complete list of alliance and associations can be found online at NatureServe Explorer Ecological Communities and Systems (http://www.natureserve.org/explorer/index.htm). Alliances and associations can be queried by state and obligate species. As an example *Distichlis spicata* was queried for New Mexico with the following the result at the association level:

Distichlis spicata Herbaceous Vegetation

Translated Name: Saltgrass Herbaceous Vegetation
Common Name: Inland Saltgrass Saline Prairie
Unique Identifier: CEGL001770
Classification Approach: International Vegetation Classification (IVC)
Summary: These grasslands occur in semi-arid and arid western North America from southern Saskatchewan to Mexico. Stands are found in lowland habitats such as playas, swales and terraces along washes that are typically intermittently flooded. The flooding is usually the result of highly localized thunderstorms which can flood one basin and leave the next dry. However, this association may also occur in other flood regimes (temporarily, seasonally, and semipermanently). Soil texture ranges from clay loam to sandy clay. These soils are often deep, saline and alkaline. They generally have an impermeable layer and therefore are poorly drained. When the soil is dry, the surface usually has salt accumulations. Salinity is likely more important than flooding as an environmental factor. Vegetation cover is sparse to dense and is dominated by *Distichlis spicata*, occurring in nearly pure stands. Minor cover of associated graminoids may include *Muhlenbergia asperifolia, Hordeum jubatum, Pascopyrum smithii, Sporobolus airoides, Carex filifolia, Eleocharis palustris, Puccinellia nuttalliana*, and *Juncus balticus*. Associated forbs, such as *Iva axillaris, Helianthus* spp., Asteraceae spp. (from lower salinity sites), *Salicornia rubra, Triglochin maritima*, and *Suaeda* spp., may also be present. Shrubs are rare, but scattered *Atriplex canescens* and *Sarcobatus vermiculatus* may be present.

Classification

---Jump to Section---

Classification Confidence: 2 - Moderate
Classification Comments: This graminoid association is characteristically dominated by *Distichlis spicata*. Closely related communities include *Pascopyrum smithii - Distichlis spicata* Herbaceous Vegetation (CEGL001580), *Sporobolus airoides - Distichlis spicata* Herbaceous Vegetation (CEGL001687), and several others.

Vegetation Hierarchy	
Formation Class	V - Herbaceous Vegetation
Formation Subclass	V.A - Perennial graminoid vegetation
Formation Group	V.A.5 - Temperate or subpolar grassland
Formation Subgroup	V.A.5.N - Natural/Semi-natural temperate or subpolar grassland
Formation Name	V.A.5.N.i - Intermittently flooded temperate or subpolar grassland
Alliance Name	*Distichlis spicata* Intermittently Flooded Herbaceous Alliance

Similar Associations	
Unique Identifier	**Name**
CEGL001481	*Leymus cinereus - Distichlis spicata* Herbaceous Vegetation
CEGL001580	*Pascopyrum smithii - Distichlis spicata* Herbaceous Vegetation
CEGL001687	*Sporobolus airoides - Distichlis spicata* Herbaceous Vegetation
CEGL001771	*Distichlis spicata* Mixed Herb Herbaceous Vegetation
CEGL001772	*Distichlis spicata - Lepidium perfoliatum* Herbaceous Vegetation
CEGL001773	*Distichlis spicata - (Scirpus nevadensis)* Herbaceous Vegetation
CEGL001834	*Eleocharis palustris - Distichlis spicata* Herbaceous Vegetation
CEGL002031	*Distichlis spicata - Hordeum jubatum - (Poa arida, Iva annua)* Herbaceous Vegetation
CEGL002039	*Polygonum* spp. - *Echinochloa* spp. - *Distichlis spicata* Playa Lake Herbaceous Vegetation
CEGL002042	*Distichlis spicata - (Hordeum jubatum, Poa arida, Sporobolus airoides)* Herbaceous Vegetation
CEGL002043	*Distichlis spicata - Schoenoplectus maritimus - Salicornia rubra* Herbaceous Vegetation
CEGL002273	*Distichlis spicata - Hordeum jubatum - Puccinellia nuttalliana - Suaeda calceoliformis* Herbaceous Vegetation
CEGL002275	*Distichlis spicata - Spartina* spp. Herbaceous Vegetation
CEGL002551	*Distichlis spicata - Hordeum jubatum - Puccinellia nuttalliana - Plantago maritima* Herbaceous

A second alternative to define alliance and associations is to work directly with state heritage officials or landscape ecologist. Working with state officials in many cases allows the access of additional plant communities not yet described in NatureServe.

In cases when the NVCS classification or heritage schema does not exist or it is inappropriate in the description of the vegetation or management needs of the refuge being mapped schema may be created to meet these needs. Care must be taken in creating new classification schema to ensure the classification remains mutually exclusive as well as exhaustive. New classification schema should be described in a fashion similar to NVCS. Coding of the new classes should follow the example bellow:

> **Example: bda-01 *Prosopus pubsesnce / Sporalbolis Aroidies* Woodland Association** – Community found in flood plain primarily on west side of the Rio Grande adjacent or within intermediately flooded areas. Other associated species include; *Distichlis spicata, Hordeum jubatum, Lycium berlandieri* and *Panicum obtusum*.
>
> Use the refuge literal '-'and a 2 integer value as the unique identifier. Use a '0' as a place holder for single digit integers.

The code (bda-01) is equal to the unique identifier used in NVCS and description of that new class equal to the alliance or association name.

In addition to a report a spreadsheet of the community alliances and associations should be generated in Excel. The spreadsheet should contain the unique identifier for each community and associated name. Within the Excel work should also be a list of dominant and common plant species on the refuge. The plant list should include scientific names (**See Appendix II: *Vegetation Communities of Bosque del Apache NWR Spreadsheet***). The generation of these lists will also support the development of attribute domain values discussed in **Chapter 5.1.**

5.1 Attribute domain values

Attribute domains are rules that describe the legal values of specific fields within RLGIS and in this case the vegetation feature class. Attribute domains are used to constrain the values allowed in particular fields. For example, 2 users collecting field data within the same NVCS Alliance may label it ***Sporobolus aroids* herbaceous alliance** and ***sporobolus airoides* alliance**. While both of these entries can be interpreted as the same plant community or habitat the database they are stored in views them as different. To keep field data collection consistent domains are created that contain NVCS Alliances, NVCS Associations, plant species list and other data collection variables. As a result of this some fields are populated from a pick-list instead of being entered, freely.

There are a number of ways to enter domain values into a GDB in this case RLGIS. To begin open **ArcCatalog** and right click on the Landcover and Habitat GDB. This will open the **Database Properties dialog**. Select the **Domains tab**. Enter the name of the domain to be entered, in this example it is '**association**'. Enter the description of the domain; '**NVCS plant association for Bosque del Apache NWR**'. Under **Domain Properties** change the field type to **text**. Under **Coded Values** the **Code and Description** columns may now be filled in (**Figure 5.1.1**). See section **5.2 Developing schema list for attribute domain values** for suggestions on how to develop domain list.

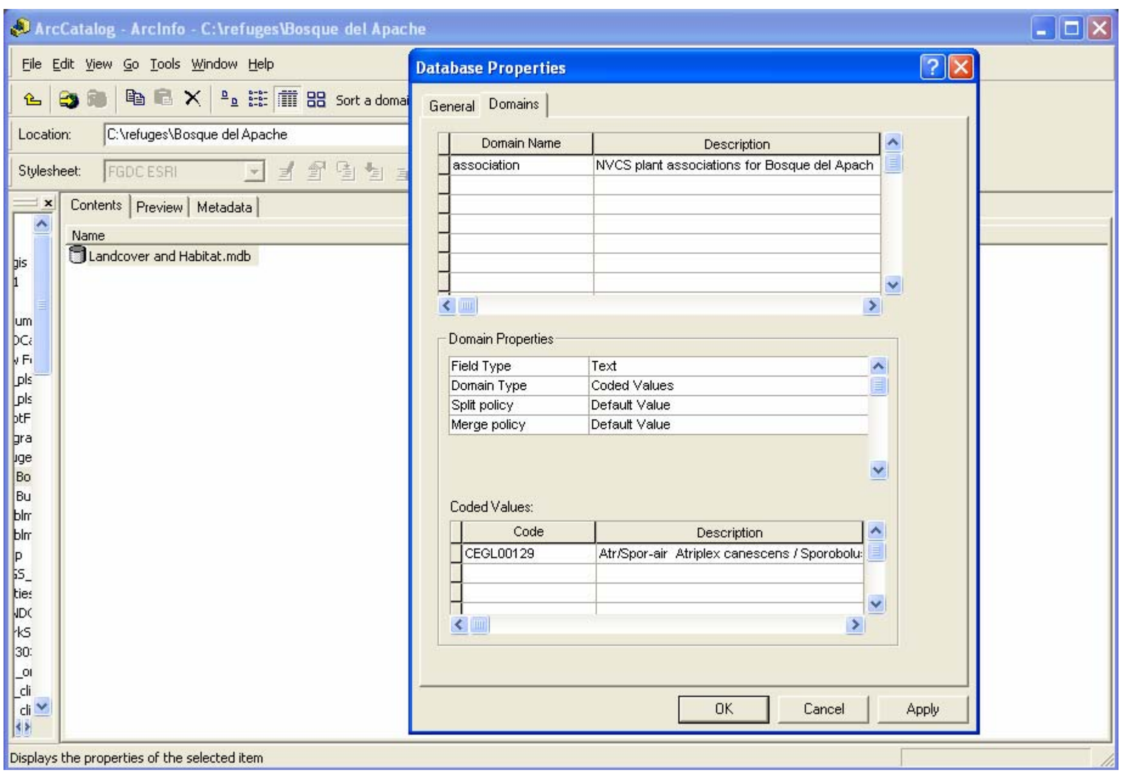


Figure 5.1.1. Manually adding text domain values to GDB

Note: Domain values may also be generated from existing tables using the Table to Domain Tool found in ArcToolbox. Add spreadsheet information for alliance, association and plant species discussed Chapter 4.3.

5.2 Developing schema list for attribute domain values

There are 3-4 domains that must be populated before field data can be collected. All of these domains must be set up as text field type with an 'other' value added to each domain as a place holder for additional information observed, but not listed.

Origin - Domain defines individual persons responsible for data collection. A list of filed data collectors should be developed prior to field data collection. It is recommended that the full name of the persons participating be used. These data should be entered as text with the code and description identical.

NVCS Alliance and/or NVCS Association - Domain defines codes and name of NVCS alliances and associations used to describe plant communities. These data should come from the documentation of existing communities on the NWR discussed in **Chapter 4.3**. Data should be entered as text with the NVCS unique identifier used as the code and the alliance or association name used as the description.

Note that in some cases the genus and species names within the description should be abbreviated to the first 3 letters so that they can be discerned from other alliance or association names when being viewed in the limited space provided by the ArcPad field form on Trimble GeoXTs. Visible characters within the forms are limited to 16-18 spaces.

> **Example: Ela-ang/Spor-air *Elaeagnus angustifolia* / *Sporobolus airoides* Alien Forest Association**

Plant Species – defines a list of common scientific plant species names present on refuge used as modifiers to NVCS alliance and/or association descriptions. These data should come from the documentation of dominant or common plants discussed in **Chapter 4.3**. Data should be entered as the scientific name of the plant species, text with the code and description identical.

> **Example: Code: *Muhlenberg asperifolia*; Description: *Muhlenberg asperifolia***

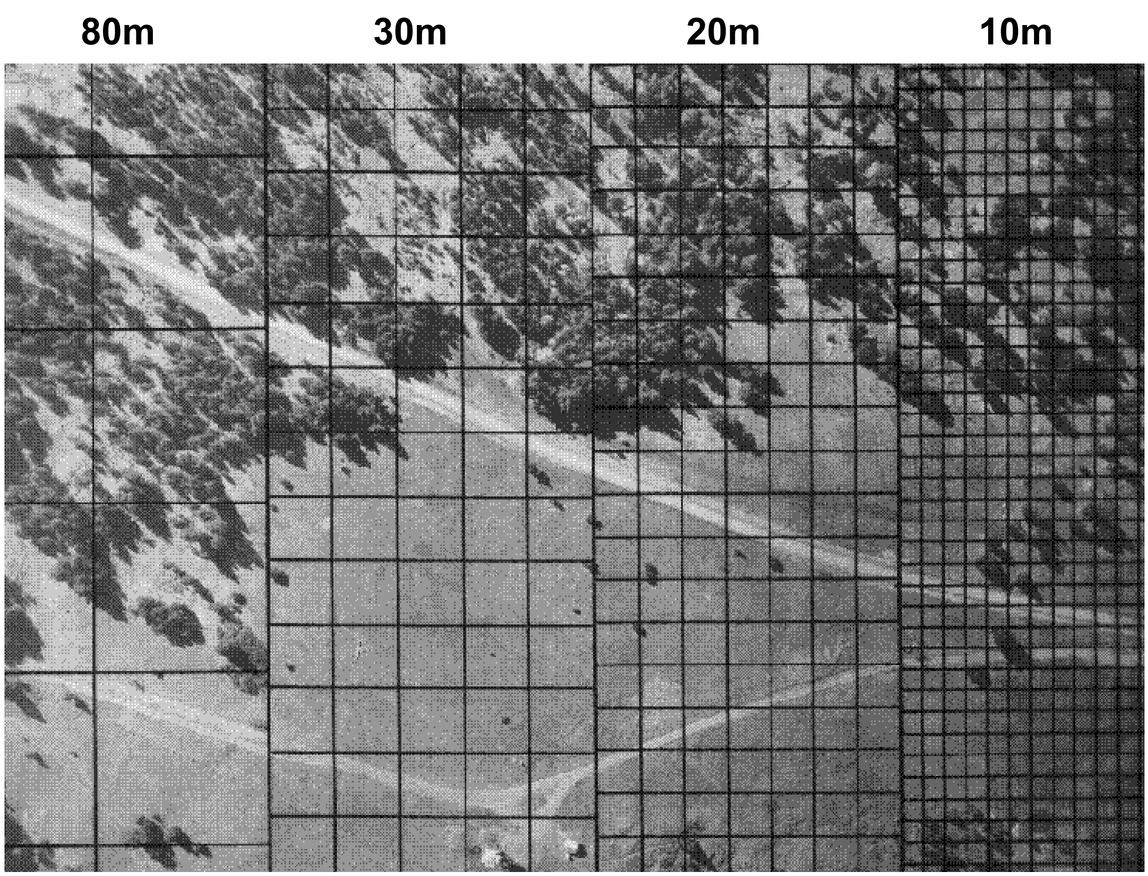
6.1 Image Acquisition: Basic considerations for selecting imagery in support of vegetation inventory and monitoring

When selecting imagery for vegetation projects there are 4 variables that should be taken into consideration, 3 of which will be discussed in this section the fourth in the following section; spatial, spectral, radiometric and temporal resolution.

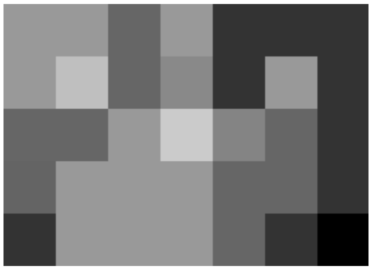
Spatial resolution is the most commonly understood imagery variable. While it is not usually the most important variable in imagery selection, considerations should be made to ensure that the spatial resolution used is appropriate to the analysis made. Spatial resolution of digital imagery can be identified by a unit of measure referred to as ground sample distance (GSD). GSD is an absolute measurement of a single pixel's dimension relative to the ground area that it represents. This is why GSD is also commonly referred to as pixel size. As an example if a single pixel within an image is representative of a 1-meter x 1-meter section of ground the GSD and pixel size is 1-meter spatial resolution.

High spatial resolution can be important in measuring and interpreting small objects on the ground. It is important to realize that usually only objects 3 to 4 x larger than the GSD can be identified in the imagery. Care should be taken to understand the spatial dimensions of the objects intended to be measured prior to image acquisition so that spatial resolution can be matched to inventory and monitoring needs.

The example below has divided up a scanned aerial photograph into 80 – 10-meter GSD pixels to demonstrate the affect large and small GSD can have spatial resolution:



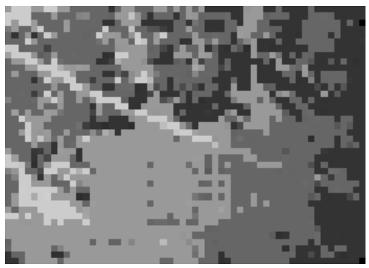
Demonstrated below are the affects pixel size can have on data. The original image was resampled at 80, 30, 20 and 10 meters to demonstrate this point.



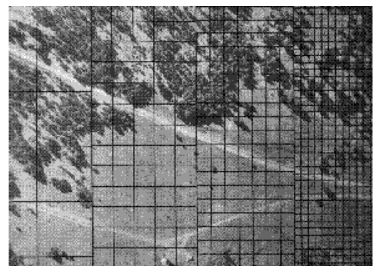
80m

30m

20m



10m



Original Photo

It is important to understand the trade offs that come with high spatial resolution imagery before it is acquired. 1) The higher the spatial resolution the more disk space the data will take up. This can also lengthen computer refresh times. 2) The higher the spatial resolution the higher the spectral diversity of the imagery. This can be an important variable depending on the classification applications applied to the imagery. 3) The higher the spatial resolution the higher the cost of the imagery in general.

Spectral Resolution is a lesser understood variable of imagery data. It is often the most important characteristic when selecting imagery for vegetation mapping. Spectral resolution refers to the number of discrete spectral bands of the electromagnetic (EM) spectrum the imagery represents. Imagery covering multiple spectral bands is referred to as multi spectral imagery. Multi spectral imagery is capable of discerning more features on the landscape because it is looking a wider range of spectral response from features on that landscape. **Figure 6.1.1** illustrates this by plotting spectral response curves of common landscape features across the spectral bands acquired by the Landsat 5 TM Satellite.

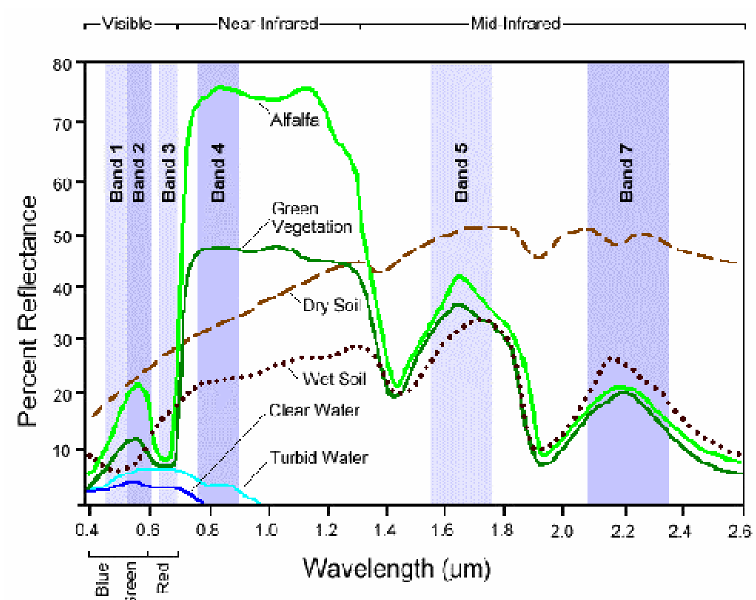


Figure 6.1.1 Spectral response curve by TM bands 1-7

Within the EM spectrum the near infrared region is the most important to vegetation mapping. Living vegetation is most reflective at this wavelength and can produce the most diversity in spectral response. It is for this reason that color infrared (CIR) imagery is commonly used to inventory vegetation. Although CIR is single band imagery it falls within the correct portion of the EM spectrum for vegetation mapping. That said additional bands of EM data can improve classification results and allow image indices and/or band ratioing to be applied to the data. **It is important to note that imagery stored in a RGB or red, green, blue format is <u>not</u> multi spectral data. It is only stored in a format that separated the original data into 3 non-discrete bands.**

In summary it should be understood that the higher the spectral resolution the higher the possibility of discerning different features on the ground. The most important region of the EM spectrum to vegetation mapping is the near infrared. Imagery used for vegetation mapping even if single band (CIR photography) should encompass a portion of the near infrared spectrum.

Radiometric Resolution is the least commonly understood variable related to imagery characteristics. It refers to the range of digital number (DN) values possible in a set of imagery data. Most commonly radiometric resolution of imagery used for vegetation mapping is 8 bit or 2^8 which is equal to 256 possible DN values. Because 8 bit data is so common it does not usually need to be specified, but the radiometric resolution of the imagery being acquired should be known prior to the acquisition; whether 4 bit, 8 bit, 16 bit or 32 bit data.

6.2 <u>Temporal and phynological considerations</u>

Beyond the considerations of imagery characteristics, the timing of the data collected can be critical to a projects success. Careful consideration must be taken to ensure that the variables being measured are present on the landscape or equally that other features which may introduce error in the analysis are not. A number of variables may need to be examined when planning the timing of image acquisition. Unfortunately there is no hard formula to follow. Timing is widely dependent on the ecological systems being inventoried coupled with the objectives of the analysis or measures calculated. In general the following guidelines should be observed:

- The majority of plant communities being targeted should be mature to maximize canopy cover and spectral response.
- If a single species is being targeted look for phynological characteristics that will most separate it from other species spectrally.
- Collect imagery as close to time of field data collection as possible. This may mean collecting data in the field the same time the following year or directly after imagery is acquired.
- Take into consideration abiotic effects on plant communities such as drought, fire and abnormally high precipitation amounts.

Most often poorly planned or under funded vegetation mapping projects are conducted with imagery that was not collected specifically for the project or that meet the specific temporal needs. As a result of using less than ideal imagery, it is important to consider the cost of increased field work, increased image processing or decreased accuracy in data. In some cases the fixes to poorly timed imagery can out weigh the cost of acquiring new imagery.

7.1 Digital Photo Ortho Rectification: ***Digital ortho rectification of airborne photography using ERDAS Imagine OrthoBase 8.7.0***

To support the development of vegetation/habitat inventory and monitoring at the floristic scale, high spatial and spectral imagery is required. Most often aerial digital and analog photography is chosen to meet these needs. To meet the temporal and budgetary constraints often associated with the acquisition of these data, the NWR Remote Sensing Lab applies common methods of digital ortho rectification. This process allows the imagery to be used with image processing and GIS software for data development and analysis.

The steps outlined in this chapter use ERDAS OrthoBase to complete the ortho rectification process of hard copy aerial photography. The Frame Camera Tour Guide chapter of the *ERDAS Imagine OrthoBase User's Guide* may be used as an additional reference to the procedures outlined below. For digital photography with IMU data please refer to the Digital Camera Tour Guide chapter of the *ERDAS Imagine OrthoBase User's Guide*. Please note that the steps outlined below assume the user has some familiarity with the software and methods being discussed.

Digital ortho rectification using ERDAS OrthoBase software requires the user to collect a number of ancillary data sources prior, as listed below are the required data needed to begin and complete the ortho rectification process.

1. **Camera Calibration Report** – This report can be obtained from the contractor or service personnel who acquired the resource photography as a paper copy or digital text file. The Lab already has a current copy of the camera calibration report for photography acquired using the Region 2 aircraft and camera. If a report cannot be obtained the rectification process can still be preformed, but expect the RMS errors to be higher as a result. Early historic resource photography often lacks calibration reports.

2. **Digital Elevation Model (DEM) –** A DEM covering the extent of the resource photography you intend to ortho-rectify must be acquired. It is recommended you navigate to the USGS EROS Data Center homepage and clip your DEM from the National Elevation Data Set (NED). This site can be reached by clicking: http://edcwww.cr.usgs.gov/products/elevation/ned.html. This process will give you a seamless DEM for your area. The extent of the DEM should cover the extent of the hydrologic unit coverage(s) (HUC) that intersect the boundary of the NWR. ArcCatalog can by used to acquire the geographic extent of the HUC.

3. **USGS Digital Ortho Quads (DOQ) –** DOQs covering the areas of the photography must be obtained. In Region 2, the Lab should already have merged copies of the DOQs for all NWR. Once acquired all DOQs should be mosaiced and color balanced. It is suggested that ERDAS Imagine be used to complete this process. Merged DOQs can be saved in any projected *.tif, *.grid, *.img, or *.sid formats.

4. **Scanning Photography –** When scanning photography please follow these specifications: 1) Always scan photos oriented to the north. This can be determined by aligning the photos to the DOQ or by studying the flight planning map. 2) Scan photos to include all fiducial marks. 3) Set the DPI from 300-600, RGB color. A setting of 300 DPI will produce a 22 MB image. A setting of 600 DPI will produce an 85 MB image. The Lab recommends you use a 350-400 DPI setting to reduce data storage issues. At 350-400 DPI the spatial resolution of the ortho-rectified image will still be ≤ 1-meter (See Naming Conventions section below for further details when scanning imagery).

Naming Conventions

A large number of temporary files are generated when ortho rectifying multiple frames of photography. DEM, merged USGS DOQ, individual ortho rectified imagery and merged ortho rectified imagery should be named following the standards outlined in the ***Region 2 Spatial (RS/GIS) Data Structure and Guidelines***. When scanning photos to be ortho rectified they should be named using the following the guidelines: NWR literal, underscore, flight line number, dash, frame number.

Example: ltr_1-12.tif = Little River NWR, flight line 1, frame 12.

The flight line and frame number should correlate to the information printed on the hard copy and scanned digital photo.

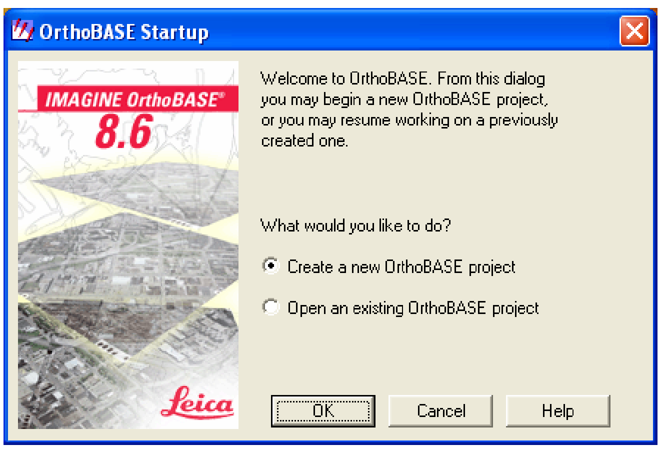
Ortho Rectification

Once ancillary data sources have been collected and photography scanned the ortho rectification process can begin using ERDAS OrthoBase.

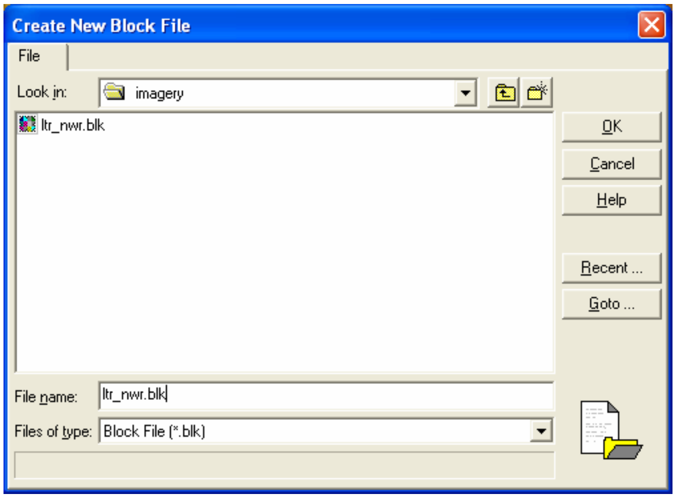
1. Start ERDAS IMAGINE and close viewer that automatically opens.

2. Click the OrthoBase icon 

on the ERDAS Imagine icon panel to open the Startup dialog. Select the **Create a new OrthoBase project** button and click **OK**.



3. The **Create New Block File** dialog opens. Navigate to the **imagery** folder under the associated NWR file the imagery covers. Name the file using the refuge literal, underscore followed NWR, Example: ltr_nwr.blk. Keep the **File Type** as Block File (*.blk) and click **OK**.

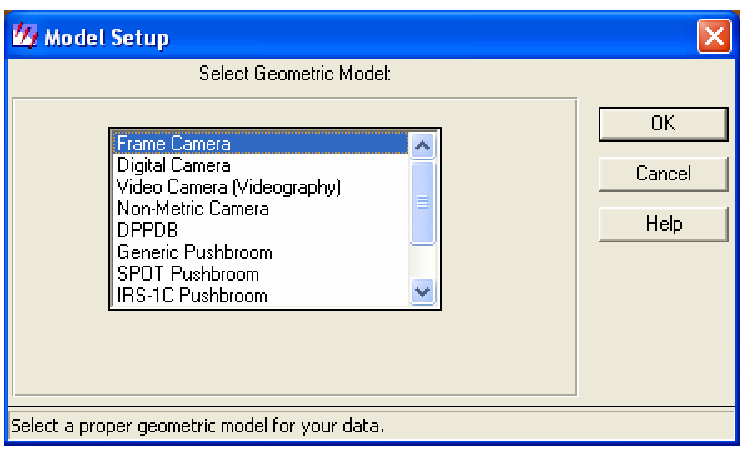


The IMAGINE OrthoBase .blk file

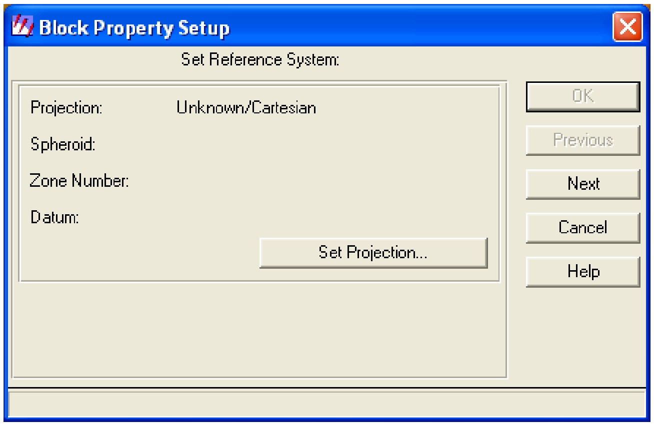
When you use **IMAGINE OrthoBase**, you create block files. Block files have the **.blk** extension. A block file may be made up of only one image, a strip of images that are adjacent to one another, or several strips of imagery.

The **.blk** file is a binary file. In it is all the information associated with the block including imagery locations, camera information, fiducial mark measurements, GCP measurements, and the like.

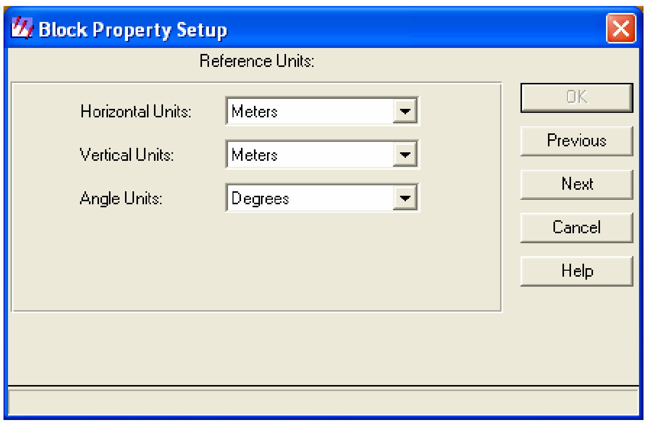
4. Once the block file is created the **Model Setup** dialog opens. Select the **Frame Camera** model and click **OK**.



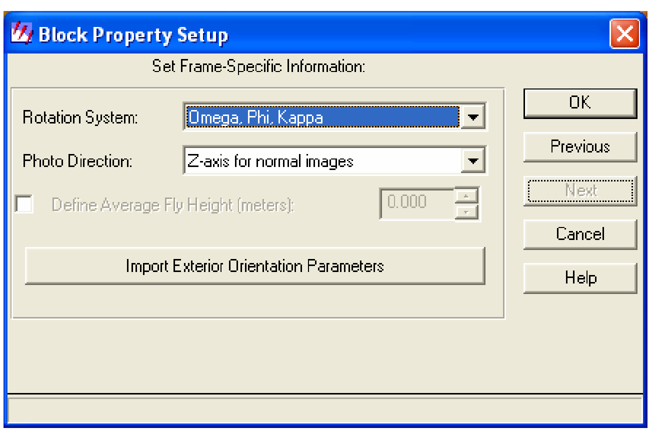
5. The **Block Property Setup** dialog now opens. Click the **Set projection** button and input the appropriate projection parameters (UTM, NAD83, GRS80, local zone).



6. Click the **Next** button and input the reference units as follows:

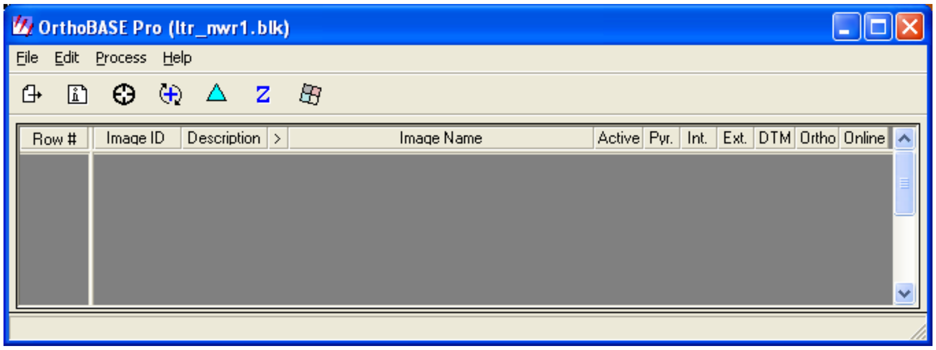


7. Click the **Next** button and input frame-specific information as follows:

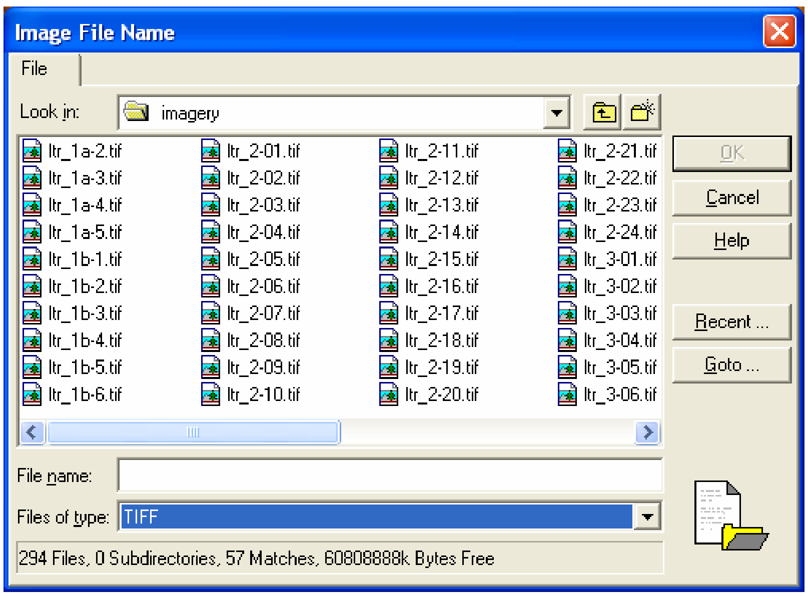


Check the box for **Define Average Fly Height (meters)** if known. If not know this parameter can be calculated using the scale of the photography and the focal length of the lens used. Click **OK**.

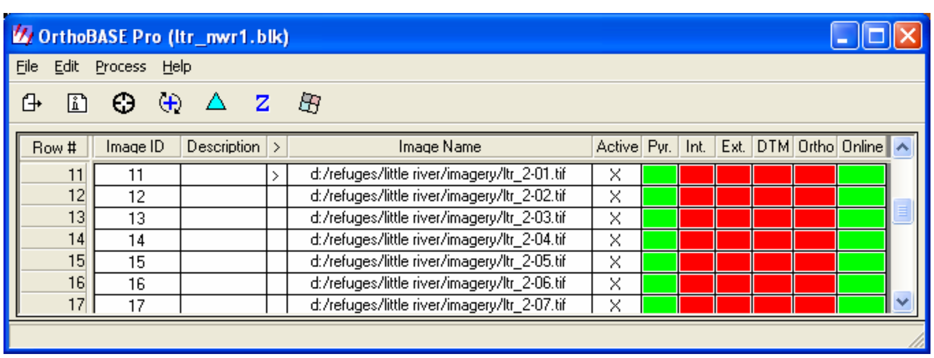
8. The **OrthoBase** dialog now opens.



Select **EDIT | Add Frame** from the menu bar or click the **Add Frame** icon to open the **Image File Name** dialog.



Set **Files of Type:** to **TIFF** and select all the files of scanned photography to be ortho rectified (Use **Shift** and **Ctrl** to select multiple images). Note that the File Type must set to the same file that the photography was saved as during the scanning process. Click **OK**.



9. Compute pyramid layers for all images added to the block file. Click the **Edit | Compute Pyramid Layers**. This will open the **Compute Pyramid Layers** dialog. Select the **All Images Without Pyramids** and click **OK**. Once done running the OrthoBase dialog should look similar to the graphic above, with the **Pyr.** column turned to green indicating the completion of this task.

   Pyramid layers generated by OrthoBase are based on a binomial interpolation algorithm and a Gaussian filter. Using this filter, image contents are preserved and computation times are reduced. Pyramid layers generated by OrthoBase overwrite those generated by ERDAS IMAGINE, which uses different methods in pyramid generation.

The OrthoBase dialog *(What you should know)*

As images are added to the block file, they are listed in the OrthoBase dialog. Each image has a series of columns associated with it.

The **Row #** column enables you to select an image specifically for use with OrthoBase, for example, you may want to generate pyramid layers for one image alone.

The **Image ID** column provides a numeric identifier for each image in the block. You can change the Image ID if you wish.

The **Description** column provides space for you to supply additional information about the image, such as date of capture.

The **>** column lets you designate the image that is currently active.

The **Image Name** column lists the directory path and file name for each image. When the full path to the image is specified, the corresponding Online column is green.

The **Active** column displays an X designating which images are going to be used in the OrthoBase processes such as automatic tie point generation, triangulation, and ortho rectification. By default, all images are active.

The final five columns' status is indicated in terms of color: green means the process is complete; red means the process is incomplete. The color of the columns is controlled by a preference setting. In the OrthoBase category of the Preference Editor, change the Status On Color and Status Off Color to different colors if you wish.

The **Pyr.** column indicates the presence of pyramid layers.

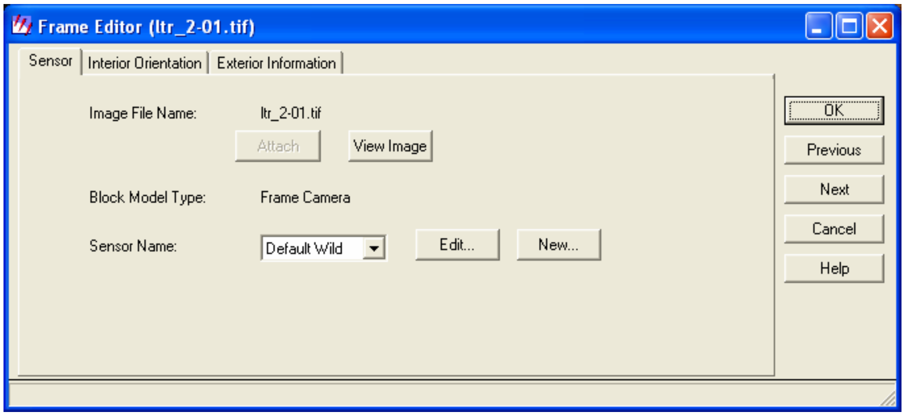
The **Int.** column indicates if the fiducial marks have been measured.

The **Ext.** column indicates if the final exterior orientation parameters are complete.

The **Ortho** column indicates if the images have been ortho rectified.

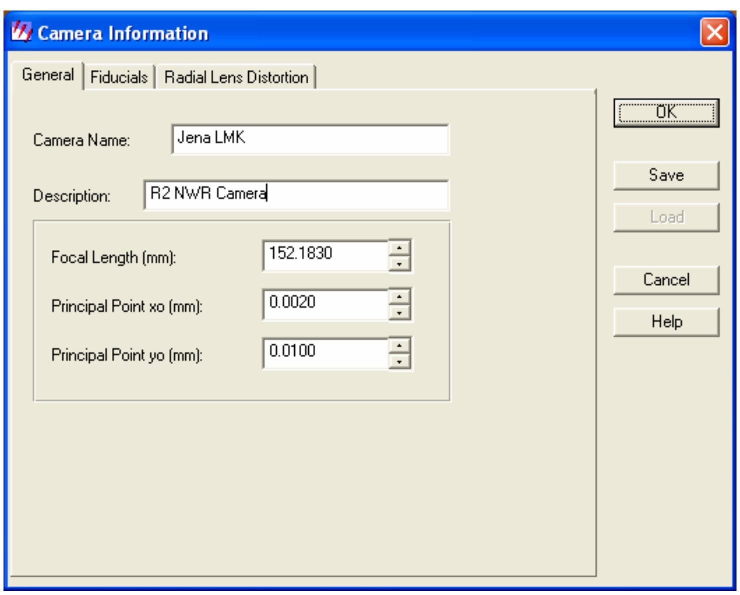
The **Online** column indicates if the images have a specified location.

10. When the camera model is defined, information about the position of the photo fiducials as well as the exterior orientation information of the camera that collected the imagery. To begin this process select **Edit | Frame Edit** or from the OrthoBase dialog menu or click the **Frame Properties** icon. The Frame Editor dialog should open displaying information about the selected image in the OrthoBase dialog.

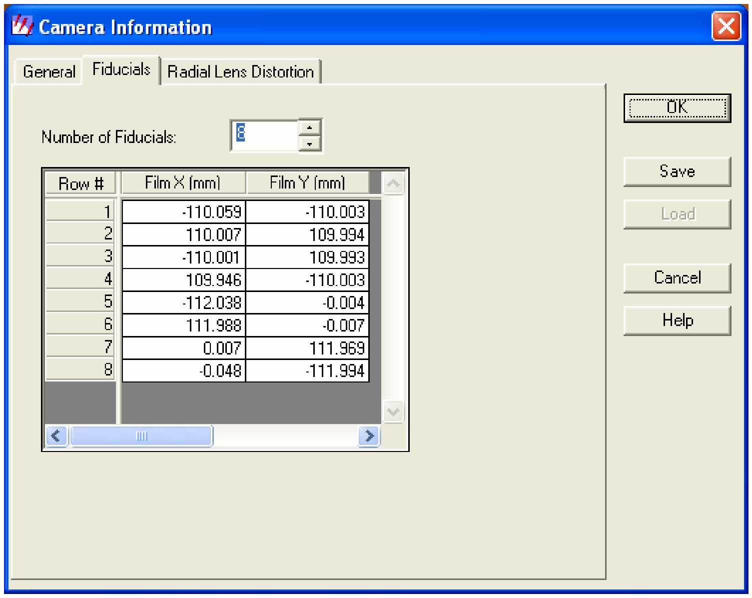


Select the **Sensor Name** tab, click the **New** button and the Camera Information dialog opens.

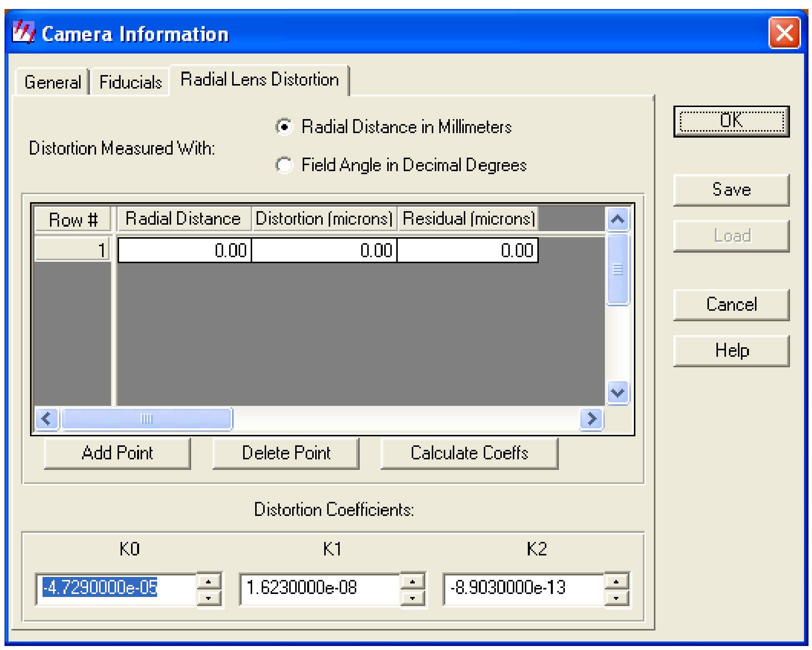
11. Under the **General** tab, enter the name of the camera under **Camera Name** and calculated focal length, principal point x0 and principal point y0 in the appropriate text boxes. This information is displayed in the **camera calibration report** for the imagery being ortho rectified.



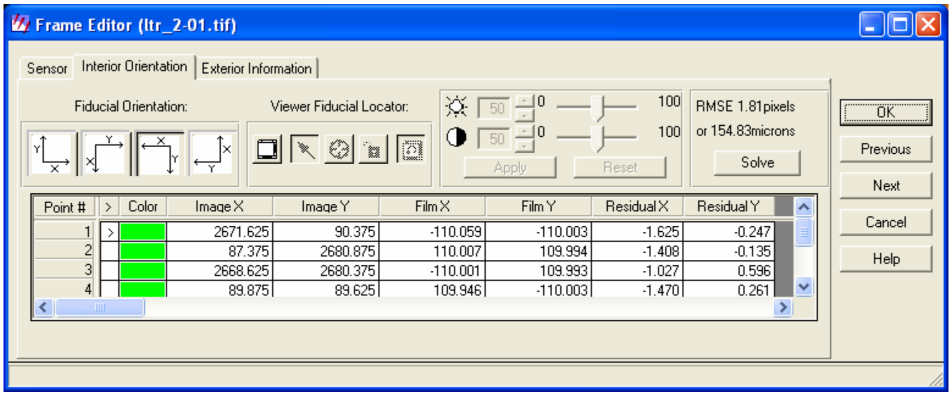
Go to the **Fiducials** tab and enter the fiducial calibration information from the calibration report for the number of fiducials in the images. Use the diagram in the calibration report to associate the fiducial with the correct Film X and Film Y measurements.

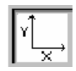


Go to the **Radial Lens Distortion** tab and enter the distortion coefficients from the calibration report for **K0**, **K1** and **K2**. Once complete click **OK. Please note that camera calibration reports can be saved and uploaded to the Camera Information dialog to avoid manual input to the system parameters.**



12. In the **Frame Editor** Dialog select the **Interior Orientation** tab. Here calibration information will be used to calculate the RMSE of the fiducials on the imagery.

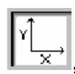


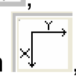
First select the correct **Fiducial Orientation** using the icon . In most cases each line of imagery should have a different fiducial orientation as a result of the plain flying in opposite directions while collecting imagery.

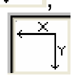
Understanding Fiducial Orientation

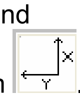
To select the proper fiducial orientation, compare the axis of the photo coordinate system, defined in the camera calibration report with the orientation of the image.

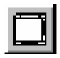
The four possible fiducial orientations are, in order:

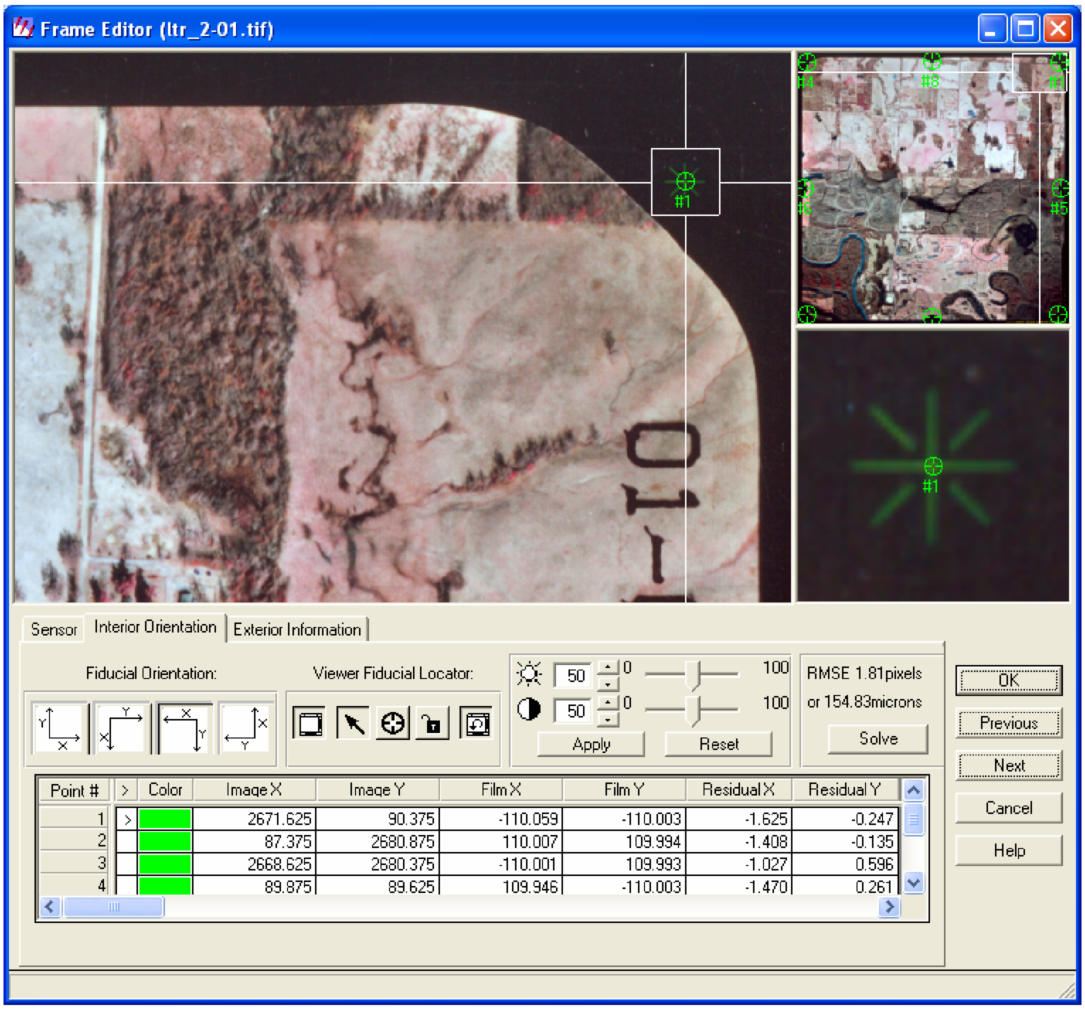
1. photo-coordinate system parallel to image orientation ,

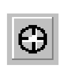
2. image rotated 90° relative to the photo-coordinate system ,

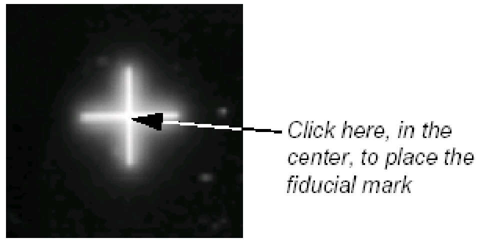
3. image rotated 180° relative to the photo-coordinate system,  and

4. image rotated 270° degrees relative to the photo-coordinate system .

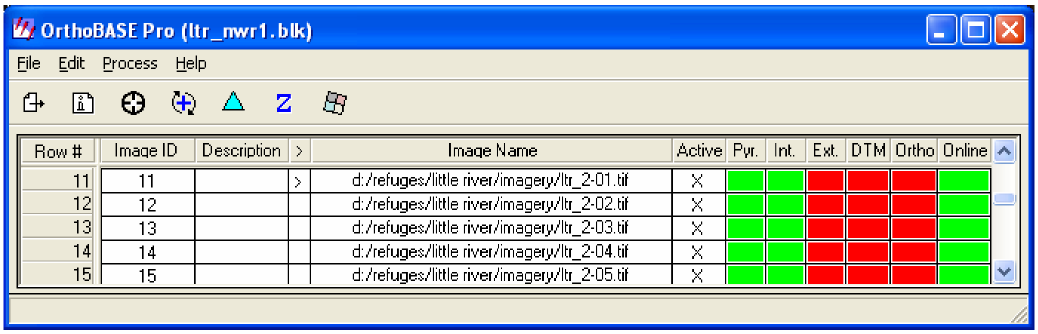
13. Click on the **View** icon  on the **Frame Editor** dialog. This will open 3 linked viewers in the **Frame Editor** dialog. The views consist of an **Over View** that shows the entire image (upper right), the **Main View** (right) that displays the imagery within the link cursor in the **Over View** and the **Detail View** that displays the imagery within the link cursor in the **Main View**.



Select the **Place Image Fiducial** icon  and begin to identify fiducial centers on the imagery (See below). If the fiducial calibration measurements and fiducial orientation are setup correctly the viewers should navigate to the approximate location of the correct fiducial automatically as they are placed on the photo. Use the arrow icon  to the right of the **Place Image Fiducial** icon to move the **Link Cursors** as needed to center the fiducial on the photo before identifying the fiducial center. Identify all fiducial centers for every fiducial on the photo, (usually 8, 4 in older photography). Once all the fiducial centers are selected the root mean square error (RMSE) is calculated. This value is calculated in both pixels and microns. The values here will vary depending on the calibrated system used and the placement of the fiducial centers. If done with some precision, adjustment of the fiducial centers usually does not result in much change of the RMSE value. In most cases the RMSE should be below 2.00 pixels for the level of precision required for natural resource monitoring. Repeat this process until all photos have an expectable RMSE value.



Once complete the **Int.** column in the OrthoBase dialog should now appear green instead of red.



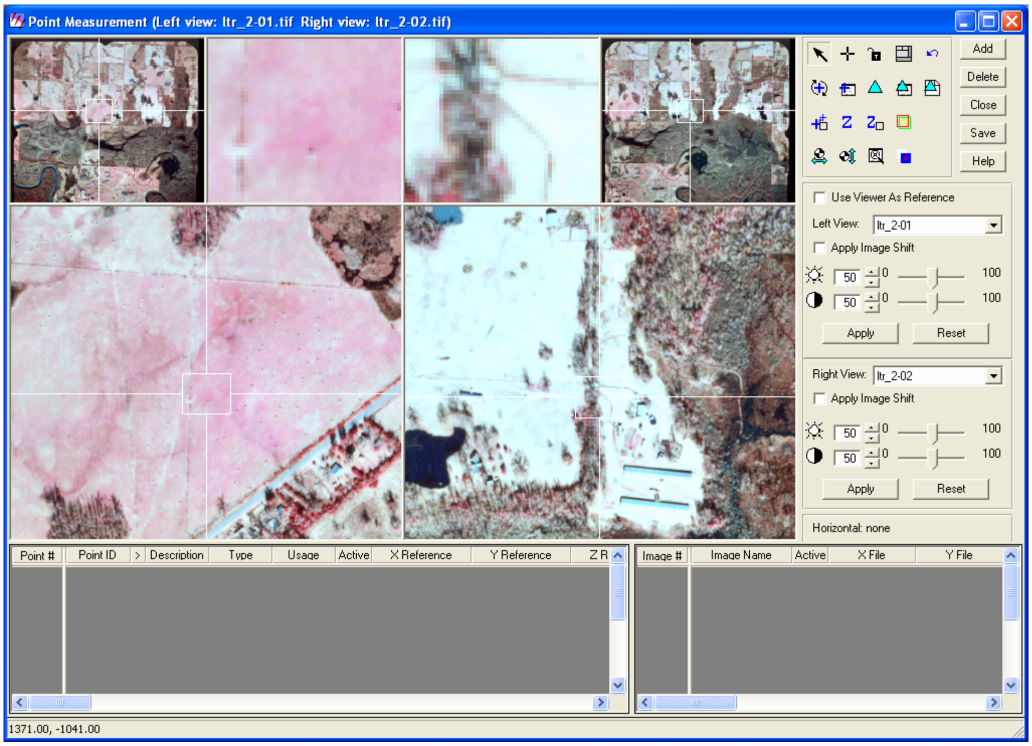
Calculating Exterior Geometry

Now that the interior geometry of the imagery has been calculated, information needed to calculate the exterior geometry must be generated before the imagery can be ortho rectified. This process can be complex and raise project specific issues that are not be addressed in this document. In addition there are software features that may enhance project specific workflow that are not discussed in this document. If software questions arise that fall outside the scope of this document refer to the ERDAS Imagine OrthoBase User's Guide. R2 users may also contact the NWR Remote Sensing Lab for technical support.

Calculating exterior geometry parameters are similar to the methods used in geo-rectification, when ground control points (GCPs) are selected and correlated to a reference image that has already been projected. In the ortho rectification process points are selected and correlated to a reference image already projected (USGS merged DOQ) to calculate the X and Y coordinates for control points as well as to an associated DEM to calculate a Z value. In addition points are only selected in areas of overlap between photos in order to converge the model. By the model rule a minimum of 2 points must be common to overlapping photos for the model to converge and triangulate. A minimum of three points is usually recommended for this method. Object recognition within the software allows the automated generation of additional tie points that are used in the model to rectify photos within the block (block processing). This reduces the number of points an analyst is required to select (3 common to overlapping photos). Only the number of points needed for the model to triangulate and generate additional tie points is required.

Selection of GCPs will affect the spatial accuracy of the ortho rectification. The difficulty of selecting and placing GCPs will vary project by project and with the experience of the analyst. As a general strategy when selecting GCPs, analyst should look for well defined features in both images. Man made features often provide the best choice, but can be subject to change through development in some areas. Natural features can also be used when well defined; vegetation can be affected by the phynological differences in land cover types resulting from temporal and spectral differences in the imagery. Avoid natural features occurring in areas subject to change, such as shore lines and river confluences. It is important to remember that in some cases a poor GCP may be the only or best option available and should be used when necessary.

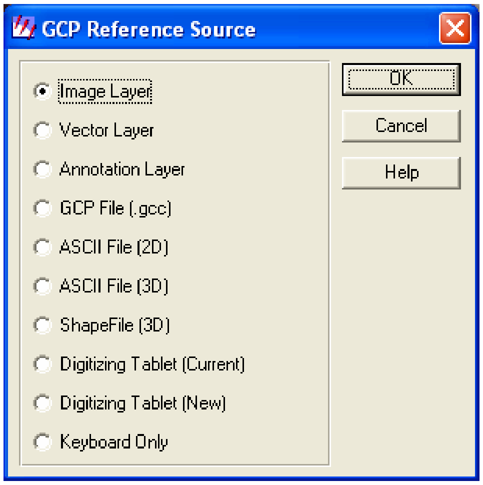
14. To start the GCP point measuring process select **Edit | Point Measurement** from the OrthoBase dialog tool bar. The **Point Measurement** icon  on the OrthoBase dialog tool bar can also be used to open the dialog. The **Point Measurement** tool should now open displaying the first 2 images in the block file.



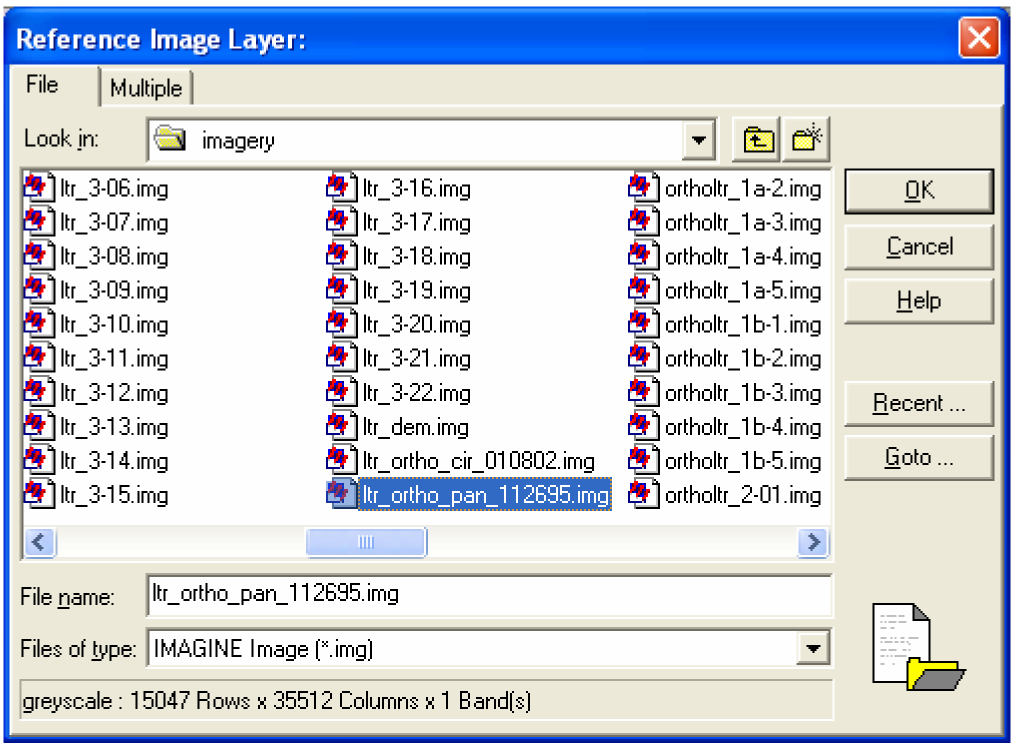
The Point Measurement tool consists of a tool palette, a reference cell array (which gives coordinate values), a file cell array (which gives image coordinate values), and six views in two groups of three. Each group displays different views of the selected image files from the block file.

Before GCPs can be collected the merged USGS DOQs and DEM must be referenced.

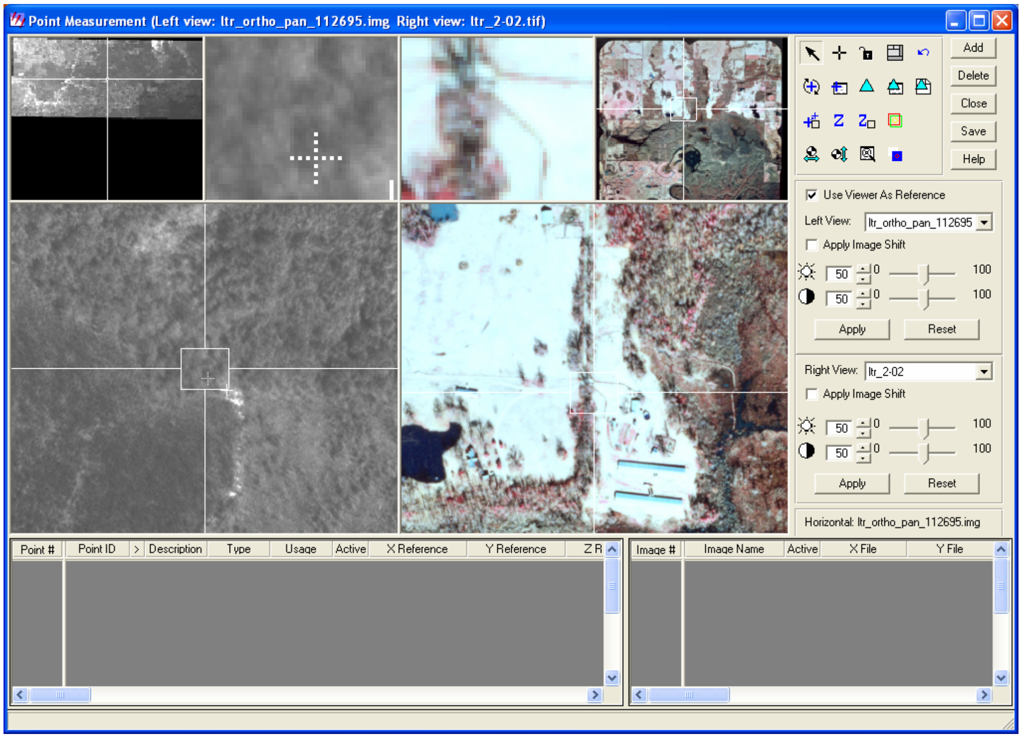
Begin by selecting the **Reference Source** icon  from the **Point Measure** tool. This will open the **GCP Reference Source** dialog.



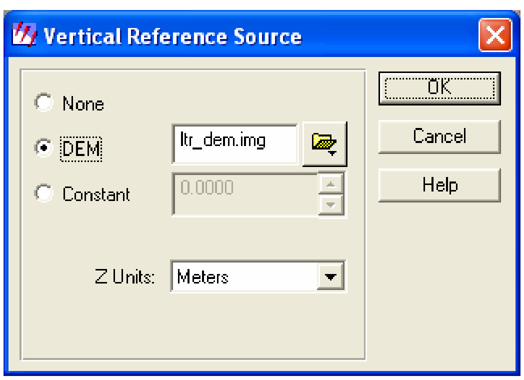
In the **GCP Reference Source** dialog select **Image Layer** and click **OK**.

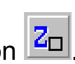
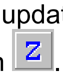


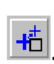
Navigate to the folder containing the merged USGS DOQs, select it and click **OK**, closing the **Reference Image Layer** dialog. Now in the **Point Measurement** dialog check the **Use Viewer As Reference** box under **Left View**. The merged DOQ will now appear in the left viewers.



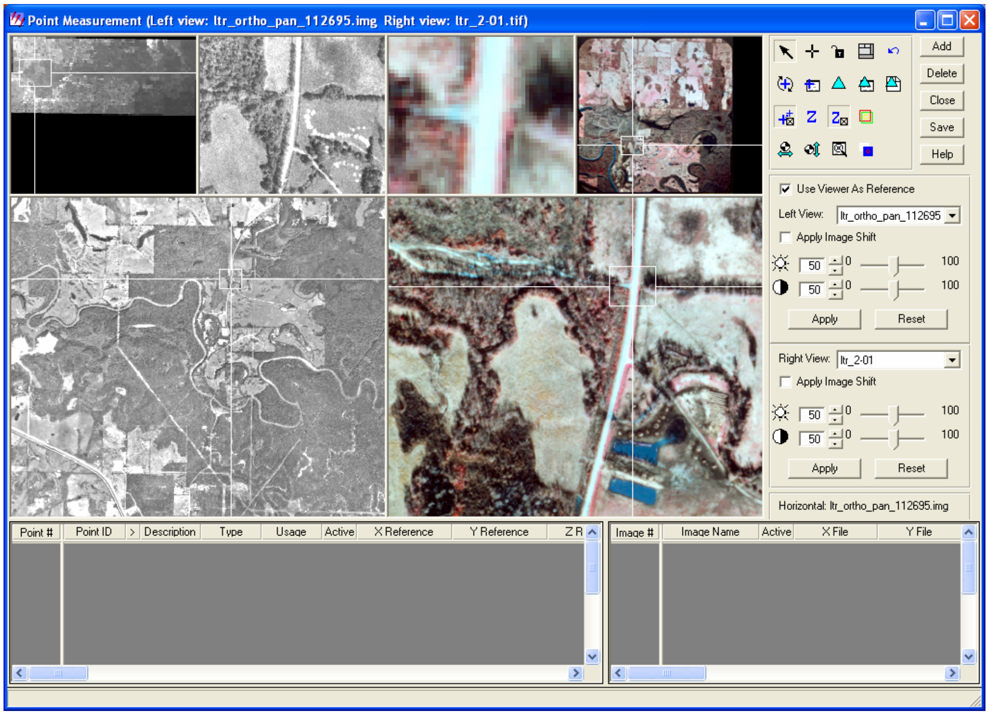
Select the **Set Vertical Reference Source** icon  from the Point Measurement tool bar. This will open the **Vertical Reference Source** dialog. Select the DEM button and navigate to the file containing the DEM and click **OK**.



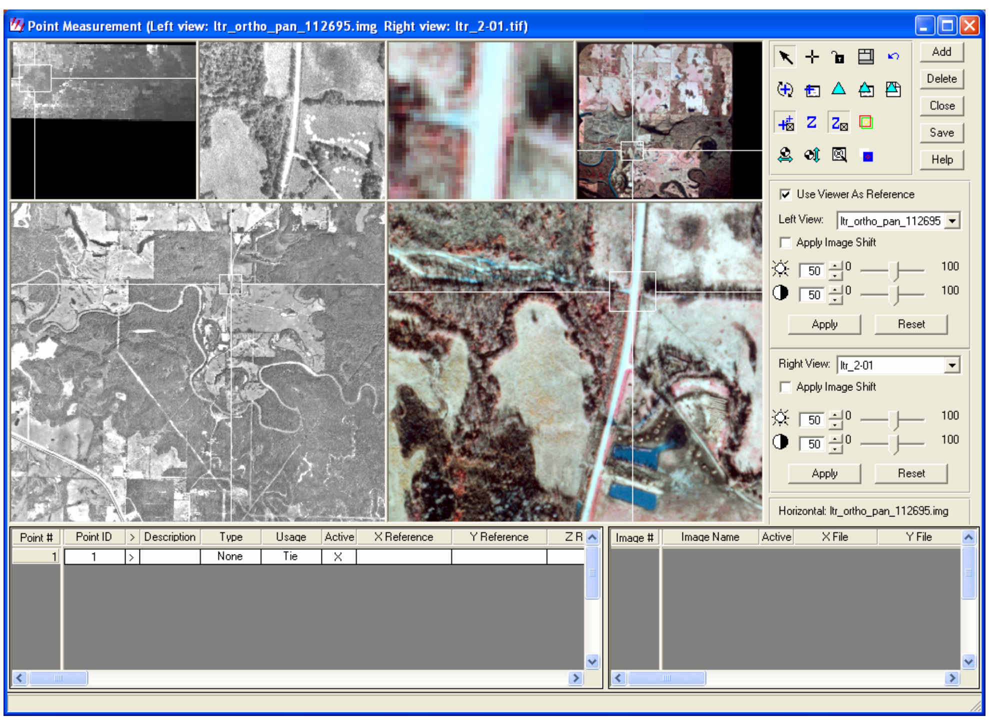
In the Point Measurement dialog select the **Automatic Z Update** icon . An **X** is displayed within the icon once it has been selected . To update Z values at any time during the GCPs collection process select the **Update Z** icon .

Select the Automatic (X,Y) Drive icon . This feature will automatically zoom to the area the GCP should be located once a point in the reference or non-reference image is selected. This capability is can only be enabled once **2 or more** points on the non-reference image have been selected. Once selected the icon changes to the following .

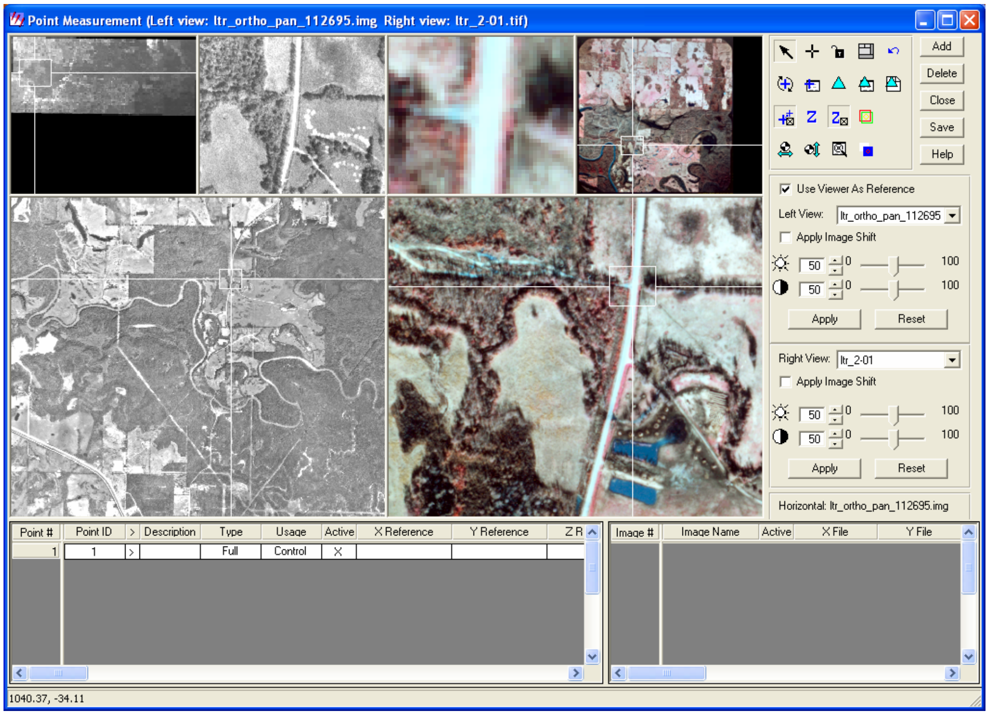
Now that all the setup steps for GCP collection are complete, the Point Measurement tool should be similar to the following:



15. To begin collecting GCPs, click the **Add** button in the upper right hand corner of the Point Measurement tool. This will add a row to the reference cell array (Point #1).



The **Type** and **Usage** columns must be changed from **None** and **Tie** to **Full** and **Control**. This can be done by right clicking in the cell containing **None** and **Tie** and selecting **Full** and **Control** from the menu that appears. This step must be repeated each time a new point is added.



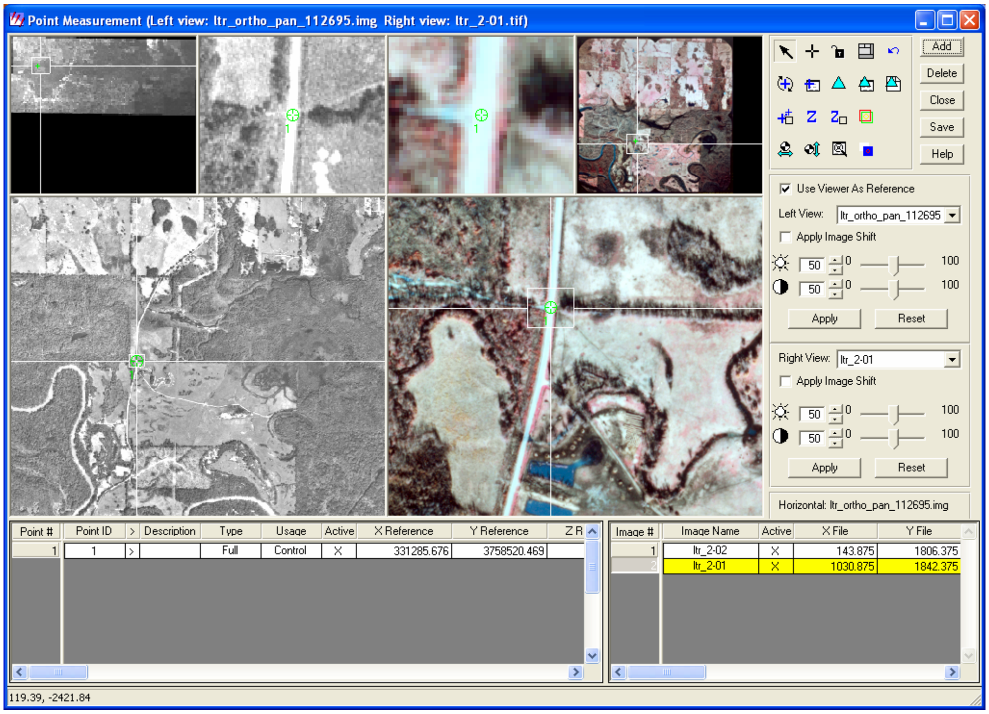
Point Collection and Ortho Rectification Strategies

To cover areas at a scale appropriate for vegetation inventory and monitoring on NWR multiple flight lines and frames of photography are often collected. OrthoBase allows an analyst to derive a solution and apply it to all the photos within the block (block file) at the same time. This allows for a spatially seamless result, but it can become a cumbersome task to accomplish when all the rules of the ortho rectification process within OrthoBase are met. When an analyst is attempting to find a solution to a large number of photos in a block file with multiple lines of imagery, the rule at least 2 GCPs per overlapping photo must be met and when dealing with 60-40 stereo imagery this task of satisfying those rules can be time consuming and tedious.

To reduce the complexity of selecting GCPs to satisfy the rules of the entire block of photos, GCPs may be collected, solutions found and photos ortho rectified one flight line at a time. GCPs common to adjacent lines of photography should be used in the solution for that line of imagery. While this process does not apply a solution to the entire block, it does apply a solution using GCPs common to adjoining photos. **The strategy explained here is the one outlined in detail below.**

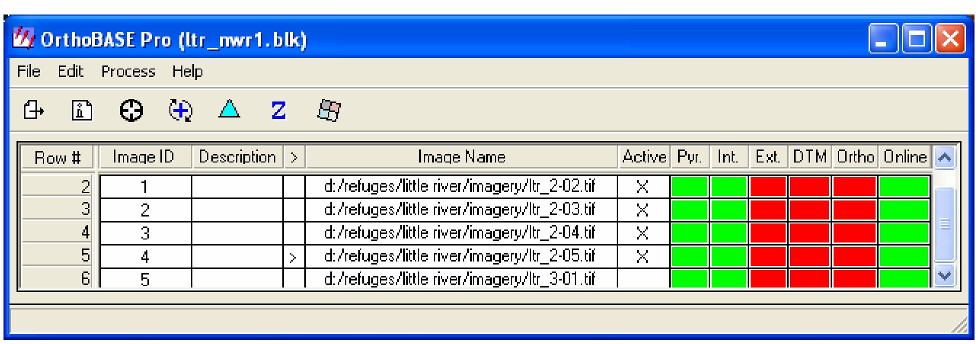
16. Select the **Create Point** icon from the Point Measurement dialog and select a point in the reference image or photography. It does not matter which is first. Use the **Link** Cursors to pan, zoom and magnify across the images. Once a point is selected in one image select the **Create Point** icon again and find the correlated point on the opposite image. Once this is done the **X Reference**, **Y Reference** and **Z reference** columns in the reference and file cell array should be populated. The file cell array will be populated with the name of the image the point has been assigned to. Because points need to be collected in areas of overlap between photos, the point selected should have a common point on 1 or more photos. To assign the same point to a second overlapping photo click the **Right View** and select the next photo in the flight line from the drop down menu. This photo will now display in the right viewers. Search and find the same correlating point on

the image and mark it using the **Create Point** icon . There are more efficient methods for assigning single points to multiple images that are not outlined in this document. Once familiar the process, it should become intuitively to find more complex but efficient solutions.

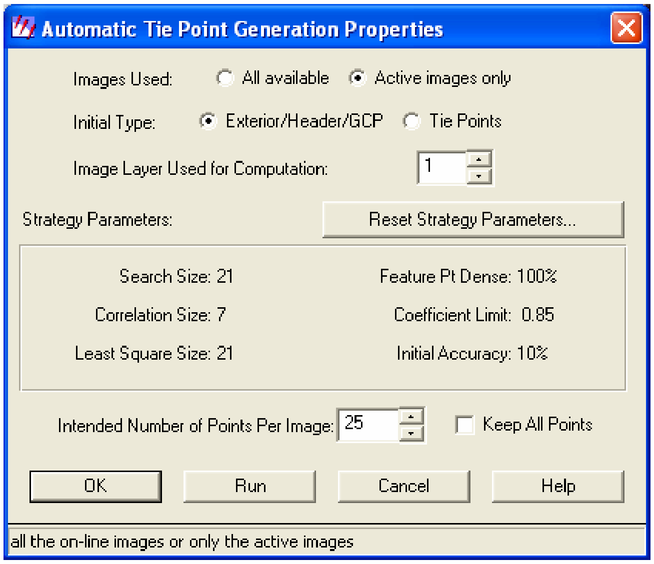


Repeat the process outlined above until all photos in the flight line have 3 GCPs common to each photo.

17. Assuming all GCPs have been entered for the first flight line, the automated tie point generation must be run (**Only for the photos in the flight line GCPs have been collected**). Before this can be done all the images in the flight line the GCPs were collected in must be made active and all remaining images made inactive. To do this click the **Save** button in the **Point Measure** dialog and close the dialog. In the OrthoBase dialog place an **X** in the **Active** column next to each photo in the flight line that GCPs have just been collected for. This can be done by clicking in the cell. Remove any **X** present in the photos not in the flight line.

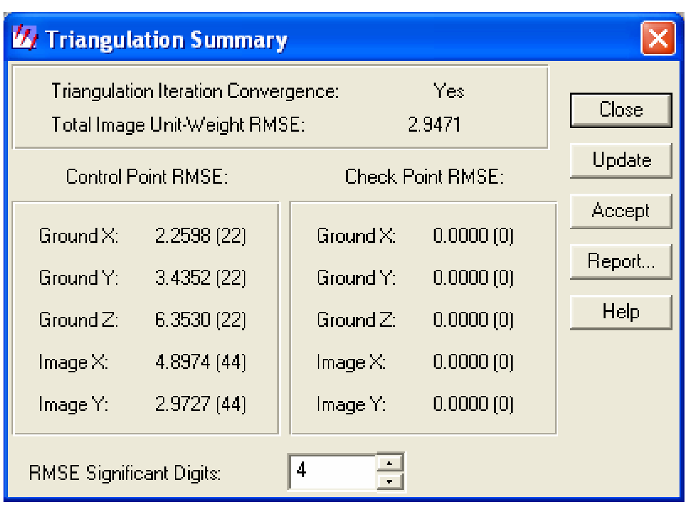


Reopen the point dialog using the Point Measure dialog icon . To start the automated tie point generation, click the **Automatic Tie Point Collection Properties** icon from the Point Measure dialog. This will open the **Automatic Tie Point Collection Properties** dialog. Under **Images Used** select the **Active images only button**. Under **Initial Type** select the **Exterior/Header/GCP** button. Set **Intended Number of Points Per Image** at 25 and click **Run** to start the process.



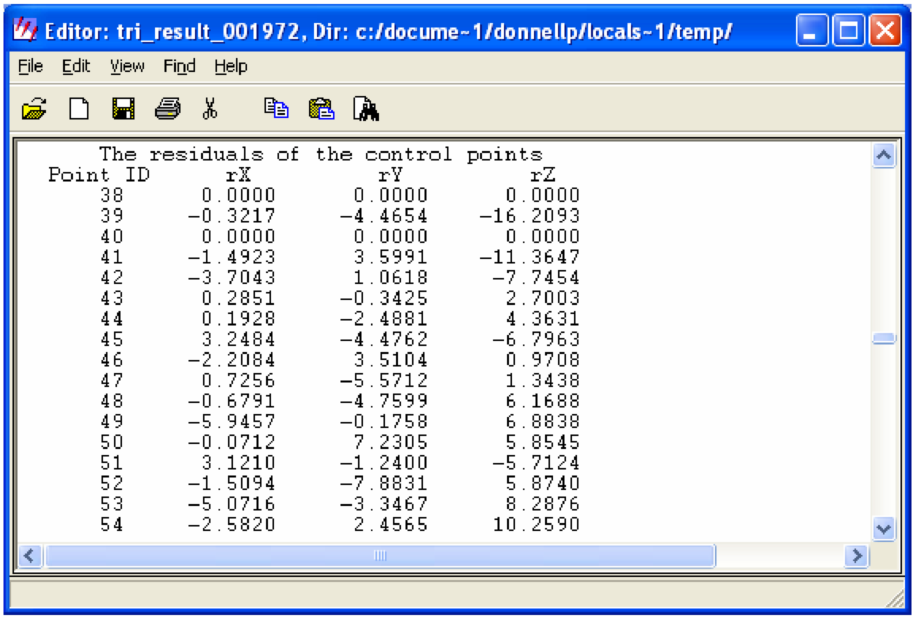
If GCPs were collected correctly there should not be any error messages. In the reference cell array will now be tie points generated through the process. The points will also be visible on the active photos and reference image.

To determine how accurate the triangulation derived from the GCPs click the **Triangulation Summary** icon . This will open the **Triangulation Summary** dialog. This dialog will indicate if the triangulation convergence was successful and reports the total image unit weight RMSE. In general a total RMSE of < 2.00 pixels is acceptable for resource inventory and monitoring applications. In some cases the quality of the reference imagery or land cover may not allow for an RMSE < 2.00 pixels.



In the example shown the total RMSE is above the recommended threshold of < 2.00

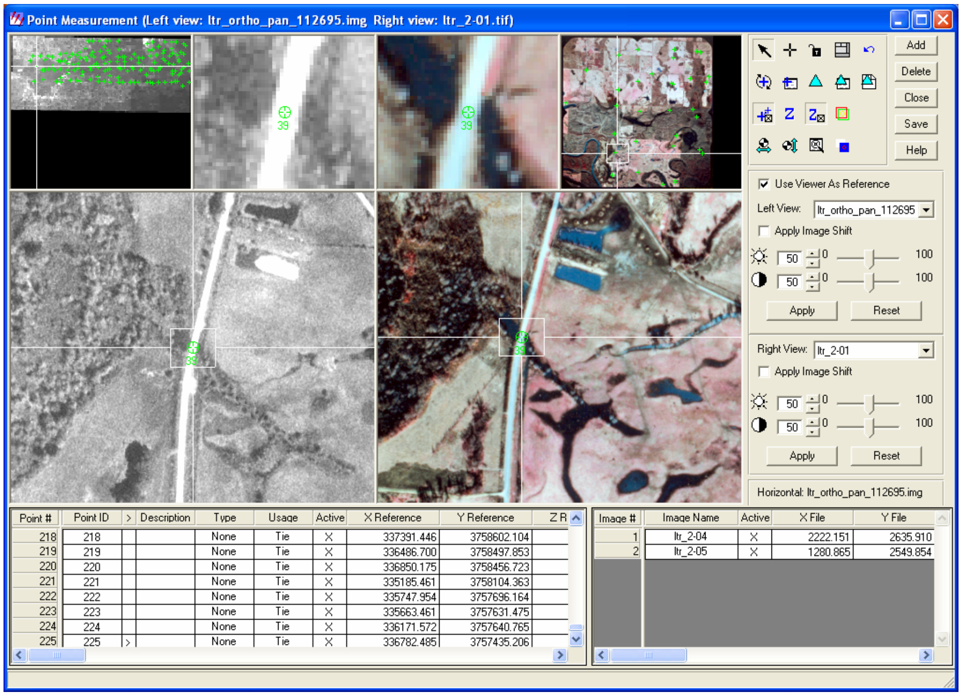
pixels. To lower the RMSE the analyst must examine the residuals of the GCPs used in the triangulation. To do this click the **Report** button in the **Triangulation Summary** dialog. This will open a text box with statistical data related to the triangulation summary. Scroll down to the heading titled **The residuals of the control points**. Review the residuals, looking for points with high residuals in the rX and rY columns. Identify these points and edit or remove them.



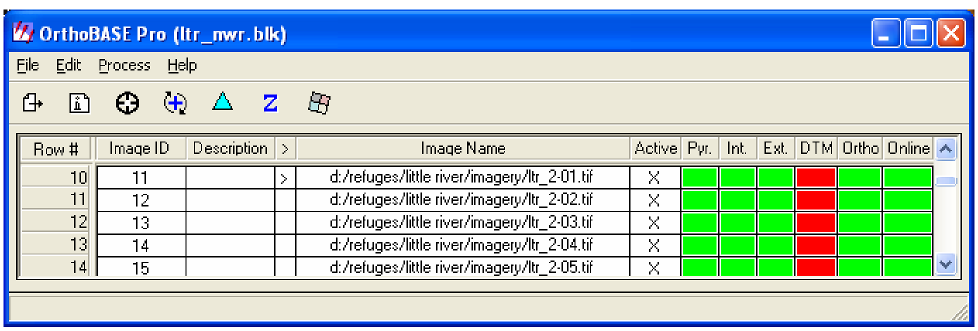
The residuals of the control points

Point ID	rX	rY	rZ
38	0.0000	0.0000	0.0000
39	-0.3217	-4.4654	-16.2093
40	0.0000	0.0000	0.0000
41	-1.4923	3.5991	-11.3647
42	-3.7043	1.0618	-7.7454
43	0.2851	-0.3425	2.7003
44	0.1928	-2.4881	4.3631
45	3.2484	-4.4762	-6.7963
46	-2.2084	3.5104	0.9708
47	0.7256	-5.5712	1.3438
48	-0.6791	-4.7599	6.1688
49	-5.9457	-0.1758	6.8838
50	-0.0712	7.2305	5.8545
51	3.1210	-1.2400	-5.7124
52	-1.5094	-7.8831	5.8740
53	-5.0716	-3.3467	8.2876
54	-2.5820	2.4565	10.2590

Once the problem points have been removed or modified, delete all tie points in the reference cell array, careful to leave the GCPs and rerun the automatic tie point collection process. Repeat these steps until the desired total RMSE has been reached. Once this is done click the **Accept** button in the **Triangulation Summary** dialog. This will update the **X Reference** and **Y Reference** and **Z Reference** in the reference cell array. Once this is done click **Close**.



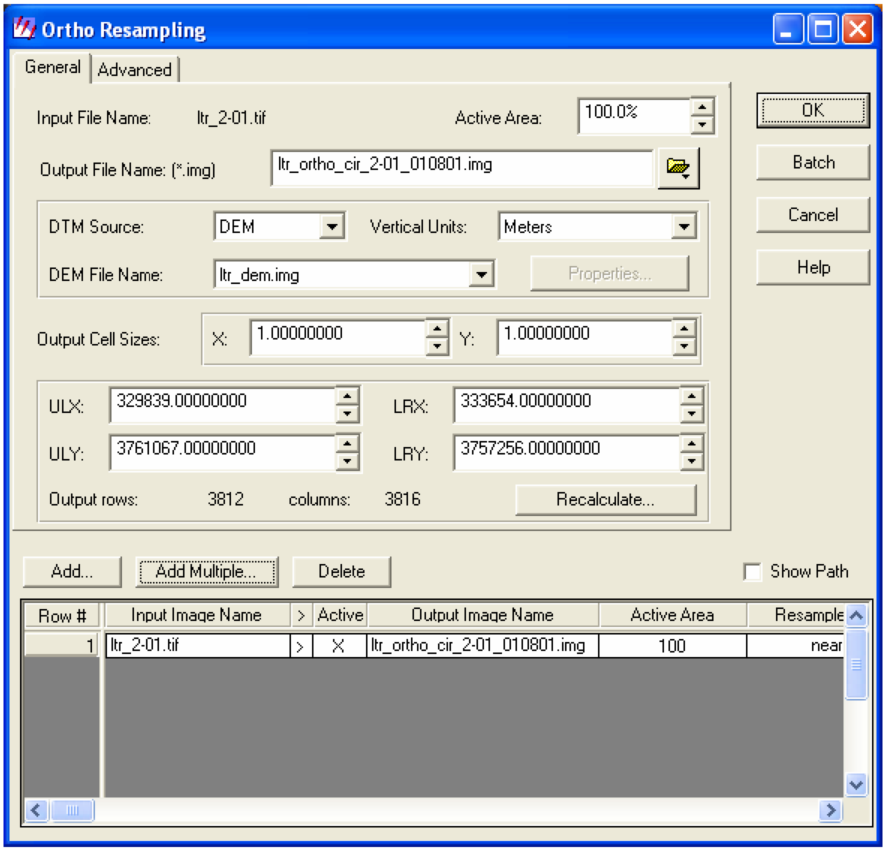
18. Save and close the Point Measurement dialog. With the same images still selected as active in the OrthoBase dialog select the Start ortho resampling process icon . (Notice the **Ext.** column has now turned green after the completion and acceptance of the triangulation process.)



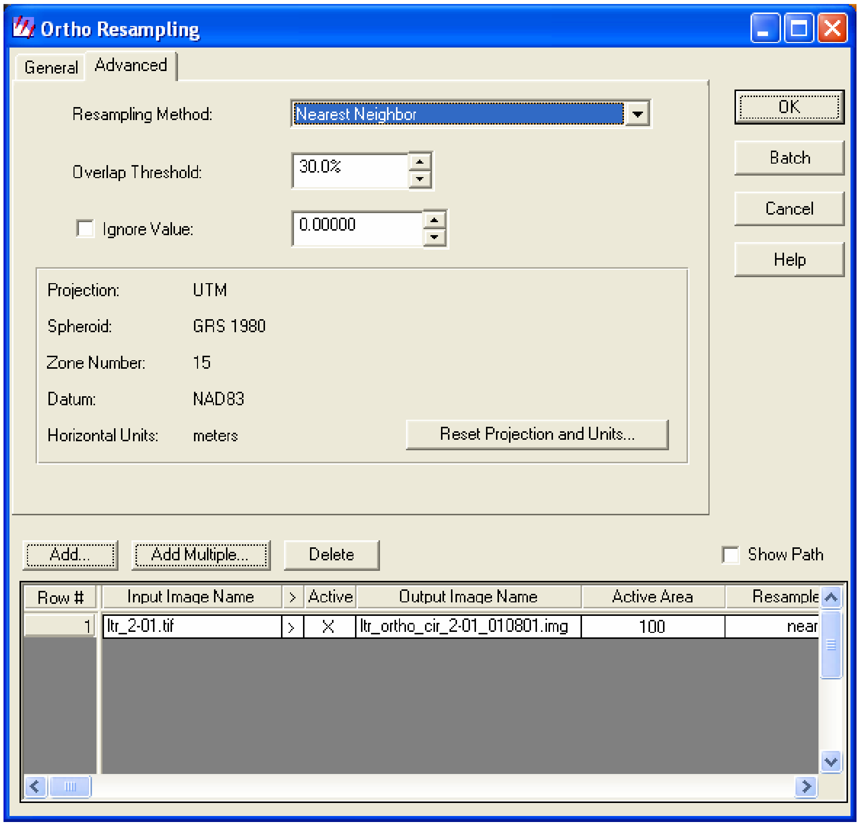
This will open the **Ortho Resampling** dialog. In the **Output File Name** box name the image according to the standards outlined in the ***Region 2 Spatial (RS/GIS) Data Structure and Guidelines***; NWR literal, underscore, rectification type, underscore, spectral type, flight line number, dash, frame number, underscore, date imagery acquired.

Example: ltr_ortho_cir_2-01_010802 = Liter River NWR, ortho rectified imagery, color infrared, flight line 2, frame 1, acquired 01/08/02.

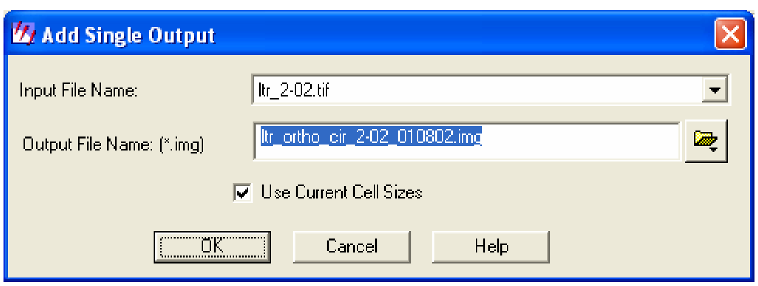
Under **DTM Source** select **DEM** from the drop down menu and select the associated **DEM** from **the DEM File Name** box. Set **Output Cell Sizes** to X: 1.000 and Y: 1.000. **Vertical Units** should match the DEM and be set to meters. Once complete the dialog should look similar to this.



Next hit the **Advanced** tab at the top of the dialog. Under **Resampling Method** select **Nearest Neighbor** from the drop down menu.



Select the **General** tab and the **Add** button. Select the next file in the flight line to be added under Input **File Name** and assign the appropriate file name, following R2 standards under **Output File Name**. Check the **Use Current Cell Sizes** box and hit **OK**. Repeat this step until all files in the flight line are added.



Once all the images in the flight line are added and named select the **OK** button in the **Ortho Resampling** dialog to begin the ortho rectification process. File will be saved to the directory the *.blk file is in by default.

19. Repeat **steps 14 to 18**, collecting GCPs and ortho rectifying imagery one flight line at a time until complete

7.2 <u>Mosaicing Digital Ortho Rectified Imagery</u>: ***Mosaicing of ortho rectified digital imagery using ERDAS Imagine Professional and Image Equalizer 8.7.0***

When digital ortho rectified imagery is derived from aerial photography it must be mosaiced before it is used in vegetation/habitat inventory applications. Often multiple images over a NWR must be acquired to encompass a full coverage of the area at scale appropriate to inventory and monitoring needs. Image mosaicing allows image processing applications to be applied across an image continuously in addition to helping normalize the spectral variability of the data.

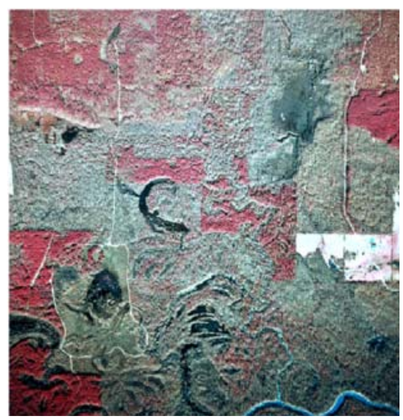
The NWR Remote Sensing Lab has documented standard image mosaicing procedures using ERDAS Imagine Professional 8.7.0. and Image Equalizer. This software was chosen because of its flexibility and ability to complete complex image processing procedures. Because image properties vary widely there are a number of additional options not demonstrated in the steps below. Consult the ERDAS Imagine online documentation for further guidance in pursuit of options tailored to specific mosaicing issues.

Mosaicing Ortho Imagery:

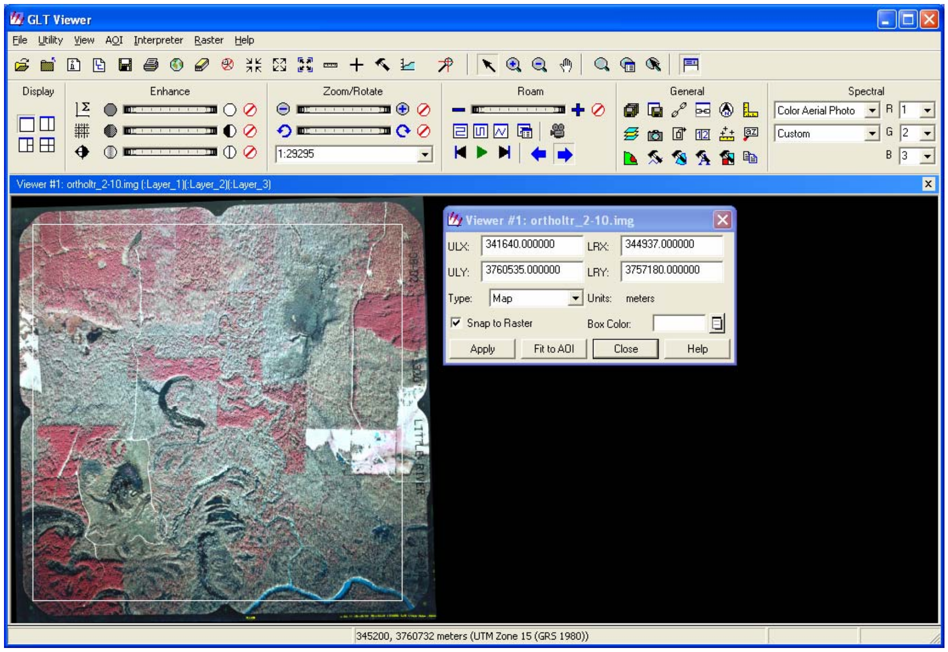
1. Before the ortho imagery can be mosaiced it must be clipped within the photo frame to remove portions of the image that are not wanted as part of the final mosaic. The image should be clipped to remove the photo frame, fiducials and any information printed on the imagery.

Ortho Rectified

Clipped Ortho Rectified



To begin clipping imagery open ERDAS Imagine Professional. The GLT Viewer should automatically open. Click the **Open Layer** icon from the main tool bar and navigate to the image file to be opened and clipped. Next from main tool bar on the GLT viewer under **General** select the **Subset Tool** icon . This will open the **Subset** dialog and **Inquire Box** dialog. Drag the inquire box to include the areas that will be clipped from the ortho rectified image.

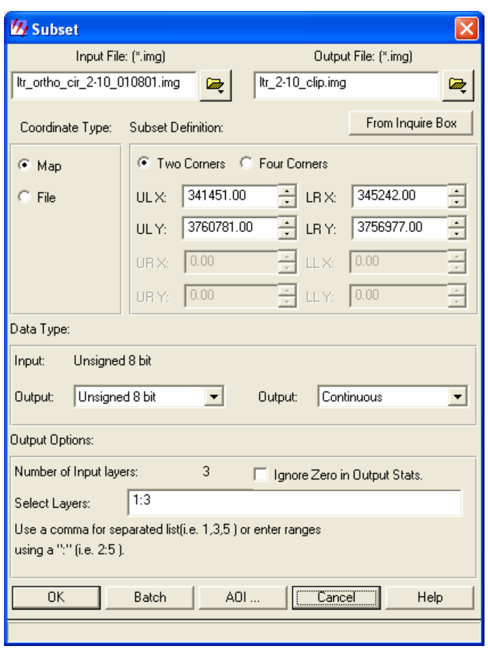


In the **Output File** box of the **Subset** dialog type the name of the clipped image. The naming convention for this file should be as follows

Example: ltr_ortho_cir_2-10_clip.img

Little River NWR, ortho rectified, color infrared, flight line 2, frame 10, clipped

Next click the **From Inquire Box** button. This will transfer the coordinates displayed in the Inquire Box dialog to the **Subset** dialog. Take the rest of the defaults and click **OK**. Repeat this step until all images to be mosaiced are clipped.

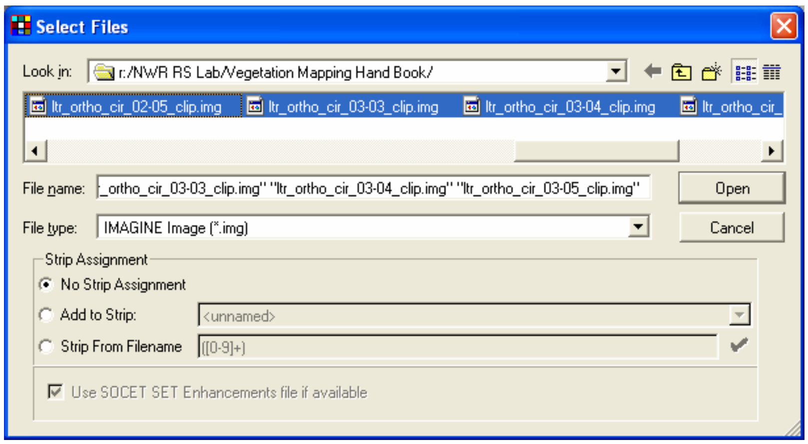


Aircraft Crab

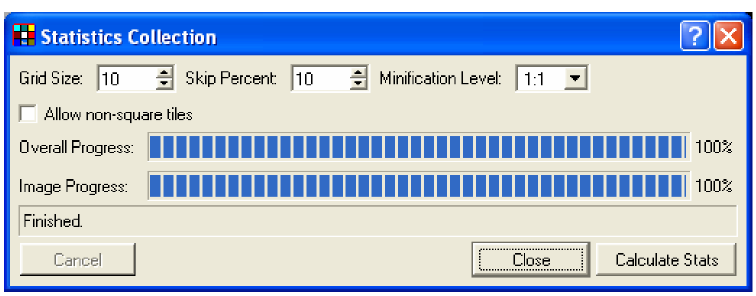
In some cases ortho rectified imagery will be off set because crab by the aircraft when the photo was taken. Large amount of crab can reduce the effective size of the clip when using a square extraction area. However, because ortho rectified imagery must be flown in stereo there will be enough side lap and end lap to cover the entire mosaic.

2. Open all the images to be used in the mosaic in the **ERDAS Imagine** viewer. Review the images to ensure there are no holidays between the images. Close the viewer.

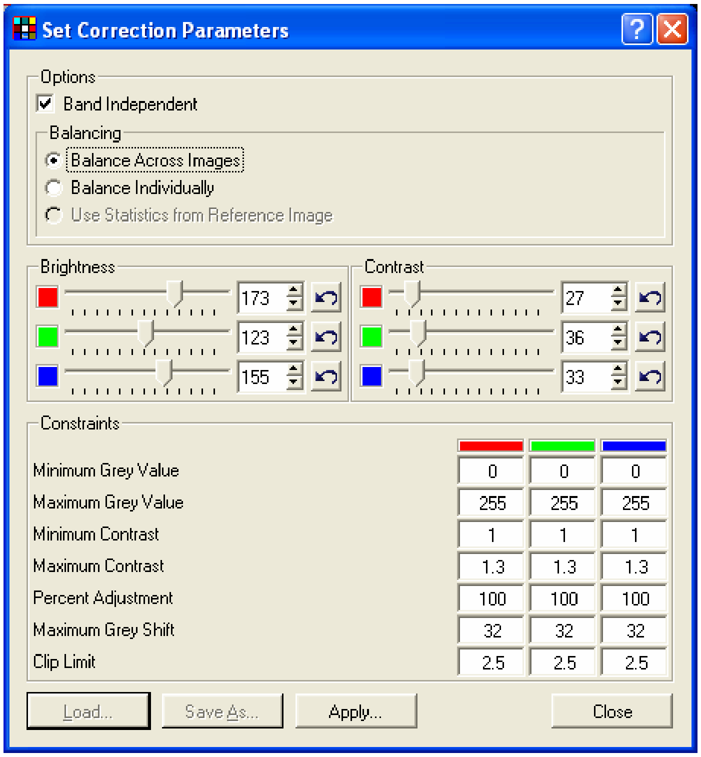
3. Start an **Image Equalizer** session. **Select File | Add Images**. Add all images clipped as outlined in **step 1**. Select **Open**



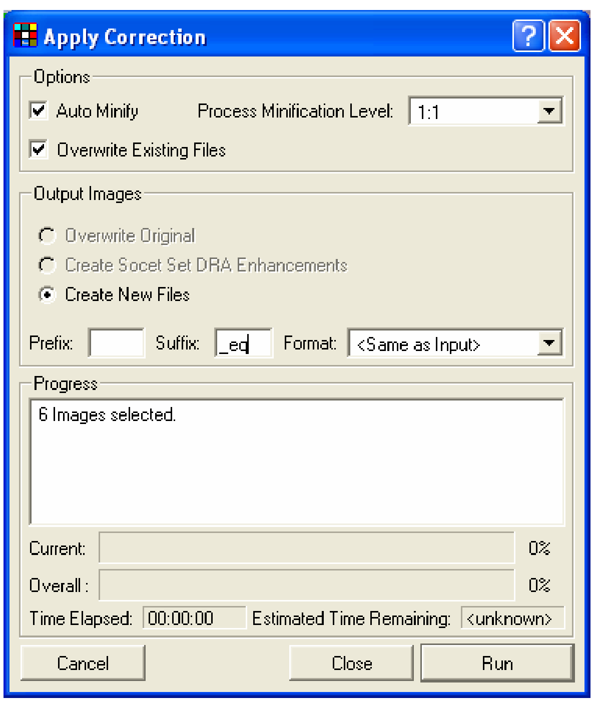
4. Select **Edit | Select All** from the main menu. All the images should now be highlighted. Select **Image | Build Statistics Tables** form the main menu. This will open the **Statistics Collection** dialog. Except the defaults and select **Calculate Stats**. Once complete select **Close**. Each photo should now have a histogram within its highlighted boundary.



5. Select **Tools | Equalize** form the main menu. This will open the **Set Correction Parameters** dialog. Under **Options** select **Band Independent**. Under **Balancing** select **Balance Across** Images. Accept the rest of the defaults and select **Apply**.

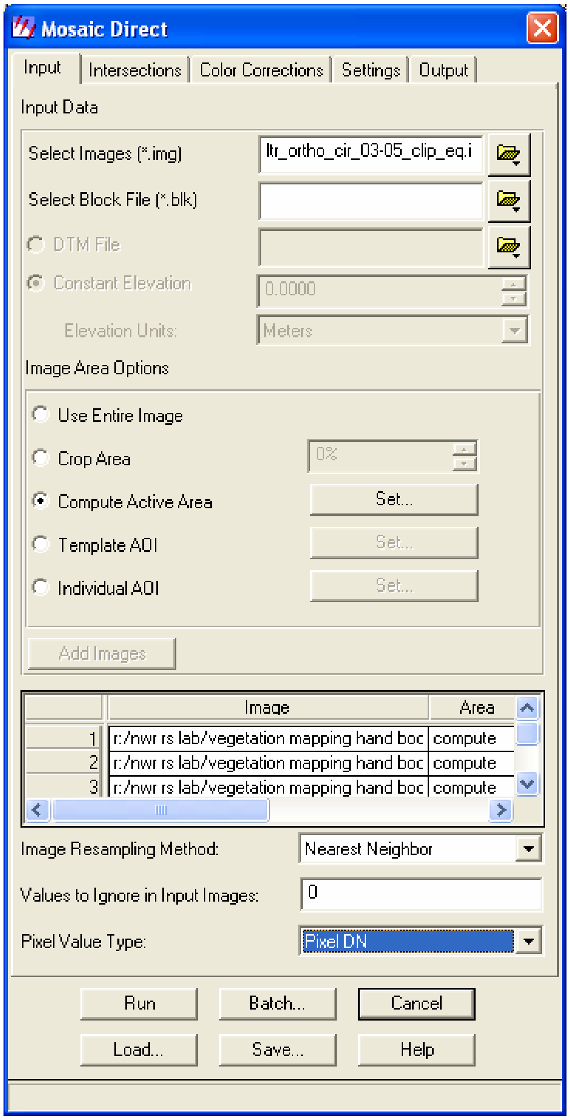


6. The **Apply Correction** dialog should have opened. Under **Options** **Unselect** the **Overwrite Existing Files**. Under **Output Images** select **Create New Files**. Make the **Suffix: _eq**. Select **Run**. Select **Close** once complete. And exit out of **Image Equalizer**.

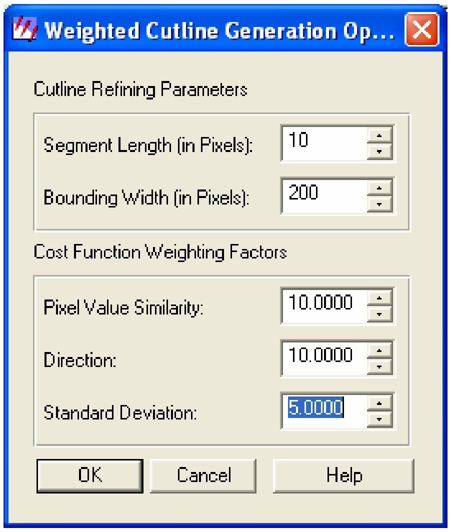


7. Start **and ERDAS Imagine** session.

8. On the main ERDAS tool bar select **DataPrep | Mosaic Images | Mosaic Direct.** This will open up the **Mosaic Direct** dialog. Select all images to be mosaiced under Input Data. Under Area Options select Compute Active Area. Select the Add Images button.



9. Select the **Intersections** tab. Check the **Use Cutlines** box. Under **Cutlines** select **Weighted Cutline Generation**. Select **Set**. This opens the **Weighted Cutline Generation Opinions**. The defaults here may be altered to meet the needs of specific imagery sets. The variables displayed below have been applied successfully, but may need to be adjusted to meet the needs of specific imagery sets. Select **OK**.



10. Select the Output tab. In the Output Image Root Name navigate to the proper directory and enter the name of the resulting refuge image mosaic. Name the file using the following naming convention:

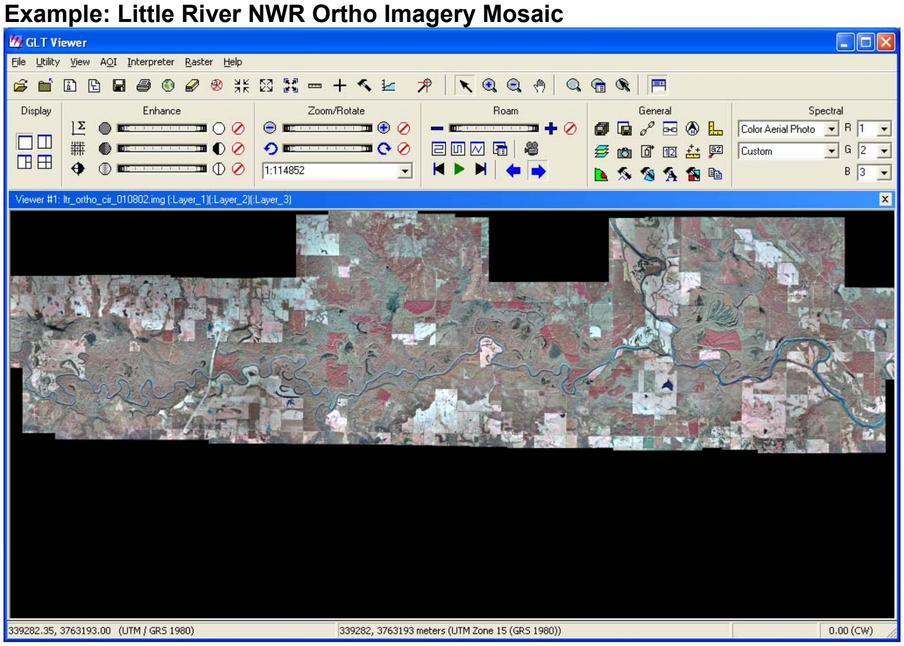
Example: ltr_ortho_cir_010802

Liter River NWR, ortho rectified imagery, color infrared, acquired 01/08/02.

Accept all other defaults and click **Run** to start the mosaic process.

11. Review the final image in the ERDAS Imagine viewer. If resulting image is unacceptable utilize the Mosaic Tool (**DataPrep | Mosaic Images | Mosaic Tool)** and follow the suggested steps in the **ERDAS Imagine** online documentation. In some cases spectral differences may be great enough between some images that a completely seamless mosaic is not possible.

Example: Little River NWR Ortho Imagery Mosaic



7.3 <u>Unsupervised / Supervised Image Classification:</u> ***Classification Based Multi-Resolution Image Segmentation (CBMRIS) For NWR Land Cover Classification with eCognition 4.X***

The steps below outline an object based classification applied by NWR Remote Sensing Lab for the delineation of image objects optimized to vegetative classes at the physiognomic level (NVCS Class level). This is approach has been applied successfully by others using different software and data (Woodcock, C., and V.J. Harward, 1992). The NWR Class Hierarchy Model in this document is presented only as a suggested standard and should be modified to meet specific land cover mapping needs on refuges. Additionally the structure of the model is only the first step in the segmentation and classification process, and does not represent the full class hierarchy of a completed vegetation classification to the alliance or association level of the National Vegetation Classification System (NVCS).

About the Process

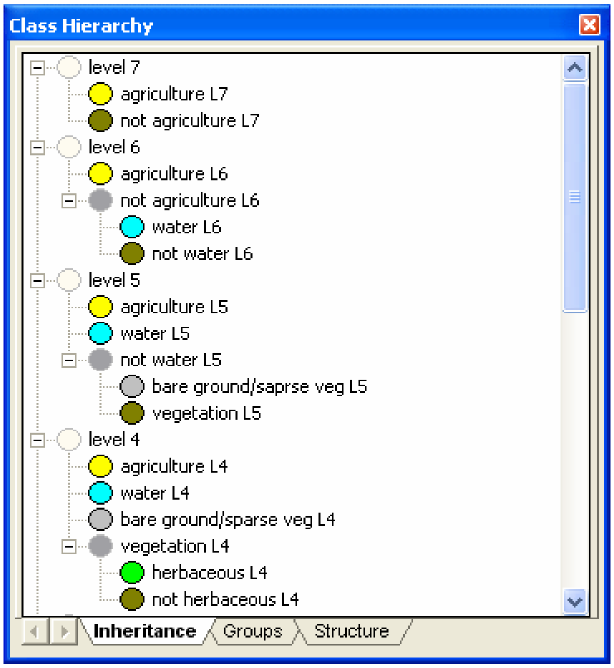
Applying a classification based multi-resolution segmentation (CBMRIS) can be seen as a selective or local segmentation. When segmenting in this mode, a multi-resolution segmentation is preformed only on the objects belonging to the structure groups (Physiognomic classed vegetation and other land cover types) targeted; all other objects remain unsegmented. The result produces a new segmentation level, wherein objects of different segmentation parameters coexist.

When CBMRIS is applied to vegetation mapping on NWR structure groups should be developed around physiognomicly based vegetation classes (Class level of the NVCS) and other homogeneous land cover types (water, agriculture, bare ground…etc.). However, it may be necessary to classify vegetation beyond the physiognomic level when the homogeneity of that class remains inconsistent. The extraction of physiognomic groups is an important step in the segmentation process as it allows for the selective segmentation within different NVCS Class classes and provides a more accurate classification of land cover types. The reasoning behind this approach will be further explained in **Chapter 11: *Supervised Image Classification***.

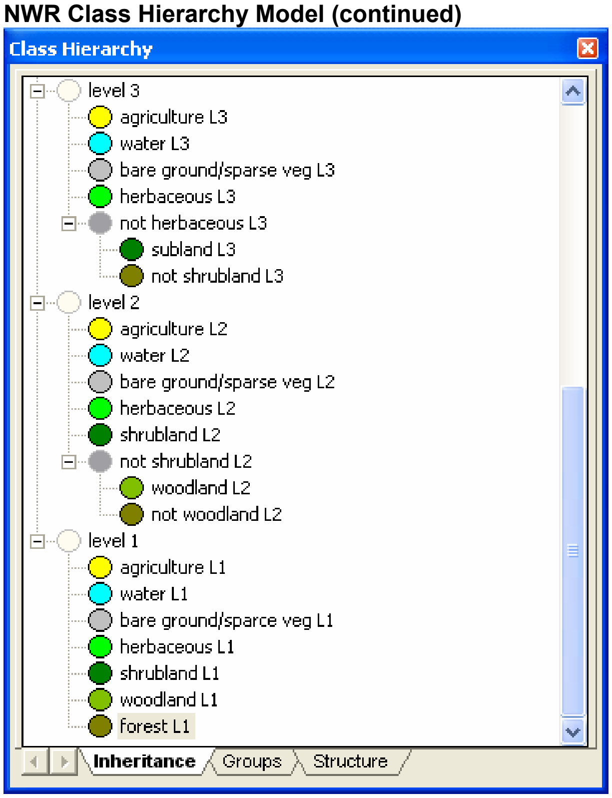
It is important to be aware that in some cases landcover types may be stratified using ecotypes in substitution for subsetting at the NVCS class level. These data may be provided as ancillary thematic data from an existing GIS layer. Such delineations may include areas of riparian verses upland or floodplain verses montane. Ecotypes may also be used to further stratify NVCS class delineations. Relative to the complexity of the classification schema this approach may be better applied to the eCognition NVCS class level output. NVCS class level polygons can be assigned ecotype membership spatially in a GIS by overlaying the classified ecotype polygon data.

NWR Class Hierarchy Model

Because CBMRIS is an iterative process, each level dependent on the other, it is important that before this process is begun a model is developed to chart the desired out come of the classification. A standard NWR Class Hierarchy Model for land cover classification on NWR is outlined below.



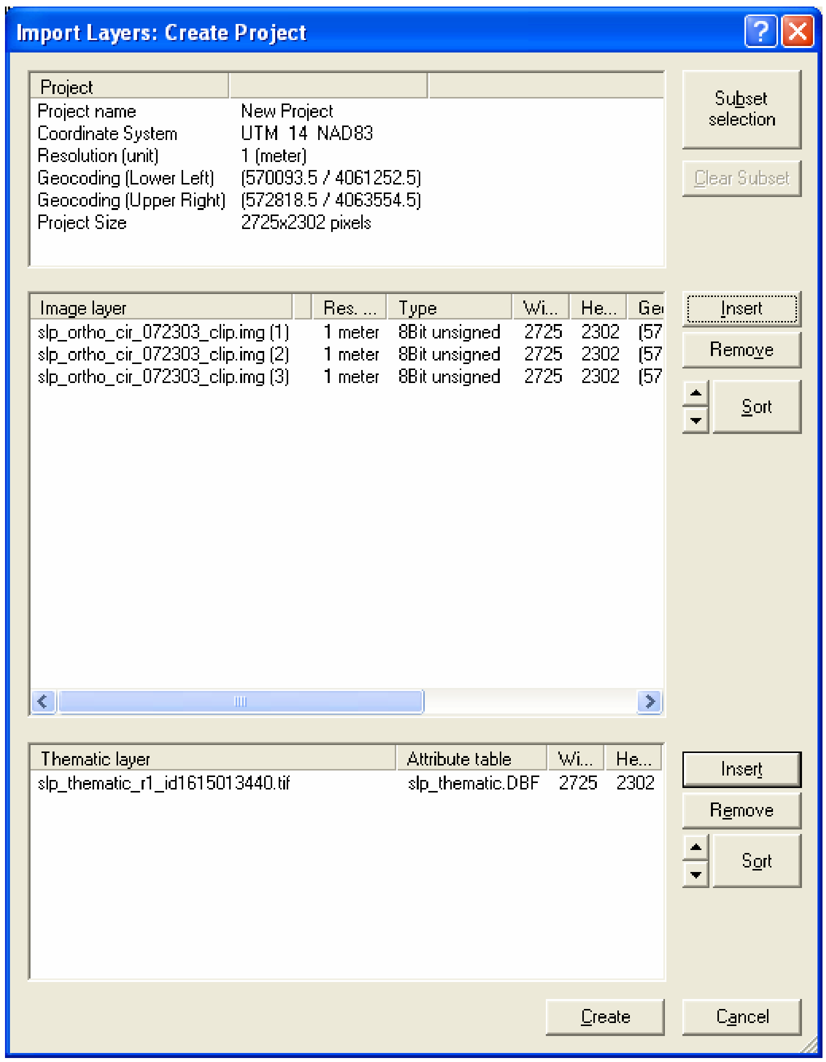
NWR Class Hierarchy Model (continued)



Note that the model shown above may be altered to meet land cover conditions specific to an individual NWR. As shown, the model represents only the landcover and physiognomic types. Once complete the classification the class hierarchy will represent vegetation to the alliance level of the NVCS.

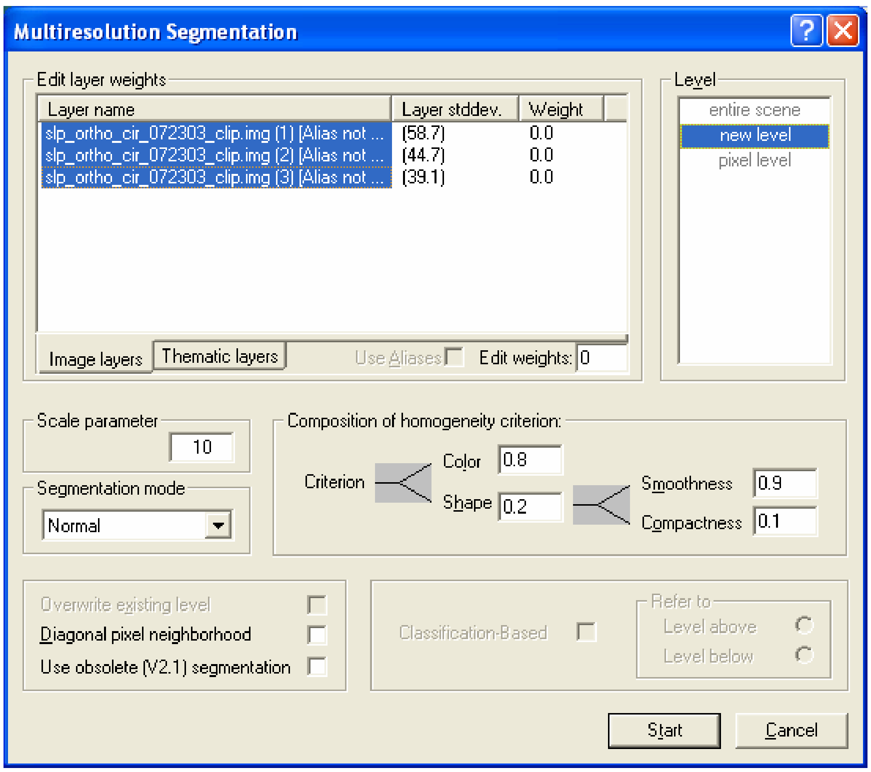
Applying the Hierarchy Model:

1. Create a new project in **eCognition 4.x** and add the imagery and thematic layers needed to complete the segmentation and classification process. To do this select **Project | New** from the main tool bar or select the new project icon to open the **Import Layers: Create Project** dialog. Add data using the **Insert** buttons under **Imagery Layer** and **Thematic Layer** windows. Shape files can be added as thematic layers. They will be converted to TIF images and associated to DBF files automatically. Select **Create** when complete. Save project by selecting Save Project icon . Use the NWR literal to name the new project.

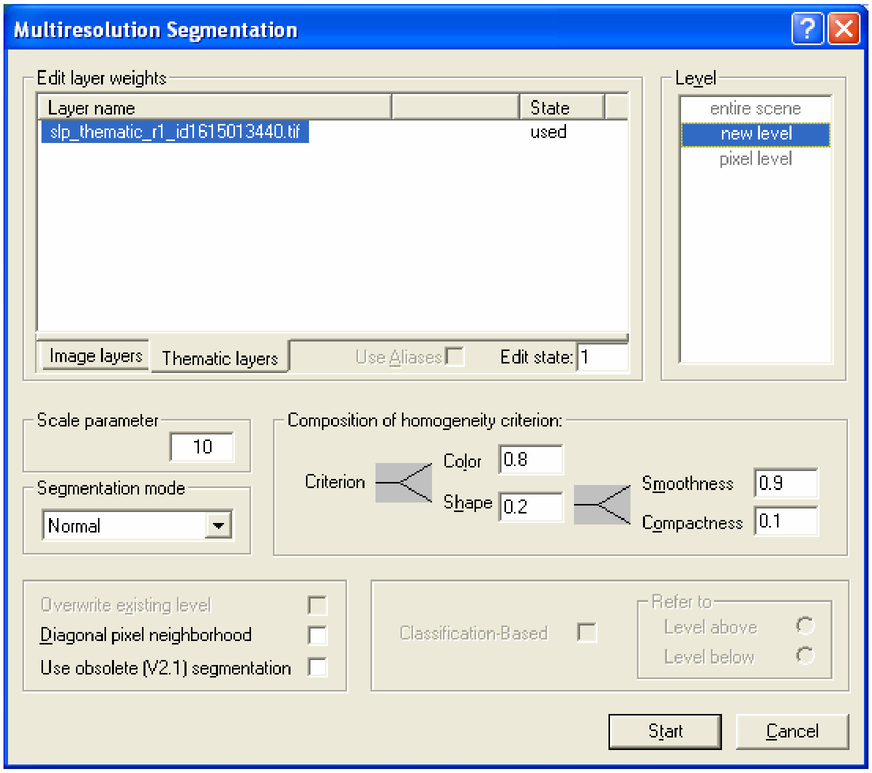


2. Generate image objects defined by the thematic layers being used in the CBMRIS process. These layers should at minimum contain the NWR boundary or extent of area to be classified and agricultural management units. Additional layers such as open water, moist soil units and urban areas may also be used. As a general rule add any layers that can be used to exclude areas from the classification or ancillary data that may be used to further subset classes or enhance their identification; i.e. soils classifications, flood plain boundaries, DEMs etc…

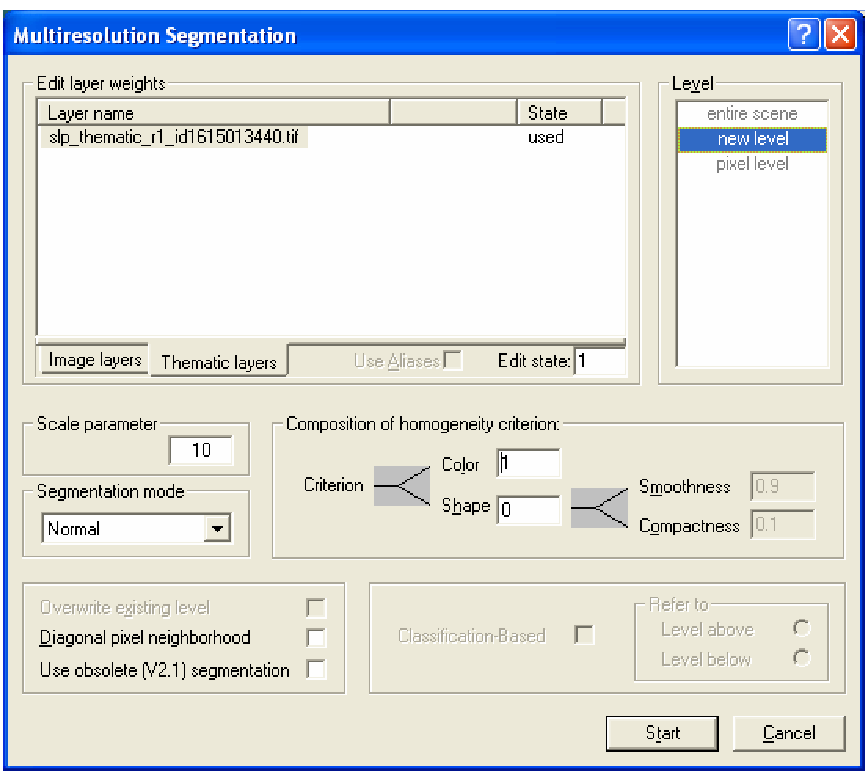
   To generate objects from thematic layers open the select the **Multiresolution Segmentation** icon  from the main tool bar. This will open the **Multiresolution Segmentation** dialog. Under the **Edit layer weights** box select the **Image layers** tab and set the image weights to **0.0**.



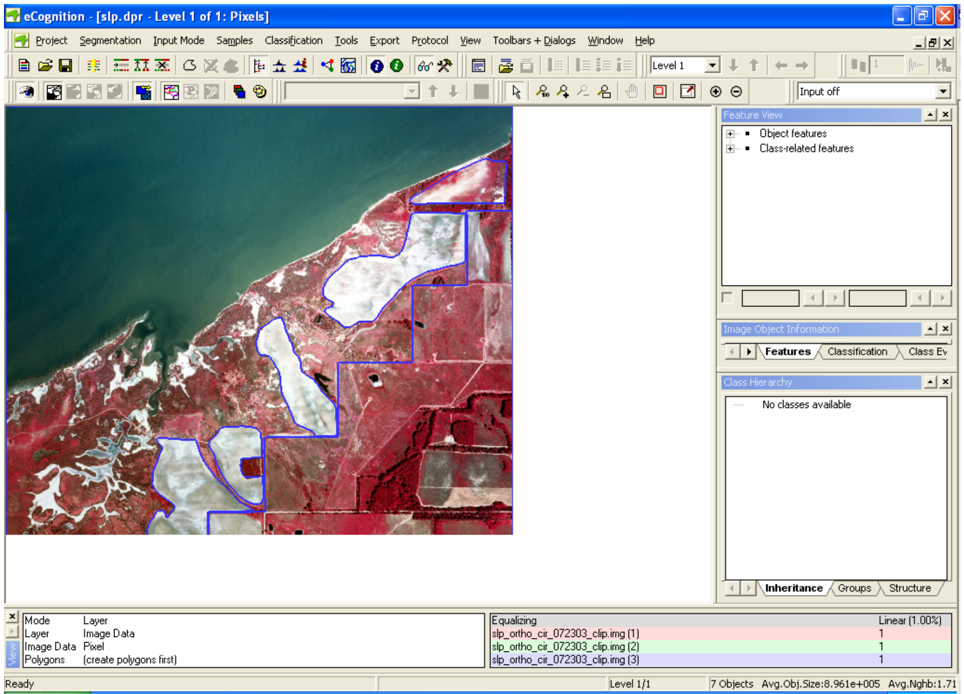
   Select the **Thematic layers** tab and set the thematic layers to **used**. It can be switched from used to not used by changing the **Edit Weight** box from **1.0** to **0.0**.



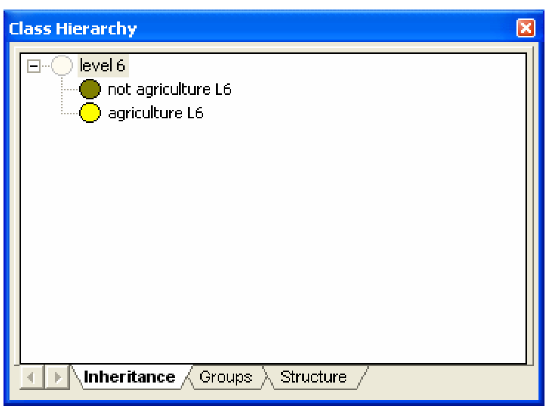
Under the **Composition of homogeneity criterion** set the **Color** box to **1.0**. This will set the **Shape** box to **0.0** and gray out the **Smoothness** and **Compactness** boxes. Select **Start** to begin the segmentation process.



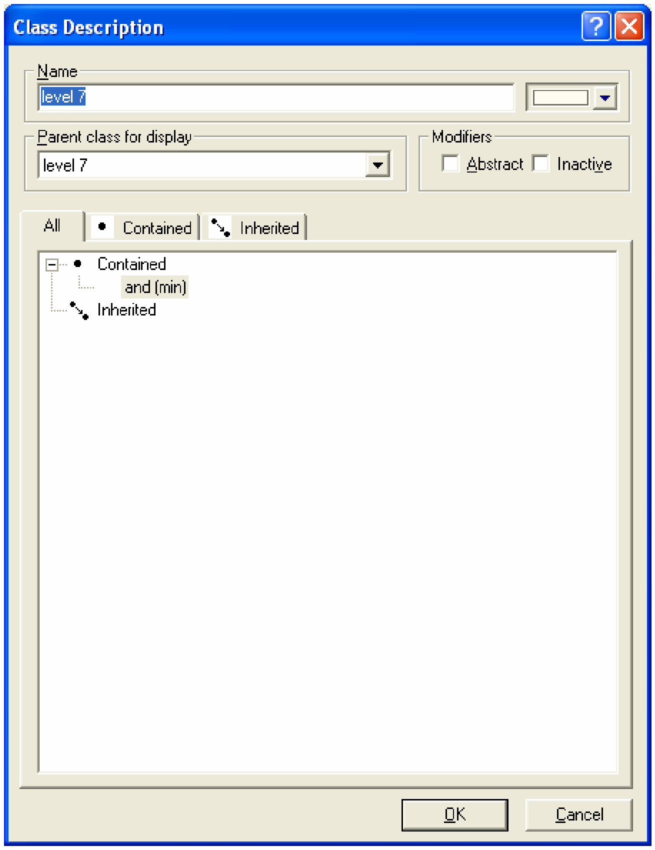
Once complete, the image objects should follow the outlines of the thematic layers used in the project.



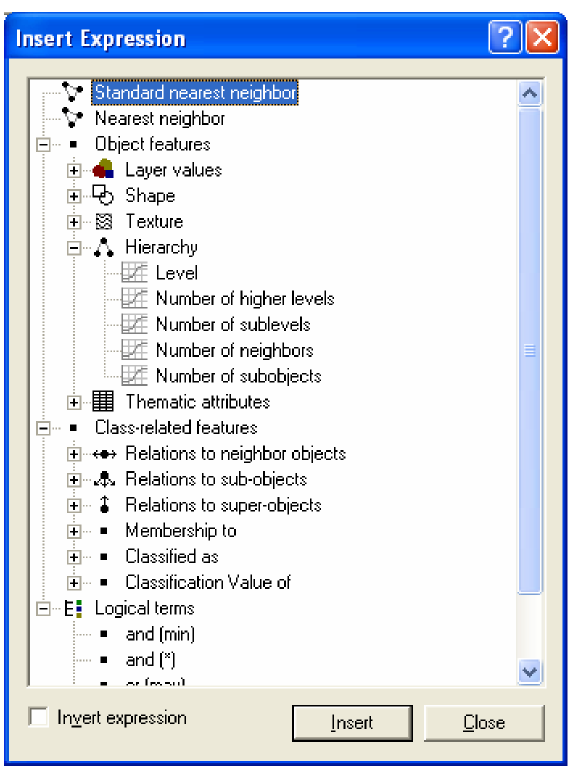
3. The image objects derived from the thematic layers must be classified. To do this add the following classes to the **Class Hierarchy** dialog: **level 6, agriculture L6,** and **not agriculture L6**. Arrange **agriculture L7, and not agriculture L7** as **child classes of level 6**. In this case areas of agriculture and not agriculture represent all NWR lands to be classified; therefore it is not necessary to define areas of NWR lands and not NWR lands.



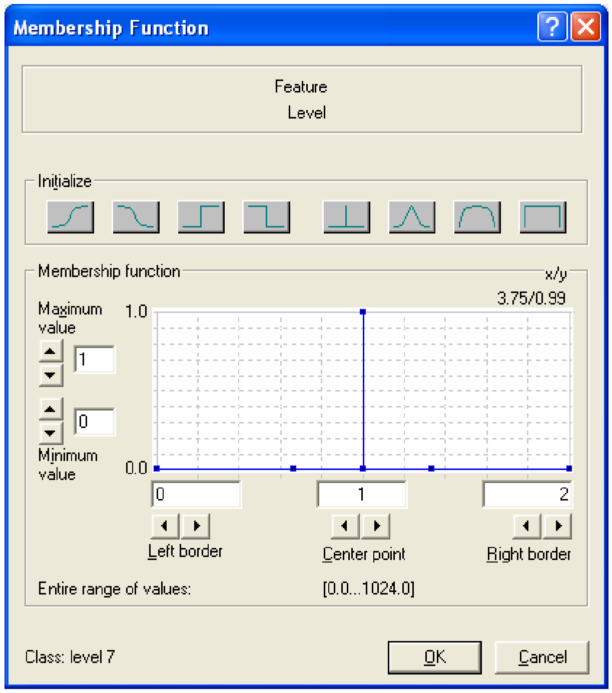
Assign classification parameters to the classes created above using the **Class Description** dialog box. This dialog can be opened by double clicking on the class to be described from the **Class Hierarchy** dialog. Beginning with **level 6**, open the class description.



Under **Contained** select the and(min). This will open the **Insert Expression** dialog. From the **Hierarchy** category select **Level**.

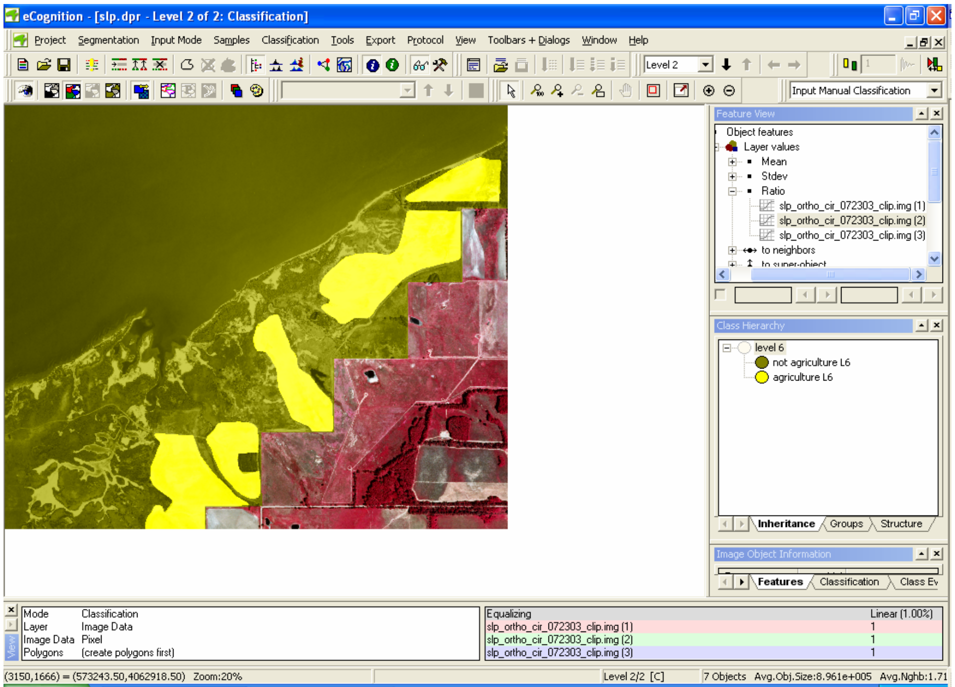


This will open the **Membership Function** dialog. Use the singleton model and assign the center point to **1.0**. Select **OK** once finished. Close the **Insert Expression** dialog and select **OK** from the **Class Description** dialog. This will be the process used to assign new level hierarchies and change level hierarchies throughout this process.



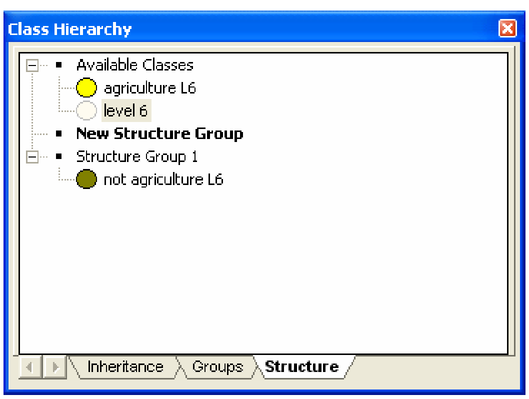
4. To classify areas of **agriculture L6** and areas of **not agriculture L6** use the **Input Manual Classification** option. The **Membership Function** could also be used, classifying image objects using thematic attributes. However, in cases when there are relatively few objects to be classified manual classification can more efficient.

   To classify image objects manually select and highlight the class to be classified manually. Next select **Input Mode | Manual Classification** from the main tool bar. At this point any image object selected in the viewer will be assigned the class currently highlighted in the **Class Hierarchy** dialog. To unclassify objects select the object a second time. Repeat this process until all classes in the Class Hierarchy dialog are classified.

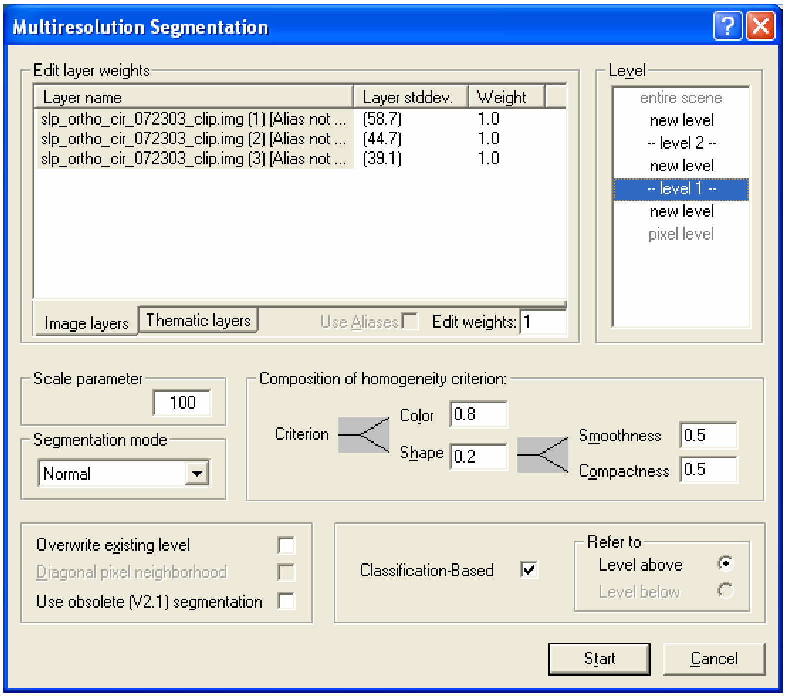


5. Next, areas of water must be identified. This is done by adding a segmented layer of image objects based on larger classified objects above referred to as **super objects**. In this step the super object of **not agriculture** from the layer above will be used to define the area to be segmented. The segmentation criteria assigned using the **Multiresolution Segmentation** dialog should be maximized to account water bodies.

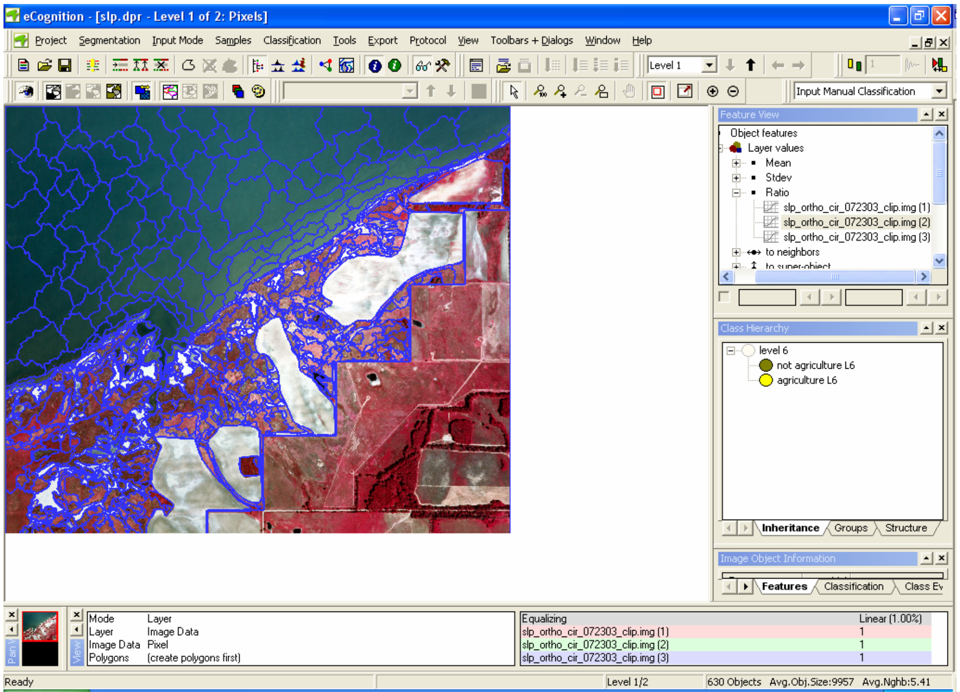
To begin select the **Structure** tab on the **Class Hierarchy** dialog. Drag and drop **not agriculture L6** from **Available Classes** to **New Structure Group**. This will create **Structure Group 1** with not **agriculture L6** under it.



Select the **Multiresolution Segmentation** icon  from the main tool bar to open the **Multiresolution Segmentation** dialog. Under the **Level** box select **new level** below **level 1**. Select the **Thematic** tab and set the thematic layers from **use** to **not used**. Select the **Image layers** tab. Set all the **Edit weights** to **1.0**. Refer to **step 2** to complete this task as necessary. Under the **Scale parameter** box enter **100**. This variable controls the merging of objects relative to their spectral Euclidian distance and detail (size) defined by objects. In the **Composition of homogeneity** criterion set **Color** to **0.8**. This automatically sets **Shape** to **0.2**. **Color** and **Shape** combined always represent a total weight of 1.0. Next set **Smoothness** to **0.5**. This will set the weight in **Compactness** to **0.5**. Like **Color** and **Shape** the combined weight of **Smoothness** and **Compactness** must equal 1.0. Check the **Classification-Based** box and the **Level above** button in the **Refer to** box. Select **Start** to begin the segmentation process.

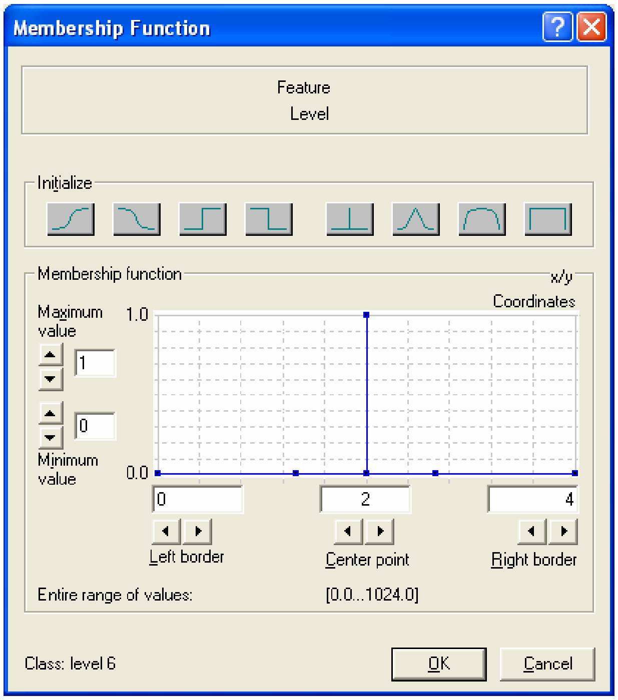


Note that an Analyst conducting these procedures should be familiar with the model and algorithms used to generate image objects. Analyst must also be aware that the results generated from these models are largely image dependent, meaning results will vary relative to spectral diversity, spectral resolution and spatial resolution. Please refer to the eCognition Users Guide for a full explanation of the models and algorithms used in these processes.

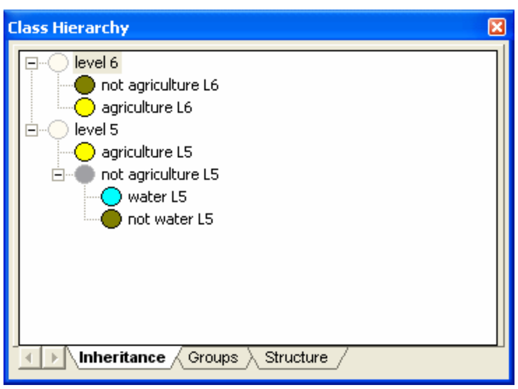


6. Running the Multiresolution Segmentation on areas classified as not agriculture has added a second layer of objects to the project based on super objects in the level above. The new segmented layer is now **level 1**. Because the first layer is above the new layer it has been renamed **level 2**. The process of CBMRIS is similar to constructing a multi story building by lifting up the floors that have already been built and adding a new floor on the bottom. When this is done the levels of the floors change. These changes must be reflected in the hierarchy assignments of each level as new levels are created.

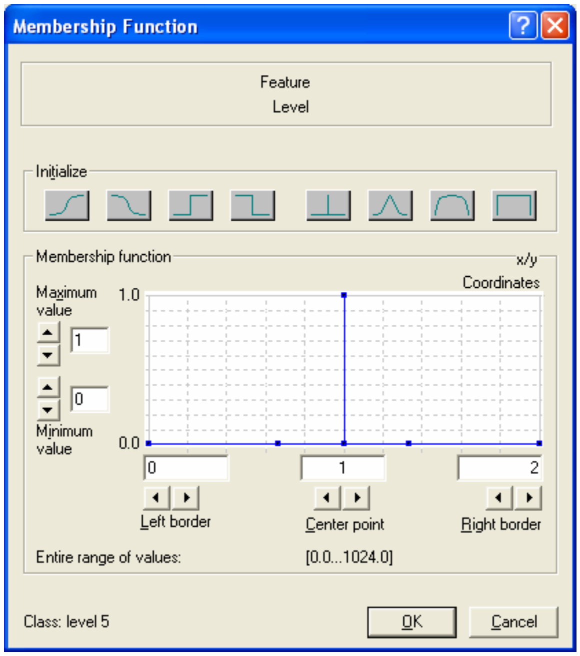
To reassign level hierarchies as new levels are added open the **Membership Function** dialog for **level 6**. Reassign the hierarchy level from 1 to **2**. Refer to **step 3** to complete this process as necessary. ***Note the process of reassigning class hierarchies to levels must be done manually every time a new level is added based on image objects occurring at a higher level.***



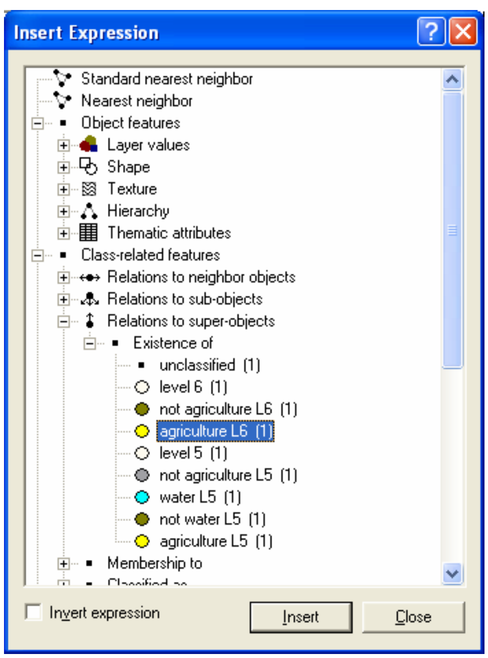
7. Insert **level 5** the **Class Hierarchy** dialog as a new class. Add 4 more classes; **agriculture L5**, **not agriculture L5**, **water L5** and **not water L5**. Make **agriculture L5** and **not agriculture L5** child classes to **level 5** and **water L5** and **not water L5** child classes to **not agriculture L5**.



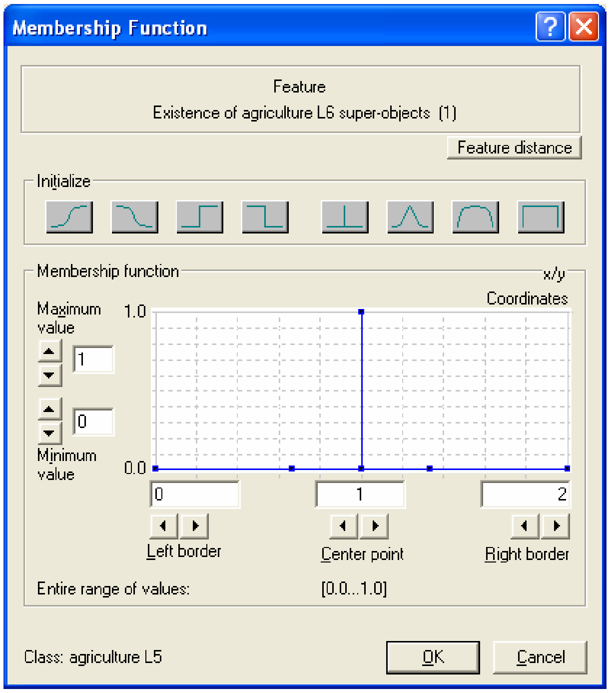
Open the **Membership Function** dialog for **level 5**. Assign the hierarchy level to **1**. Refer to **step 3** to complete this process as necessary.

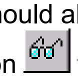


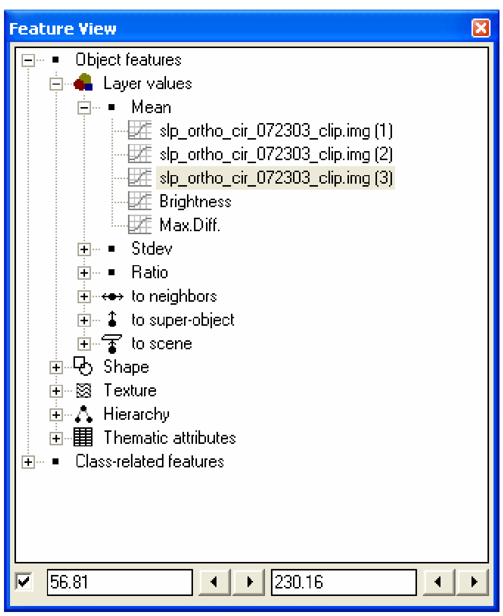
Open the **Class Description** dialog for **agriculture L5** and under the **Relationship to super-objects | Existence of** select **agriculture L6 (1)**. This references **agriculture L5** to super object **agriculture L6** in the level above.



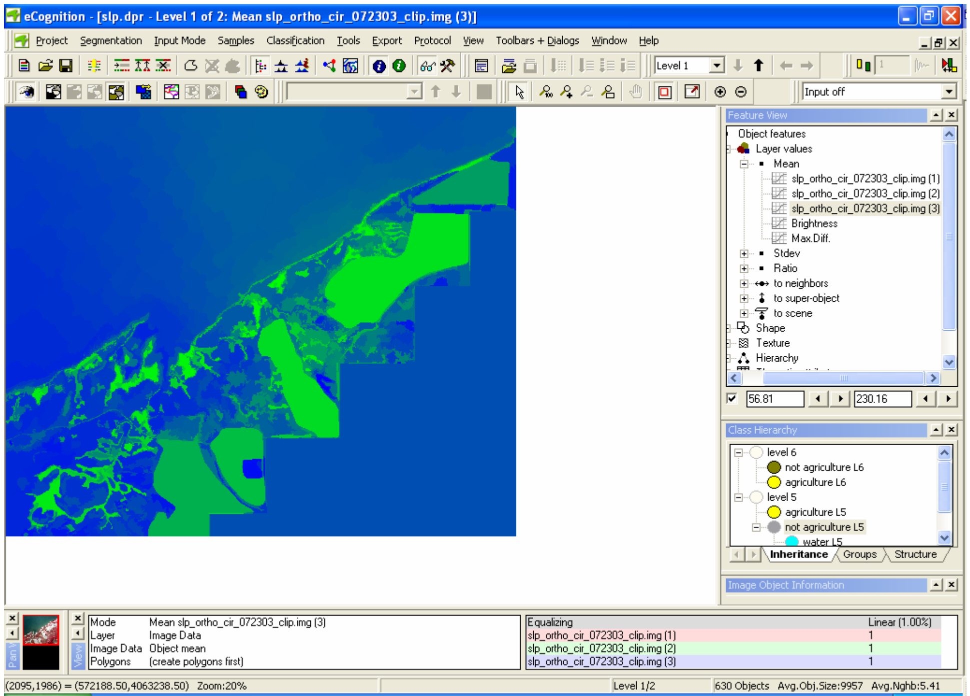
Select **Insert**. This opens the **Membership Function** dialog. Use the singleton function to set the number of levels the super object is above the object being referred to. In this case it is 1 level above. Repeat this process for **not agriculture L5**, referring to **not agriculture L6** as the related super object.



8. To define areas of water go to the Feature View dialog. This dialog should already be open, but if it is not it can be opened by selecting the Feature View icon  from the main tool bar. Under **Layer values | Mean, Stdev, and Ratio** the spectral statistics of each object may be examined. Begin with **Layer values | Mean** by double clicking on the first of the 3 layers. Check the box at the bottom of the **Feature View** dialog and right click and select **Update Range** from the popup-menu.

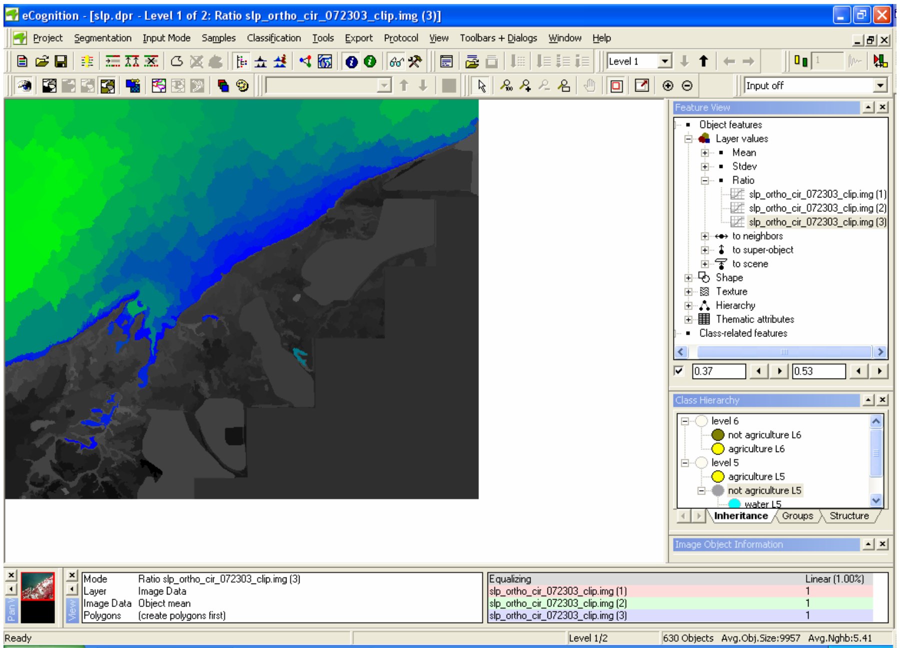


Once this is done the data (image) being displayed in the viewer will look similar to this:

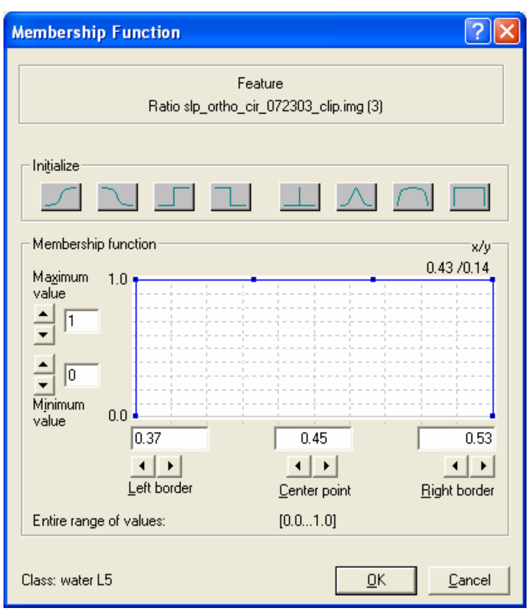


Using the arrows next to the ranges at the bottom of the **Feature View** dialog adjust the associated ranges of the data to isolate areas of the image to be classified as water. This technique should be used on all 3 bands of data under Mean, Stdev, and Ratio. Note the range(s) and statistical layers which best isolate the targeted class. These values will be used in the **Membership Function** dialog to classify the imagery.

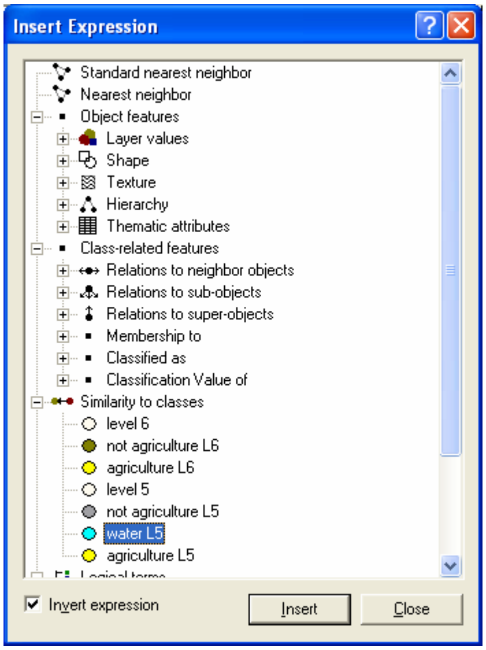
In this case **band 3** of the **Layer values | Ratio** between the range of .37 and .53 do the best job of isolating areas of water.

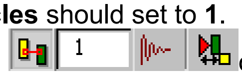


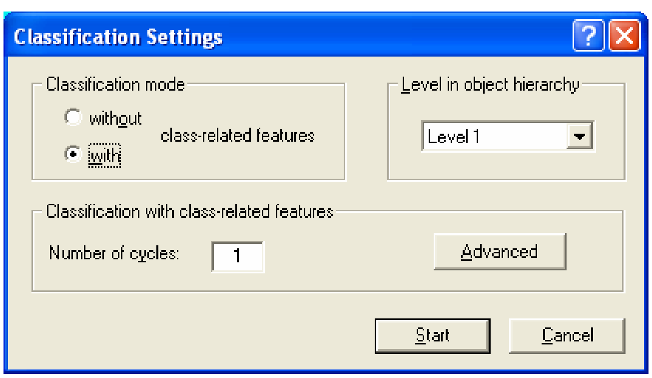
9. Now that the **Layer Value** and range have been identified to isolate water, select the **water L5** from the **Class Hierarchy** dialog. Under **Contained | and(min)** open the **Insert Expression** dialog. Select **Layer values | Ratio | band 3 (slp_ortho_cir_072303_clip.img)**. This will open the **Membership Function** dialog. Using different models available under **Initialize,** model the expression to fit the range of values identified as water. See graphic below for function used. For a full explanation of the use and function of the **Initialize** functions please refer to the **eCognition Users Guide**.



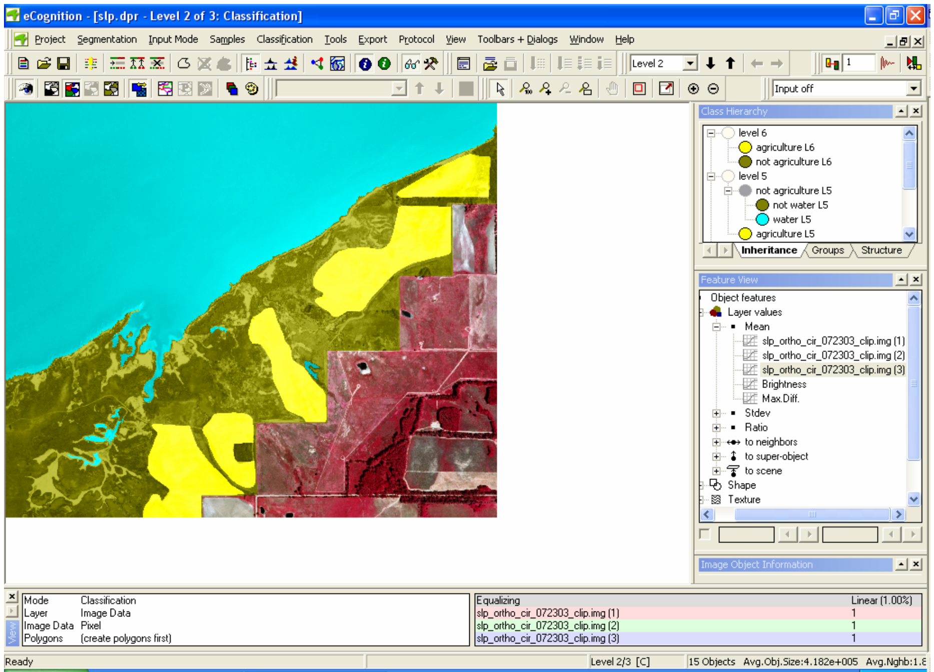
To classify areas that are not water, open the **Insert Expression** dialog for the **not water L5**. **Select Similar to Classes | water L5**. At the bottom of the dialog check the **Invert expression** box. Select **Insert** when done.



10. Now that the classification variables have been identified for areas of water, not water and agriculture for **Level 6** (Currently Level 1) the image objects must be classified. To do this select **Classification | Classify** from the main menu. This will open the **Classification Settings** dialog. Under **Classification mode** select the **with class-related features** button. The level should be set to **Level 1** under the **Level in object hierarchy**. **Number of cycles** should set to **1**. Select **Start** when complete. The **Classification Setting** icon  on the main tool bar can also be used to complete the classification process.

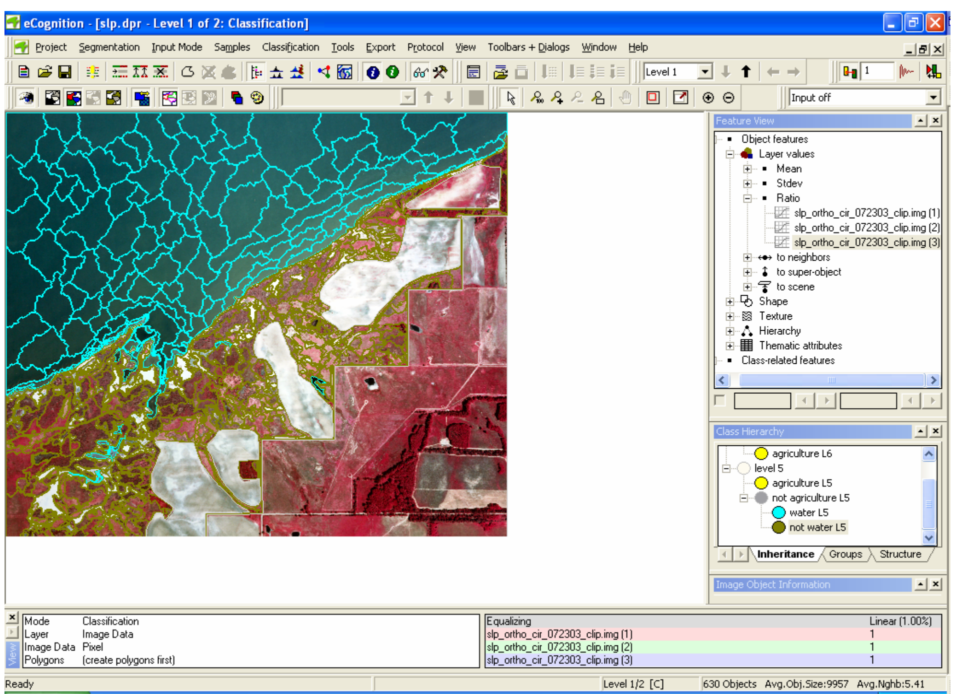


Once complete the classification results will appear similar to this:

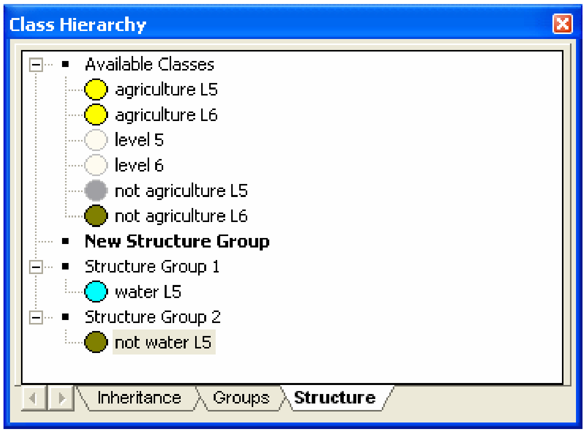


Use the **Input Manual Classification** mode to reassign any areas that were misclassified. This process is explained in **step 4**.

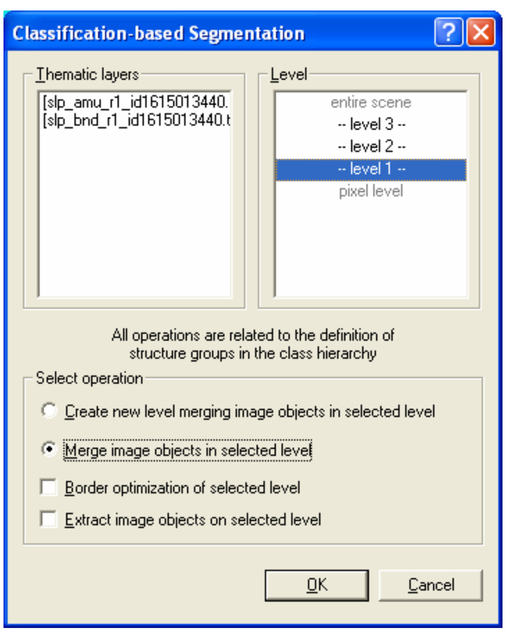
11. Areas classified as water and not water are made up many image objects. For these areas to be used as super objects and to create the ability optimize the segmentation criteria of classes at lower levels in the model, the objects classified as **water L5** and **not water L5** must be merged (dissolved) by class.

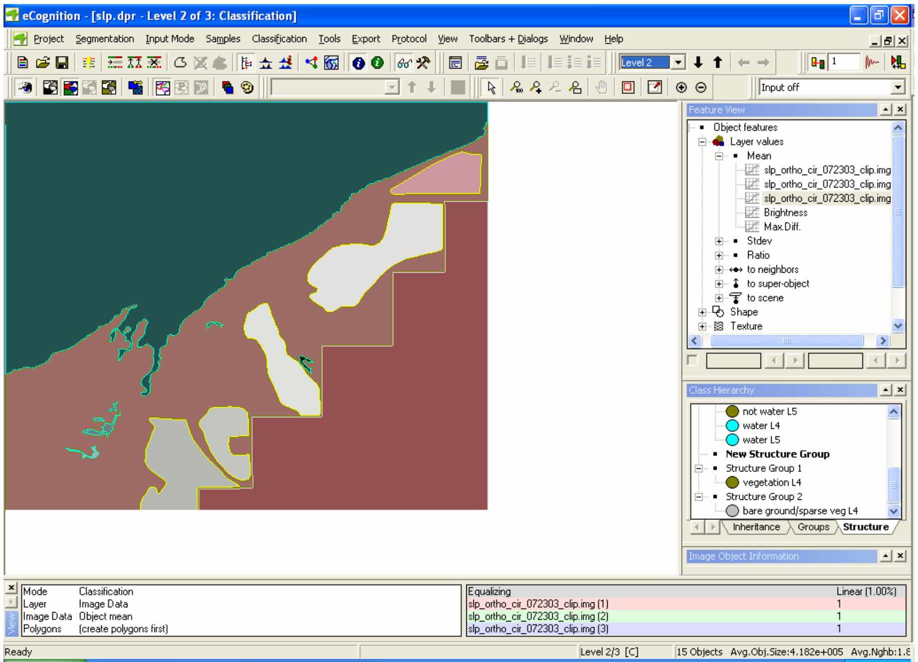


To merge adjacent classified objects (**water L5** and **not water L5**) into single objects select the **Structure** tab from the **Class Hierarchy** dialog. Move any existing classes form the **New Structures Group** back to **Available Classes**. Next drag and drop **water L5** on **New Structure Group**, do the same with **not water L5**. The results should be 2 structure groups (**Structure Group 1, Structure 2**). Each structure group should have only one class within it (**water L5** and **not water L5**). The structure groups will be used as the delimiter for the process to generate the merge.



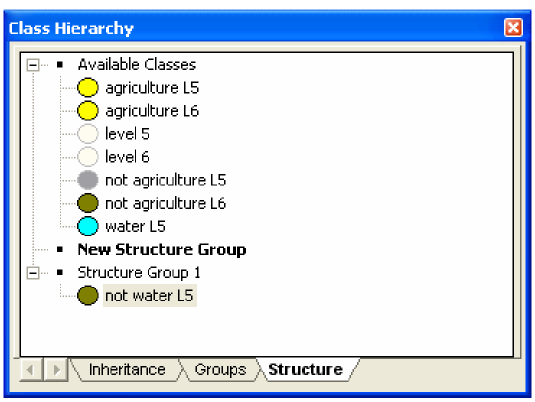
To dissolve by structure group select **Segmentation | Classification-based Segmentation** or the **Classification-based Segmentation** icon from the main tool bar. **Level 1** should be highlighted under the **Level** box. Check the **Merge image objects** button under the **Select operation** box. Select **OK** once complete. This will begin the process of merging all the objects by **structure group** (classification) and produce super objects of water bodies and areas of not water.



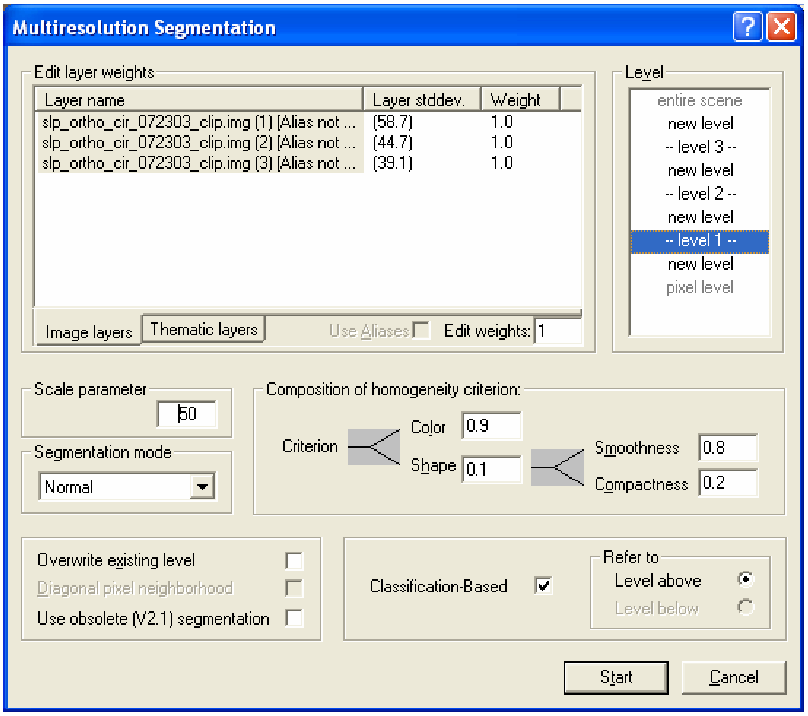


12. Next, image objects must be generated in a new level based upon the **not water L5** super object to identify areas of bare ground/sparse vegetation. The segmentation criteria will be will be optimized to identify areas of bare ground/sparse vegetation.

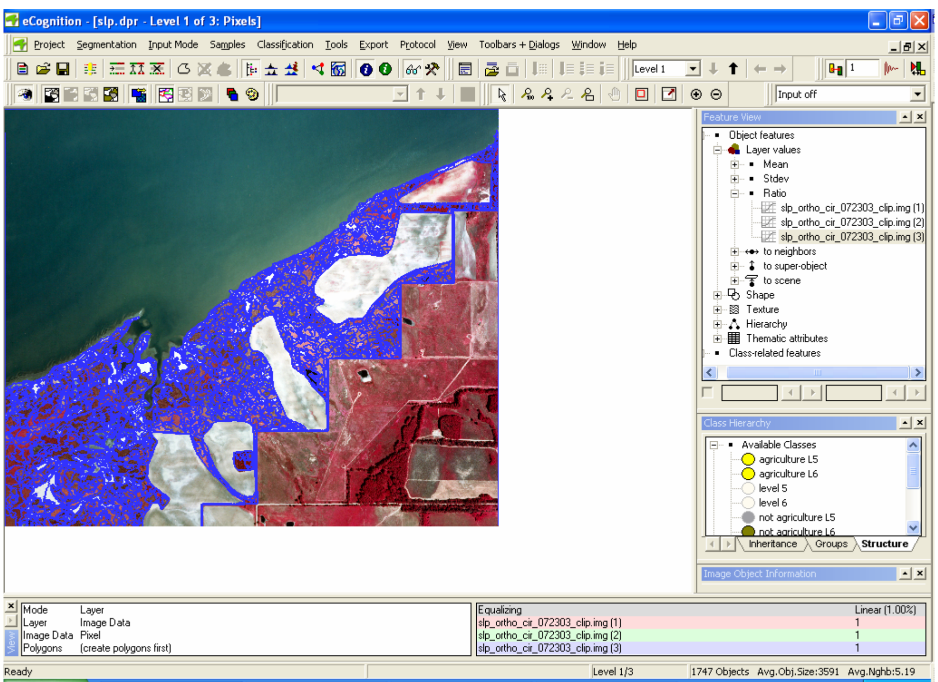
To begin the process, remove **water L5** from **Structure Group 1** and leave **not water L5**.



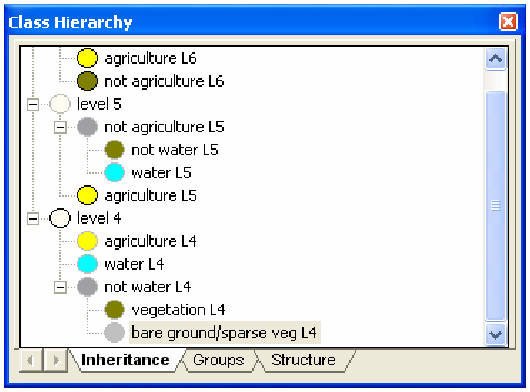
Follow the processes outlined in **step 5** to complete segmentation procedure. Alter the segmentation criteria and run the model (overwriting the new level 1 each time) until a best fit solution is found for identifying areas of bare ground/sparse vegetation. Refer to the criteria that were used in this example in the graphic below.



The results of the segmentation should appear similar to the graphic below.

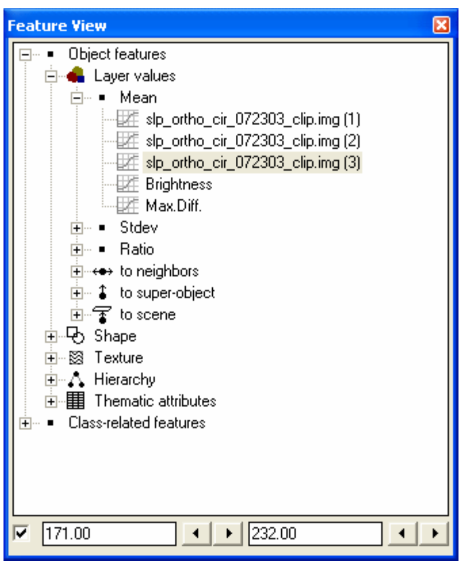


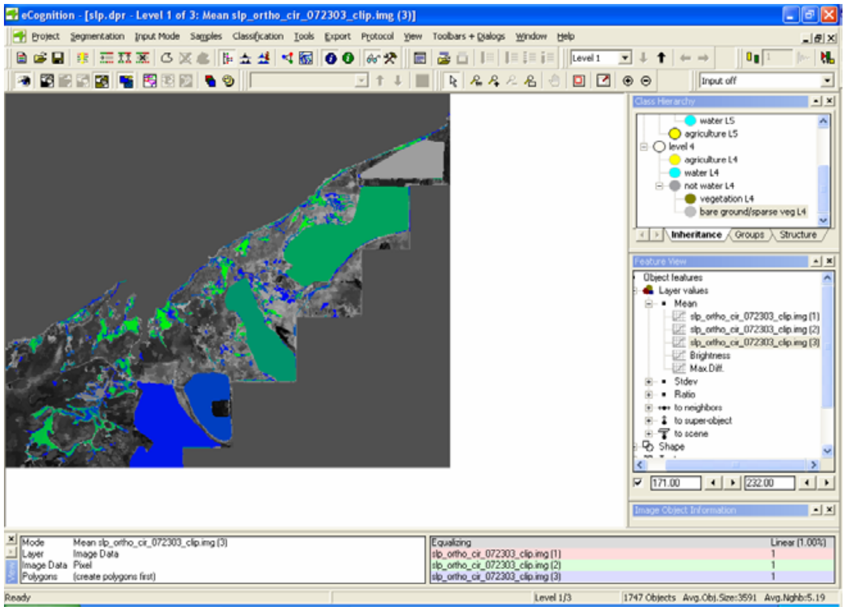
13. The generation of image objects within the area of **not water L5** has added a new level to the project (3 total). Following the procedures outlined in **step 6,** insert class **level 4** to the **Class Hierarchy** dialog and assign it a class hierarchy of **1**. Reassign the current class hierarchies to **level 5** to **2** and to **level 6** to **3**. Next insert the following classes into the **Class Hierarchy** dialog; **not water L4, water L4, agriculture L4, vegetation L4, and bare ground/sparse veg L4**. Make **agriculture L4, water L4 and not water L4** child classes to **level 4**. Make **vegetation L4** and **bare ground/sparse veg L4** child classes to **not water L4**.



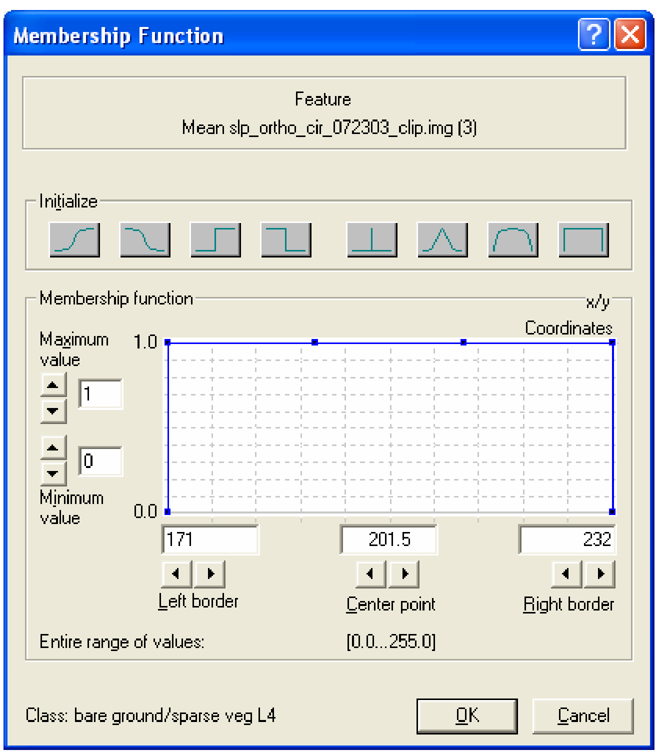
Associate **agriculture L4**, **water L4** and **not water L4** with their related super objects in **level 5**. Refer to **step 7** to complete this process as necessary.

14. Next, areas of bare ground must be classified. This is done again by observing ranges of data selected form the **Object features | Layer values** in the **Feature View** dialog. Follow the same processes outlined in **step 8**, but define the range of values to identify bare ground and sparse vegetation. The ranges identified and used in this exercise are displayed below along with the associated graphic.

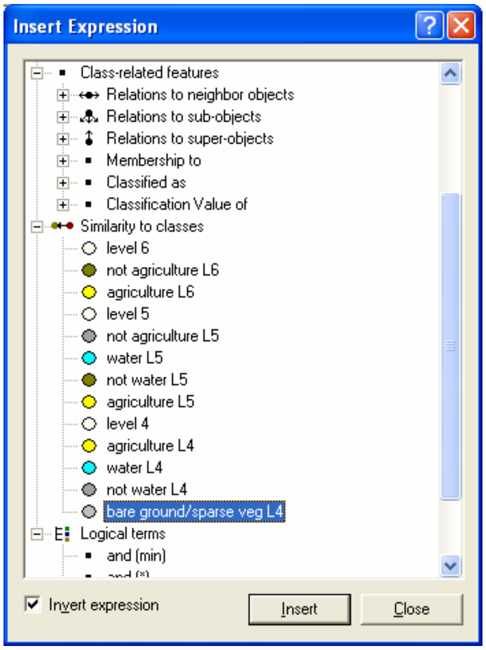




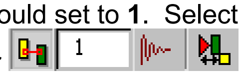
15. Now that the layer value and range have been selected to isolate areas of bare ground and sparse vegetation, follow the processes outlined in **step 9** to assign the associated layer(s) and defined range(s) using the **Membership Function** dialog to **bare ground/sparse veg L4**.

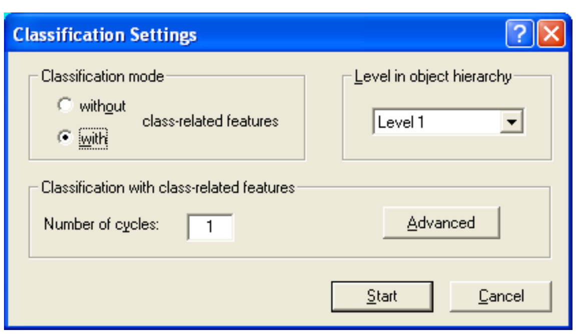


To define the ranges associated with areas of vegetation (**vegetation L4**) select **Similar to classes | bare ground/sparse veg L4** in the **Insert Expression** dialog. Check the **invert expression** box and select **Insert** to apply.

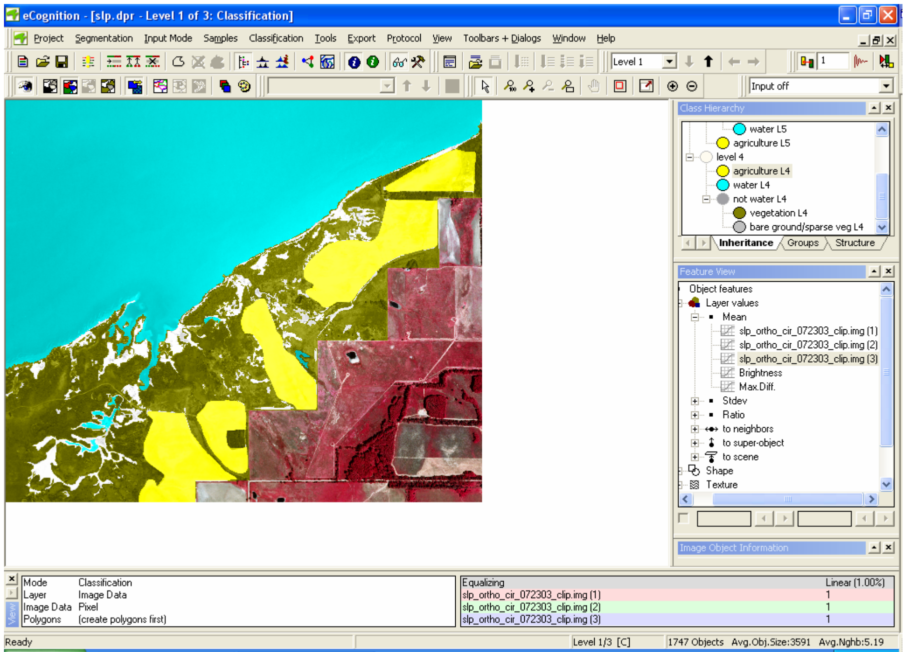


At this point all the classes in **level 4** should be assigned classification values either by relationship to super object in levels above or by classification parameters assigned to through ranges in layer values in the **Feature View** dialog.

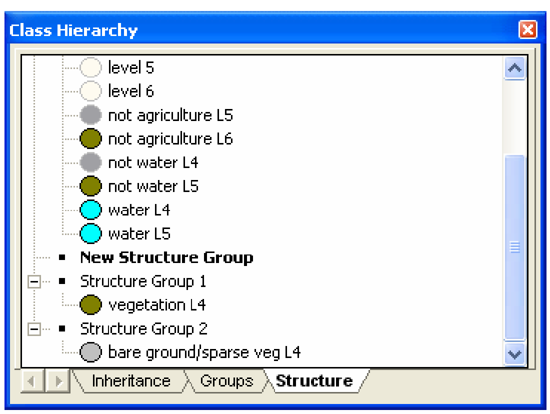
16. Now that the classification variables have been identified, objects in **level 4** can be classified. Refer to **step 10** as necessary to complete this process. To do this **select Classification | Classify** from the main menu. This will open the **Classification Settings** dialog. Under **Classification mode** select the **with class-related features** button. The level should be set to **Level 1** under the **Level in object hierarchy**. **Number of cycles** should set to **1**. Select **Start** when complete. Classification Setting icon on the main tool bar  can also be used to complete the classification process.



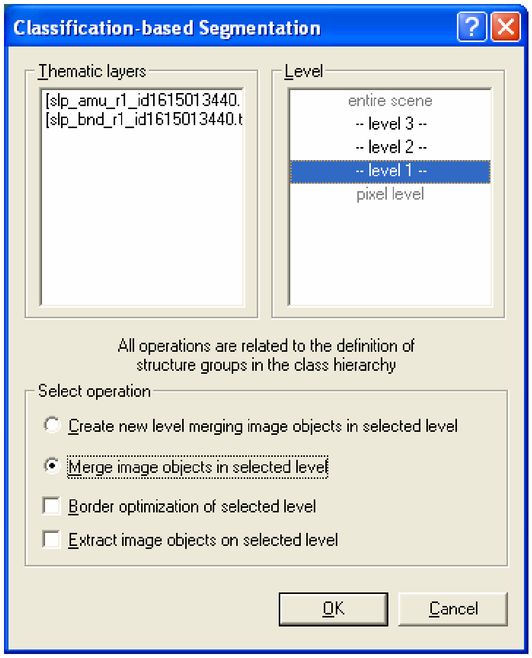
Once the classification is complete it should appear as below:



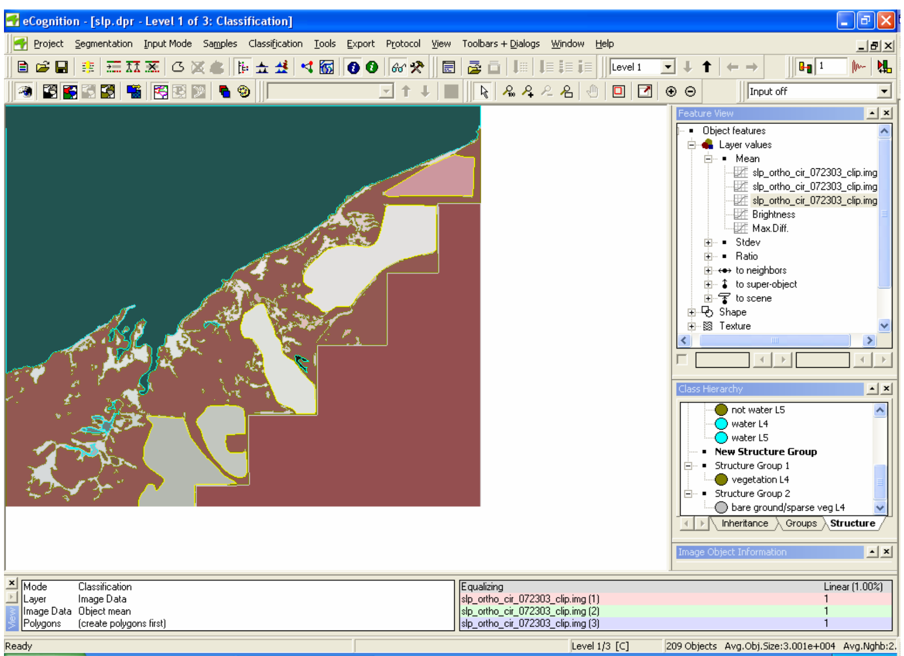
17. Now that areas of bare soil and vegetation have been classified, they must be merged into single objects to continue the CBMRIS process. Refer to **step 11** to complete this process as necessary. To dissolve adjacent classified objects (**bare soil/sparse L4** and **vegetation L4**) into single objects select the **Structure** tab from the **Class Hierarchy** dialog. Move any existing classes form the **New Structures Group** back to **Available Classes**. Drag and drop **bare soil/sparse veg L4** on **New Structure Group**, do the same with **vegetation L4**. The results should be 2 structure groups (**Structure Group 1, Structure 2**). The structure groups will be used as the delimiter for the process to generate the merge.



To dissolve by structure group select **Segmentation | Classification-based Segmentation** or select the **Classification-based Segmentation** icon from the main tool bar. **Level 1** should be highlighted under the **Level** box. Check the **Merge image objects** button under the **Select operation** box. Select **OK** once complete. This will begin the process of dissolving all the objects by **structure group** (classification) and produce super object of bare ground/sparse vegetation and areas of vegetation.



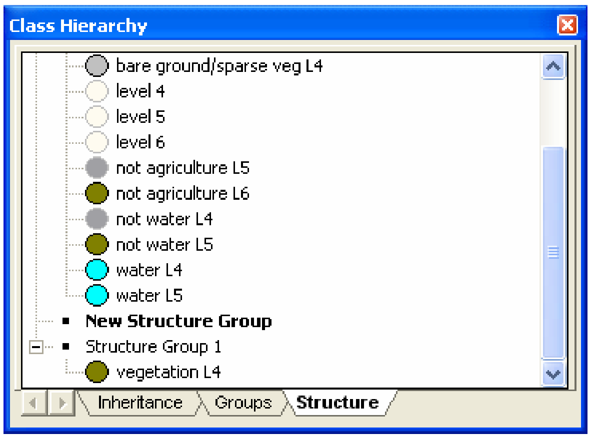
The resulting objects should look similar to this:



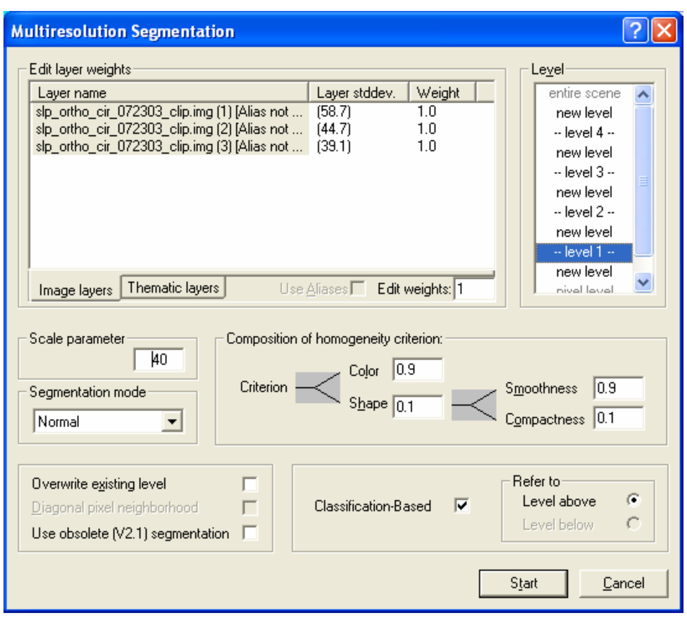
Now that areas of vegetation have been isolated from agriculture, water and bare ground; following the R2 CBMRIS Model; different physiognomic areas of vegetation (herbaceous, shrub land, woodland, forest) must be segmented and classified. This can be done using the processes outlined above, (Identifying range values from feature space in the Feature View dialog and developing membership functions), but because variations in spectral diversity are often more complex among vegetative communities than the classes that have already been identified (agriculture, water and bare ground) a more automated method of image classification is often required (**standard nearest neighbor**). Nearest neighbor is a classifier used to classify image objects based on given sample objects in a feature space based. Unclassified objects are plotted and assigned a class relative to their Euclidian distance to the sample objects collected. The steps outlined below explain this process. The resulting classified objects here will form the basis of a floristic level land cover classification and be used to produce a sample design for the collection of field data required to complete the vegetative mapping model.

18. To begin this process image objects must be generated in a new level based upon the **vegetation L4** super object to identify areas of herbaceous vegetation. The segmentation criteria should be will be optimized to identify these areas.

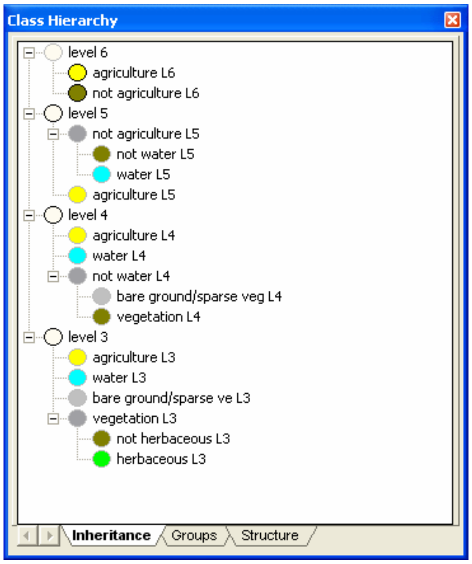
    Select the **Structure** tab from the **Class Hierarchy** dialog, remove **bare soil/sparse veg L4** from the **Structure Group** and leave **vegetation L4**.



    Follow the processes outlined in **step 5** to complete a segmentation procedure. Alter the segmentation criteria and run the model (overwriting level 1 each time) until a best fit solution is found for identifying areas of herbaceous vegetation (Be sure to select **new level** below **level 1** in the **Level** box of the **Multiresolution Segmentation** dialog before the model is run). Refer to the criteria that were used in the graphic below as needed.

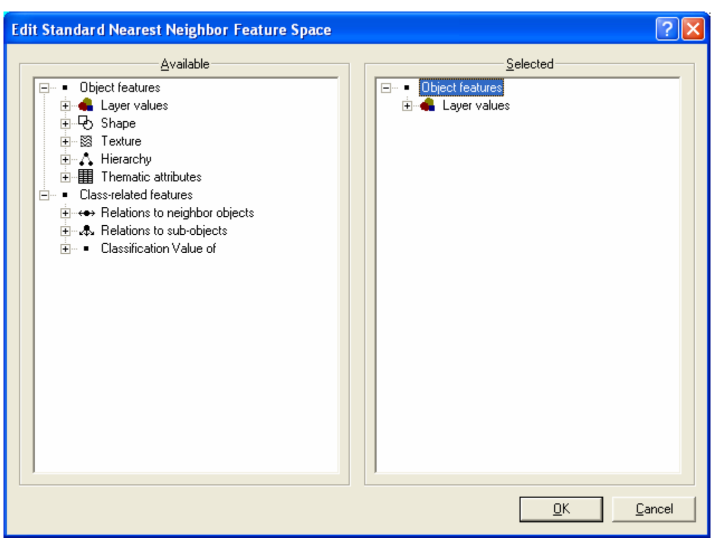


19. Now that the areas classified as **vegetation L4** have been merged and re-segmented to a new level, add the following classes to the **Class Hierarchy** dialog; **level 3, agriculture L3, water L3, bare ground/sparse veg L3, vegetation L3, herbaceous L3,** and **not herbaceous L3**. Make **agriculture L3, water L3, bare ground/sparse veg L3** and **vegetation L3** child classes to **level 3**. Make **herbaceous L3** and **not herbaceous L3** child classes to **vegetation L3**.

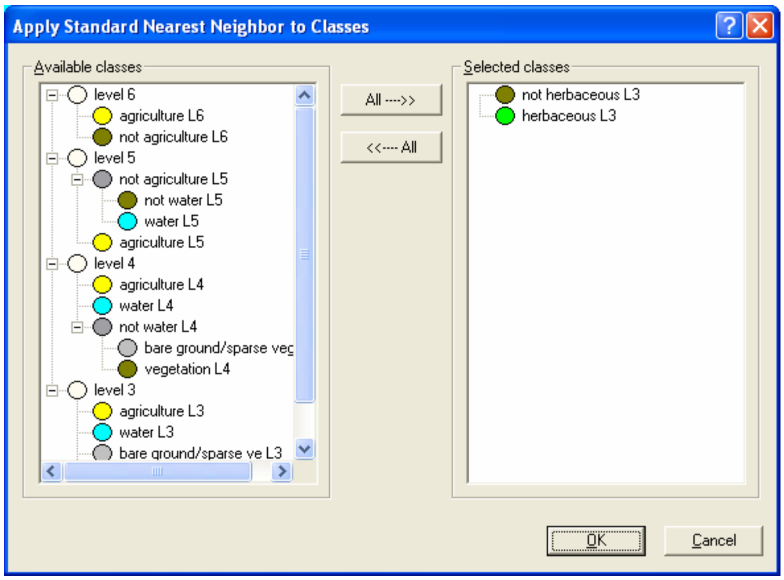


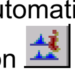
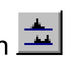
20. Use the **Class Description** dialog to assign the proper class hierarchies to level 6-3 and associate the proper super objects to all the child classes of **Level 3**. Refer to earlier steps outlined in this document to complete this process as necessary.

21. To begin the nearest neighbor classification process select **Classification | Nearest Neighbor | Edit NN Feature Space**. This will open the **Edit Nearest Neighbor Feature Space** dialog. The **Selected** box should contain all the layers intended to be used in the classification process. In most cases this will be the **Object features | Layer values**. Once the appropriate features have been selected, select **OK**.

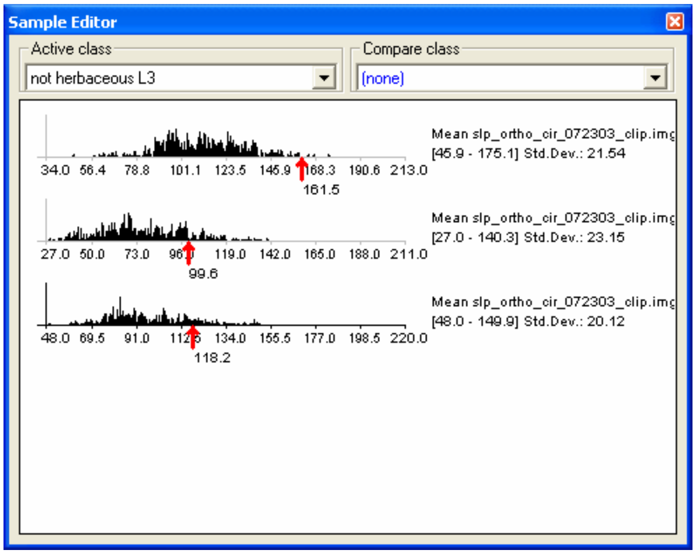


22. The classes in the nearest neighbor classification must be selected. To do this select **Classification | Nearest Neighbor | Apply Standard NN to classes**. This will open the **Apply Standard Nearest Neighbor to Classes** dialog. Use the selection arrows to move the classes **not herbaceous L3** and **herbaceous L3** from **Available classes** to **Selected classes** and select **OK**. Double click in the **Class Hierarchy** dialog on **not herbaceous L3** and **herbaceous L3** to check they have been assigned a standard nearest expression in the **Class Description** dialog. Select **OK** once done.

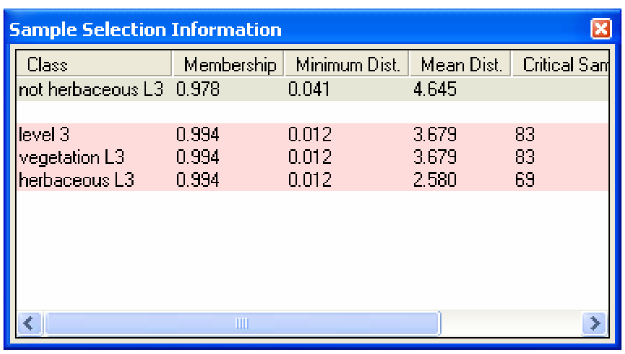


23. Now that classes have been selected for standard nearest neighbor classification, representative samples used in the classification process must be identified. To do this select **Input Mode | Select samples** or change the **Input Mode** to **Input samples** from the drop down menu on the main tool bar. This will open the **Sample Selection Information** dialog and the **Sample Editor dialog** automatically. They can also be opened using the **Sample Selection Information** icon  and **Sample Editor** icon  from the main tool bar.

The **Sample Editor** is used to display the feature values (histograms) of the samples used in the nearest neighbor classification for all layers (bands) used in the analysis. The **Active class** box displays and allows the analyst to change the class that samples are being collected for. The active class can also be changed from the **Class Hierarchy** dialog.

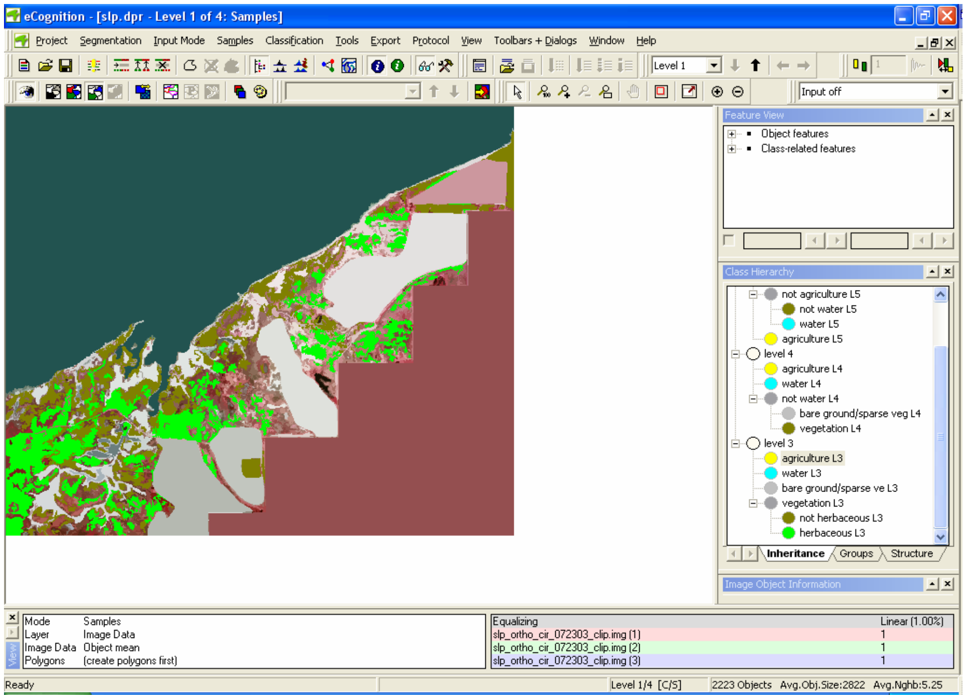


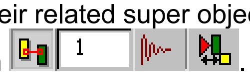
The **Sample Selection Information** dialog is used to determine the level of membership of a selected object to the class it may be used to identify. Membership determination is calculated from the classes already selected as samples. A relatively high membership is an indicator the selected object is similar to other samples already selected. If a low membership is indicated and the object is represented of the class, similar objects should be collected until their membership values are high (relatively).

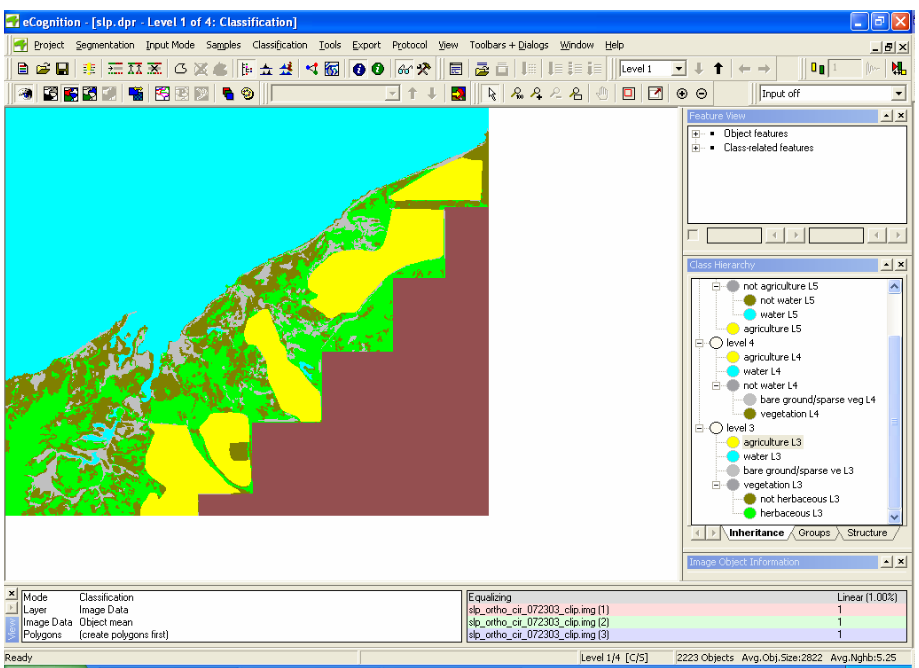

Sample Selection Information

Class	Membership	Minimum Dist.	Mean Dist.	Critical Sam
not herbaceous L3	0.978	0.041	4.645	
level 3	0.994	0.012	3.679	83
vegetation L3	0.994	0.012	3.679	83
herbaceous L3	0.994	0.012	2.580	69

To begin selecting representative samples (image objects) for the **herbaceous L3** class change the **Input Mode** to **Input Samples** and make the active class **herbaceous L3**. Using the arrow icon begin to select objects known to be or interpreted as herbaceous. Double clicking in the object will select the object as a sample and change it to the color the class has been assigned in the **Class Hierarchy** dialog. Once the first sample has been selected click in the next, membership information for that object will now be displayed in the **Sample Selection Information** dialog. If it is acceptable click it again to add the object to the sample set. The samples selected will be consolidated, as histograms in the **Sample Editor**. Collect as many samples as needed to obtain a desired classification. Repeat this process for the class **not herbaceous L3**. Additional samples can be collected and the classification rerun if required. See examples of sample selections below.



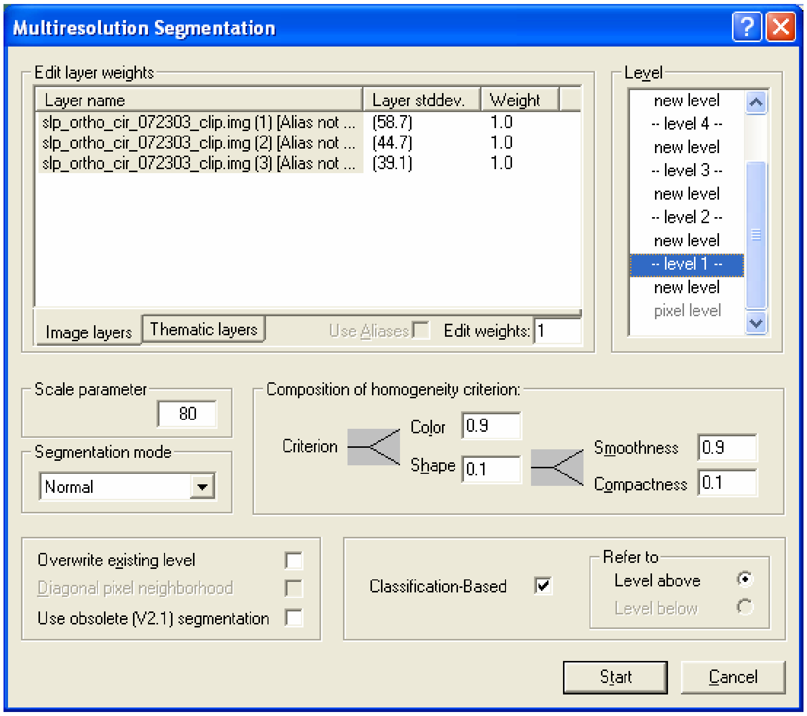
24. Now that representative sample have collected for **herbaceous L3** and **not herbaceous L3**, the classification can be run. Be sure the other classes under **level 3** have been associated with their related super object. Run the classification with class related features turned on . Refer to earlier steps outlined in this document to complete this process as necessary. Once complete the classification should appear similar to the graphic below.



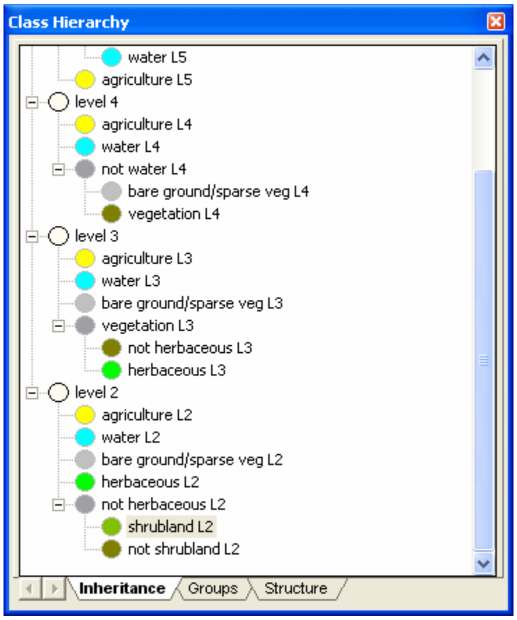
25. Continuing to follow the R2 CBMRIS Model, the next vegetative physiognomic class to be isolated is shrubland. To begin this process merge the areas classified as **not**

herbaceous L3. Refer to **step 11** as necessary to complete this process. Do not merge areas classified as **herbaceous L3**, they will be used in the sample design process and field data collection to classify image objects to the floristic level.

Segment the areas classified as **not herbaceous L3**, optimizing objects to represent areas of shrubland. Refer to **step 5** as necessary to complete this process. The parameters used in the example are shown in the graphic below.

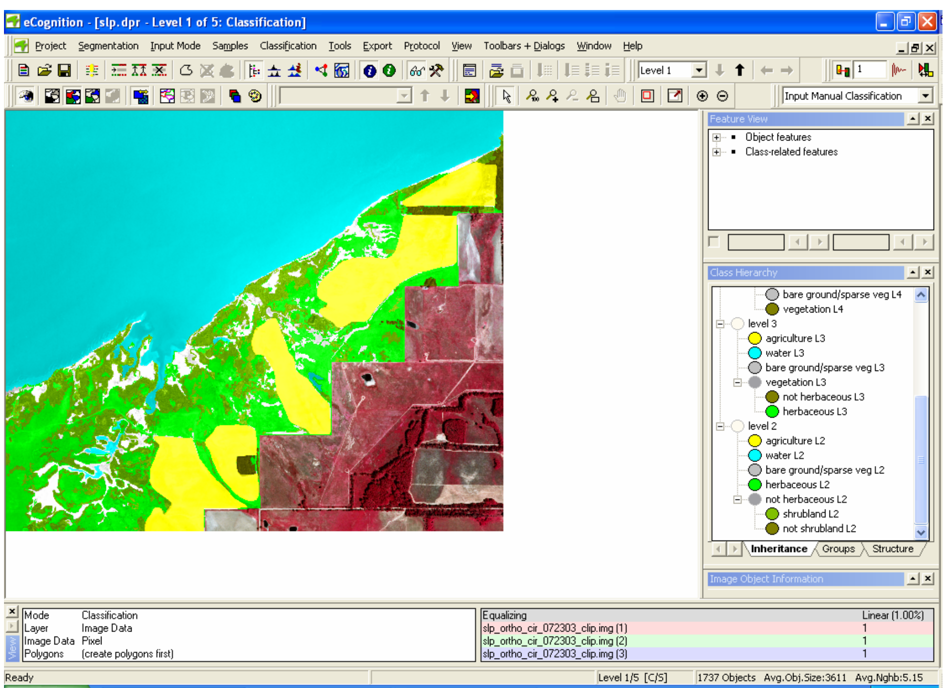


26. Now that the areas classified as **not herbaceous L3** have been merged and segmented add the following classes to the **Class Hierarchy** dialog; **level 2, agriculture L2, water L2, bare ground/sparse veg L2, vegetation L2, herbaceous L2,** and **not herbaceous L2, shrubland L2 and not shrubland L2**. Make **agriculture L2, water L2, bare ground/sparse veg L2, herbaceous L2** and **not herbaceous L2** child classes to **level 2**. Make **shrubland L2** and **not shrubland L2** child classes to **not herbaceous L2**.



27. Use the **Class Description** dialog to assign the proper class hierarchies to level 6-2 and associate the proper super objects to all the child classes of **Level 2**. Refer to earlier steps outlined in this document to complete this process as necessary.

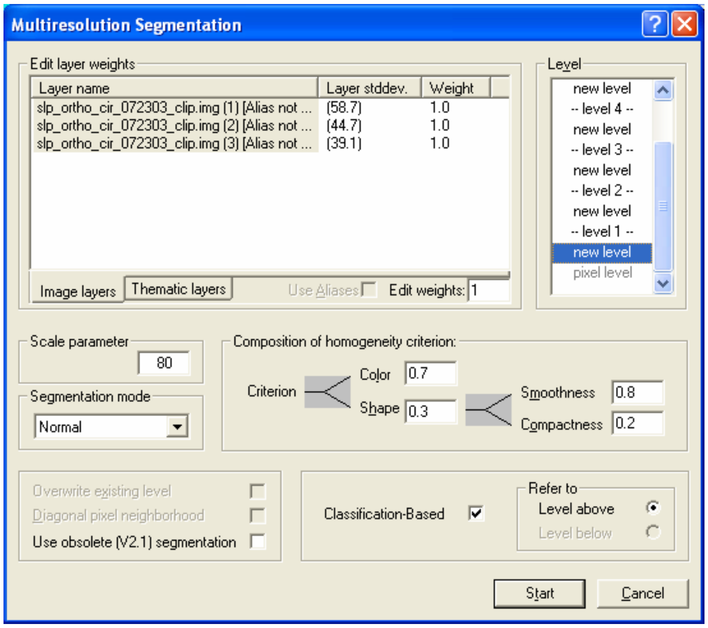
28. Refer to **steps 23-24** to complete a standard nearest neighbor classification for areas of shrubland (**shrubland L2**) and areas of not shrubland (**not shrubland L2**). Run the classification. The graphic below represents the completed classification.



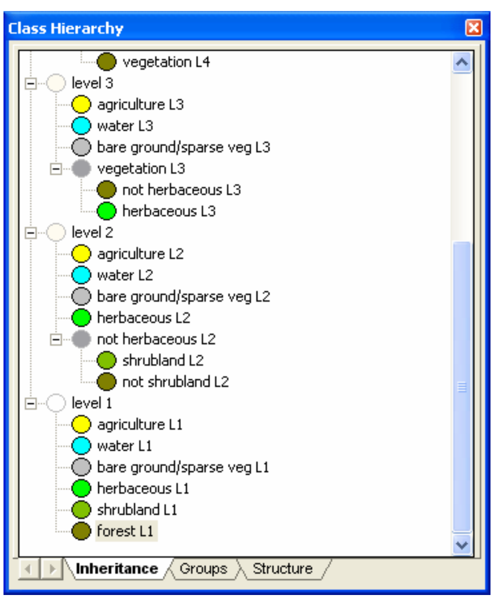
29. The R2 CBMRIS Model now calls for areas of woodland to be isolated and classified, but because there are no areas of woodland on this image the final vegetative physiognomic class needed to be identified is forest. To begin this process first merge the areas classified as **not shrubland L2**. Refer to **step 11** as necessary to complete this process.

Do not merge areas classified as **shrubland L2**, they will be used in the sample design process and field data collection to classify objects to the floristic level.

Next, create a new level, segmenting the areas classified as **not shrubland L2**, optimizing objects to represent areas of forest. Refer to **step 5** as necessary to complete this process. The parameters used in the example are shown in the graphic below.



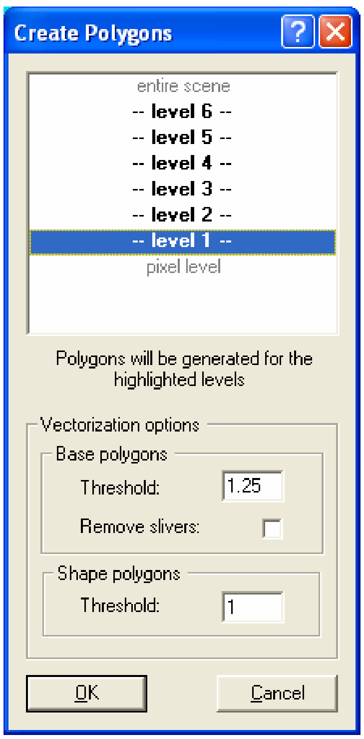
30. Now that the areas classified as **not shrubland L2** have been merged and a new level segmented, add the following classes to the **Class Hierarchy** dialog; **level 1, agriculture L1, water L1, bare ground/sparse veg L1, herbaceous L1, shrubland L1 and forest L1**. Make **agriculture L1, water L1, bare ground/sparse veg L1, herbaceous L1** and **forest L1** child classes to **level 1**.



31. Use the **Class Description** dialog to assign the proper class hierarchies to level 6-1 and associate the proper super objects to all the child classes of **Level 1**. Refer to earlier steps outlined in this document to complete this process as necessary. Refer to the super object **not shrubland L2** to classify image objects as forest.

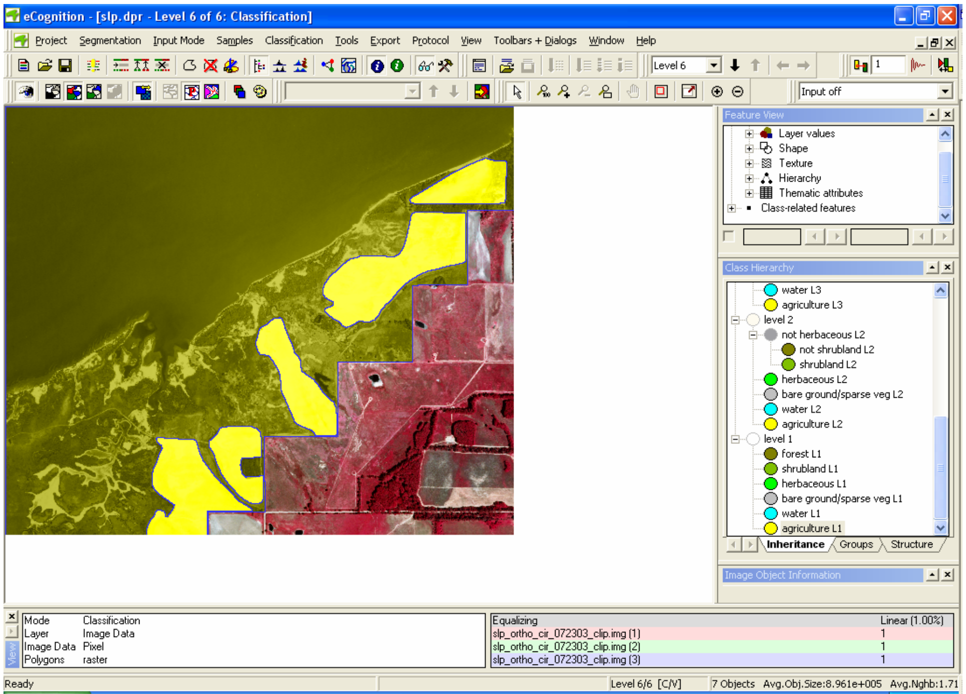
To utilize image objects in ArcGIS/ArcPad for sample design and field data collection for vegetation classification to the floristic level, objects in level 1 must be exported as a shapefile and imported as a feature class to a Geodatabase.

32. To begin this process convert image objects to polygons. This can be done by selecting the **Create/Modify Polygon** icon from the main tool bar. This will open the **Create Polygons** dialog. Select **level 1** and take all the defaults and select **OK**. Polygons will be generated for each level 1-6.

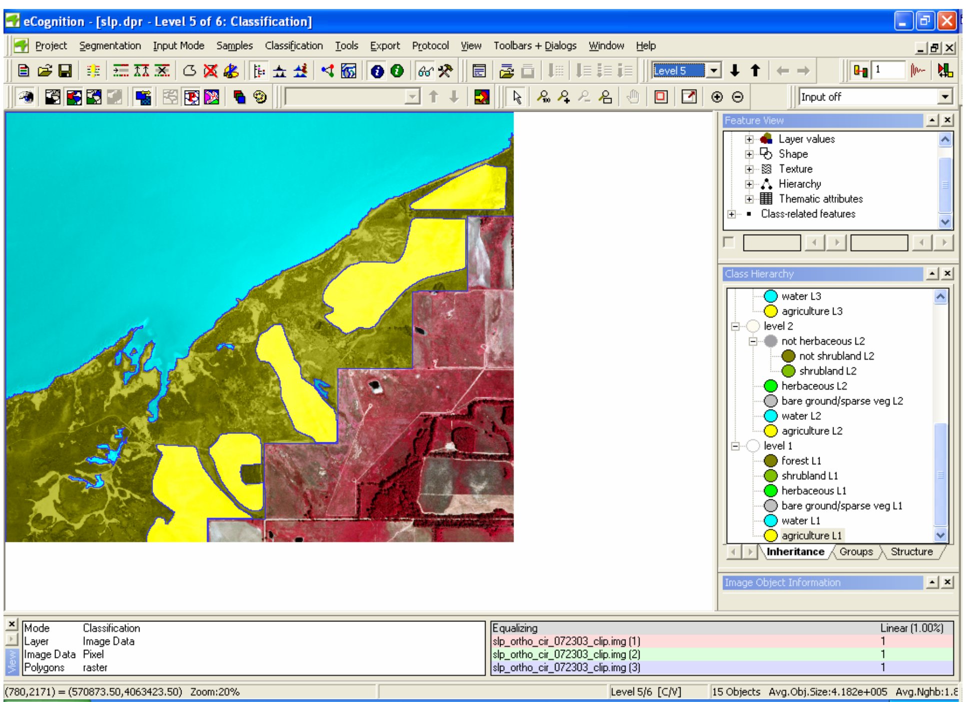


Review each level to be sure polygons were generated successfully.

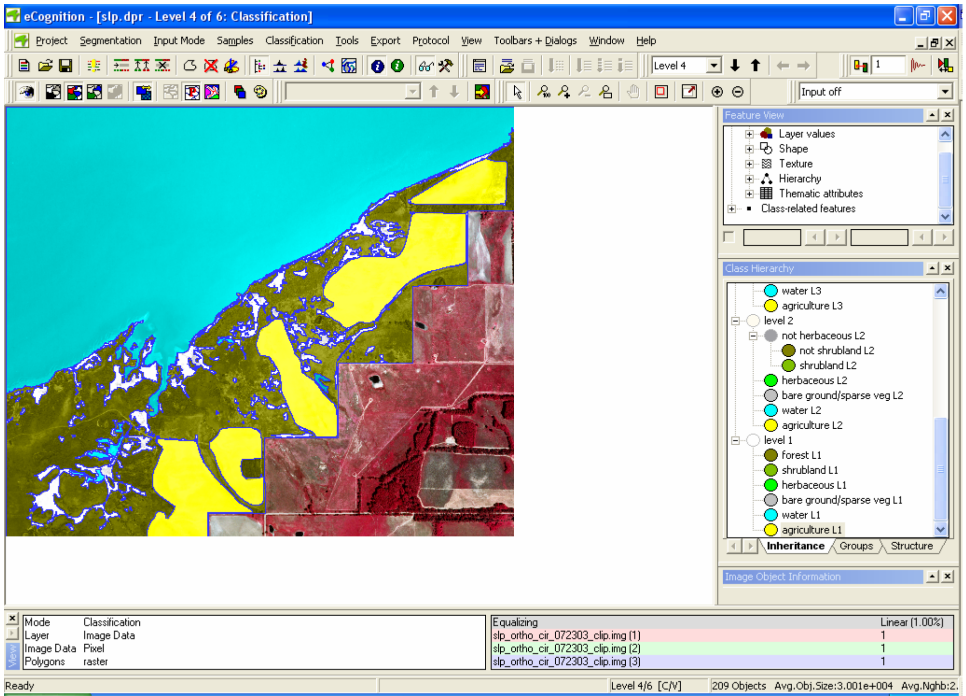
Level 6



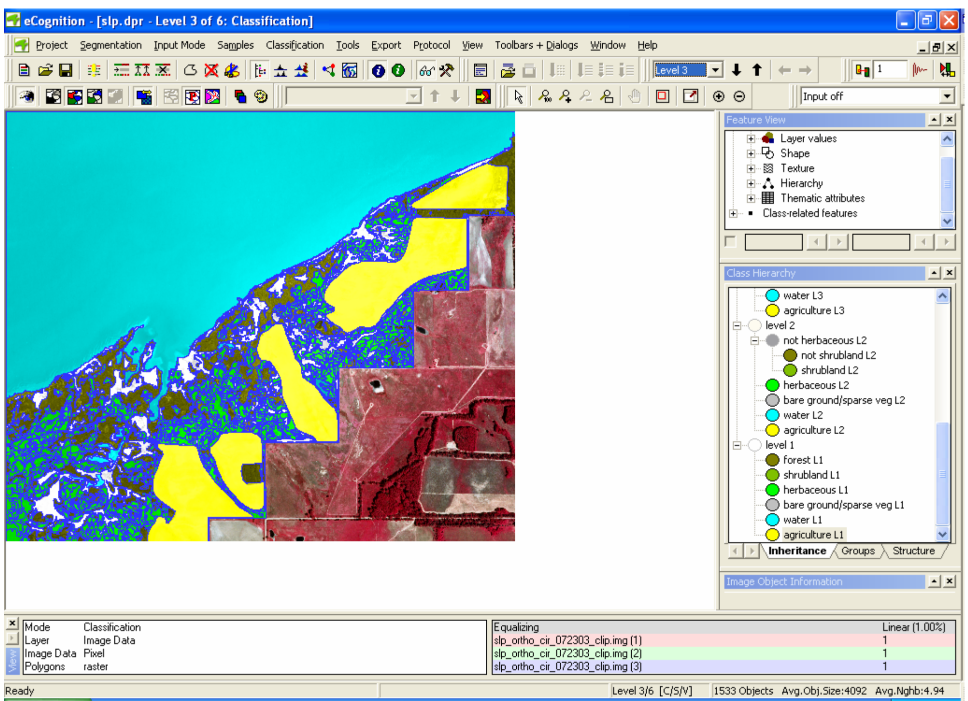
Level 5



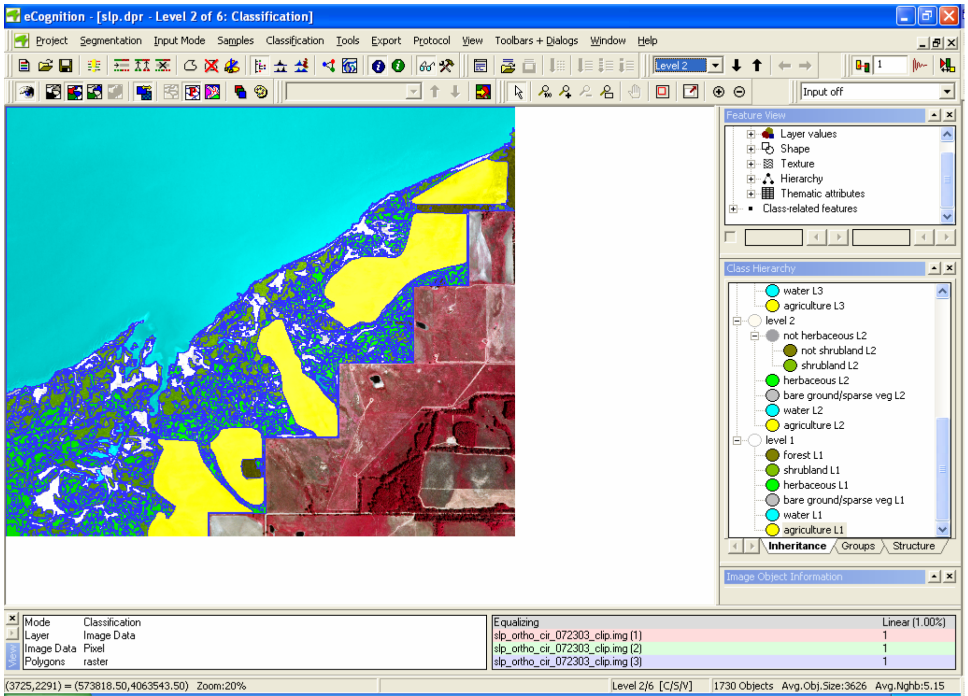
Level 4



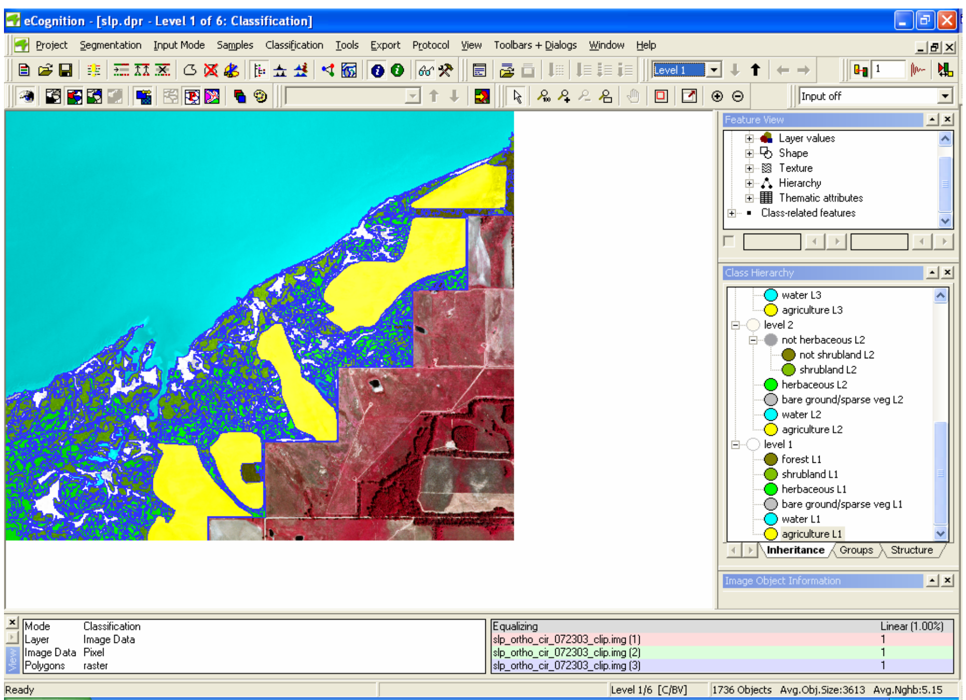
Level 3



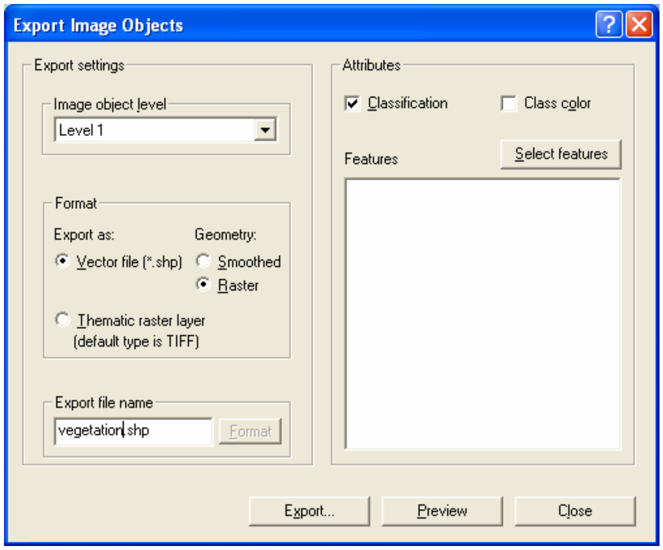
Level 2



Level 1



33. Select **Export | Image Objects** form the main menu. Under **Export settings** set Image object level to **Level 1**, set **Format to Vector file (*.shp)**, set **Geometry** as **Raster** check **Classification** and uncheck **Class Color**. Change the **Export file** name to **vegetation.shp**. Select **Export**. Select a folder for the data to be saved in and select **OK**.



34. Start an **ArcCatalog** session and navigate to the **vegetation.shp**. Open the **Shapefile Proprieties** dialog and set the correct projection information for **vegetation.shp**. **Load** the shapefile into the vegetation feature class in the **Landcover and Habitat GDB**. Calculate the NVCS Class field from the field exported from eCognition that contains the NVCS class classification. If a bounding polygon exists it should be deleted in an Edit session in ArcMap.

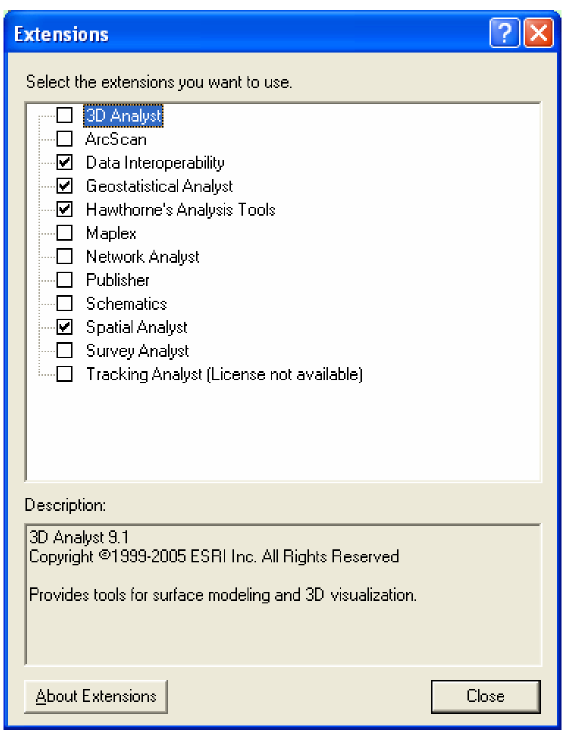
8.1 Training Site Sample Design: ***Stratified random selection training sites for vegetation classification and accuracy assessment using ArcInfo 9.1 and Hawthorn's Tools Extension***

At this point in the project development process a feature class has been created and attribute table developed and partially populated. Before data can be ported to ArcPad (Trimble GeoXT) for field data collection, training polygons must be identified. So that bias is not introduced into the model these training site polygons must be selected randomly and at a frequency that statistically validates the analysis produced. The randomized selection process can be completed through **ArcMap | Hawth's Tools**.

To determine how many samples should be selected for a completely random sample multiply the number of classes (NVCS alliances or associations) known to be present on the refuge by 65 ***(number of NVCS alliances or associations x 65) = total number of training sites needed***. This number of training sites should be adequate for providing training data as well as accuracy assessment (Congalton, R.G. 1991).

To select field samples they should be stratified by NVCS class. This information is already populated within the vegetation feature class in the NVCS Class field. To determine the number of samples to be collected within a NVCS class multiply the number of Alliances that are children of the NVCS Class being used as a stratification variable by 65 ***(number of forest alliances or associations x 65) = total number of forest alliances or association training sites needed when the NVCS Class 'forest' is used as the stratification variable***.

1. To begin a copy of the vegetation feature class should be opened in **ArcMap**. If the **Hawthorne's Analysis** tool bar is not already active select **Tools | Extensions** from the main tool bar. Check the box next to **Hawthorne's Analysis Tools**.

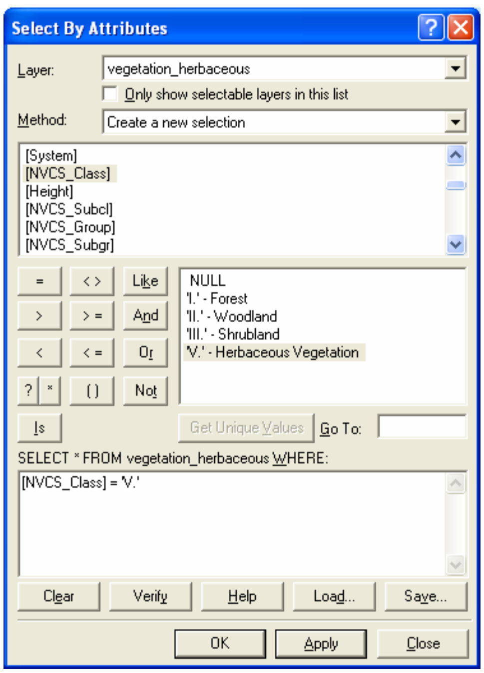


2. Select **View | Tool Bars** and check the box next to **Hawth's Tools**. This should open and activate the **Analysis Tools** toolbar.

Sample Considerations
When selecting sample sites there are a number of landcover types that should not be considered when selecting training sites for vegetation classification. These would be areas that can be easily photo interpreted such as water, agriculture or bare ground. This also includes alliance and association level vegetation communities. Any areas that can be photo interpreted to a level of direct recognition should not be included into the sample and given to the classification model.

Sampling considerations should also be given to the possibility of additional alliances or associations being added to the sample design at a later date. It is common to add additional vegetation communities as field work is conducted. Often communities are discovered that went undetected during field reconnaissance. Adding additional training sites on the front end will help account for this possibility.

3. To randomly select field data collection sites each **NVCS Class** must be subset and saved as a shapefile. This is a cumbersome step. At this point there has not been a tool developed to generate a random selection from a select set of features. To work around this issue each NVCS class must be saved as a shapefile (Hawth's Tools only works in shapefiles). Select **Selection | Select By Attributes**. This will open the **Select By Attribute** dialog. Type or select **NVCS_Class = V. Herbaceous Vegetation** in the **Select From** window. Select **Apply**. All the polygons classified as Herbaceous Vegetation should now be highlighted.



4. Right click on the vegetation feature class and select **Data | Export Data**. This will open the **Export Data** dialog. In the **Export** box select Selected features. Use the same coordinate system as the layers source data. Name the file using the following naming convention:

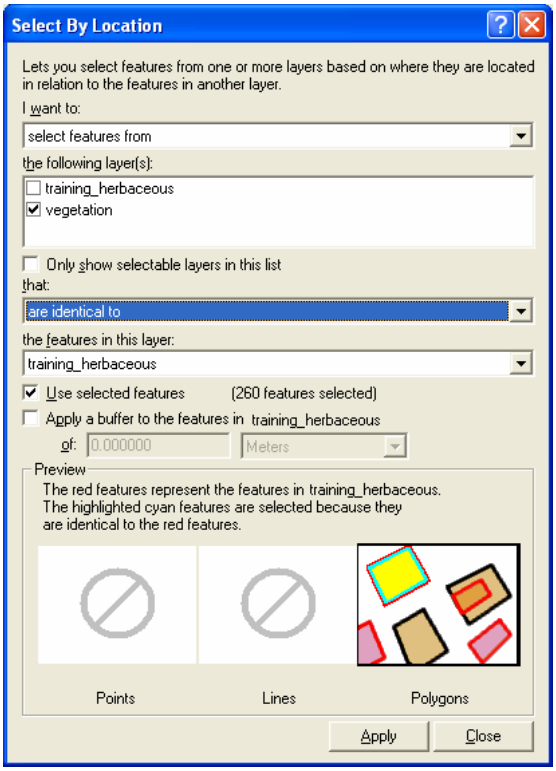
   Example: training_herbaceous.shp

   Select **OK** and add shapefile to **ArcMap** session.

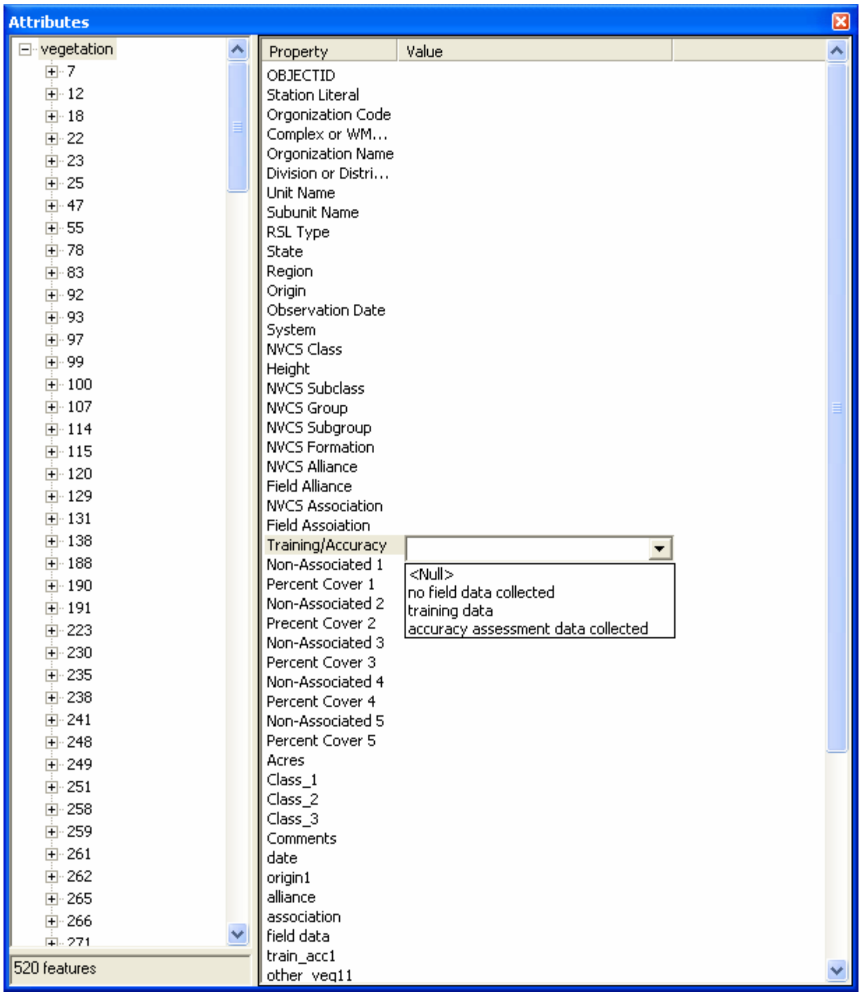
5. Select **Analysis Tools | Create Random Selection** from **Hawth's Tools** toolbar. This opens the **Random Selection** dialog. In the **Layers to select features** in box select **training_herbaceous**. Select the **This number of features button**. Calculate the number of polygons to be selected. In this example it will be assumed that there are 3 known herbaceous alliances present on the refuge. An additional alliance is added to account for any undiscovered

alliances that may exist bringing the total to 4. This number is multiplied by 65 to reach a total of 260 sample sites. Type 260 in the **this number of features** box. There now should be 260 features selected from the **training_herbaceous** shapefile.

6. With the randomly selected polygons still highlighted select **Selection | Select By Location**. This will open the **Select By Location** dialog. In the dialog **select features from** the **vegetation** feature class that are identical to the **features in training_herbaceous layer**. Check the box **Use selected features**. Select **Apply** and **Close**. The highlighted polygons should not have changed.



7. Open the **Editor** toolbar if not already open. Select **Editor | Options**. This opens the **Editing Options** dialog. Under the **General** tab type **30** in the **Sticky move tolerance** box. This will prevent any unintentional movement of selected polygons while in edit mode.
8. Select **Editor | Start Editing**. Select source as the **Landcover and Habitat.mdb** and select **OK**. The **Target box** on the **Editor** toolbar should now say **vegetation**. Select the **Attributes** icon  form the **Editor** toolbar. This will open the **Attribute** editing dialog. In the feature selection window highlight vegetation at the top of the column. This allows any changes in attributes to be applied to all features selected at once. Click to the right of the **Training/Accuracy** field. A dropdown should appear. Select **training data**. This will populate all the selected polygons stratified by herbaceous with a **training data** designation. These stratified randomly selected polygons will be used to collect field data and generate spectral signatures to run the classification model.



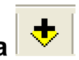
9. Repeat **steps 1-8** for all NVCS Class communities present on refuge.

9.1 <u>RLGIS Geodatabase Check In, Check Out</u>: *Preparing data for checkout to Trimble GeoXT*

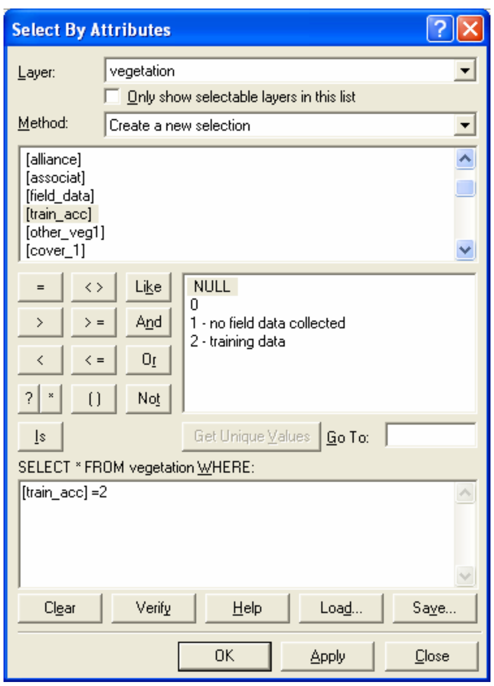
The ability to bring a ruggedized GIS platform with an integrated GPS is a tremendous advantage when collecting field data. The steps outlined below describe the data transfer process used by the Lab when porting sample training site polygons from a Geodatabase to **ArcPad 7.X** and **Trimble GeoXT** units for collection of field data.

Selecting training polygons from vegetation polygons for use in field data collection

1. Launch ArcMap.

2. To your project add the vegetation feature class of the national wildlife refuge or wetland management district you will be collecting field data on. This data should contain vegetation polygons derived through segmentation. Adding this can be done using the **Add Data**  button from the main menu.

3. Use the **Select By Attribute** dialog to select all the training polygons. These should be all polygons calculated to **2 – training data** completed in **Chapter 8.0**.

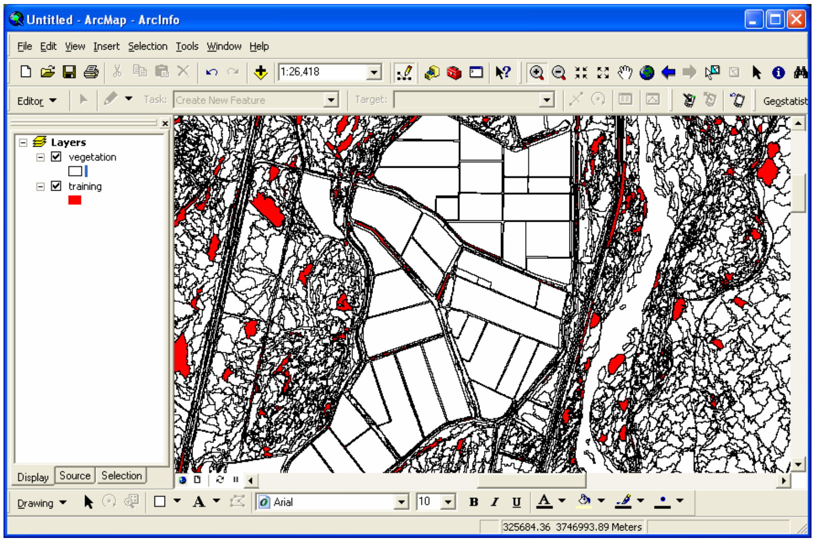


4. Now that all the training polygons are selected right click **vegetation feature class** from the **Layers** window and select **Data | Export data**. Save selected features back to the **Landcover and Habitat GDB**. Name new feature class **training**. ***After field data collection is complete this feature class should be deleted.***

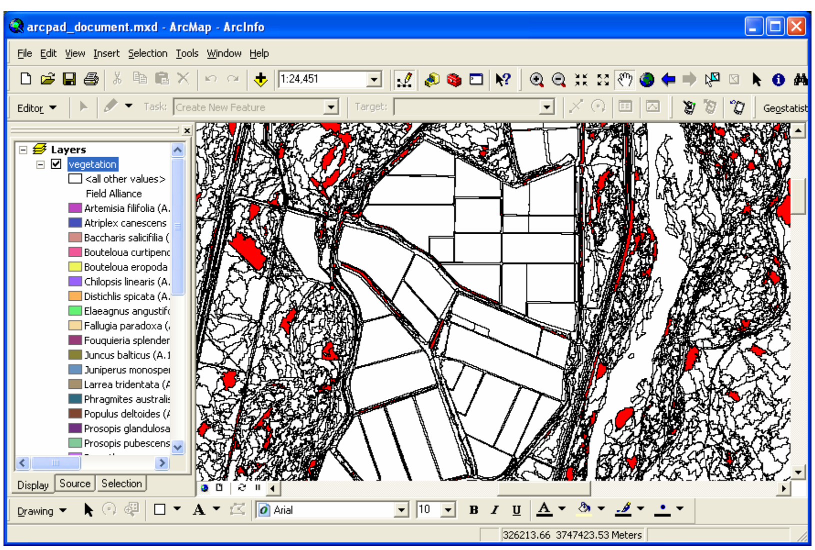
Adding data layers to ArcMap for field data collection

Now that the training polygons have been subset from the vegetation feature class these layers should be added to an ArcMap session if they are not already. The steps to complete this are listed above if needed.

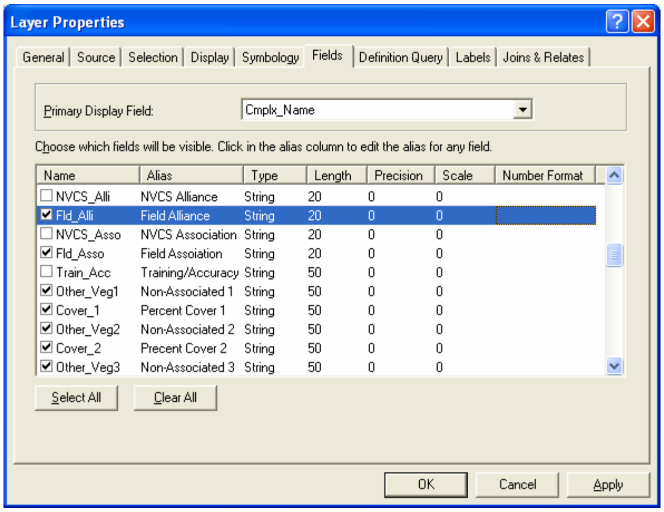
1. With the **vegetation** and **training** feature classes added to an ArcMap session change the symbology of the training feature class to solid red and place it under the vegetation feature class in the Layers window.



2. Right click the vegetation feature class and select **Properties**. This will open the **Layer Properties** dialog. Select the **Symbology** tab. In the Show window select **Categories | Unique values**. In the **Value Field** select **Field Association** or **Field Alliance** depending on what level of NVCS you are mapping to. Select the **Add All Values** button. All the NVCS association or alliance domain values should be added. Change the **<all other values>** symbol to black outline by double clicking on the symbol and making a new selection in the **Symbol Selector**. The color ramp can be changed to what is most appropriate. Click **OK** to apply symbology changes.



3. Next from the **Layer Properties** dialog for the vegetation feature class select the **Fields** tab. This will display all the fields in the vegetation feature class with a box checked next to each. Unchecking the box will cause the field not to be displayed in the table or digital field form in **ArcPad**. To increase efficiency in the field a number of fields can be turned off. It is recommended that all but the following fields are turned off: **Origin**, **Observation Date**, **Field Alliance**, **Field Association**, **Non-Associated1-5**, **Percent Cover1-5** and **Comments**. **Class 1-3** may be left on as well for additional classification needs. Click OK when done.



4. Save the **ArcMap** session to a *.mxd using the following naming convention; refuge literal_vegetation.

   Example: bda_vegetation.mxd

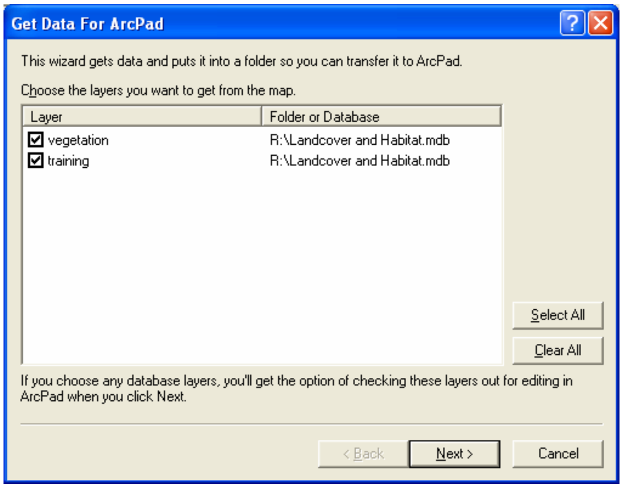
Transferring data from ArcMap to ArcPad using Check in Check out Wizard

1. Launch ArcMap and open saved project created in steps 1 – 4 above, if not already opened. This can be done by selecting the **File** button and **Open** from the drop down menu that appears. It may also be done by selecting the **Open** project button  from the main menu.

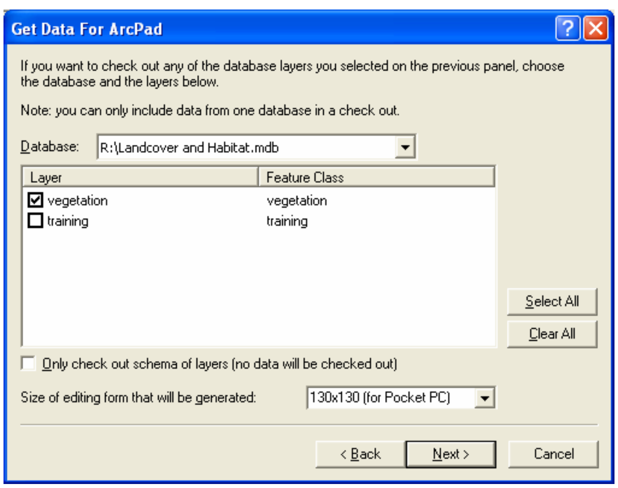
2. Zoom to the area that data is to be collected from. The extent of the screen will define the subset of data being checked out. Keep in mind that the space available on a Trimble GeoXT is limited and large datasets will affect the performance of the unit. An option of selected features may also be used to subset data during checkout.

3. Activate the ArcPad menu if it is not already. To do this select **View** from the main menu and **Toolbars** from the dropdown menu that appears. Place a check next to **ArcPad**. This loads the ArcPad Tools for ArcMap toolbar . Dock or move the toolbar if desired.

4. Select the get data for ArcPad button form the ArcPad menu . This will open the **Get Data For ArcPad** dialog. On the first page of the dialog select the vegetation and training layers by placing a check in the box to their left. Once complete select **Next >**.



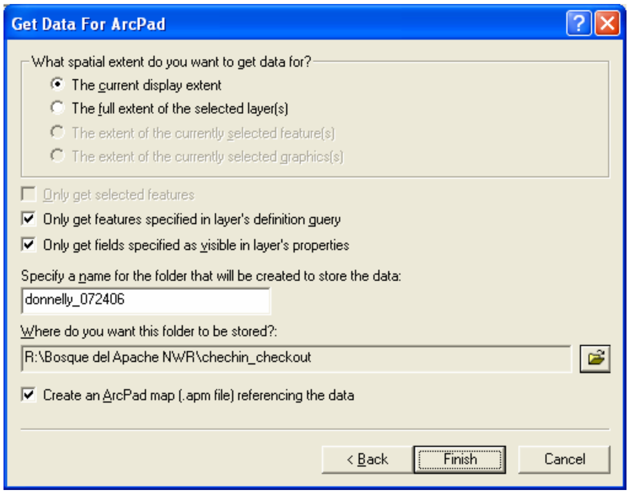
5. Select the vegetation database layer. This will checkout the vegetation database to be edited in the field. Be sure the editing form size id set to **130x130 (for Pocket PC)**. Once complete select **Next >**.



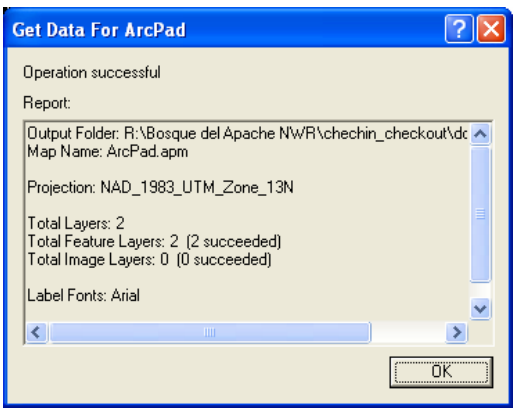
6. Select **The current display extent** button. This will set the extent of your project to the current display of the ArcMap project. **The full extent of selected layers** button may used if layers are being subset using a selection. Take the defaults for **Only get features specified in layer's definition query** and **Only get fields specified as visible in layer's properties**. Name the folder the data will be checked out to. This name should include the name of the individual collecting the data and the date it was checked out.

   Example: donnelly_072406

   Specify the appropriate location to store this file and check the box next to **Create an ArcPad map (.apm file) referencing the data**. Once complete select **Finish**.



7. After a couple of seconds you will be notified if the operation was successful. Select **OK** to complete the check out process. Minimize or close ArcMap.



Considerations and Errors when checking out data to ArcPad

Checking out the same data to multiple Trimble GeoXTs:
If multiple data loggers are to be used to collect the same data an individual dataset must be checked out for each unit. Each dataset checked out must have a different name following the suggested naming convention outlined above. This will allow the project manager to track edits more efficiently and prevent data loss. ***If a single checked out dataset is used each successive dataset checked in will overwrite the other!***

Data projection errors when checking out for ArcPad:
ArcPad does not support reproject on the fly. Because of this limitation all data being checked out to ArcPad must be in the same projection. If they are not you will receive an error message during the check out process.

Raster Errors when checking out data for ArcPad:
ArcPad has file size limitation for encoding raster data. All users of ArcMap can only encode individual, uncompressed raster smaller than 50 MB. The 50 MB size rule will be evaluated as follows: Image Width * Image Height * Number of Bands cannot be greater than 50 million. If you purchase the MrSid extension from Lizard Tech, then your limit is 500 MB with the added ability to mosaic images.

9.2 <u>RLGIS Geodatabase Check In, Check Out:</u> *Transferring checked out data layers to and from Trimble GeoXT*

In this section you will learn how to transfer checked data layers to and from GPS data logger for use in field data collection with ArcPad.

The software used to transfer data between your GPS data logger device and PC is called ActiveSync. This software is free and can be downloaded from:

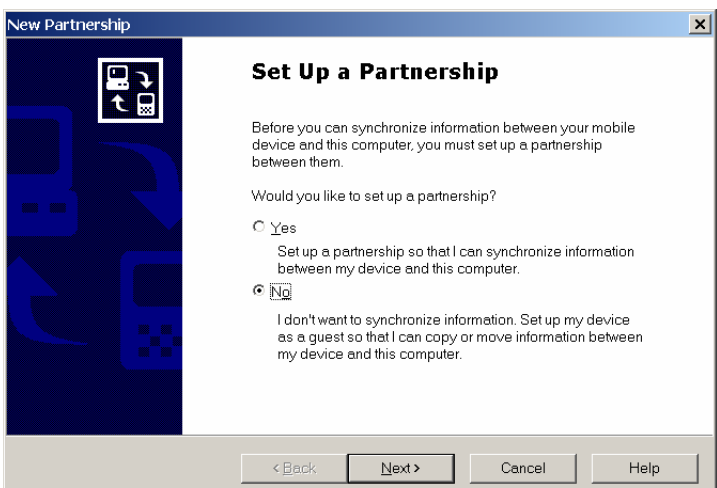
http://www.microsoft.com/windowsmobile/resources/downloads/pocketpc/default.mspx

These instructions were developed using ActiveSync version 3.8 and assume that you have not established a partnership between the GPS data logger device and your PC. The GPS data logger used in this example is a Trimble **GeoXT**, however these steps should work with most GPS data loggers capable of running ArcPad.

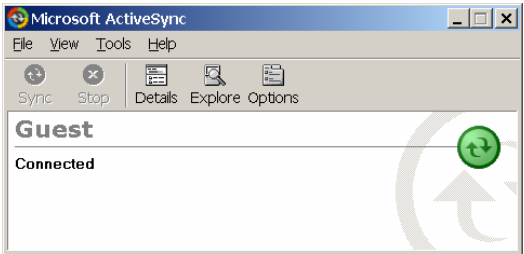
1. Ensure the cradle of your GeoXT data logger is connected to the USB port of the computer containing the ArcPad data.

2. Place your GeoXT onto the cradle. ActiveSync software should detect your device. If it doesn't, check cabling or try another USB port and then lift your device off the cradle, turn it off and then place back on the cradle. ActiveSync can sometimes be finicky software.

3. Check **NO**, when asked to set up a partnership and connect as a guest. Select **<u>N</u>ext>**.



4. The Microsoft ActiveSync dialog appears and your connection status is displayed in the window below **Guest**. Ensure you have a connection (Connected appears below Guest in the dialog window).



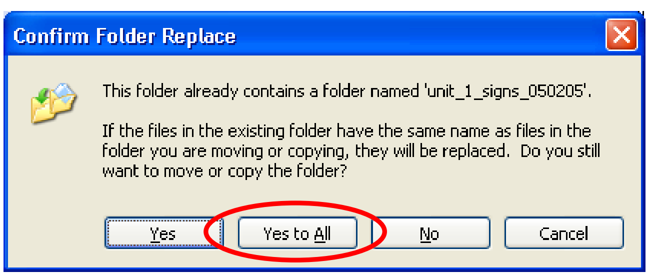
5. Select the **Explore** button 

form the Active Sync dialog. This will launch the windows explorer for the GeoXT. Once open copy and past the folder containing the ArcPad .apm files (unit_1_signs_053005). Accept any data formatting dialogs that may appear during the transfer by selecting **OK**. The folder and files containing the checked out data should now be transferred to the GeoXT.

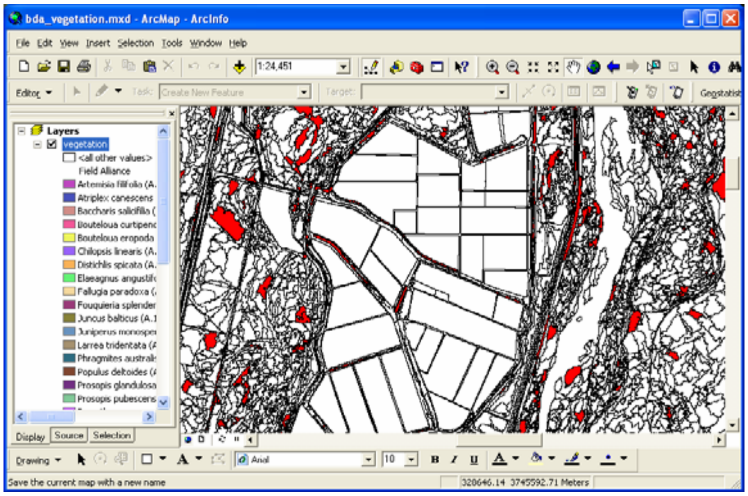
Checking in field data from ArcPad

In this section you will learn how to check in field data from ArcPad back into the RLGIS Geodatabase Model in ArcMap. For this example we will continue to use the Bosque del Apache NWR sign data collection example.

1. Follow the steps outlined above **- Transferring checked out data layers to and from GPS data loggers (GeoXT).** ***When transferring files from the GeoXT to your PC be sure to place the checked out folder from the GeoXT containing the edits in the same location on the PC as it was copied from.*** When this is done you should be asked if you would like to overwrite the existing folder and all of its contents. Select **Yes to All**.



2. Launch an **ArcMap** session. Open up the .mxd project file which contains the data you originally checked out. You can also add the data layers that were checked out if you did not save them as a .mxd project.

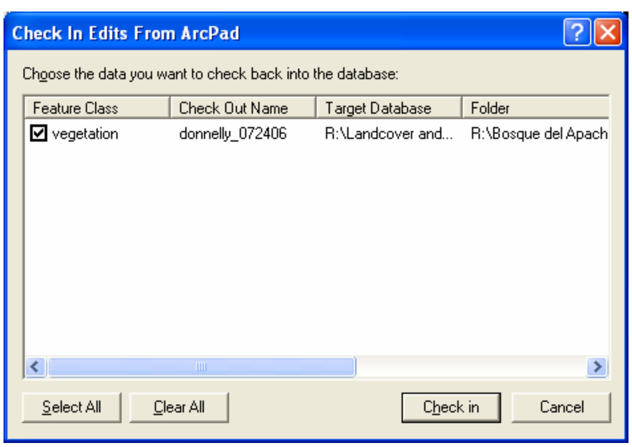


3. Open your **Editor Toolbar** if is not already open. You can do this going to **View** button on the main menu, selecting **Toolbars** and placing a check next to **Editor**. This will open the **Editor Toolbar**.

4. Start an edit session by selecting the **Editor** button on the Editor Toolbar and select **Start Editing** from the drop down menu that appears. Select the vegetation feature class in the **Target** box.

5. Select the **Check In Edits From ArcPad**  button on the **ArcPad Toolbar**. This button is activated only when you are in an edit session.

6. The **Check In Edits From ArcPad** dialog should now appear. Select the edits you would like to check in form **ArcPad** and select **Check in**.



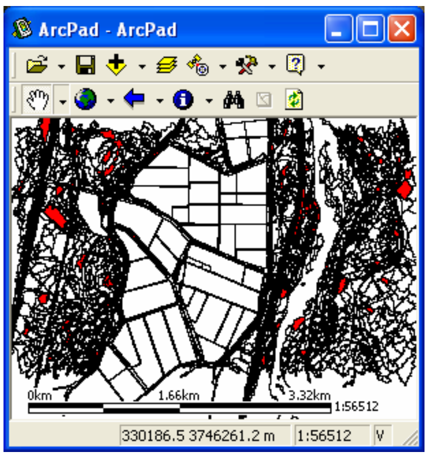
7. After the check in, edits made in the field should appear in your project. From the Edit Toolbar select the **Editor** button and **Save Edits** from the drop down menu that appears. The **check in checkout** process is complete.

9.3 ArcPad and the Trimble GeoXT: *Opening a vegetation mapping project for editing and activating the GPS*

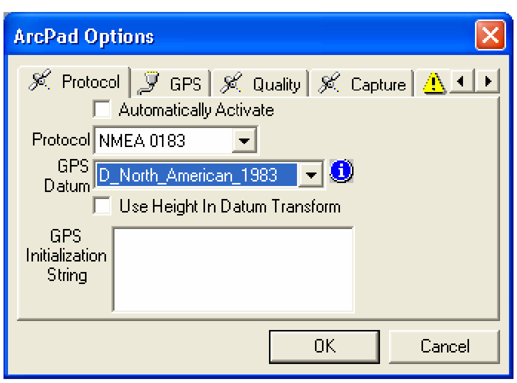
1. Tap the start button on the Trimble GeoXT and select Backup Now. This will backup all data saved to the unit.

2. Once the backup is complete launch ArcPad by selecting the **Start | ArcPad** icon  from the menu that appears.

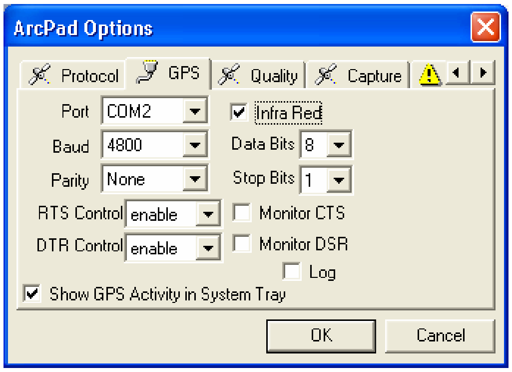
3. Open the .apm file containing the checked out data that has been transferred to the GeoXT. This can be done by selecting the **Open Map** button  form the main toolbar in ArcPad. Double tap or highlight the correct .apm file and select **OK**. The .apm file should now load.



4. Select the tools icon  from the main toolbar. This will open the **ArcPad Options** dialog. Select the Protocol tab. In the **GPS Datum** box select **D_North_American_1983** from the drop down menu.



5. Select the GPS tab. In the **Port** box select **COM2** from the dropdown menu, from the **Baud** box select **4800** from the dropdown menu and check the box next to **Infra Red**. Select **OK** once complete. These setting are now saved and should not to be reset.



6. Select the **Layers**  button from the main toolbar. This will open the **Layers** dialog. This dialog controls which layers are active for editing. Select the box in the edit column  next to the vegetation layer. Select the **Close** button in the upper right corner of the **Layers** dialog when done . The **Editing Toolbar** should now appear in our ArcPad session.

7. Before editing can begin the GPS must be turned on and activated within ArcPad. To do this select the **F1** button in the upper right corner of the screen. This will launch the GPS Controller.

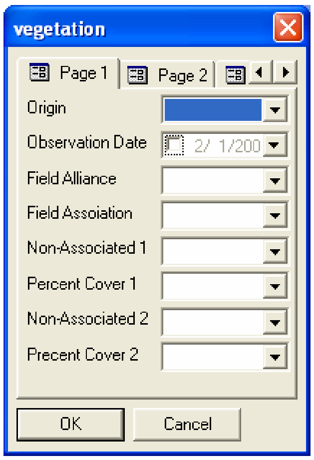
8. Once the GPS Controller is launched move to an open area to receive satellite signals. It is usually a good idea to just set the unit down on the hood or tailgate of your field vehicle for a few minutes to allow this to occur. The GPS will inform you when it has acquired enough satellites to obtain a position fix. Set the precision of the GPS signal to the desired level. Contact you regional expert if you are unsure what precision setting is appropriate.

9. Select **Start** from the upper left corner of the screen and the ArcPad icon  from the menu that appears. This will reopen ArcPad. From the **Main Toolbar**, click on the **GPS Position Window**  icon. Choose **Yes** when asked to activate your GPS. You should now see a red circle with cross hairs representing your position within the project. Data is now ready to be collected.

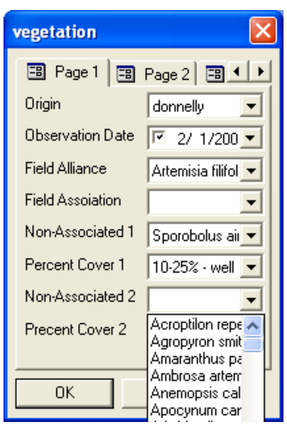
9.4 <u>ArcPad and the Trimble GeoXT</u>: *Attributing field data*

1. Open **ArcPad** on the **GeoXT** and ready the project for field data collection. Enable editing of the vegetation layer and activate the GPS. Follow **steps 1-9** in the section above if necessary.

2. Navigate to a training polygon. Transect the polygon and/or walk the perimeter to assess the obligate plant species it contains and correlate it to an existing plant alliance or association. Label the training polygon by double tapping it or selecting it and then selecting the **Proprieties** icon . Both methods will open the digital field form for the selected polygon.



3. Label the NVCS alliance and association present within the polygon and other dominate species not associated to the community description or any other variable that would affect the spectral response of the site. Use the **Non-Associated 1-5**, **Percent Cover 1-5** fields to complete these ocular estimations. Add any additional comments to the Comment field.



4. Conduct a backup of the data by selecting the **Backup Now** from the **Start** menu option as often as necessary. Every 1-2 hours is appropriate for most work. Doing so will automatically shutdown **ArcPad** and the **GPS** receiver. These functions will have to be restarted after every backup.

5. Once field data collection is complete conduct a final backup. The data can now be transferred back to the PC for **check in** to the **ArcMap** project.

9.5 Considerations for assessing vegetation communities in the field

Assessing Field Plots

It can be difficult initially to assess plant communities through ocular estimates and associate those observations to an existing schema. It is important to realize that plant communities occur on a sliding scale of dominance and edges of transition from one community to the next. The descriptions of these communities must be viewed in the same light, not absolute. When interpreting lines placed on the landscape it very important to place yourself at the scale the measurement was made, a **landscape scale**. This is the scale refuges are most often managed and the scale vegetation and habitat are inventoried. Secondly, it is important to understand the variables used to make that measurement as well as the temporal affects that may have occurred to alter its interpretation between the time the imagery was collected and the field observation was made. Spectral response is being measured. This response is correlated to all landscape features not just vegetation. What spectral response or past spectral response generated that line on the landscape is the question that must be asked. Taking these perspectives into consideration will better prepare field data collectors to interpret vegetation and habitats at the landscape scale.

With a landscape perspective must still come a basic understanding of the vegetation and ecological processes at the species level. This is critical in interpreting the landscape correctly and efficiently. Time must be taken to calibrate field data collectors with technology as well as the biology and ecology of the local area.

Much of the efficiency and comfort with the approach outlined in Chapter 9 comes with experience. Users new to this approach should contact others more experienced with these methods when questions arise. Field work is most often the most costly input to vegetation and habitat inventory projects. Completing field work correctly and as efficiently as possible can be important to the success of the project.

Field Equipment

Proper field equipment can greatly decrease the amount of time spent in the field. The greatest amount of time spent in the field is traveling from one plot to the next. Vehicular transportation should be used in areas where it is possible. The most common vehicles used are ATVs. They allow a field technician to move directly from one site to the next with all the field equipment necessary to collect data. Trimble GeoXT mounts should be used when operating ATVs (**Figure 9.5.1**). This allows a rider to keep both hands on the handlebars. In this position the GeoXT can be used as a navigation devise to guide a technician to the next plot. Storage boxes also allow plant presses and data collection tools to be transported easily.

Figure 9.5.1. ATV GeoXT Mount

Field technicians should also have access to communication equipment while collecting field data. Foremost, communication is a safety issue and second, the ability to communicate and answer questions while collecting data can eliminate errors and promote data consistency.

Planning
Before field data collection is attempted a plan should be developed. The plan should be developed by the crew chief or project manager. It should begin to address the following issues:

1. **Access to field data plots** – Any access restrictions due the physical environment, land designation, land management or public use restrictions should be known. The general locations, boundaries and timing of these restrictions should be included in field data collection map.

2. **Roads, trails, rivers, canals, bridges** – All transportation corridors or impedances to transportation should be known or included in the field data collection map. Knowing this can greatly reduce time moving to and from field sites and assist in the planning of field data collection.

3. **Transportation** – Arrange access to the appropriate field vehicles; truck, AVT, airboat, helicopter. Note the increased cost and planning when using aircraft or airboats for field data collection.

4. **Fuel** – Arrange access to fuel for field vehicles with the refuge.

5. **Fix a Flat** – Each field technician should have a can of Fix a Flat and tire repair kits when using ATVs. This will greatly reduce the amount of time lost to flat tires.

6. **Keys** – Obtain keys for field crew to access locked gates and restricted areas.

7. **Laptops, GeoXTs and radios** – All laptops GeoXTs and radios should be integrated, tested, fully charged and functional prior to the start of field work.

8. **Backup equipment** – Bring or ensure access to backup equipment such as laptops, GeoXTs, radios and **Trimble pens**.

9. **Data** – Data should be completely processed and prepared for field data collection with multiple copies on different media available.

10. **Data backup** – Plan for daily data backups on external storage devices or media.

11. **Workflow plan** – A plan should be established to designate responsibilities and procedures for data check in, data, checkout and data backup.

12. **Working area** – Arrange for office space to setup field equipment; laptop computers, GPS chargers, radio chargers, etc…

13. **Housing** – Arrange for refuge housing if available and required. Staying on site will increase the amount of time spent in the field collecting data and allow access to field equipment in the evenings to complete data reviews and maintain field equipment.

14. **Comp time** – Arrange with supervisor in advance for comp time. Work hours should be maximized while collecting data and are often required to complete field work.

10.1 <u>Selecting Accuracy Assessment Polygons from Field Data:</u> ***Stratified random selection of accuracy assessment sites (polygons) for vegetation classification using ArcInfo 9.X and Hawthorn's Tools***

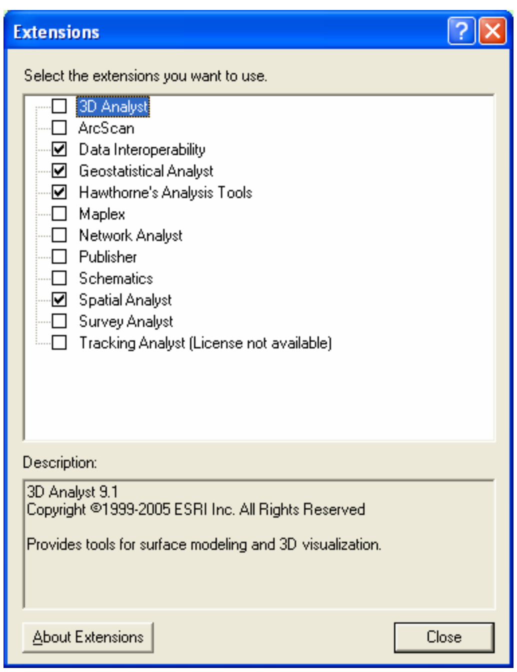
During the sample design process of a project (outlined in **Chapter 8.1** of this document) the number of samples chosen for field data collection accounts for training and accuracy assessment data. To reduce bias while collecting data in the field, sites are not designated for training or accuracy assessment until the field data collection process is complete. This process also eliminates the need to return to the field to collect additional field data to measure data accuracy requirements.

The random selection of accuracy assessment polygons from the field data is an important step which must be taken prior the image classification process. Failure to complete this step before image classification procedures are conducted will invalidate data accuracy measurements and require additional field work to collect accuracy assessment sites (polygons).

Accuracy assessment sites are chosen using a stratified random process. The strata used for this process are the NVCS alliances or association classes identified on the NWR during field data collection. Of the alliance or association data collected in the field 30% of each class must be selected randomly for use in accuracy assessment or ***(total number of training site polygons classified as Populus deltoides Forest Alliance x .30) = number of Populus deltoides training polygons designated as accuracy assessment polygons when Populus deltoides Forest Alliance is the defined strata***.

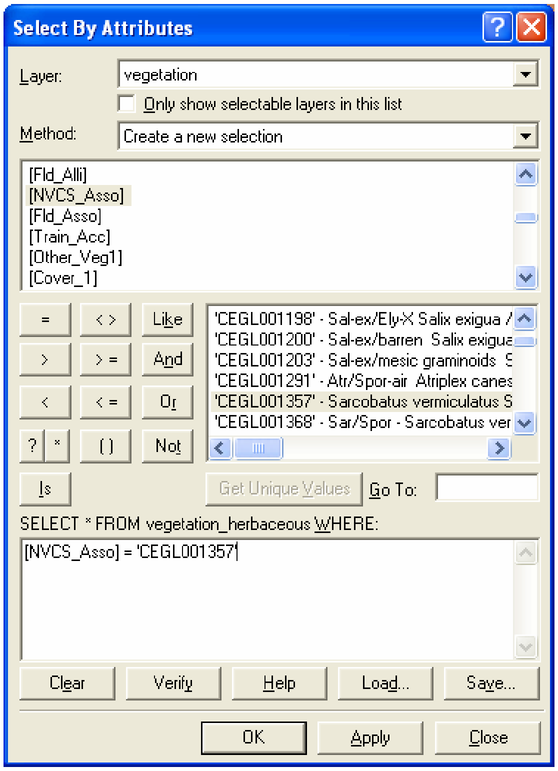
Note that prior to this process all data collected in the field should be reviewed for quality control.

1. To begin, a copy of the vegetation feature class should be opened in **ArcMap**. If the **Hawthorne's Analysis** tool bar is not already active select **Tools | Extensions** from the main tool bar. Check the box next to **Hawthorne's Analysis Tools**.



2. Select **View | Tool Bars** and check the box next to **Hawth's Tools**. This should open and activate the **Analysis Tools** toolbar.

3. To randomly select field data collection sites each **NVCS alliance or association** must be subset and saved as a shapefile. This is a cumbersome step. At this point there has not been a tool developed to generate a random selection from a select set of features. To work around this issue each NVCS alliance or association must be saved as a shapefile (Hawth's Tools only works in shapefiles). Select **Selection | Select By Attributes**. This will open the **Select By Attribute** dialog. Type or select **NVCS_Alli or NVCS_Asso = name of alliance or association.** in the **Select From** window. Select **Apply**. All the polygons classified as that alliance or association should now be highlighted.



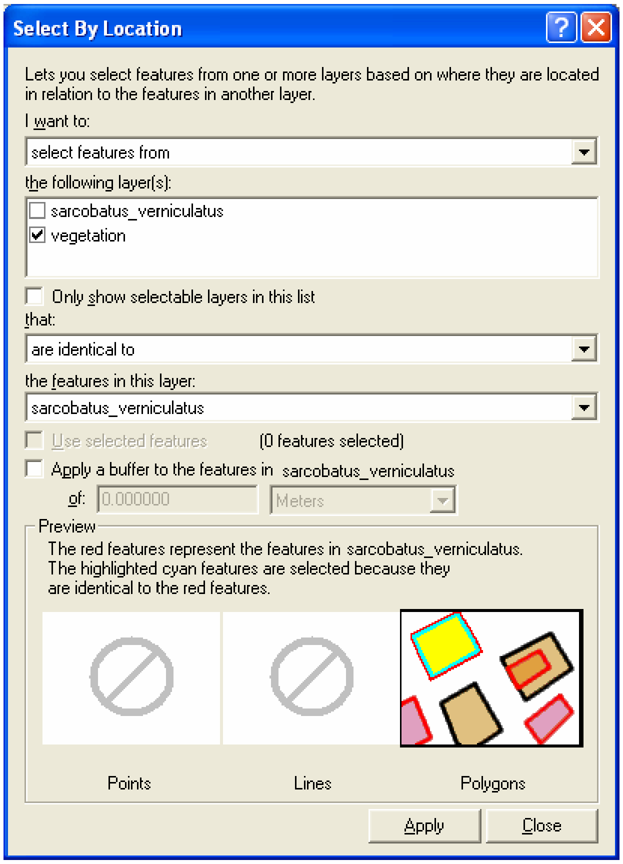
4. Right click on the vegetation feature class and select **Data | Export Data**. This will open the **Export Data** dialog. In the **Export** box select Selected features. Use the same coordinate system as the layers source data. Name the file using the following naming convention:

   Example: sarcobatus_vermiculatus.shp

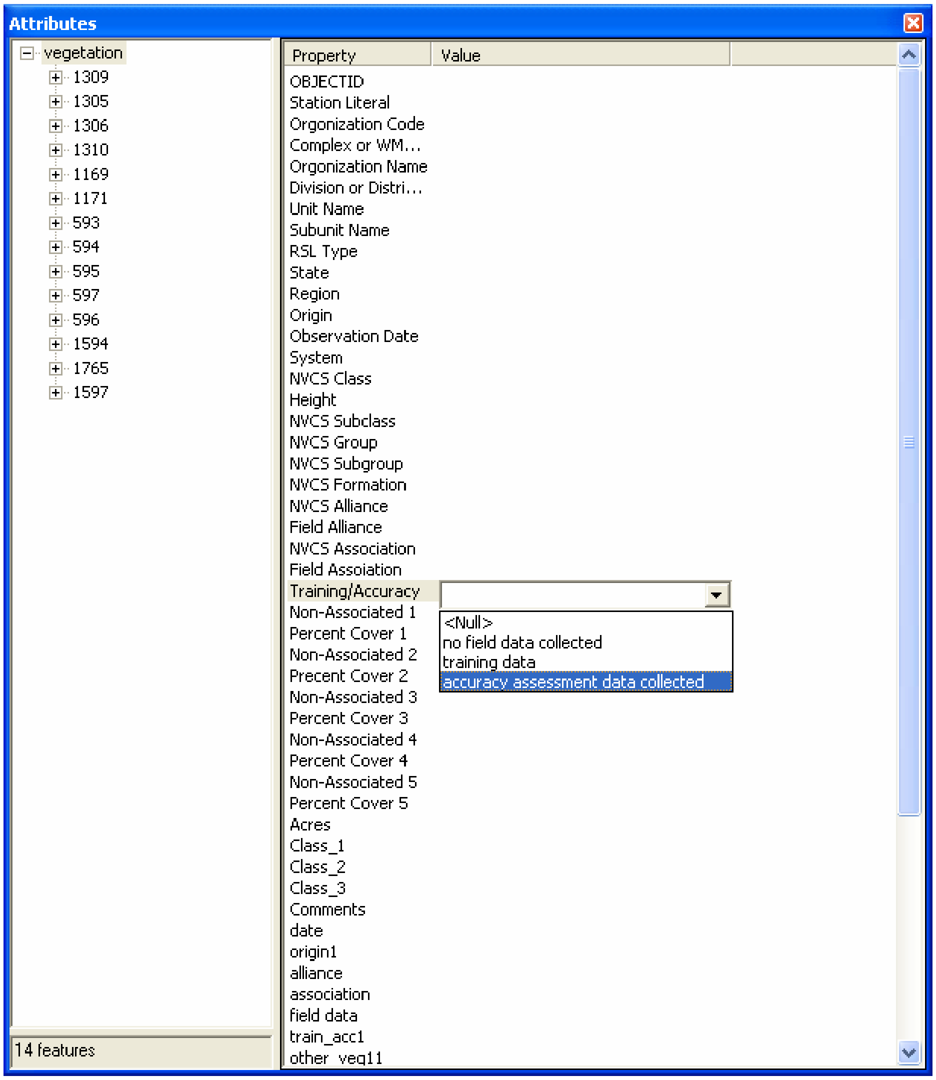
   Select **OK** and add shapefile to **ArcMap** session.

5. Select **Analysis Tools | Create Random Selection** from **Hawth's Tools** toolbar. This opens the **Random Selection** dialog. In the **Layers to select features** in box select **sarcobatus_vermiculatus**. Select the **this percentage of features** button and type **30** in the box to the right. Select OK. Now a 30% random selection of the *Sarcobatus vermiculatus* shrubland association should be highlighted.

6. With the randomly selected polygons still highlighted, select **Selection | Select By Location**. This will open the **Select By Location** dialog. In the dialog **select features from** the **vegetation** feature class that are identical to the **features in sarcobatus_vermiculatus layer**. Check the box **Use selected features**. Select **Apply** and **Close**. The highlighted polygons should not have changed.



7. Select **Editor | Start Editing**. Select source as the **Landcover and Habitat.mdb** and select **OK**. The **Target box** on the **Editor** toolbar should now say **vegetation**. Select the **Attributes** icon  form the **Editor** toolbar. This will open the **Attribute** editing dialog. In the feature selection window highlight vegetation at the top of the column. This allows any changes in attributes to be applied to all features selected at once. Click to the right of the **Training/Accuracy** field. A dropdown should appear. Select **accuracy assessment data**. This will populate all the selected polygons stratified by herbaceous with an **accuracy assessment data** designation. These stratified randomly selected polygons will be used to collect field data and generate spectral signatures to run the classification model.



8. Repeat **steps 1-7** for all NVCS alliance or association communities present on refuge.

This section will discuss methods to support a supervised classification. In the following chapters most classification procedures will be run independently within the NVCS Class or ecotype classifications that came out of eCognition in Chapter 7.3. This is done to simplify the possibility of spectral confusion and maximize the possibility of spectral separation among training signatures. The additional steps required in this approach have, through observation and simple testing, improved classification accuracy results markedly when classifying at the floristic level.

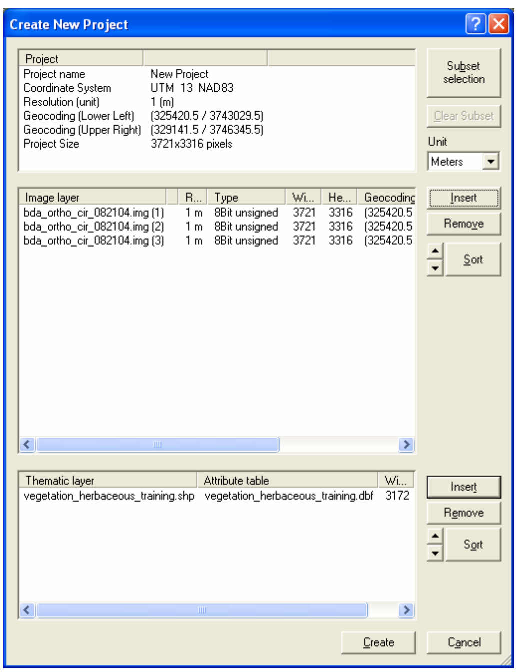
11.1 Generating Sub-Polygons for Signature Extraction: *Utilizing eCognition 4.X to generate training sub-polygons for signature generation*

In this section, training data polygons containing field data will be segmented into sub-polygons using eCognition. The resulting segmentation will convert image objects to polygons and export them as a shapefile to be attributed and applied to a supervised classifier.

1. Before sub-polygons can be generated, training polygons populated from the field data collection process must be subset from the vegetation feature class. There are a number of ways to complete this task in ArcMap. At this point users should be aware of these procedures. The resulting subset must be exported as a shapefile to be utilized in eCognition. It is suggested that the following naming convention be used for subsets:

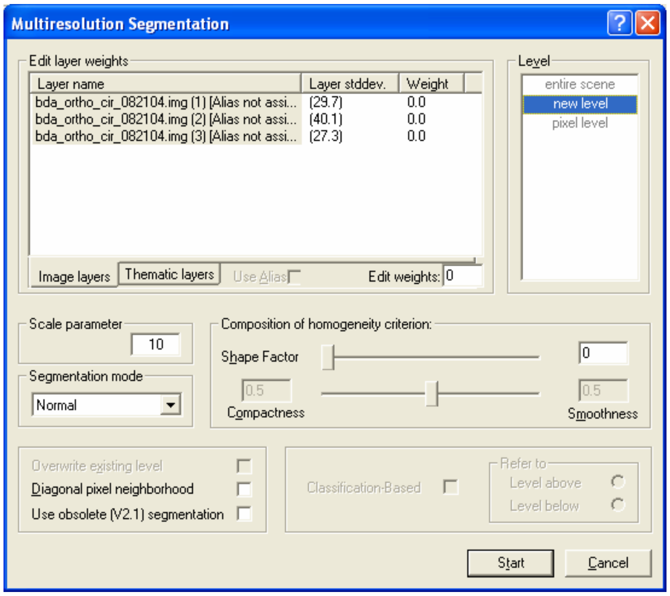
   Example: vegetation_training

2. Begin a session of **eCognition**. Start a project by selecting the **Create New Project** icon. Add the imagery used in the segmentation procedures (of your project) discussed in **Chapter 7.3** of this document. In the **Thematic layer** window add the subset of training polygons discussed above. Select **Create** once complete and save the project.

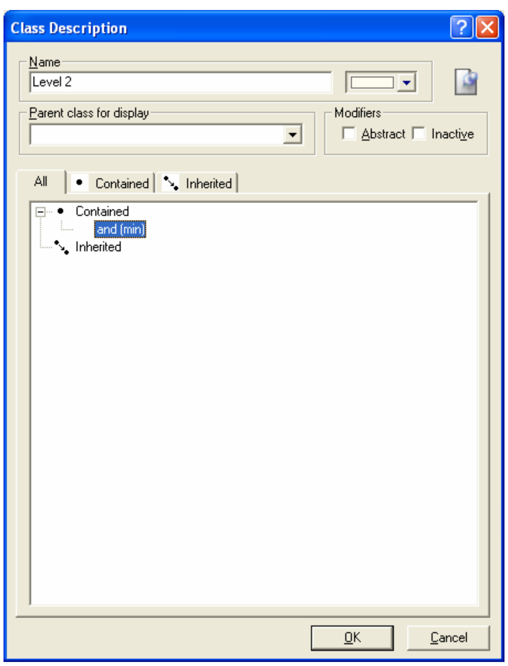


3. Select the **Multiresolution Segmentation** icon. In the **Multiresolution dialog** that appears turn the weights of the image bands to **0**. Select the **Thematic layers tab** and be sure the

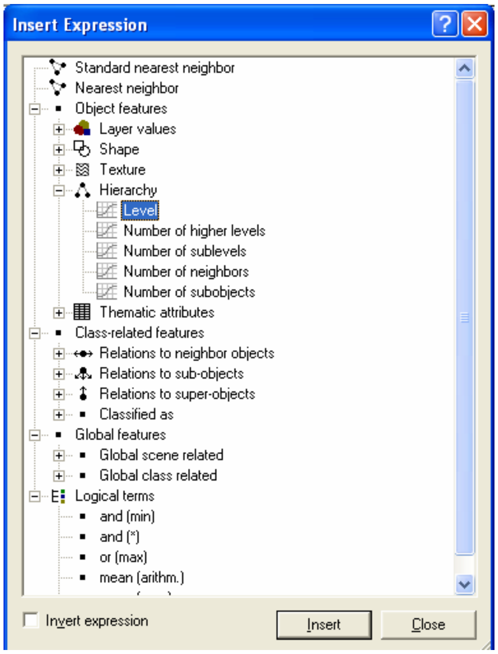
thematic layer is set to **used**. Set the **Shape Factor** to **0** and select **Start**.



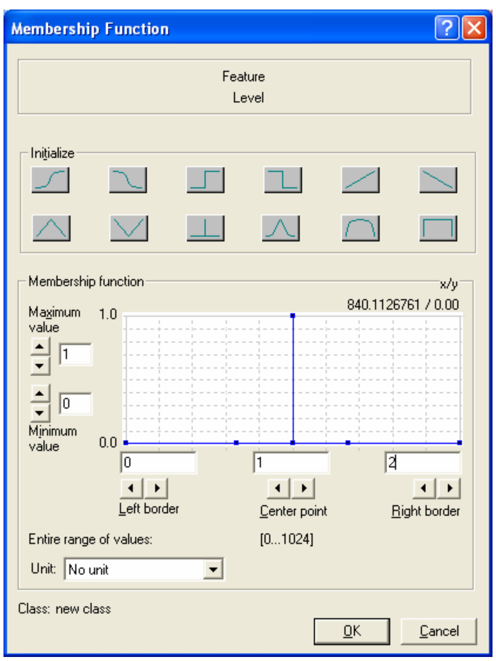
4. Completed, the segmentation should only show the outlines of the training polygons. These areas must now be classified as training sites so that they can be segmented at finer scale. Begin by selecting **Classification | Class Hierarchy** to opening the **Class Hierarchy** dialog. Within the **Inheritance** tab right click and select **Insert Class**. This opens the **Class Description** dialog. Under name type **Level 2**. Make the color of the class white.



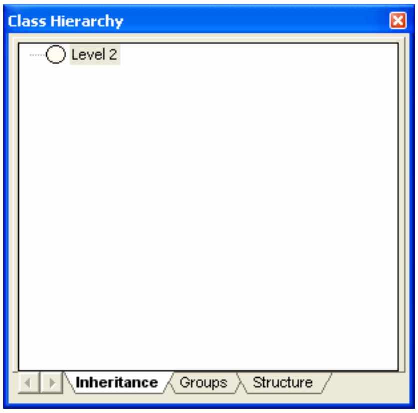
Double click **and(min)**. In the **Insert Expression** dialog that appears expand the tree under **Hierarchy** and double click **Level**.



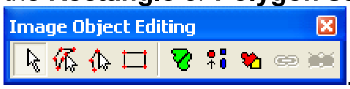
In the **Membership Function** dialog that appears use the singleton function and set the left boarder to **0** and the right border to **2**. Select **OK** when done, close the **Insert Expression** dialog and select **OK** in the **Class Description** dialog.

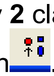


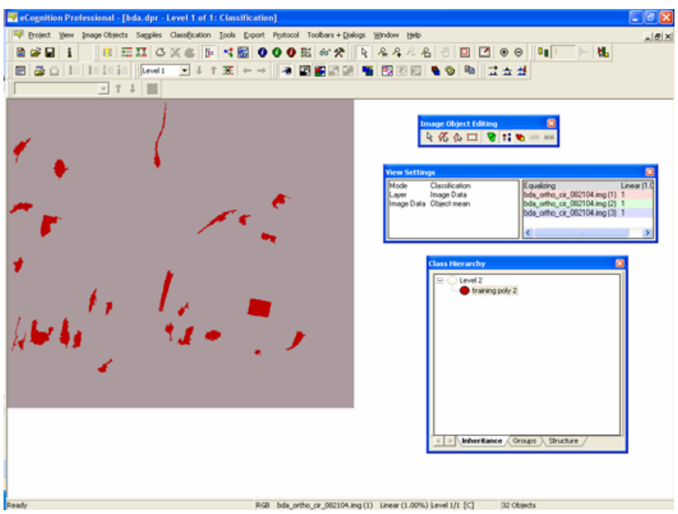
The **Class Hierarchy** dialog should now look like this.



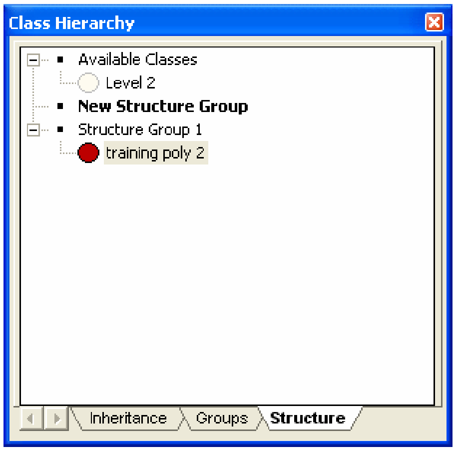
5. Add a second class to the **Class Hierarchy** dialog named **training poly 2** and make its color red and a child class of **Level 2**. This class will be used to classify the segmented training polygons. This can be done a number of ways. The easiest is to mass select all the training polygons using the **Rectangle** or **Polygon selection** tool found on the **Image Object Editing** toolbar,



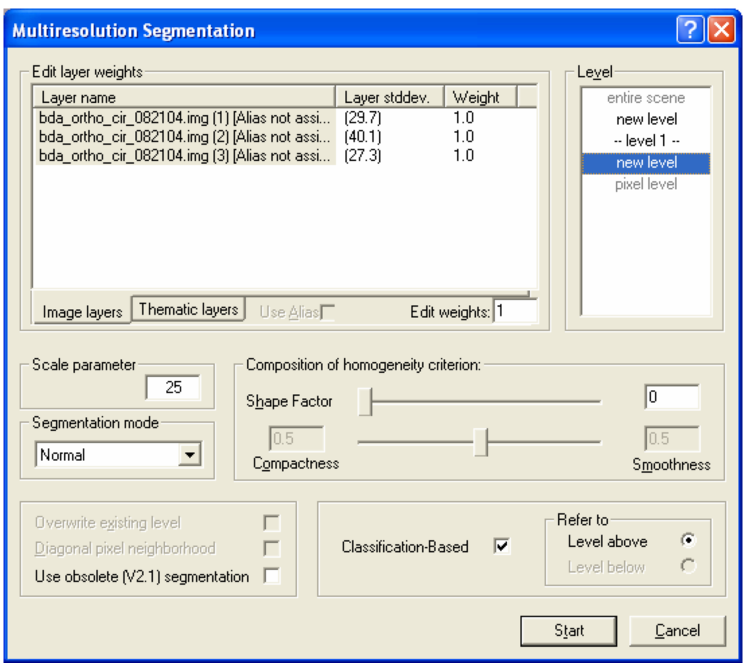
. Use this tool to select all the training polygons. Unselect the bounding polygon if selected during this process. Once selected used the use the **Manual Image Object Classification** tool from the **Image Object Editing** toolbar to classify the polygons. To do this highlight the **training poly 2** class in the **Class Hierarchy** dialog and select the **Manual Image Object Classification** icon . All the training polygons should now be red.

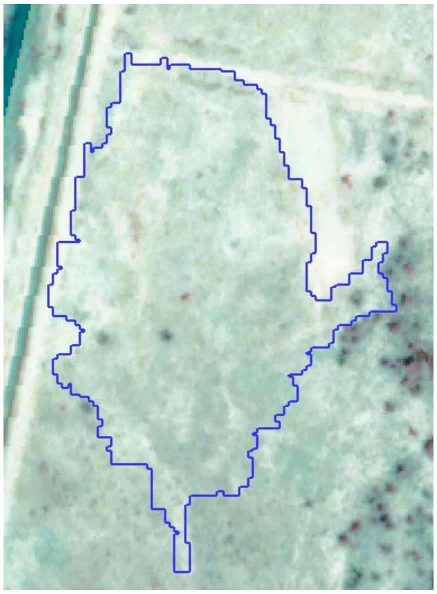


6. In the **Class Hierarchy** dialog select the **Structure** tab. In the **Structure** tab window select and drag **training poly 2** over **New Structure Group**.

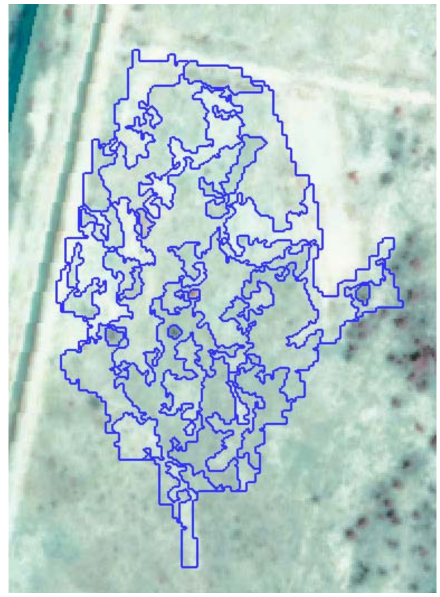


7. Open the **Multiresolution Segmentation** dialog. Change the edit weights of the imagery back to 1. In the **Level** window select **new level** below **– level 1-**. The **Classification-Based** button should now be activated. Select it. Keep the **Shape factor** set to **0**. The settings of the **Scale parameter** will vary relative to spectral diversity found on the projects imagery. For 1 meter (GSD) digital CIR imagery a scale factor between 20 and 30 was found to be most appropriate. Once all settings have been made, select the **Start** button and let the segmentation run. The resulting segmentation should have only segmented within the training polygons. The results should be reviewed to ensure the correct level of detail was achieved. The segmentation can be overwritten using new parameters if necessary.



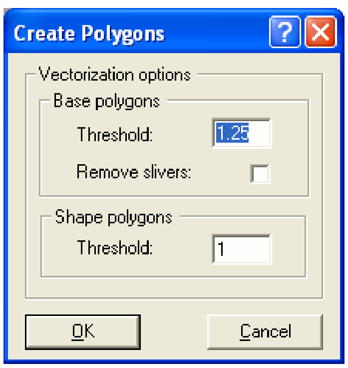


Training Polygon

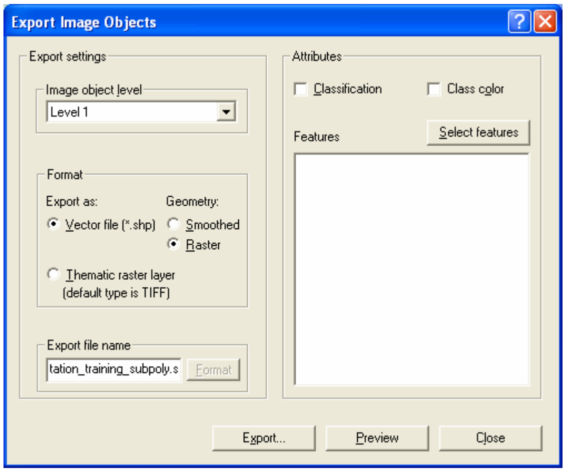


Training Sub-Polygons

8. Select the **Create/Modify polygon** icon . This will open the **Create Polygon** dialog. Accept the defaults and click **OK**.



9. Select **Export | Image Objects** from the main menu. Under **Export settings** set Image object level to **Level 1**, set **Format to Vector file (*.shp)**, set **Geometry** as **Raster** and unselect **Classification** and **Class Color**. Change the **Export file** name to **vegetation_training_subpoly.shp**. Select **Export**. Select a folder for the data to be saved in and select **OK**.

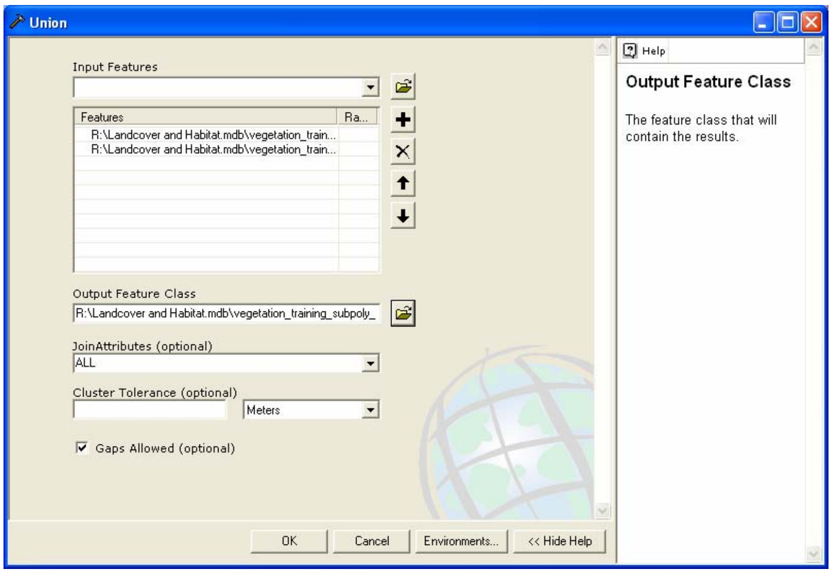


10. Start an **ArcCatalog** session and navigate to the **vegetation_training_subpoly.shp**. Open the **Shapefile Proprieties** dialog and set the correct projection information for **vegetation_training_subpoly.shp**. Import the shapefile into the **Landcover and Habitat GDB**. If a bounding polygon exists it should be deleted in an Edit session in ArcMap.

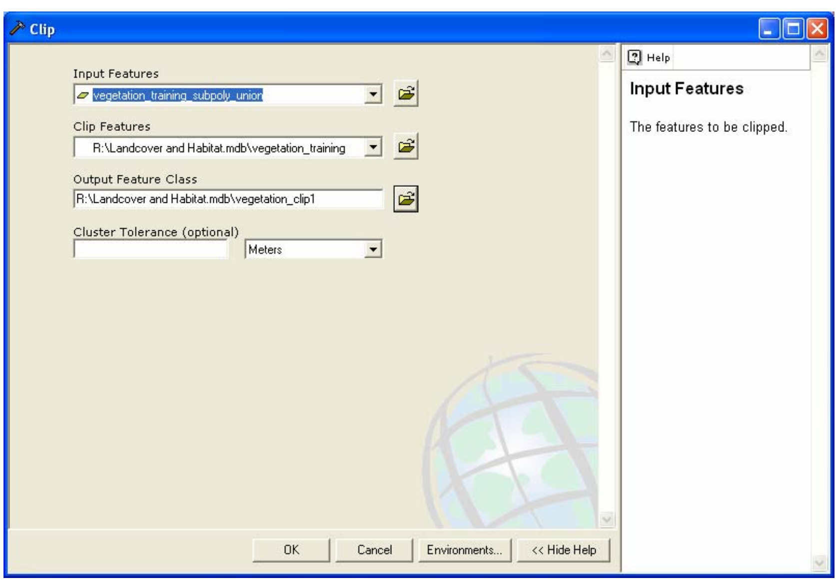
11.2 <u>Attributing Sub-Polygons:</u> *Utilizing ArcMap to attribute and stratify sub-polygons*

In this section, field data from original training polygons will be unioned with sub-polygons and assigned a unique identifier linking them together.

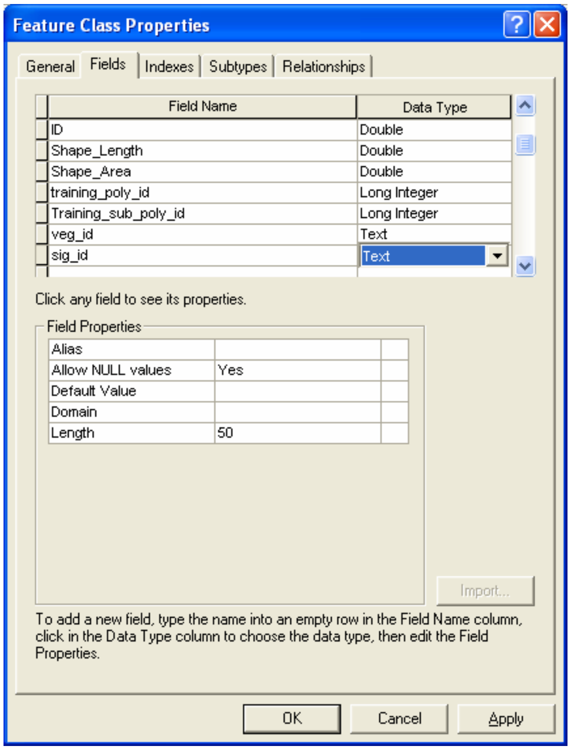
1. From **ArcCatalog** or **ArcMap** launch **ArcToolbox**. Open the **Union** tool from **ArcToolbox**. **Input Features vegetation_training** and **vegetation_training_subpoly**. Make the **Output Feature Class vegetation_training_subpoly_union** and save it to the **Landcover and Habitat GDB**. Select **OK**.



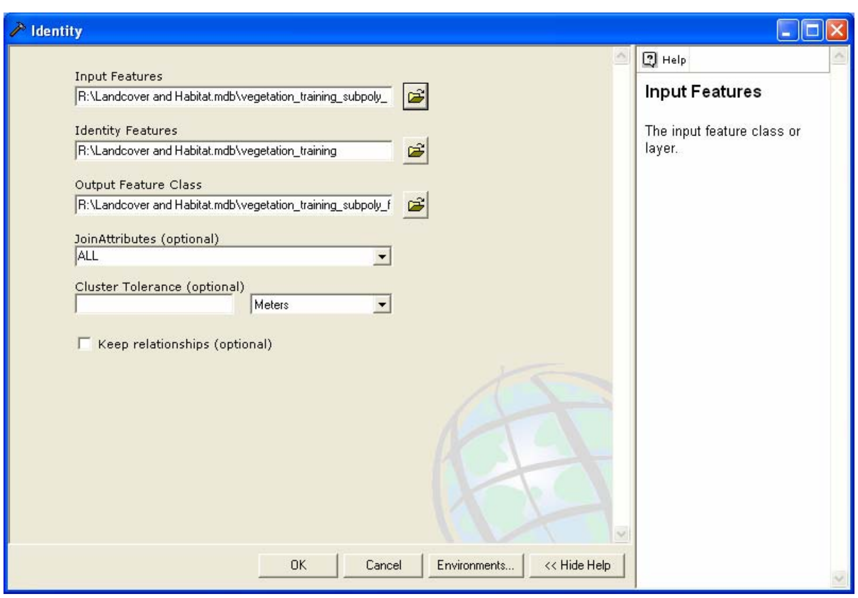
2. Open the **Clip** tool from **ArcToolbox**. Clip the **vegetation_training_subpoly_union** feature class with the **vegetation_training** and **vegetation_training_subpoly** feature class. This will remove any slivers and holes in the data caused as a result of the union. Name the resulting file **vegetation_training_subpoly_clip**.



3. Open an **ArcCatalog** session. Right click on the **vegetation_training_subpoly_clip** feature class and open the **Feature Class Properties** dialog. Select the **Fields** tab. Delete all removable fields from the feature class. Add the following fields; **training_poly_id**, **training_sub_poly_id**, **veg_id** and **sig_id**. Make the **Data Type** for **training_poly_id** and **training_sub_poly_id Long Integer**. Make the **Data Type** for **veg_id** and **sig_id Text Length 50**. Select **OK**.

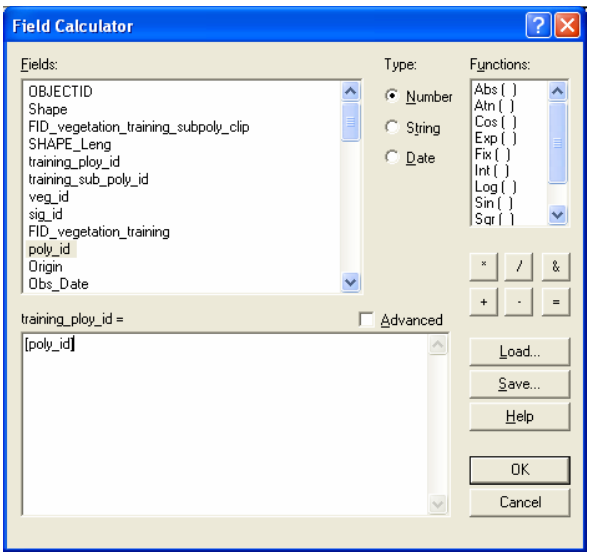


4. Open the **Identity** tool from **ArcToolbox**. Use the **vegetation_training_subpoly_clip** as the **Input Feature** and the **vegetation_training** as the **Identity Feature**. Name the output feature class **vegetation_training_subpoly_final**.

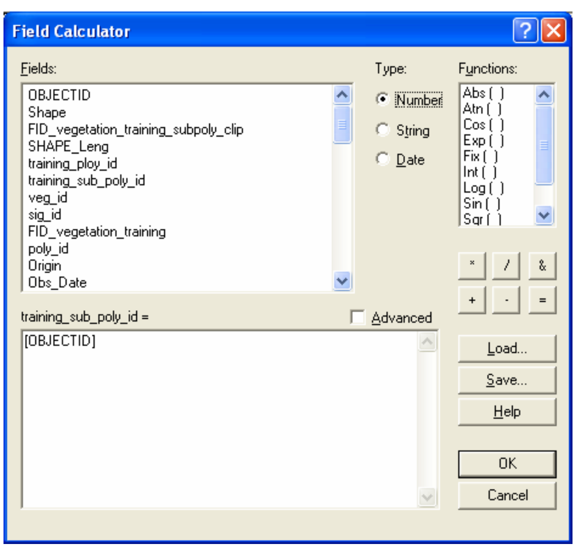


5. At this point any polygons falling below a minimum area requirement for use in image classification can be removed from the sub-polygon the training set. This can be done by starting an edit session and by selecting polygons using **Select By Attribute**. A minimum area is usually calculated by multiplying the pixel size of the base imagery by 10. This may not always be appropriate given the spectral diversity of the vegetation or habitat being mapped. These data may also be removed at a later point in the signature generation process in **ERDAS**.

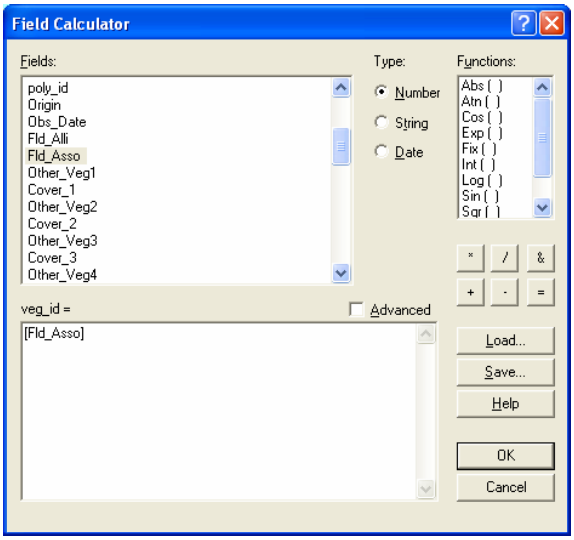
6. To calculate the **training_poly_id**, **training_sub_poly_id**, **veg_id** and **sig_id** in the **vegetation_training_subpoly_final** feature class, have the feature class open in an **ArcMap** session. Right click on the feature class and select the **Open Attribute Table** icon. Right click the column heading for **training_poly_id** and select **Calculate Values**. The **Field Calculator** dialog should now appear. Click in the box under **training_poly_id=** and select **polygon_id**. This is the unique identifier from the original vegetation feature class. Select **OK**.



Right click the column heading for **training_sub_poly_id** and select **Calculate Values**. The **Field Calculator** dialog should now appear. Click in the box under **training_sub_poly_id=** and select **OBJECTID**. This will be the unique identifier for the vegetation sub-polygons. Select **OK**.



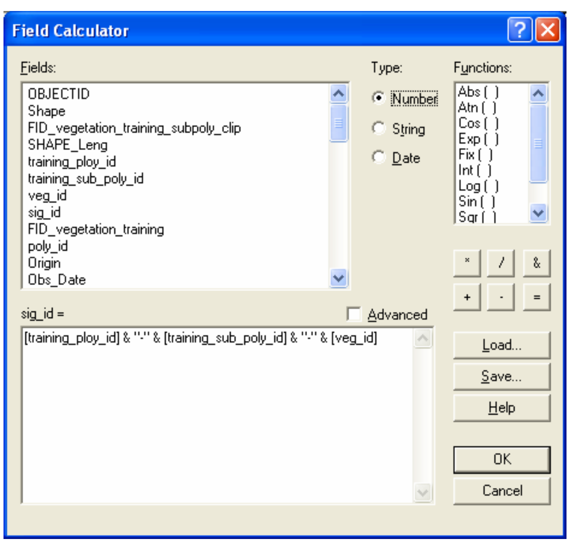
Right click the column heading for **veg_id** and select **Calculate Values**. The **Field Calculator** dialog should now appear. Click in the box under **veg_id=** and select **Fld_Asso** or **Fld_Alli**. This will be the unique identifier for the vegetation sub-polygons alliance or association type. Select **OK**. Be sure the alliance or association domain is associated to the field.



Right click the column heading for **sig_id** and select **Calculate Values**. The **Field Calculator** dialog should now appear. Click in the box under **sig_id= [training_ploy_id] & "-" & [training_sub_poly_id] & "-" & [veg_id]**. This will be the unique identifier for signatures used in the classification. Select **OK**. The items in the **sig_id** column should now appear similar to this:

Example: 231-3476-CEGL00191

The unique identifier for the signature can be interpreted from right to left as *Sporobolus airoides* monotypic herbaceous association, from training sub polygon 3476, from training polygon 231.



7. Use the aggregated **NVCS Class** level polygons; forest, woodland, shrubland, herbaceous or **ecological units**; riparian, upland, floodplain ect… to subset the **vegetation_training_subpoly_final** feature class. Export the subset versions by **NVCS Class** or **ecotype** to shapefiles. Individual signature sets will be derived for each subset and applied as individual classifications in **ERDAS Imagine**.

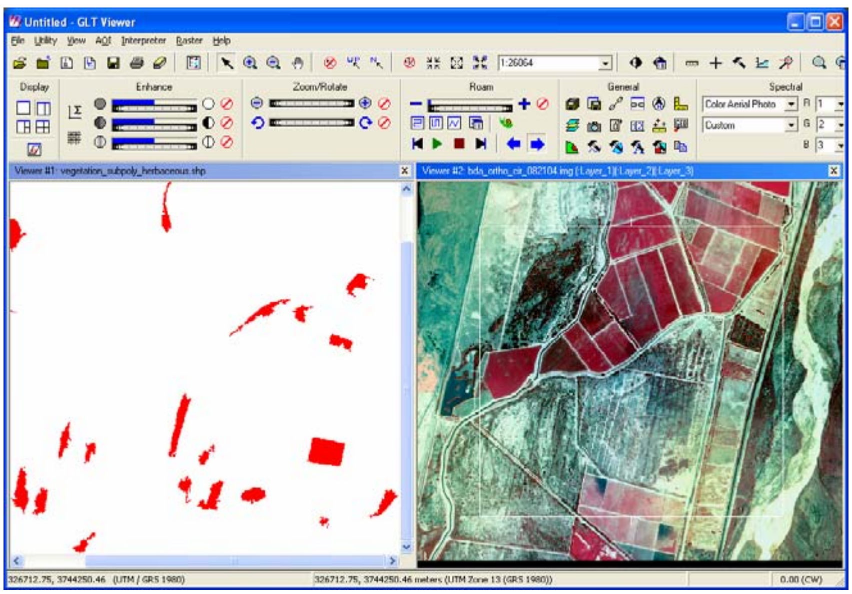
11.3 <u>Generating Training Signatures:</u> ***Utilizing ERDAS Imagine 8.X to generate training signature sets for supervised image classification***

In this section the shapefile subsets of the vegetation_training_subpoly_final will be used to generate signature sets for supervised image classification.

1. Start a session of **ERDAS Imagine** and open 2 viewers. In the left viewer open the shapefile containing the segments of the physiognomic type you will classify. In the right viewer open the imagery you will use to generate the classification. This should be the same imagery used since the beginning of the project. If any indices are to be used within the classification model these layers should be stacked within the imagery used to extract the signature set.

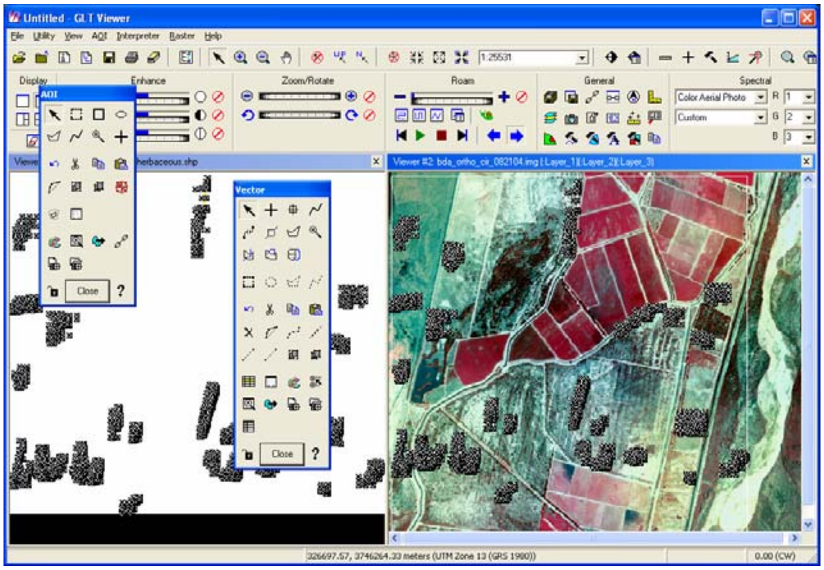
2. Link the 2 viewers geographically. To do this select highlight the left viewer and from the main viewer menu select **View | Link/Unlink Viewers | Geographically.** Click anywhere in the right viewer to complete the link.

3. Change the viewing properties of the shapefile polygons to solid red. This is a user preference and not required. To do this from the viewer menu select **Vector | Viewing Properties**. Change the polygon color in **Viewing Properties** dialog that opens.

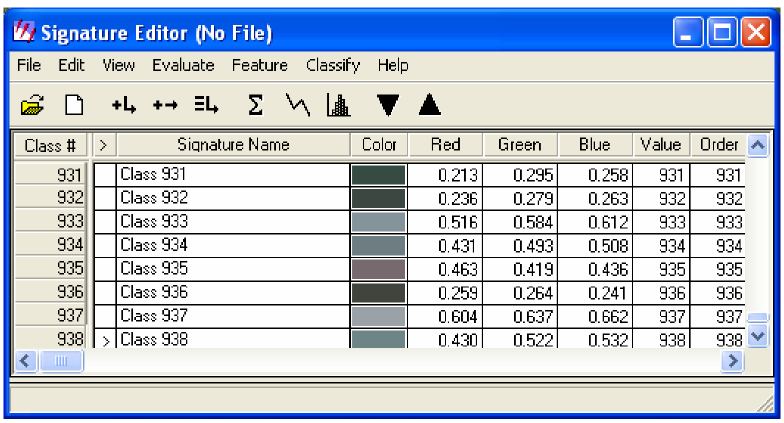


4. Select up 2000 polygons from the left viewer. This can be done through the select features with a rectangle or polygon tools. These tools can be found on the viewer menu under Vector | Tools. Selections can also be made through the Vector Attribute Table and Selection Criteria dialog. The selection Criteria dialog can be open by right clicking in the Record column of the Vector Attribute Table. It is possible to select more than 2000 records at a time, however when generating signatures from the selected polygons it may cause the system to crash. Other systems may be able to handle a larger or lesser amount of polygons during signature generation.

5. Highlight the viewer containing the imagery (right viewer). From the main viewer menu select **AOI | Copy Selection To AOI.** The AOI's should now be visible on the imagery in the right viewer. Next open the **AOI Tools** by selecting from the main view menu **AOI | Tools.** Use the **Box Select AOI** tool to select all the AOI's on the image.



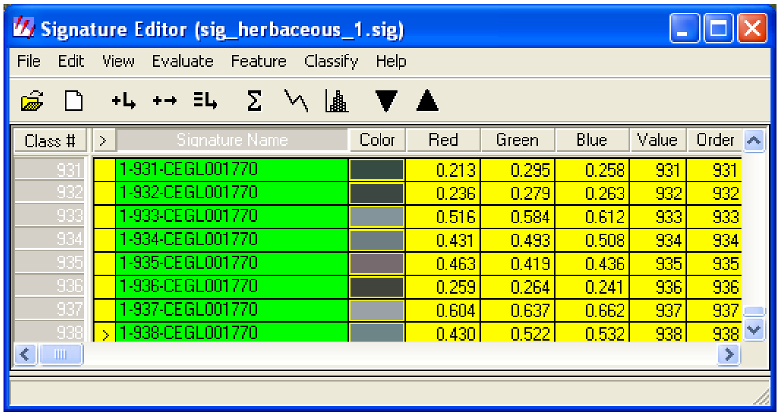
6. From the main menu select **Classifier | Signature Editor**. This will open the **Signature Editor** dialog. Select the **Create New Signature from AOI** icon from the **Signature Editor** menu.



7. Open the **Vector Attribute** table and select the **sig_id** column. Do not unselect the records currently selected. From the **sig_id** column heading right click and select **Copy**. In the **Signature Editor** right click in the **Class #** column and select, **Select All**. Right select the **Signature Name** column and select **Paste**. **Select File | Save** from the **Signature Editor**. Save the file using the following naming convention:

   Example: sig_herbaceous_1

   Once all the signatures are generated for a **NVCS Class** or **ecotype** they should be appended using the **Signature Editor**. As an example **sig_herbaceous_1**, **sig_herbaceous_2 and sig_herbaceous_3** should be merged to a single file **sig_herbaceous.**



8. From the **Signature Editor** select **View | Columns**. This will open the **View Signature Column** dialog. From **the View Signature Column** select the **Statistics button**. This opens the **Column Statistics** dialog. Check the **Std. Dev.** (standard deviation) button. This will add a standard deviation correlated to spectral diversity by imagery data layer within each sub-polygon a signature was collected within.

9. From the signature editor right click in the **Class #** column and select **Criteria**. This opens the **Selection Criteria** dialog. This dialog will be used to select those signatures that have a **pixel count ≥ 10** and a standard deviation less than a value acceptable for the spectral diversity found within the plant communities being mapped. For this example a standard deviation of ≤ 10 across all layers will be used to subset signatures. To do this enter the following in the Criteria: window; **$"Count" >= 10 and $"Std. Dev.(Layer_1)" <= 10 and $"Std. Dev.(Layer_2)" <= 10 and $"Std. Dev.(Layer_3)" <= 10**. Click Select. All the signatures that fall within the determined criteria should now be highlighted in yellow. Right click in the Class # column and select Invert Selection. All the signatures that were yellow should now be white. Right click in the Class # column again and select Delete Selection. Save the signature set.

Standard Deviation Considerations

The level of standard deviation found acceptable within signature sets will vary depending on the spectral diversity present within the plant communities and landcover types being mapped as well as the spatial and spectral resolution of the imagery used. Take time to examine the data and discuss with others that have completed similar projects for guidance. For this example herbaceous communities are used which tend to have a lower spectral diversity than some shrubland, woodland and forest communities.

10. Repeat steps 1-9 for all signature sets that are over 2000 signatures with **NVCS Class** or **ecotype** groups. Append subsets of signatures within each **NVCS Class** or **ecotype** group to a single signature set. Append signatures sets by selecting the **Append** button from the **Load Signature File** dialog. Once complete select Edit | Image Association from the Signature Editor and select the image used in the signature generation as the associated image for the signature files.

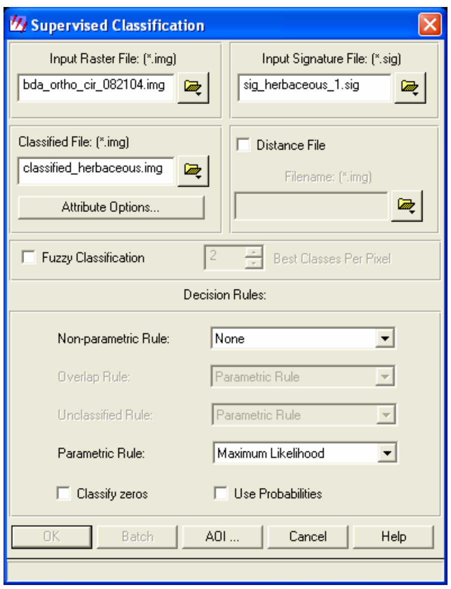
11.4 <u>Maximum Likelihood Image Classification:</u> ***Utilizing ERDAS Imagine 8.X to complete supervised maximum likelihood classification***

This section will discuss the application of supervised classification in ERDAS Imagine. A separate classification will be produced for each NVCS Class or ecotype identified on the refuge. This is done to simplify the possibility of spectral confusion and maximize the possibility of spectral separation among training signatures.

It is important to note that a number of variables beyond the basic function of the software will not be discussed due the variability in project specific inputs that may be required. It will be up to the users of this manual to explore additional variables and inputs that may increase the accuracy of the data produced.

1. Start an **ERDAS Imagine** session. From the main menu select **Classifier | Supervised Classification**. Input the imagery and signature file into the **Input Raster File** and **Input Signature File** boxes. Set the **Parametric Rule** to **Maximum Likelihood**. If probabilities have been applied check the **Use Probabilities** box. If a fuzzy classification output is to be used check the **Fuzzy Classification** box. Apply non-parametric rules as applicable. Name the classified file as follows:

   Example: classified_herbaceous.img

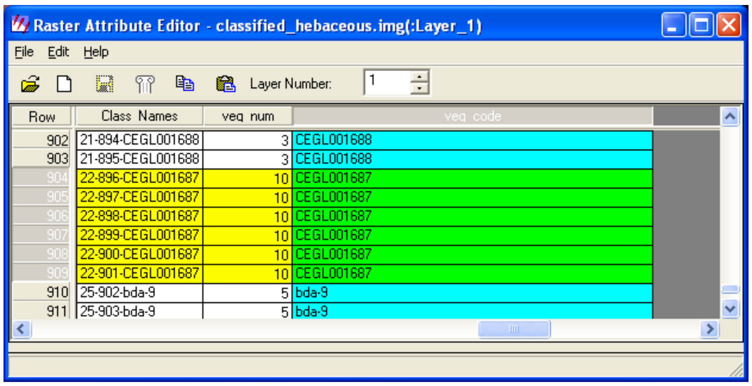


2. Open the resulting classification in ERDAS. From the main viewer select **Raster | Attributes**. This opens the **Raster Attribute Editor**. Add the fields to the raster attribute table; **veg_num** and **veg_code**. Open the **Column Properties** from the **Raster Attribute Editor** under **Edit | Column Properties**. Select the **New** button, change the **Title** to **veg_num**. Set the **Type** to **Integer** and **Display Width** to **6**. Add **veg_code** as a new column. Set the **Type** to **String** and the **Display Width** to **25**.

3. In the **Raster Attribute Editor,** calculate the **veg_code** column from the **Class Name** column in the attribute table. The class name is the unique identifier given to each signature or sub-polygon demonstrated in **Chapter 11.2** of this document. The **veg_code** is represented by the text string following the second '**-**' in the **Class Name** column:

   Example: 235-56432-**CEGL001291** ←
   Calculating the **veg_code** can be done using the **Selection Criteria** dialog. Right click the **Row**

column and select **Criteria**. This opens the **Selection Criteria** dialog. In the Criteria window, select or type **$"Class_Names" contains "*enter veg code*" and $"veg_num" == 0**. Once selected review the selection to ensure that only the records intended to be selected are actually selected. Highlight the column heading for **veg_code** and right click. Select **Formula**. This will open the **Formula** dialog. In the **Formula** window enter alliance or association code in double quotes; “CEGL001291”, and select **Apply**. All selected records in the **veg_code** column should now have been populated with CEGL001291. With the same records selected, calculate the **veg_num** column to 1. Repeat this process until all alliance and association codes have been calculated. Calculate a different value for each code in the **veg_num** column, consecutively **1,2,3,4**... Save attribute edits once complete.

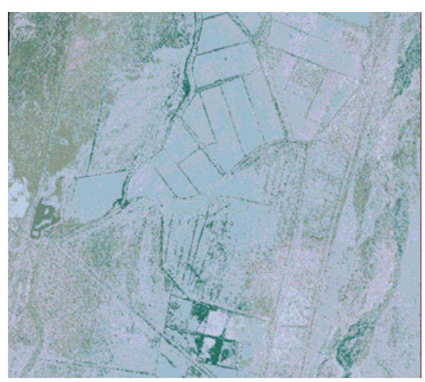


4. Save a copy of the classified image containing the attribute edits. Rename using the following naming convention:

Example: classified_herbaceous_rc.img

5. Open the **classified_******_rc.img** in **EDAS Imagine**. Select **Raster | Recode** from the main viewer menu. This will open the **Recode** dialog. Right select the **Row** column and select, **Select All**. All records should now be highlighted yellow. Highlight the **veg_num** column and right click. Select **Copy**. Highlight the **New Value** column, right click and select **Paste**. The **veg_num** values should have populated the **New Value** column. Select **Apply**. The image should now appear as if the radiometric resolution has been reduced sharply. From the main viewer menu, select **File | Save | Top Layer** to save edits made to recoded image.

Classified Image



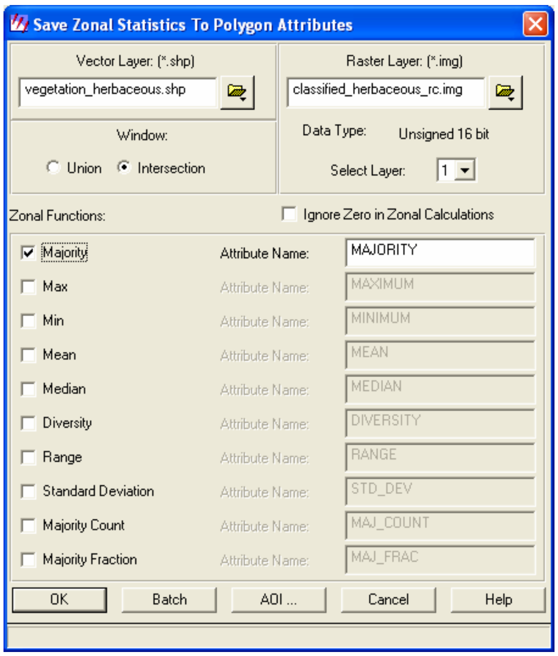
Classified Recoded Image

6. Complete **steps 1-5** for every **NVCS Class** or **ecotype** identified on the refuge.

11.5 <u>Zonal Attributes:</u> *Utilizing ERDAS Imagine 8.X Tools to label vegetation polygons*

In this section the zonal attributes function in ERDAS Imagine will be used to populate vegetation polygons by NVCS Class or ecotype regions. The vegetation feature class will need to be subset by NVCS Classes or ecotypes identified on the refuge and exported as shapefiles. Each subset will be populated using its associated classification completed in Chapter 11.4.

1. Start an **ERDAS Imagine** session. From the main menu select **Vector | Zonal Attributes**. This will open the **Save Zonal Statistics To Polygon Attributes** dialog. In the **Vector Layer** box enter the shapefile subset of the vegetation feature class to be attributed. In the **Raster Layer** box enter the classified recoded image associated to the vegetation subset being attributed. Under Window select **Intersection**. Under **Zonal Functions** select **Majority**. Select **OK**.



2. Import the attributed shapefile back into the **Landcover and Habitat GDB**. Review the results and reestablish any domain linkages. At the end of the subset feature class table should be an added field with the heading of **MAJORITY**. The value represents the **veg_num** value assigned to the alliance or association code during the recode process. Unfortunately text strings can not be used in the recode process, so the raster attribute table must be used as a guide to select and calculate the NVCS Alliance or NVCS Association fields in vegetation subset feature class. There are a number efficient ways to complete this process in ArcMap. At this point users should be able to complete this task on their own. Delete the **MAJORITY** field once complete. Complete this process and repeat steps 1-2 until all NVCS Class or ecotype subsets have been attributed and NVCS Alliance or NVCS Association fields have been calculated (**Figure 11.5.1**).

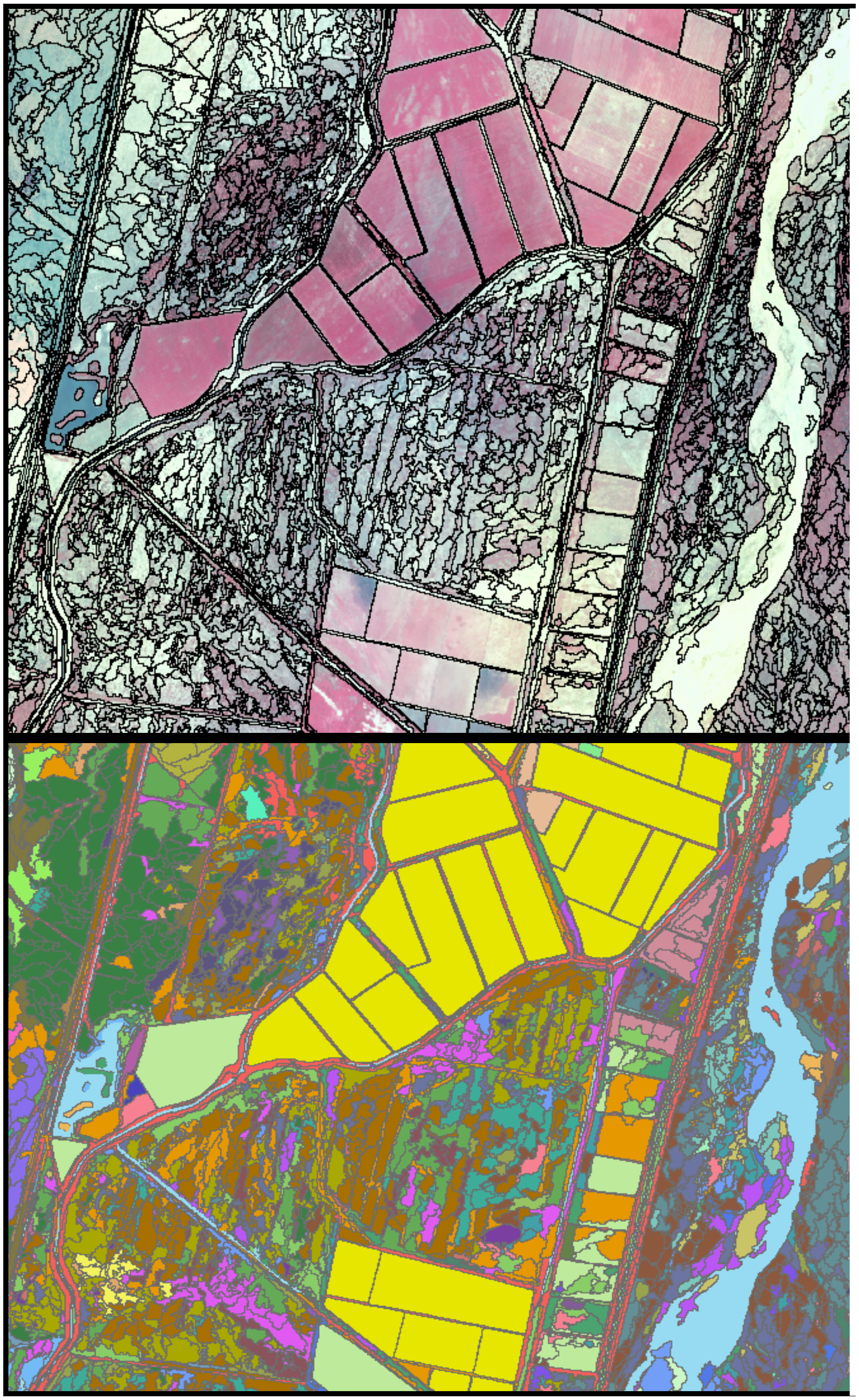


Figure 11.5.1. Example of vegetation polygons labeled using the Zonal Attribute function in ERDAS Imagine. The Polygons were originally derived as image objects in eCognition.

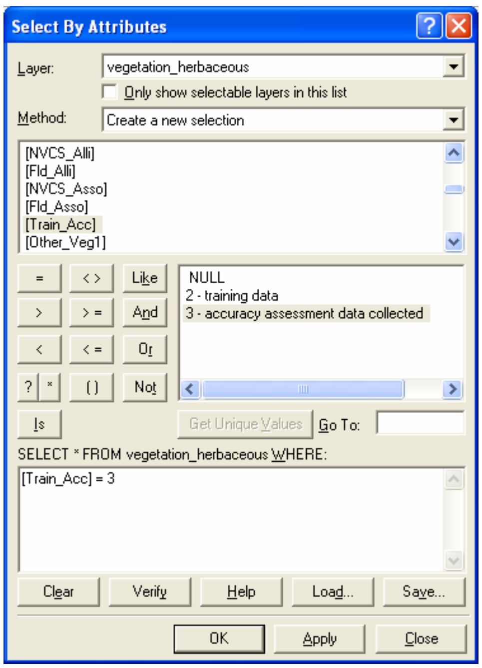
Image shows vegetation polygons overlaid on 1-meter CIR ortho imagery.

Image shows labeled polygons displayed with symbology associated to plant

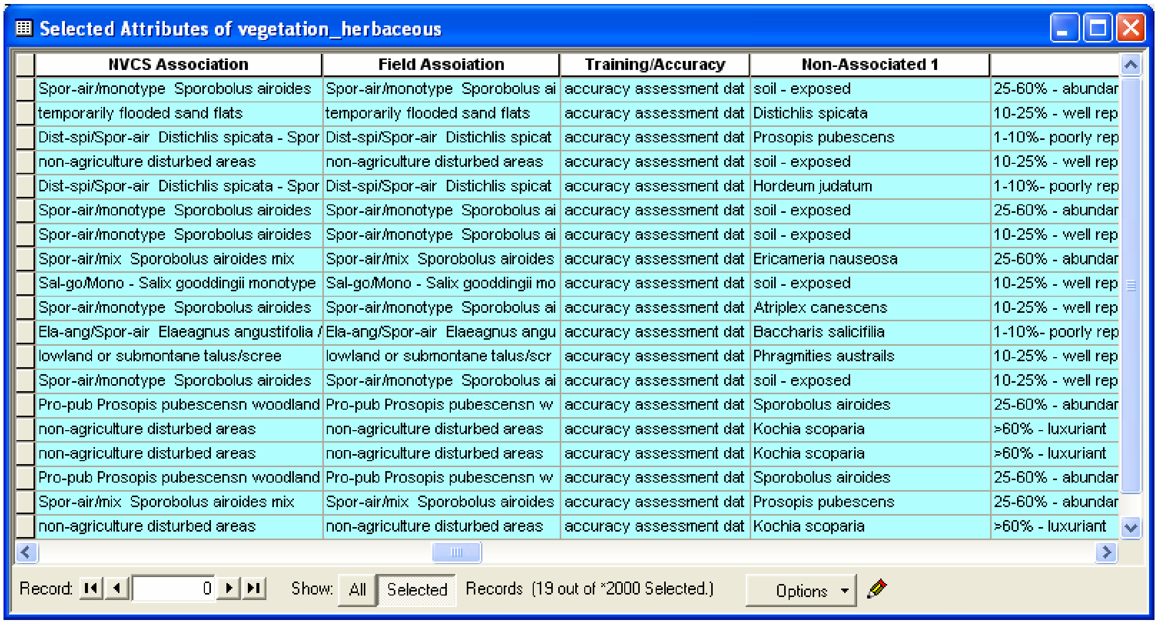
12.1 <u>Data Accuracy:</u> *Conducting individual and overall accuracy assessments of vegetation inventory and monitoring data.*

This section will discuss the steps taken to develop individual and overall accuracy; errors of omission and commission. The process should be applied to the NVCS Class subset classifications as well the final merged dataset. When developed for subsets, the results should be used as a guide to improve classification results or change classification strategies.

1. Start an **ArcMap** session. Add the NVCS Class or ecotype vegetation subset feature class data to the session. **Select | Select By Attributes** from the main toolbar. This will open the **Select By Attributes** dialog. In the **Layer** box select the vegetation subset feature class being used. In the **Method** box select **Create a new selection**. Select **Train_Acc** from the **Fields** box to add it to the **Select From** window and set the values to be selected equal to **3 – accuracy assessment data collected**. All the accuracy assessment polygons should now be highlighted. Polygon records assigned a **3** in the accuracy assessment field are reserved for accuracy assessment procedures only.



2. Open the attribute table for the subset vegetation feature class. Set the table to Display only the selected records. Review data to ensure the selection was made correctly. Both the **NVCS Alliance** and **Field Alliance** or the **NVCS Association** and **Field Association** should be populated depending on what level the classification is to be derived. The **Training/Accuracy** field should also show accuracy assessment data. If the **Acres** field has not been updated or calculated be sure it is at this point. This can be done through the Field Calculator or through XTools.


Selected Attributes of vegetation_herbaceous

NVCS Association	Field Assoiation	Training/Accuracy	Non-Associated 1	
Spor-air/monotype Sporobolus airoides	Spor-air/monotype Sporobolus ai	accuracy assessment dat	soil - exposed	25-60% - abundar
temporarily flooded sand flats	temporarily flooded sand flats	accuracy assessment dat	Distichlis spicata	10-25% - well rep
Dist-spi/Spor-air Distichlis spicata - Spor	Dist-spi/Spor-air Distichlis spicat	accuracy assessment dat	Prosopis pubescens	1-10%- poorly rep
non-agriculture disturbed areas	non-agriculture disturbed areas	accuracy assessment dat	soil - exposed	10-25% - well rep
Dist-spi/Spor-air Distichlis spicata - Spor	Dist-spi/Spor-air Distichlis spicat	accuracy assessment dat	Hordeum judatum	1-10%- poorly rep
Spor-air/monotype Sporobolus airoides	Spor-air/monotype Sporobolus ai	accuracy assessment dat	soil - exposed	25-60% - abundar
Spor-air/monotype Sporobolus airoides	Spor-air/monotype Sporobolus ai	accuracy assessment dat	soil - exposed	10-25% - well rep
Spor-air/mix Sporobolus airoides mix	Spor-air/mix Sporobolus airoides	accuracy assessment dat	Ericameria nauseosa	25-60% - abundar
Sal-go/Mono - Salix gooddingii monotype	Sal-go/Mono - Salix gooddingii mo	accuracy assessment dat	soil - exposed	10-25% - well rep
Spor-air/monotype Sporobolus airoides	Spor-air/monotype Sporobolus ai	accuracy assessment dat	Atriplex canescens	10-25% - well rep
Ela-ang/Spor-air Elaeagnus angustifolia /	Ela-ang/Spor-air Elaeagnus angu	accuracy assessment dat	Baccharis salicifilia	1-10%- poorly rep
lowland or submontane talus/scree	lowland or submontane talus/scr	accuracy assessment dat	Phragmities austrails	10-25% - well rep
Spor-air/monotype Sporobolus airoides	Spor-air/monotype Sporobolus ai	accuracy assessment dat	soil - exposed	10-25% - well rep
Pro-pub Prosopis pubescensn woodland	Pro-pub Prosopis pubescensn w	accuracy assessment dat	Sporobolus airoides	25-60% - abundar
non-agriculture disturbed areas	non-agriculture disturbed areas	accuracy assessment dat	Kochia scoparia	>60% - luxuriant
non-agriculture disturbed areas	non-agriculture disturbed areas	accuracy assessment dat	Kochia scoparia	>60% - luxuriant
Pro-pub Prosopis pubescensn woodland	Pro-pub Prosopis pubescensn w	accuracy assessment dat	Sporobolus airoides	25-60% - abundar
Spor-air/mix Sporobolus airoides mix	Spor-air/mix Sporobolus airoides	accuracy assessment dat	Prosopis pubescens	25-60% - abundar
non-agriculture disturbed areas	non-agriculture disturbed areas	accuracy assessment dat	Kochia scoparia	>60% - luxuriant

Record: 0 Show: All Selected Records (19 out of *2000 Selected.) Options

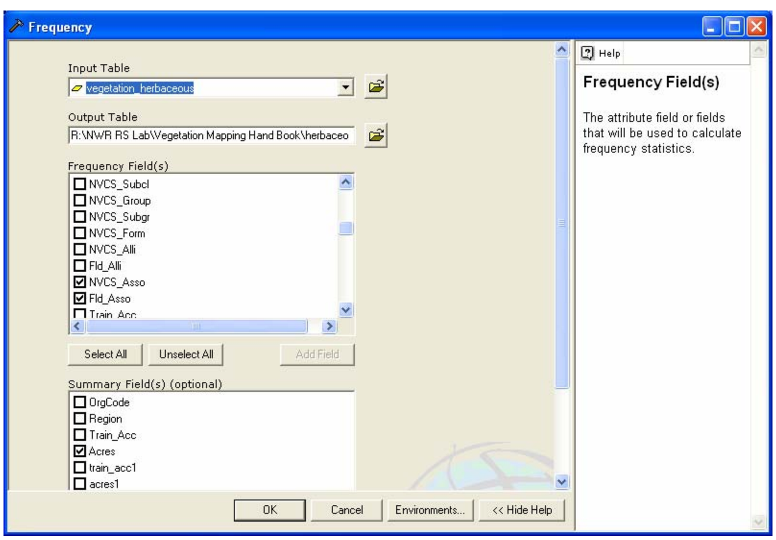
3. Export the selected records from the attribute table. To do this select **Options | Export**. This will open the **Export Data** dialog. Export only selected records. Save the data as a ***.dbf** file. Name the file using the following naming conventions:

Example: herbaceous_accuracy.dbf

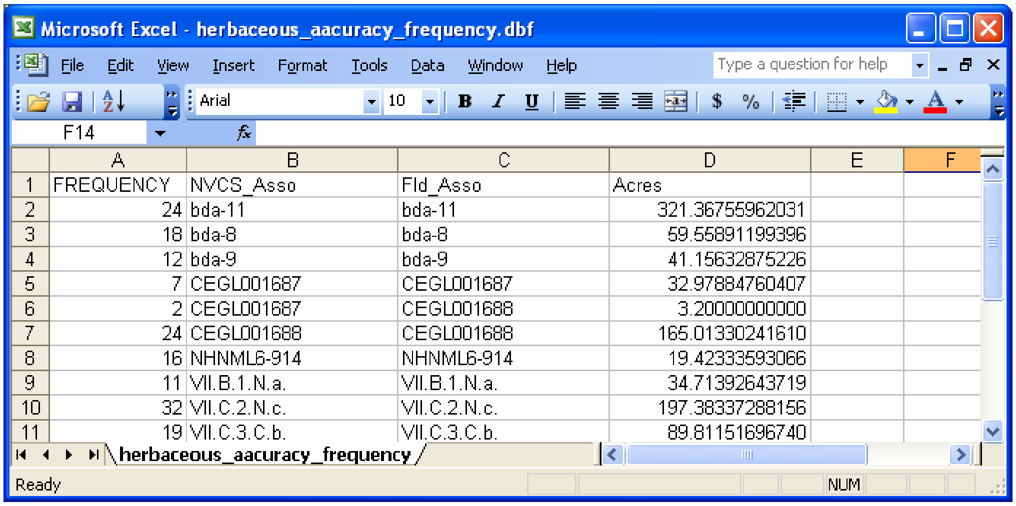
4. Open the **Frequency** tool from **ArcToolbox**. In the **Input Table** box add the ***.dbf** table just exported. In the **Output Table** box name the file using the following naming convention:

Example: herbaceous_accruacy_frequency.dbf

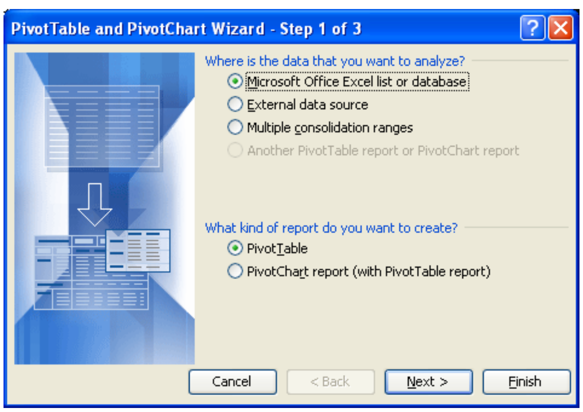
Under the **Frequency Fields** select **NVCS_Ali** and **Fld_Ali** or **NVCS_Asso** and **Fld_Asso**. In the **Summary Fields** select **Acres**. Select **OK** to complete.



5. Open the exported **frequency *.dbf** file in **Excel**. Opened in **Excel** the data will appear different then it did in **ArcMap** as part of the **Landcover and Habitat GBD**. All the fields associated with domains containing coded values and descriptions will now only display the coded value. In this case all the NVCS alliance or association descriptions that appeared in the vegetation feature class will now only show the associated NVCS alliance or association code.

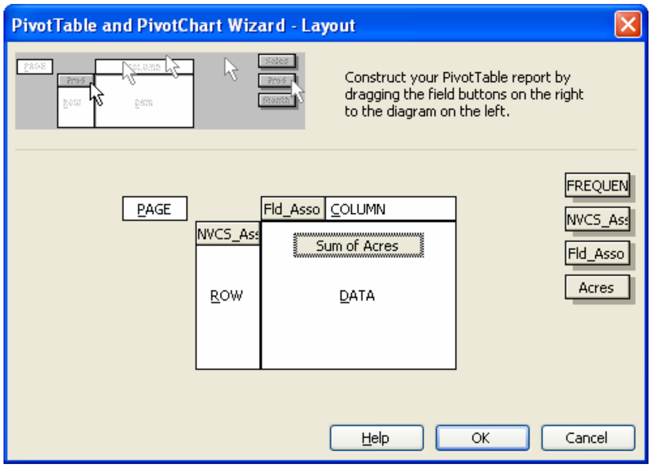


6. In **Excel** select **Data | Pivot Table and PivotChart Report**. This will open **Pivot Table and PivotChart Report Wizard** dialog. Except the defaults in **Step 1 of 3**; **Microsoft Office Excel** list or **Database and Pivot Table**. Select **Next>**.



7. Select the extent of the data that will be used in the pivot table (accuracy assessment). Within the spreadsheet all the data to be used should be within a flashing black and white dashed line. Select **Next>**.

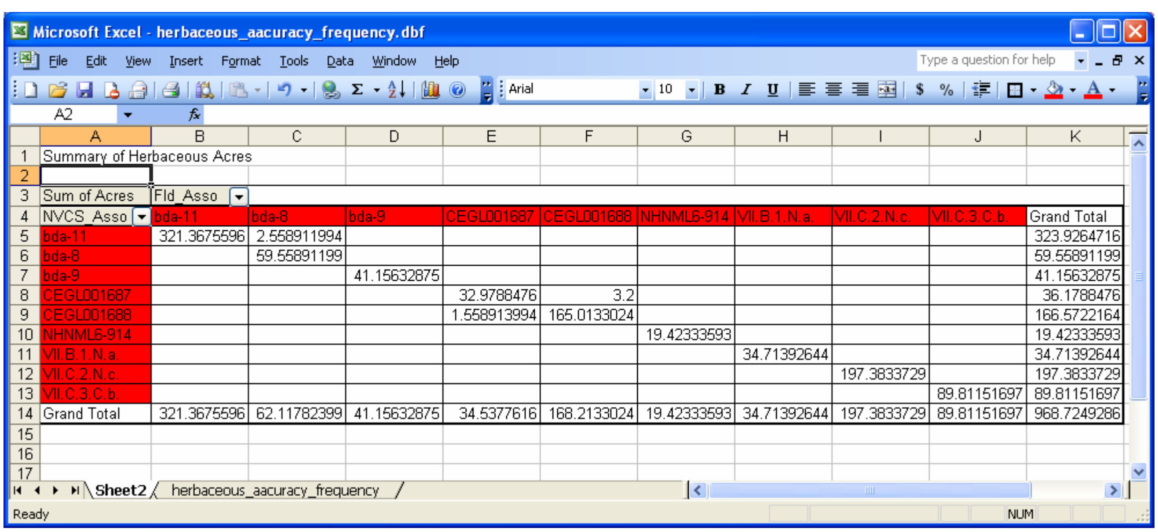
8. In the next window select the **Layout** button. This opens the **Pivot Table and Pivot Chart Wizard – Layout** dialog. In the dialog drag the **NVCS_Alli** or **NVCS_Asso** box (**classified data**) to the **ROW** window. Drag the **Fld_Alli** or the **Fld_Asso** box field (**accuracy assessment data**) to the **COLUMN** window. Drag the **Acres** box into the **DATA** window. This will summarize the classified data and accuracy assessment data by acres. Because the areas defining vegetation communities vary, the data must also be summarized by frequency. This will help to identify any outliers relative to size and frequency that could be skewing the accuracy assessment of the data. Complete **steps 6-8** above but substitute **FREQUENCY** for **Acres** in the **DATA** window. Save the resulting second pivot table to a new page of the **Excel** spreadsheet. Select **OK**.



Summarizing Data by Acres and Frequency
Data should be summarized by both frequency of occurrence and acres. Because the acreage of delineated plant communities on the ground can vary widely among the same community type, looking at one summary and not the other can be misleading. For example, summarizing data from a frequency of occurrence normalizes the affect a single accuracy assessment polygon has, even if that polygon has a very large acreage figure attached to it. Looking at the same example from acreage summary perspective, that same polygon can have an abnormal affect positive or negative on the error of its associated community type inventoried. Conversely, a very small polygon can have the same affect on a frequency summary. When reporting final errors by community and overall, both results should be provided.

9. Select **New worksheet** in **step 3 of 3** from the **Pivot Table and Pivot Chart Wizard** dialog and select **Finish**.

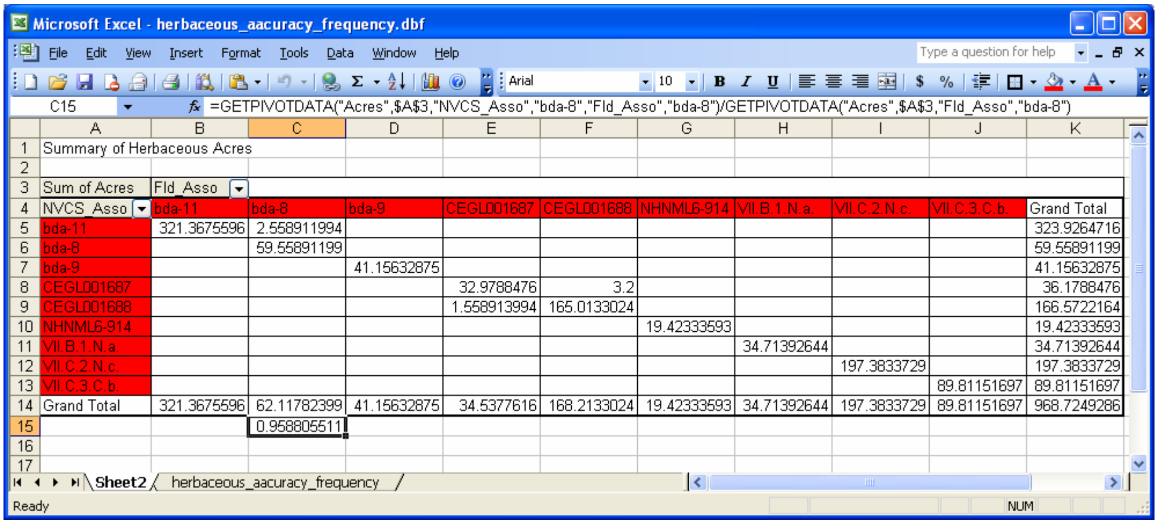
10. A new worksheet should have been added to the **Excel** session containing a pivot table report. The cells highlighted in red below are the NVCS alliance or association codes. The code descriptions may be taken from an existing spreadsheet or exported as a domain directly from the **Landcover and Habitat GDB** if necessary.


Summary of Herbaceous Acres

Sum of Acres	Fld_Asso									
NVCS_Asso	bda-11	bda-8	bda-9	CEGL001687	CEGL001688	NHNML6-914	VII.B.1.N.a.	VII.C.2.N.c.	VII.C.3.C.b.	Grand Total
bda-11	321.3675596	2.558911994								323.9264716
bda-8		59.55891199								59.55891199
bda-9			41.15632875							41.15632875
CEGL001687				32.9788476	3.2					36.1788476
CEGL001688				1.558913994	165.0133024					166.5722164
NHNML6-914						19.42333593				19.42333593
VII.B.1.N.a.							34.71392644			34.71392644
VII.C.2.N.c.								197.3833729		197.3833729
VII.C.3.C.b.									89.81151697	89.81151697
Grand Total	321.3675596	62.11782399	41.15632875	34.5377616	168.2133024	19.42333593	34.71392644	197.3833729	89.81151697	968.7249286

11. To calculate the **producers accuracy** and **error of commission** for the vegetation communities mapped, the total number of acres classified correctly as an individual NVCS alliance or association must be divided by the sum of acres classified correctly and incorrectly by that

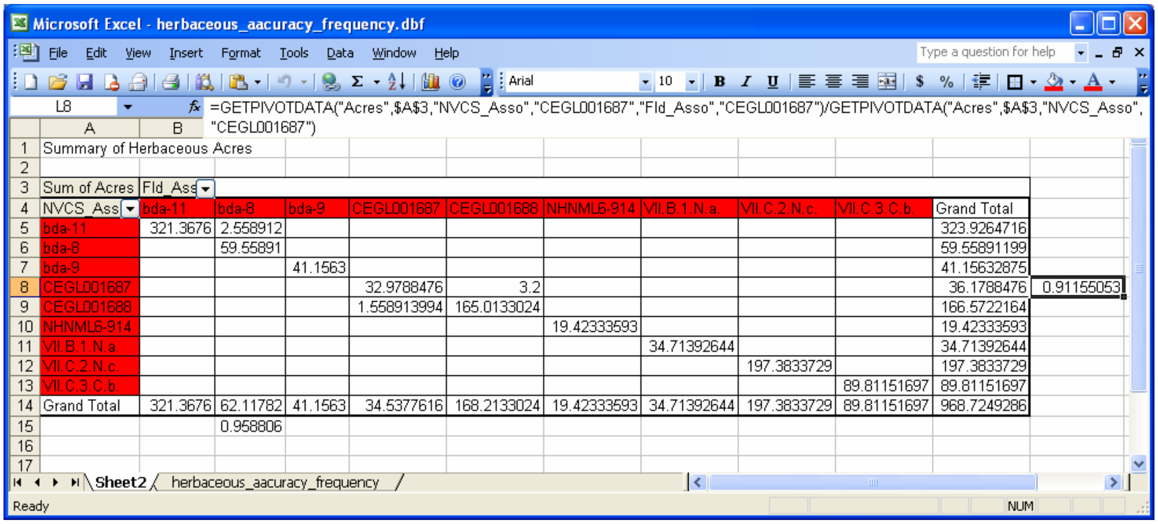
alliance or association. In this example, the code **bda-8** (*Sporobolus aroids* mixed herbaceous grassland) will be calculated. Select cell **C15**. Next type an equals '**=**' sign in the **Formula Bar** at the top of the table. Select cell **C6 (acres classified as bda-8 correctly)**. Code should now have appeared in the **Formula Bar**. At the end of the code place a divided by sign '/'. Select the cell **C14** (**acres total classified as bda-8**). Hit **Enter**. The fraction now appearing in the cell is the **produces accuracy (.9588 or 96%)**. The error of commission is equal to **1 - .9588 = .0422 or 4.2%**. Repeat this process to calculate **produces accuracy** and **errors of commission** for all alliances or associations mapped.



	A	B	C	D	E	F	G	H	I	J	K
1	Summary of Herbaceous Acres										
2											
3	Sum of Acres	Fld_Asso									
4	NVCS_Asso	bda-11	bda-8	bda-9	CEGL001687	CEGL001688	NHNML6-914	VII.B.1.N.a.	VII.C.2.N.c.	VII.C.3.C.b.	Grand Total
5	bda-11	321.3675596	2.558911994								323.9264716
6	bda-8		59.55891199								59.55891199
7	bda-9			41.15632875							41.15632875
8	CEGL001687				32.9788476	3.2					36.1788476
9	CEGL001688				1.558913994	165.0133024					166.5722164
10	NHNML6-914						19.42333593				19.42333593
11	VII.B.1.N.a.							34.71392644			34.71392644
12	VII.C.2.N.c.								197.3833729		197.3833729
13	VII.C.3.C.b.									89.81151697	89.81151697
14	Grand Total	321.3675596	62.11782399	41.15632875	34.5377616	168.2133024	19.42333593	34.71392644	197.3833729	89.81151697	968.7249286
15			0.958805511								
16											
17											

Producers Accuracy and Error of Commission
Producers accuracy and error of commission are derived as a percentage of the total number of units taken from accuracy assessment classified correctly for a given class divided by the total number of units classified correctly for that class plus the sum of the units misclassified by that given class. Producers accuracy represents the level of accuracy the producer was able to achieve. Error of commission is the error being committed by an individual class towards other classes or the percent of other sites being classified incorrectly by that class (Congalton, R.G. Green, K. 1999).

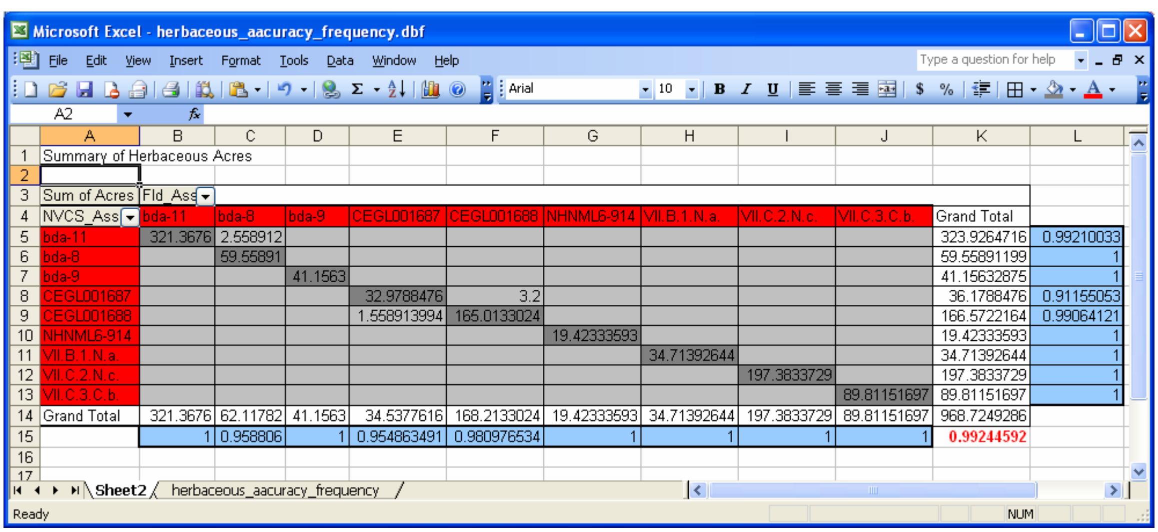
12. To calculate the **users accuracy** and **error of omission** for the vegetation communities mapped, the total number of acres classified correctly as an individual NVCS alliance or association must be divided by the sum of acres classified correctly and incorrectly by that alliance or association. In this example the code **CEGL001687** (*Sporobolus aroids* mixed herbaceous grassland) will be calculated. Select cell **L8**. Next type an equals '**=**' sign in the **Formula Bar** at the top of the table. Select cell **E8 (acres classified as bda-8 correctly)**. Code should now have appeared in the **Formula Bar**. At the end of the code place a divided by sign '/'. Select the cell **K8** (**acres total classified as bda-8**). Hit **Enter**. The fraction now appearing in the cell is the **users accuracy (.9115 or 91%)**. The error of commission is equal to **1 - .9115 = .0895 or 9.0%**. Repeat this process to calculate **users accuracy** and **errors of omission** for all alliances or associations mapped.



Sum of Acres	Fld_Ass										
NVCS_Ass	bda-11	bda-8	bda-9	CEGL001687	CEGL001688	NHNML6-914	VII.B.1.N.a.	VII.C.2.N.c.	VII.C.3.C.b.	Grand Total	
bda-11	321.3676	2.558912								323.9264716	
bda-8		59.55891								59.55891199	
bda-9			41.1563							41.15632875	
CEGL001687				32.9788476	3.2					36.1788476	0.91155053
CEGL001688				1.558913994	165.0133024					166.5722164	
NHNML6-914						19.42333593				19.42333593	
VII.B.1.N.a.							34.71392644			34.71392644	
VII.C.2.N.c.								197.3833729		197.3833729	
VII.C.3.C.b.									89.81151697	89.81151697	
Grand Total	321.3676	62.11782	41.1563	34.5377616	168.2133024	19.42333593	34.71392644	197.3833729	89.81151697	968.7249286	
		0.958806									

Users Accuracy and Error of Omission
Users accuracy and error of omission are derived as a percentage of the total number of units taken from accuracy assessment that are classified correctly for a given class divided by the total number of units classified correctly for that class plus the sum of the units in that class misclassified as other classes. Users accuracy represents the level of accuracy the user of the data should expect when applying it. Error of omission is the error of omitting sites from a class when those sites are being classified as another class incorrectly or the percent of that class misclassified by another classes (Congalton, R.G. Green, K. 1999).

13. To derive the overall accuracy the number of acres classified correctly must be divided by the total number of acres classified. For this example select cell **K15**. Type an equals sign '**=**' in the **Formula Bar** followed by a beginning bracket '**(**'. Begin selecting the cells for each class that represent the total number of acres classified correctly for that class. Between each selection insert a plus '**+**' sign. The cells containing acres classified correctly for each class are highlighted in dark gray below. At the end of the code add an ending bracket '**)**' followed by a divided by sign '**/**' and select the cell that represents the total number of acres classified (**K14** for this example) and hit **Enter**. The resulting number should represent the overall accuracy of the inventory (**99.2%**).



Sum of Acres	Fld_Ass										
NVCS_Ass	bda-11	bda-8	bda-9	CEGL001687	CEGL001688	NHNML6-914	VII.B.1.N.a.	VII.C.2.N.c.	VII.C.3.C.b.	Grand Total	
bda-11	321.3676	2.558912								323.9264716	0.99210033
bda-8		59.55891								59.55891199	1
bda-9			41.1563							41.15632875	1
CEGL001687				32.9788476	3.2					36.1788476	0.91155053
CEGL001688				1.558913994	165.0133024					166.5722164	0.99064121
NHNML6-914						19.42333593				19.42333593	1
VII.B.1.N.a.							34.71392644			34.71392644	1
VII.C.2.N.c.								197.3833729		197.3833729	1
VII.C.3.C.b.									89.81151697	89.81151697	1
Grand Total	321.3676	62.11782	41.1563	34.5377616	168.2133024	19.42333593	34.71392644	197.3833729	89.81151697	968.7249286	
	1	0.958806	1	0.954863491	0.980976534	1	1	1	1	0.99244592	

Overall Accuracy
Overall accuracy is derived as a percentage of the total number of units taken from the accuracy assessment sites classified correctly divided by the total number of units classified. The question usually arises pertaining to the level of overall accuracy which is acceptable. This question is usually only answered intelligently when management needs are considered relative to application of the data. The NWR Remote Sensing Lab has made a standard of ≥ 80% accuracy. This is inline with the NPS and USGS for some of their inventory and monitoring standards.

Rare Classes
In most classifications there are a number of classes that are under represented. If the sample design was set up correctly and field data collection protocols were followed it can be assumed that these vegetation communities are rare across the refuge sampled. In these cases it is recommended these classes not be used in the overall accuracy of the classification. In cases when inventory of rare types are important to refuge objectives additional field reconnaissance is required to locate rare communities on the ground. These data can be added to the classification at a latter date.

14. Repeat **steps 1-14** for all vegetation subset classifications. If accuracy assessments for these areas are acceptable, union all the subsets back into a single feature class and populate the all the NVCS hierarchy fields between NVCS Class and NVCS Alliance or NVCS Association. Use the field calculator to calculate Field Alliance or Field Association equal to NVCS Alliance or NVCS Association. If any subset feature classes have accuracy that are unacceptable continue onto **Chapter 12.2**.

12.2 Improving Data Accuracy: ***Using training data and ERDAS Imagine to track and remove spectrally confused signature files.***

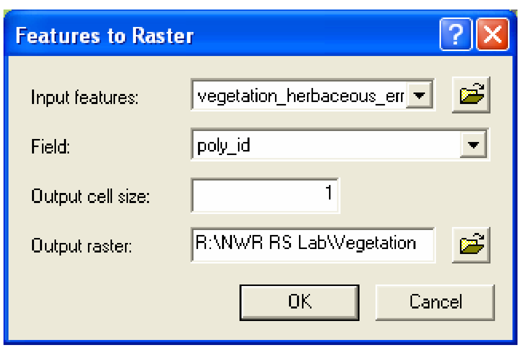
Once an accuracy assessment has been completed for all or a single subset and it has been determined that the overall or individual class accuracies are at unacceptable levels, steps can be taken to improve the classification. Signatures may be identified **in the training data** that have caused spectral confusion (errors of omission and commission) between classes. These signatures can be removed from the signature file and the classification rerun.

1. Start an **ArcMap** session and open the vegetation NVCS Class or ecotype subset feature class with low accuracy. The subset feature class should contain all the classification data, field data and training/accuracy delineations. Select **Selection | Select By Attributes** from the main menu. This will open the **Select By Attributes** dialog. From the **Train_Acc** field select the **Train_Acc = 2 – training data**. From that selection, select **Fld_Alli not = to NVCS_Alli** or **Fld_Asso not = to NVCS_Asso**. Save the select polygons as a feature class in the **Landcover and Habitat GDB**.

Note: Do not use accuracy assessment data for this procedure. Doing so will bias the independence of the sample and bias any accuracy assessment results in all following reclassifications. Only training data may be used to complete this process.

2. Open the **Spatial Analyst** toolbar in **ArcMap**. Select **Spatial Analysis | Convert | Features to Raster**. This opens the **Feature to Raster** dialog. Set the **Input features** to the exported feature class selection made in step 1, above. Set the **Field** to **poly_id**. Set the **Output cell size** to **1**. Set the **Output raster** to ***img** format. Use the following naming convention:

   Example: vegetation_herbaceous_error1.img

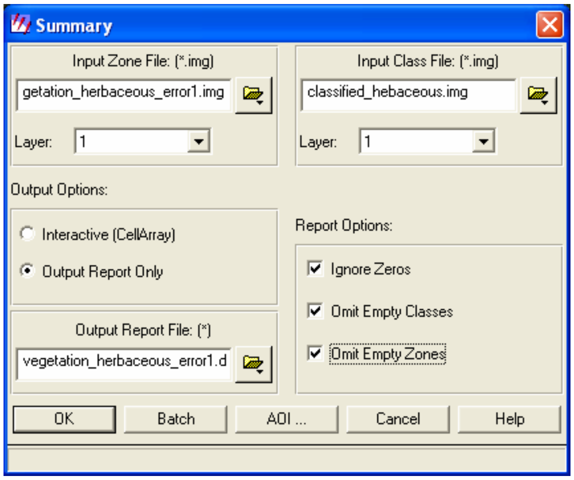
   

3. Start an **ERDAS Imagine** session. From the main menu select **Session | Tools | Image Information**. This opens the **ImageInfo** dialog. Select **File | Open**. Navigate to the **vegetation_herbaceous_error1.img** (used for this example) just created in **ArcMap** and select **OK**. Select **Edit | Change Layer Type** from the dialog menu. This will change the layer type from **Continuous** to **Thematic**. Close dialog when finished

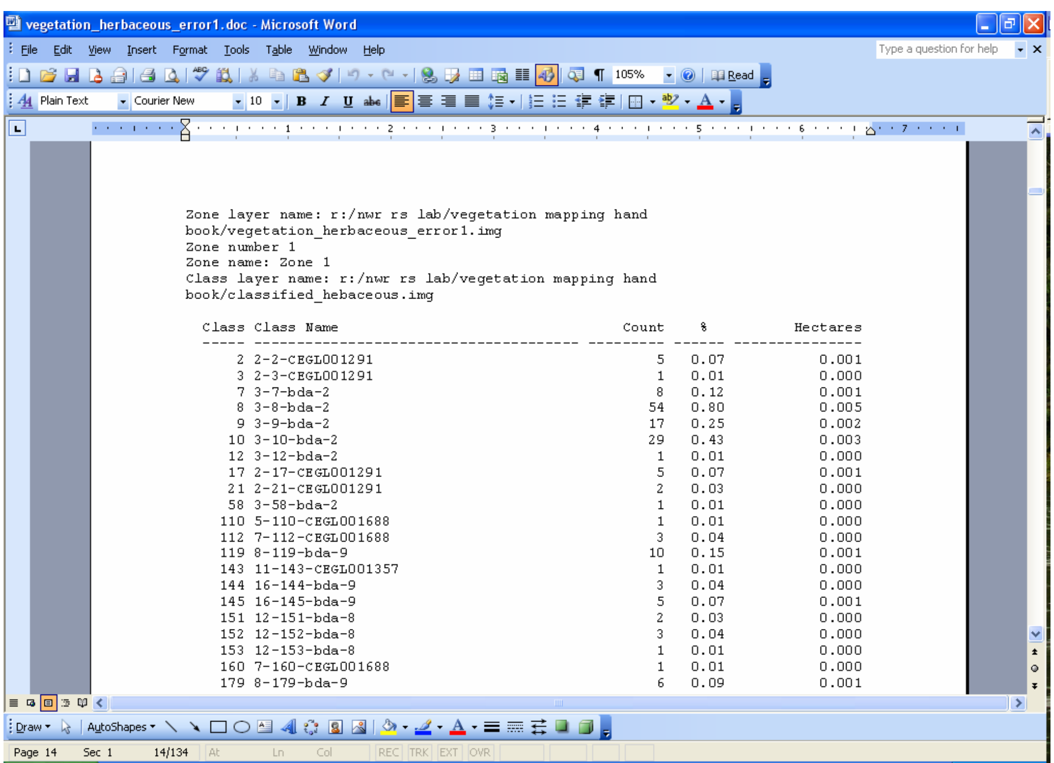
4. From the main **ERDAS Imagine** menu, select **Interpreter | GIS Analysis | Summary**. This opens the **Summary** dialog. In the **Input Zone File** box select the **vegetation_herbaceous_error1.img** just created in **ArcMap**. In the **Input Class File** select the classified image associated with zone file image. **The classified image should be used not the recoded image**. Under **Output Options** select **Output Report Only**. Check all the **Report Options**. Name the report using the following naming convention:

   Example: **vegetation_herbaceous_error1.doc**

   Select **OK**.



5. Open the output report in **Word**. The **Zone number** within the data is the equivalent to the **Poly_id** in the vegetation feature class. From the associated subset feature class the misclassified polygons were extracted from select the **Poly_id** matching the **Zone number** using the **Select By Attribute** dialog in **ArcMap**. Note the **Field Alliance** or **Field Association** assigned to that polygon. This should have been populated through field data collection. Look for signatures within the report that show significant levels of misclassification relative to the field data. Refer to the **Count** column for numbers of individual pixels assigned to spectrally confused signatures within the misclassified polygon. Record the class names of these signatures. These are the **sig_id,** unique identifiers generated for all signatures in **Chapter 11.2**. This can be a long process considering the length and complexity of many classifications, especially when using high resolution imagery.



Zone layer name: r:/nwr rs lab/vegetation mapping hand book/vegetation_herbaceous_error1.img
Zone number 1
Zone name: Zone 1
Class layer name: r:/nwr rs lab/vegetation mapping hand book/classified_hebaceous.img

Class	Class Name	Count	%	Hectares
2	2-2-CEGL001291	5	0.07	0.001
3	2-3-CEGL001291	1	0.01	0.000
7	3-7-bda-2	8	0.12	0.001
8	3-8-bda-2	54	0.80	0.005
9	3-9-bda-2	17	0.25	0.002
10	3-10-bda-2	29	0.43	0.003
12	3-12-bda-2	1	0.01	0.000
17	2-17-CEGL001291	5	0.07	0.001
21	2-21-CEGL001291	2	0.03	0.000
58	3-58-bda-2	1	0.01	0.000
110	5-110-CEGL001688	1	0.01	0.000
112	7-112-CEGL001688	3	0.04	0.000
119	8-119-bda-9	10	0.15	0.001
143	11-143-CEGL001357	1	0.01	0.000
144	16-144-bda-9	3	0.04	0.000
145	16-145-bda-9	5	0.07	0.001
151	12-151-bda-8	2	0.03	0.000
152	12-152-bda-8	3	0.04	0.000
153	12-153-bda-8	1	0.01	0.000
160	7-160-CEGL001688	1	0.01	0.000
179	8-179-bda-9	6	0.09	0.001

6. Open the **Signature Editor** in **ERDAS Imagine**. Use the Criteria dialog to select the spectrally confused signatures and remove them from the signature set. Save the signature file and rerun

the classification and accuracy assessment. Repeat these steps until a desired level of accuracy is reached.

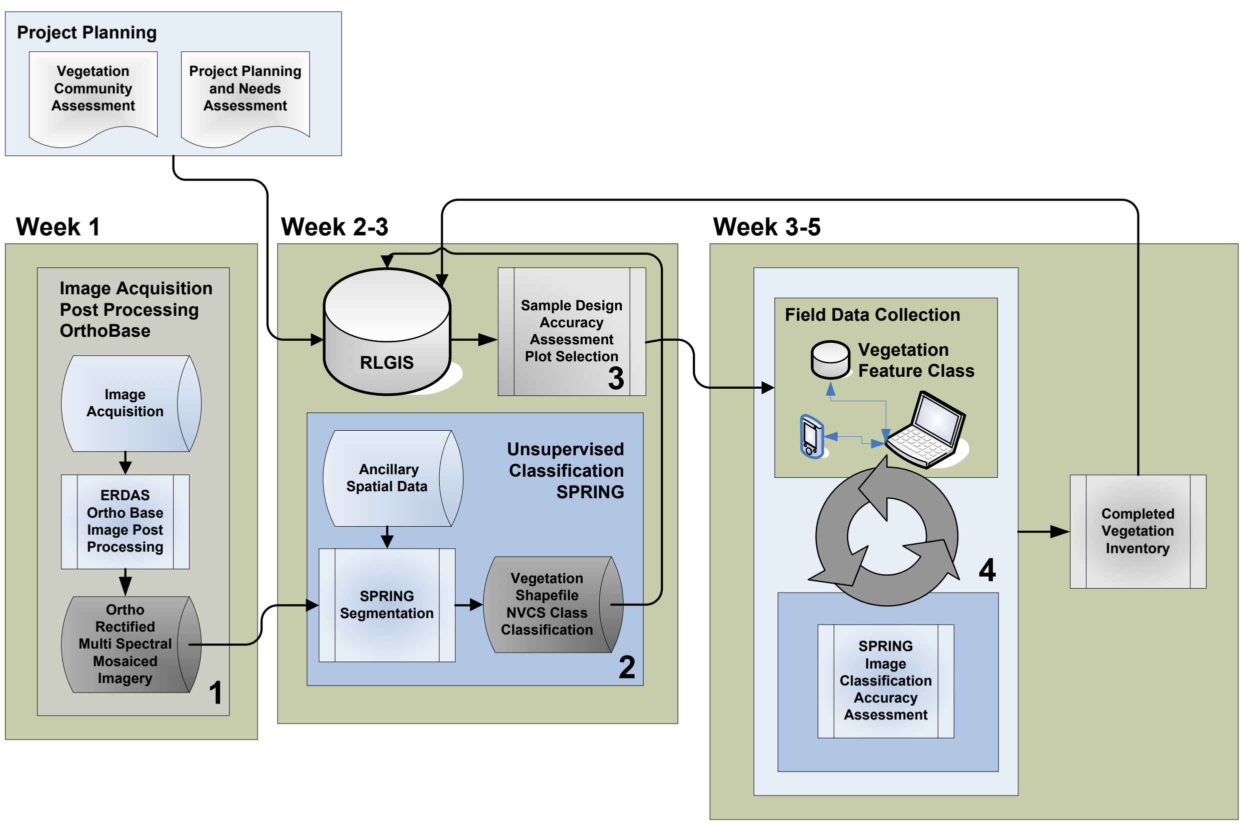
The methods outlined above are a snapshot of a single approach to complete a vegetation/habitat inventory. Projects completed by the Lab can deviate widely in some areas from what has been documented. This is done to meet individual project needs and to take advantage of new technology and efficiencies when available. Briefly discussed below are 2 software packages the Lab is currently working with to incorporate into our current approach.

13.1 SPRING: *Utilizing SPRING software to complete image segmentation and supervised classification*

SPRING is an object oriented data model image/classification software similar to eCognition. The software takes advantage of innovative algorithms for spatial indexing, image segmentation, region-based classification by neural networks and TIN generation. Segmentation tests between SPRING and eCognition show no notable differences between the ability of the software packages to derive image objects within vegetation communities. SPRING reaches beyond eCognition in terms of classification algorithms, allowing users to apply far more than an object based nearest neighbor classification.

Because the software was developed by the Brazilian government, the help document and user guide is in Portuguese. This has made the learning curve a little bit steeper, but plans to translate the user's guide to English may overcome this limitation of the software will be become much more apparent. The **software is FREE** and can be downloaded at: http://www.dpi.inpe.br/spring/english/index.html .

The Lab plans to continue application and testing of this software. If successful it could **greatly reduce the image processing steps required to generate vegetation/habitat inventories, further reduce the dependency on ERDAS Imagine and end use of eCognition.** The following will be tested during the summer, 2006.



13.2 <u>Genie Pro:</u> *Utilizing Genie Pro software to complete supervised classification*

GENIE Pro is an image classification software developed by Los Alamos National Lab in New Mexico. GENIE is an evolutionary computation (EC) software system (Image Classification Software), using a genetic algorithm (GA) to assemble image-processing tools from a collection of low-level image operators (e.g., edge detectors, texture measures, spectral operations, various morphological filters). Each candidate tool generates a number of feature planes, which are then combined using a supervised classifier (Fisher linear discriminant) to generate a final boolean feature mask. A population of candidate tools is generated, ranked according to a fitness metric measuring their performance on some user-provided training data, and fit members of the population permitted to reproduce. Several standard fitness metrics have been implemented, including Euclidean distance and Hamming distance. The process cycles until the population converges to a solution, or the user decides to accept the current best solution. The user is also able to modify the training data as Genie reports its initial results, to help refine the search. The burden of low-level programming is thus shifted to the genetic algorithm, leaving the analyst free to concentrate on the critical task of making judgments. GENIE may choose ignore the spatial information in the image and rely wholly on spectral operations and the supervised classifier module, but in practice GENIE will construct integrated spatio-spectral algorithms.

Testing on this software package will begin spring of 2006. After speaking with developers it is anticipated the software could support image classification procedures currently being run in ERDAS Imagine. The **software is <u>FREE</u>** to U.S. Federal agencies. Additional information can be obtained at: http://genie.lanl.gov/ or by contacting Steven P. Brumby, PhD by email at: brumby@lanl.gov.

Congalton, R.G. 1991. A review of assessing the accuracy of classifications of remotely sensed data, *Remote Sensing of Environment*, 37:35-46.

Congalton, R.G. Green, K. 1999. Assessing the Accuracy of Remotely Sensed Data: Principals and Practices. CRC Press, New York. 137 pgs.

Woodcock, C., and V.J. Harward, 1992. Nested-hierarchical scene models and image segmentation, *International Journal of Remote Sensing*, 13(16):3167-3187.

Vegetation Communities of Bosque del Apache National Wildlife Refuge Appendix I.

See Attached

Vegetation Communities of Bosque del Apache NWR Spreadsheet Appendix II.

See Attached

Object Based Classification Using SPRING Software Appendix III.

See Attached