DESIGN, COMMUNITY & ENVIRONMENT

Using Remote Sensing to Map the Evolution of Marsh Vegetation in the South Bay: Methods and Results for 2009-10

South Bay Salt Pond Restoration Project

South Bay Science Symposium 2011

PROJECT TEAM

Remote Sensing of Vegetation and GIS analyses

- **Brian Fulfrost** *Project Manager*
- **Charlie Loy** *GIS Analyst*
- **Will Fourt** *GIS Analyst*

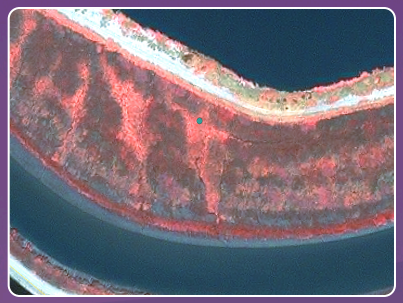
Marsh Ecology and Ground Truthing

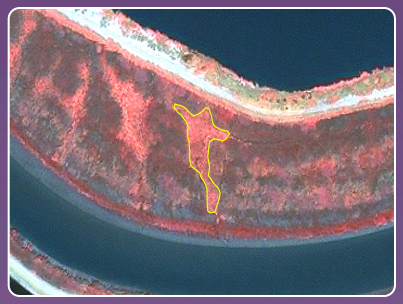
- **David Thomson** *Lead Biologist*

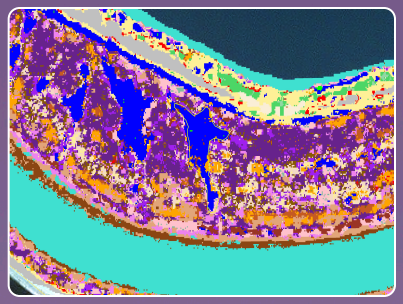
OVERVIEW – GOALS and PROGRESS

Goals

- Build a semi-automated "model" using satellite imagery to track evolution of marsh vegetation and sediment as part of adaptive restoration
- Map ~30,000 acres (twice size of restoration area) @ 80% attribute accuracy
- 3 year pilot project (2009-2011) timed with Phase One breaches





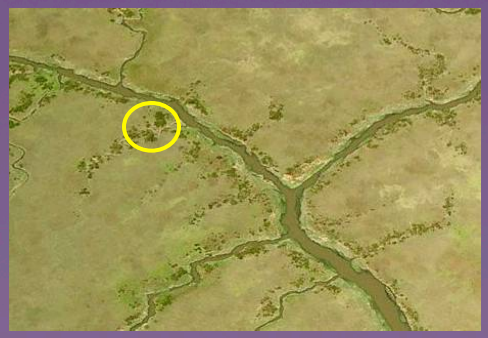


Progress

- **Year One and Year Two classifications 90% complete**

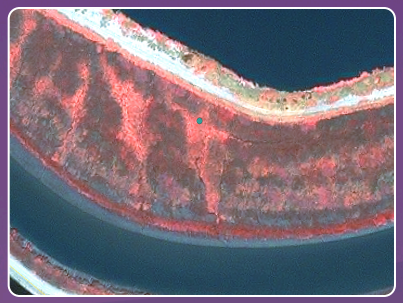
OVERVIEW – METHODS

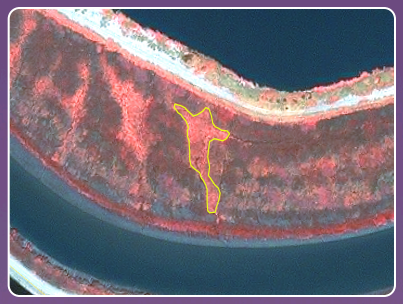
- **MMU and Scale of Analysis**
  - ¼ Hectare (working)
  - 1:1800 to 1:2400 scale (working)
  - Size and shape of marsh (low, mid, high)
- **Imagery Acquisition**
  - Ikonos 1 meter multi-spectral
  - June or July (once a year) at MLLW
- **Image Normalization**
  - relative correction: *Histogram Matching*
  - absolute correction (image based): Exoatmospheric, DOS, COST

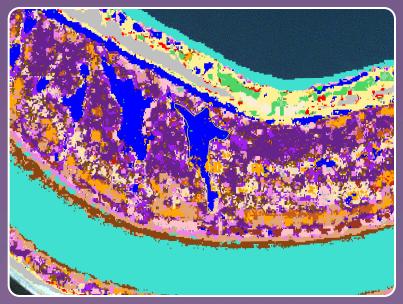


OVERVIEW –METHODS

- **Step #1: Habitat Classifications**
  - Based on *Manual of California Vegetation*
  - Field surveys using *CNPS Rapid Assessment*
- **Step #2: Habitat Model**
  - Create *Training Sites (AOI)* of each Habitat Classification
  - Create *Spectral Signature* files from AOI for each Habitat Classification
  - Run *supervised classification* (maximum likelihood) of Ikonos 1 meter

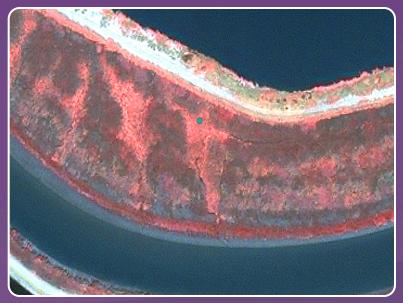


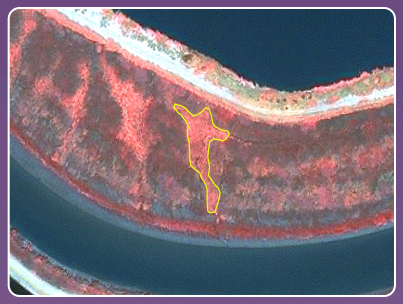


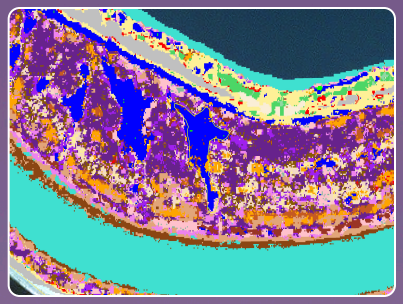


OVERVIEW –METHODS

- **Step #3: Habitat Classification Review**
  - Review model results in lab with grid (1/4 km2)
  - Calibrate model results in the field using sub-set of *Rapid Assessment* survey for focused areas
  - Re-run supervised classifications





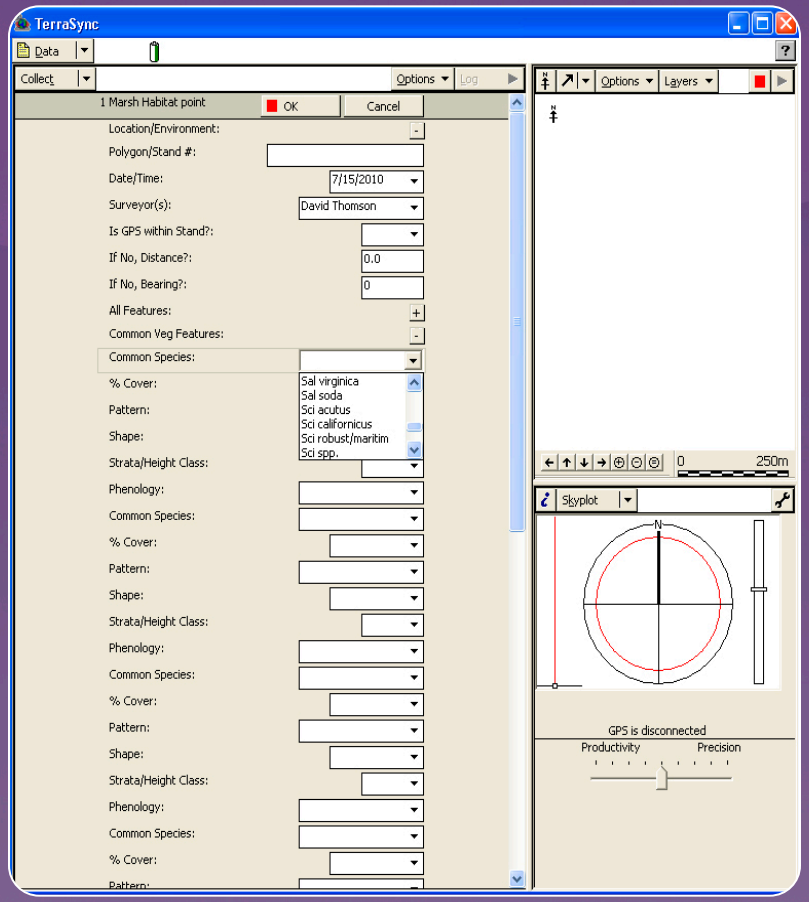


- **Step #4: Model Validation**
  - **Stratified random sample of study area using radius (20 meter) based survey in the field**

STEP #1: HABITAT CLASSIFICATIONS

Rapid Assessment

- Characterize common and rare plant associations based on simple rules of dominance
- Digital surveys with Trimble Terrasync



EXAMPLES OF HABITATS TO BE MAPPED

Pickleweed

Gumplant

Pepperweed

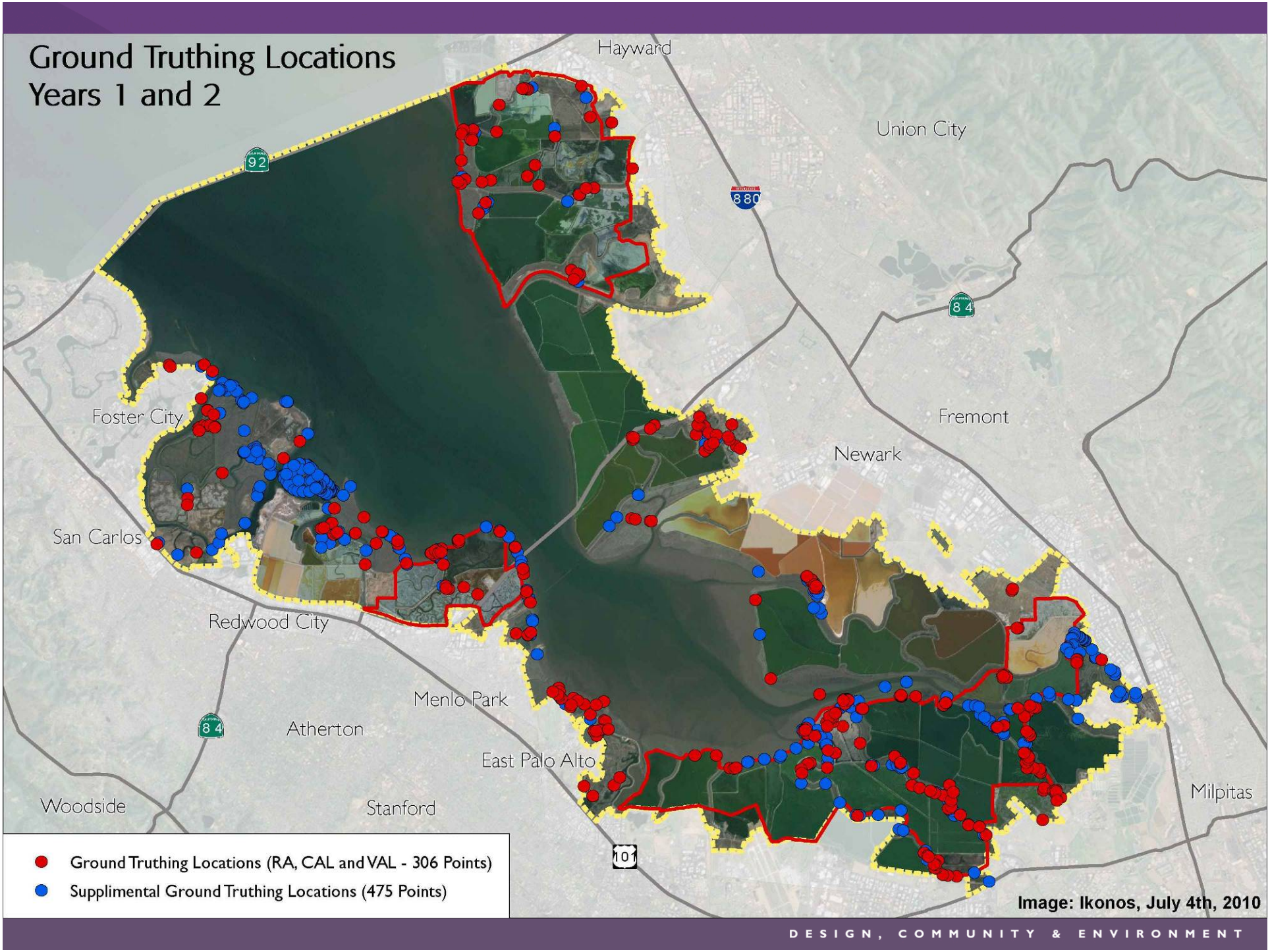
Alkali Heath

Cordgrass

Annual Pickleweed

KEY RAPID ASSESSMENT ENTRIES

- **Points, Line or Polygons**
- **Abiotic Features (bare earth, mud, rock, etc.) -** % cover class
- **Size of Stand** (size class)
- **Vegetative Species**
  - % Cover Class
  - Phenology
  - Pattern & Shape
  - Height Class
- **Adjacent Habitats (alliance/association)**
- **Photos (each compass bearing)**

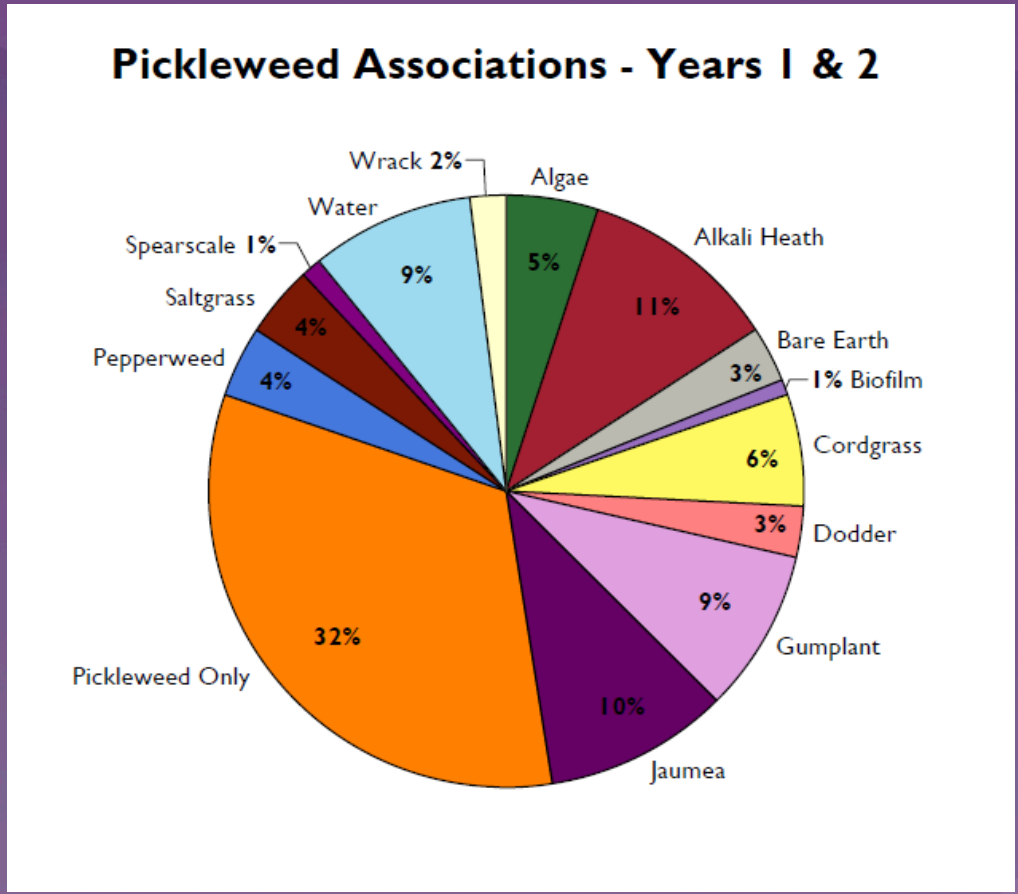

Ground Truthing Locations
Years 1 and 2
Hayward
Union City
Foster City
Fremont
Newark
San Carlos
Redwood City
Menlo Park
Atherton
East Palo Alto
Woodside
Stanford
Milpitas
92
880
84
84
101
Ground Truthing Locations (RA, CAL and VAL - 306 Points)
Supplimental Ground Truthing Locations (475 Points)
Image: Ikonos, July 4th, 2010
DESIGN, COMMUNITY & ENVIRONMENT

VEGETATION ALLIANCES/ASSOCIATIONS (FROM FIELD SURVEYS)

NOT INCLUDING LEVEE AND UPLAND

Vegetation Alliances – Years 1 & 2

Dominant Association	Total Occurances
Algae	4
Alkali Bulrush	17
Alkali Bulrush-Cattail	1
Alkali Bulrush-Perennial Pepperweed	1
Alkali Bulrush-Pickleweed	1
Alkali Heath	13
Alkali Heath-Saltgrass	3
Annual Pickleweed	7
Avena	1
Bulrush	8
Cattail	4
Clump Grass	1
Cordgrass	12
Coyote Bush	1
Dodder	1
Gumplant	4
Iceplant	5
Jaumea	7
Mixed	3
Mustard	1
Perennial Pepperweed	7
Pickleweed	87
Pickleweed-Algae	1
Pickleweed-Alkali Heath	1
Pickleweed-Cordgrass	3
Pickleweed-Gumplant	4
Pickleweed-Jaumea	5
Pickleweed-Perennial Pepperweed	1
Saltgrass	1
Saltgrass-Jaumea	1
Saltwort	2
Saltwort-Saltgrass	1
Spearscale	5
Stinkwort	1
Total	**215**



HABITAT CLASSIFICATIONS TO BE MAPPED

- Coastal Freshwater Marsh
  - **Bulrush**
  - **Cattail**
  - **Bulrush/Cattail**
- Coastal Brackish Marsh
  - **Alkali Bulrush**
  - **Alkali Bulrush/Pepperweed**
  - **Alkali Bulrush/Pickleweed**
  - **Pepperweed**
- Coastal Salt Marsh
  - **Pickleweed (annual and perennial)**
  - **Cordgrass**
  - **Pickleweed/Cordgrass**
  - **Pepperweed**
  - **Pickleweed/Pepperweed**
  - **Alkali Heath**
  - **Gumplant**
  - **Jaumea**
  - **Saltgrass**

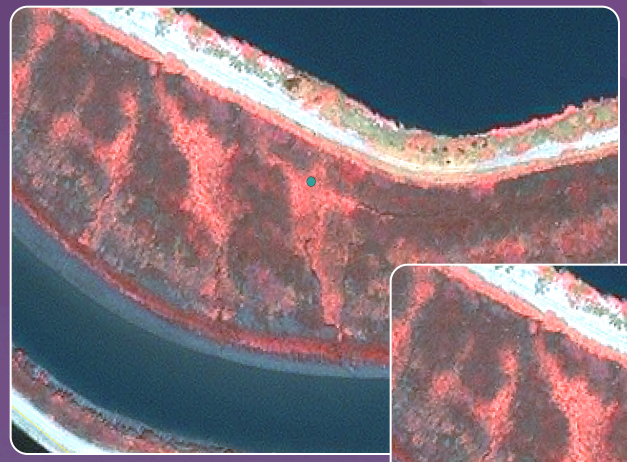
HABITAT CLASSIFICATIONS TO BE MAPPED

- Upland/Levees
  - **Perennial Pepperweed**
  - **Alkali Heath**
  - **Slender Leaf Iceplant**
  - **Saltgrass**
  - **Mustard**
  - **Fennel**
  - **Alkali Grasses**

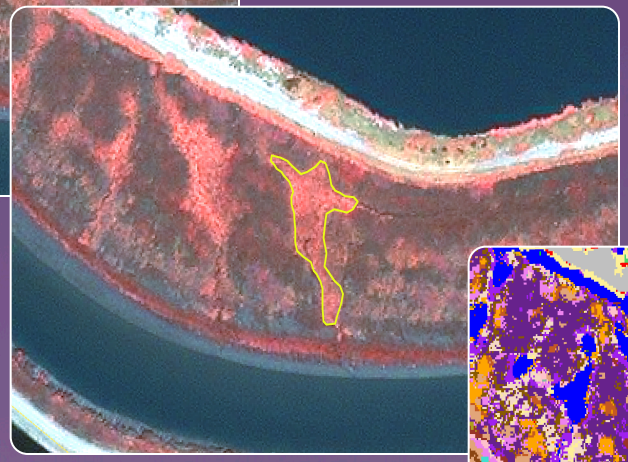
- Non-vegetative
  - **Mudflat**
  - **Mudflat with Biofilm**
  - **Algae**
  - **Wrack**
  - **Bare Earth**
  - **Water**

STEP #2: HABITAT MODEL

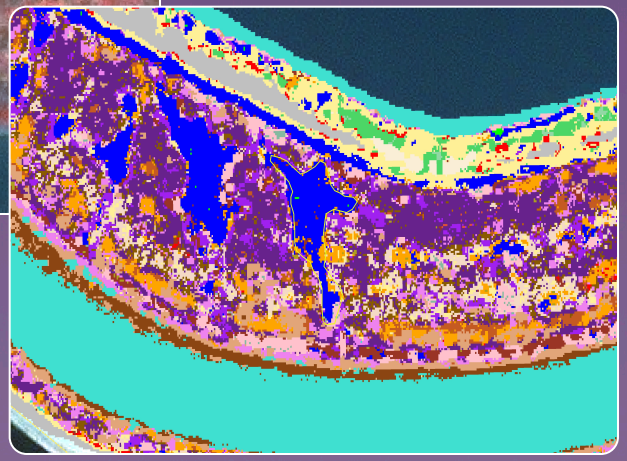
Create Training Sites (AOI)



- Point taken in field with GPS

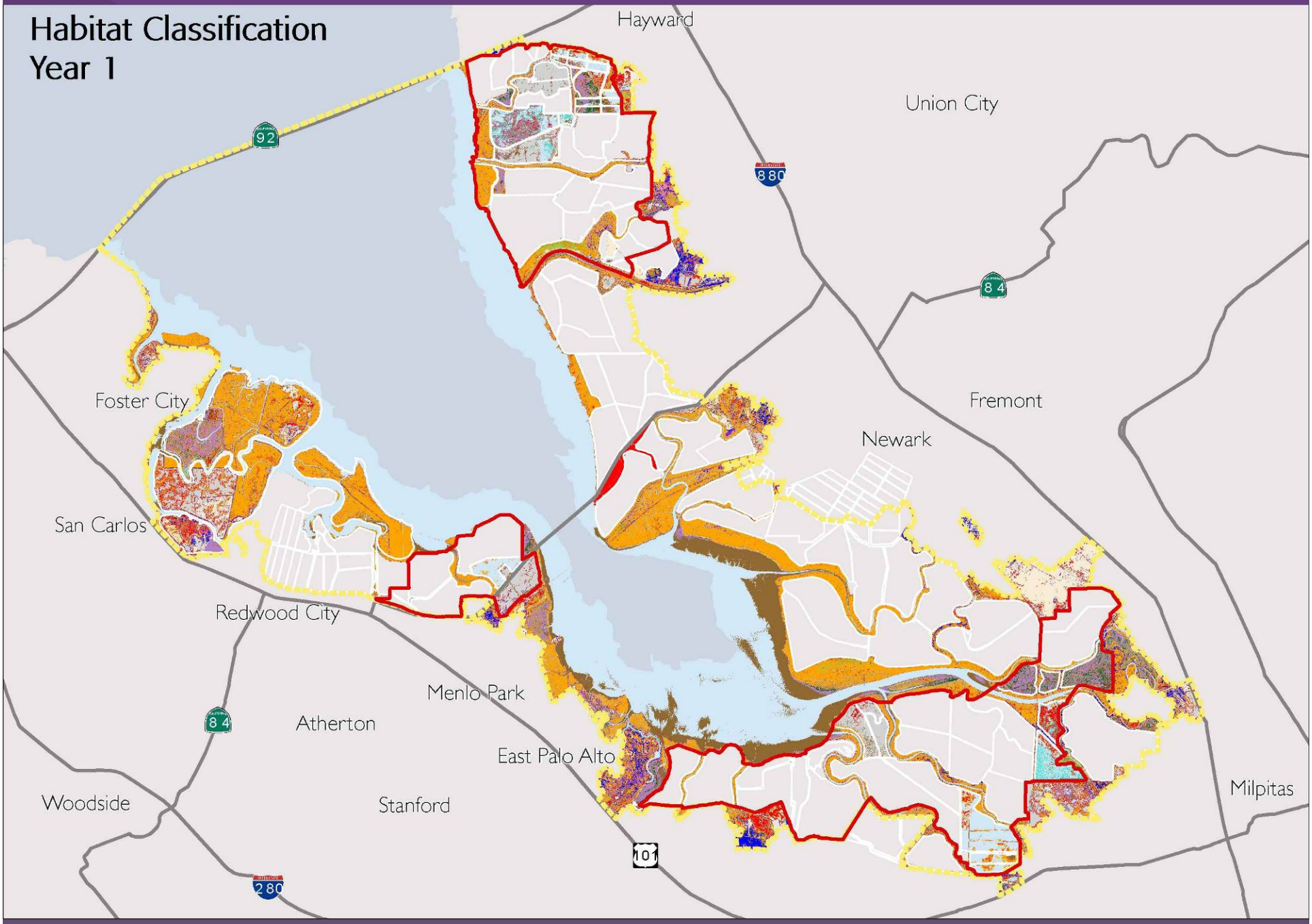


- Digitized in lab to create **training site**

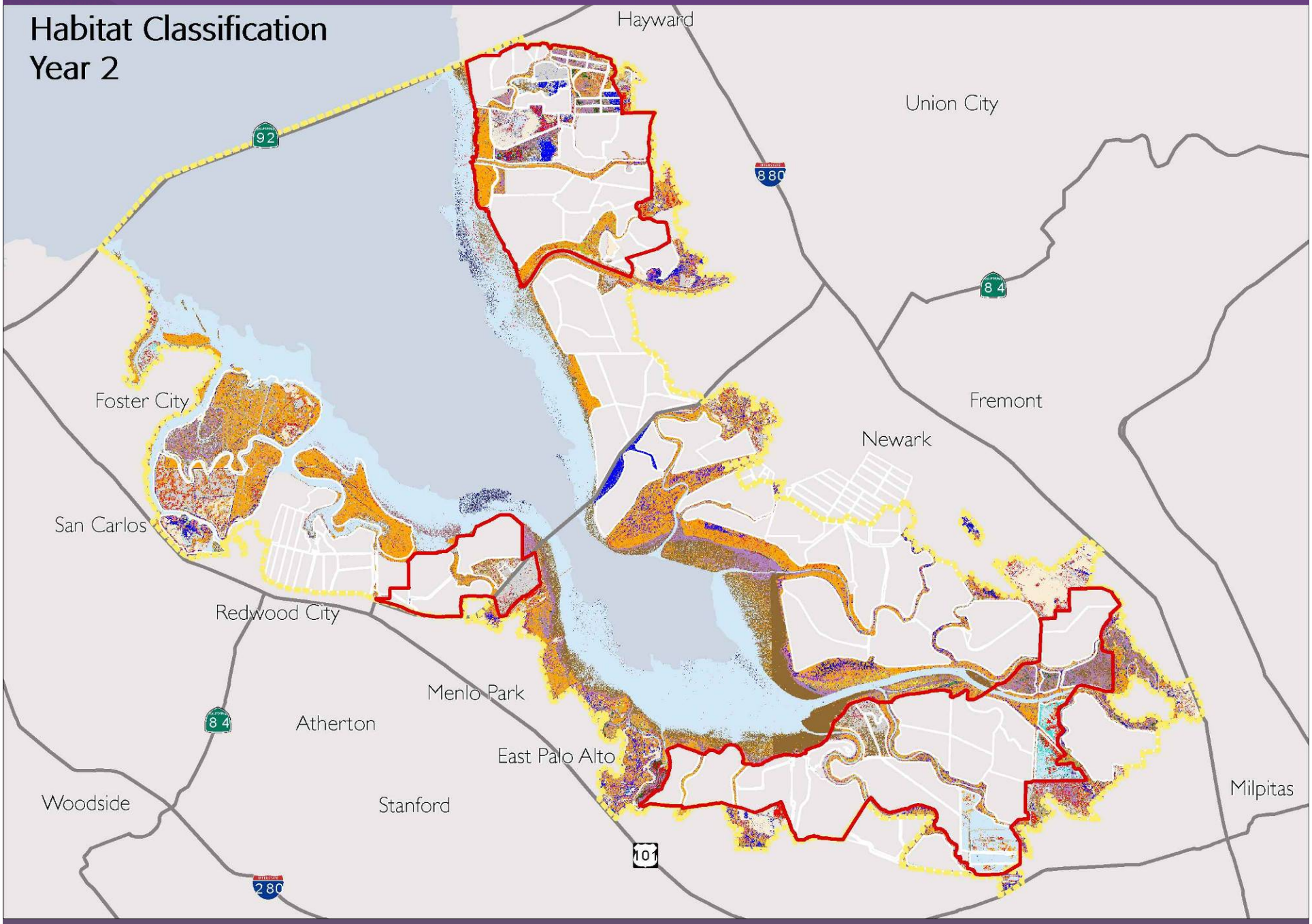


- Training sites used to create *signatures* for habitat classification

Habitat Classification
Year 1

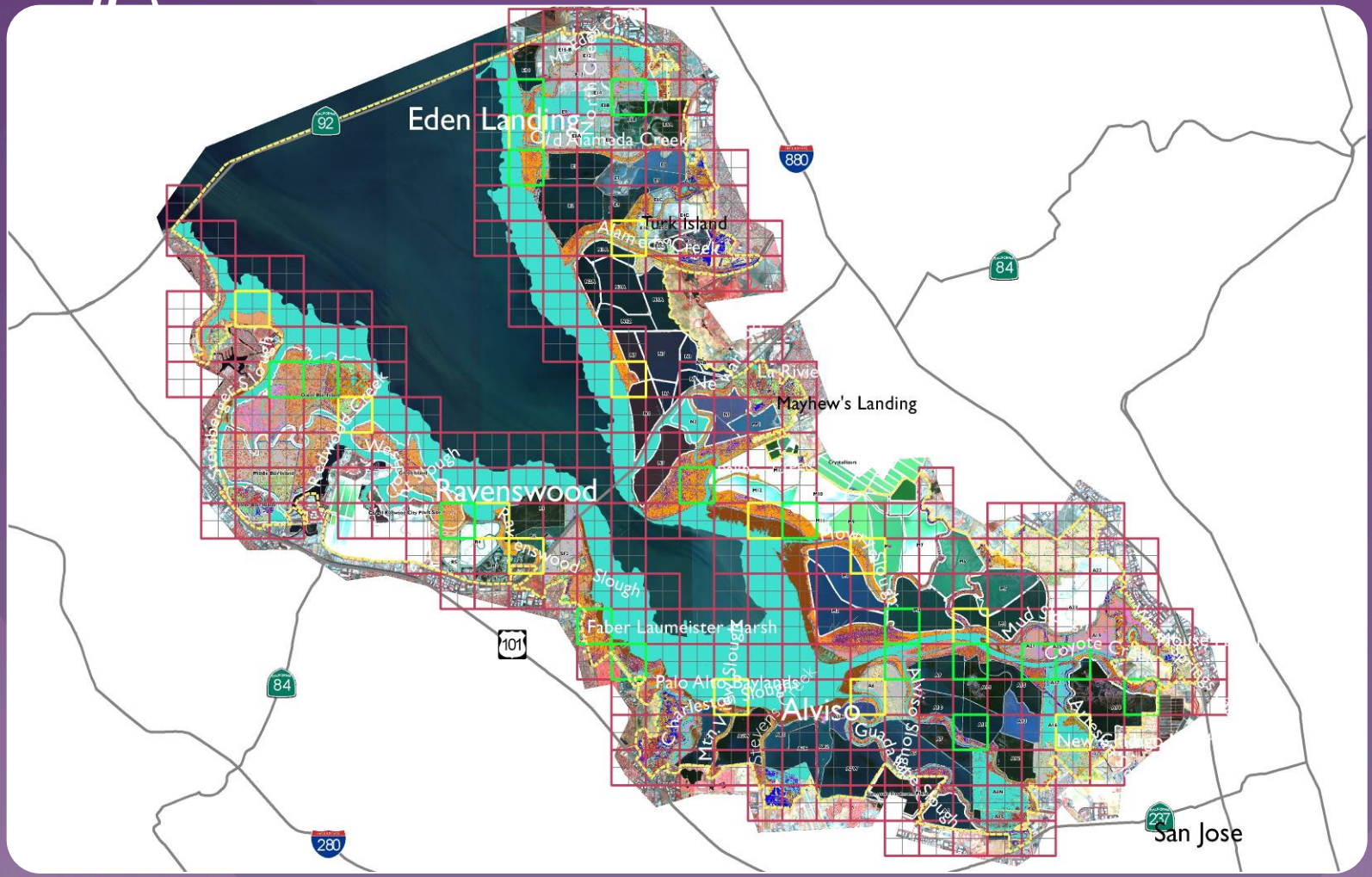


Habitat Classification
Year 2

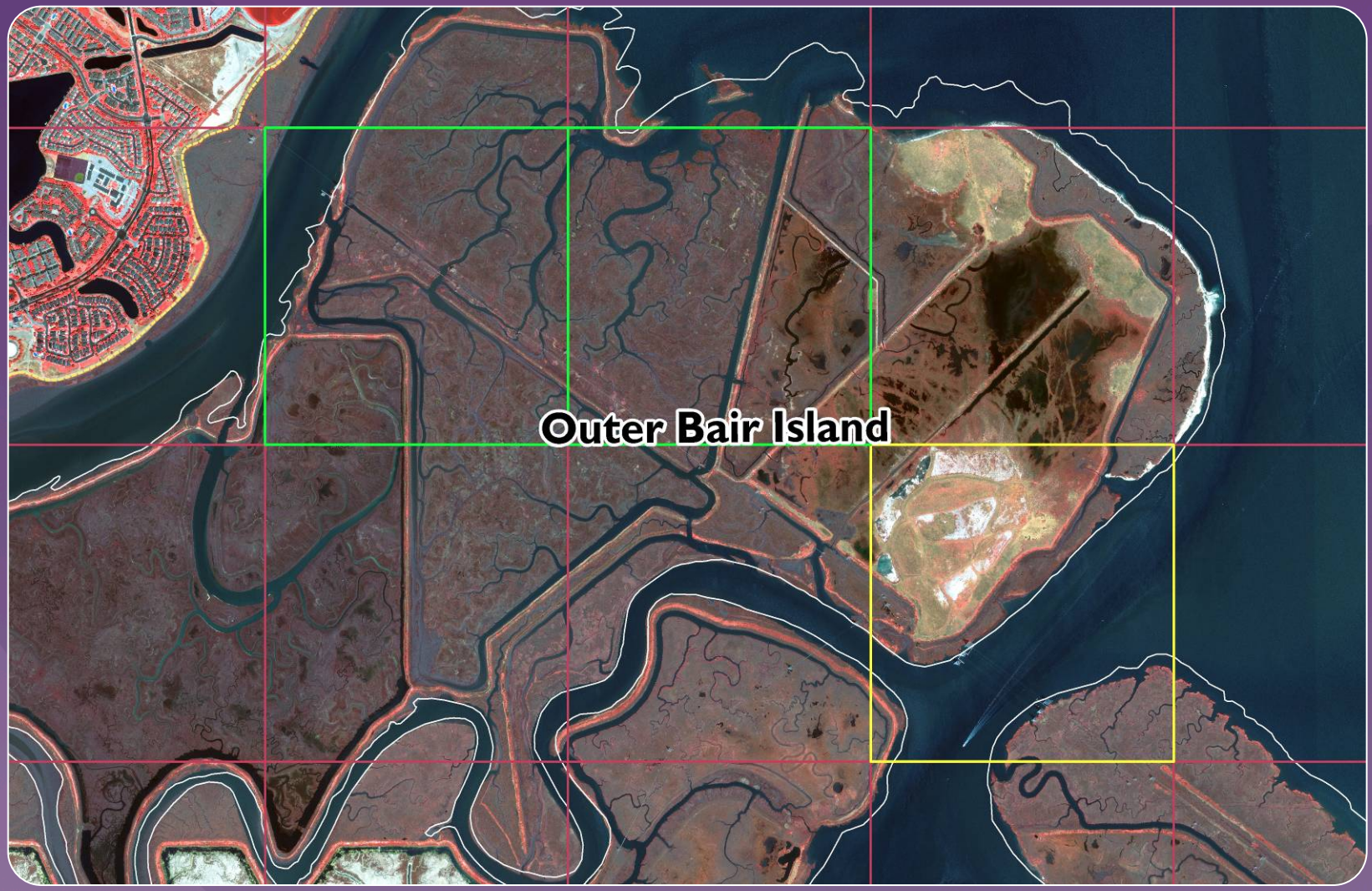


Step #3: HABITAT CLASSIFICATION REVIEW

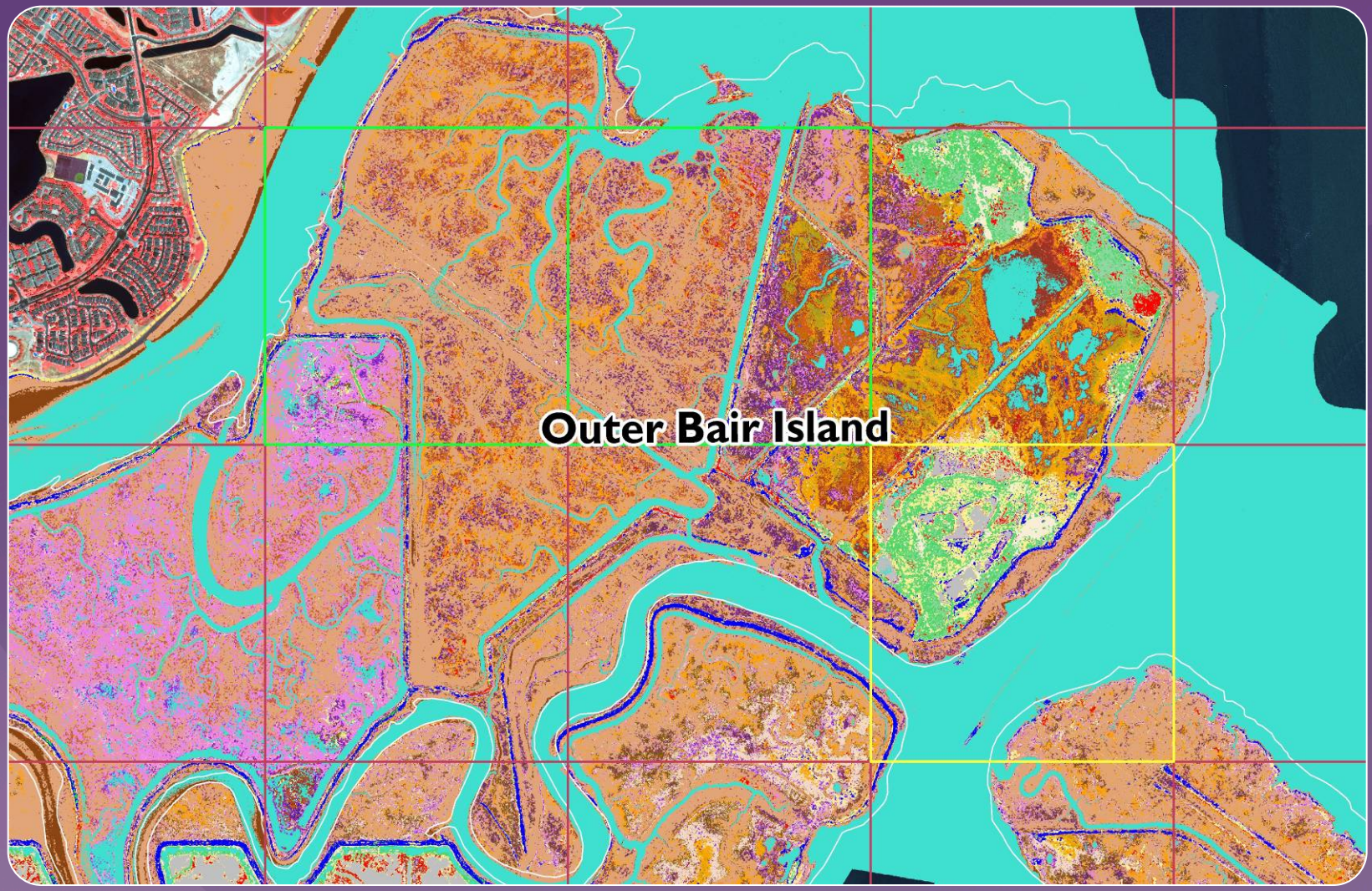
Systematic Review of Results (1/4 km2 grid



HABITAT CLASSIFICATION REVIEW



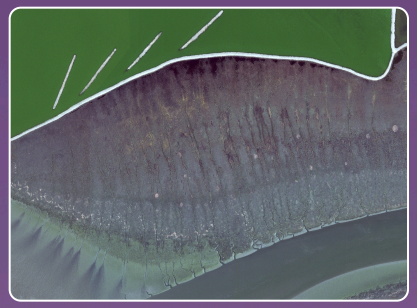
HABITAT CLASSIFICATION REVIEW



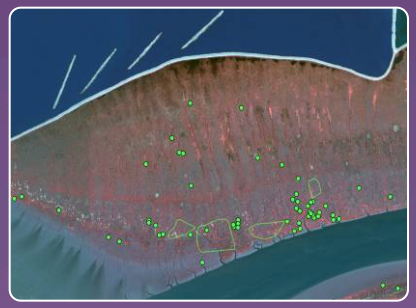
CALIBRATION WITH A RANGE OF DATASETS and HABITAT INTERPRETATION GUIDE

Habitat Ground Truthing

City of San Jose '08

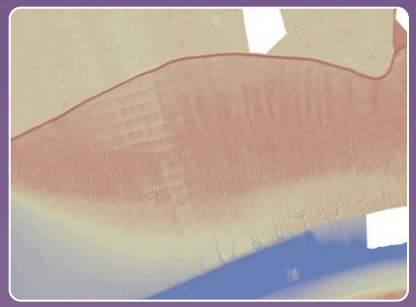


IKONOS True



Invasive Spartina Project

IKONOS False

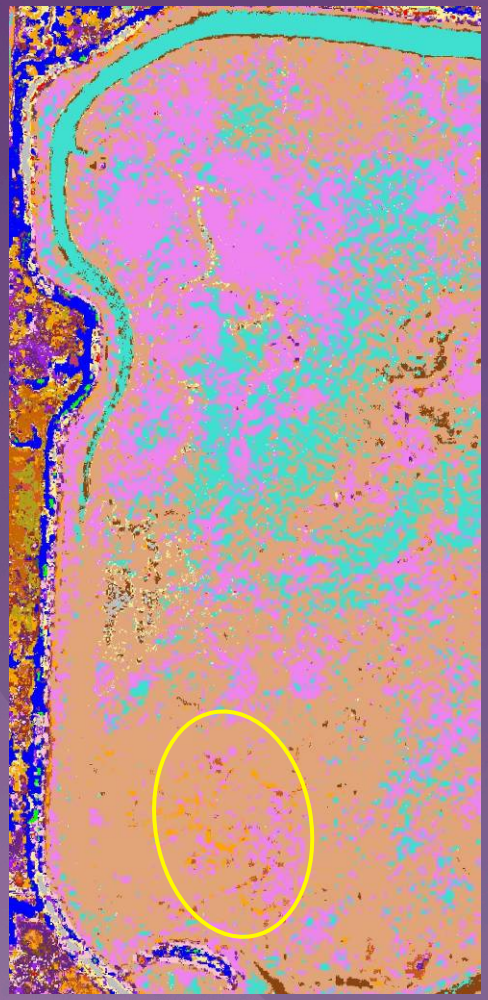


LIDAR (USGS)

CALIBRATION IN THE FIELD

MISASSIGNMENT

Pond A21 (breached in 2006)



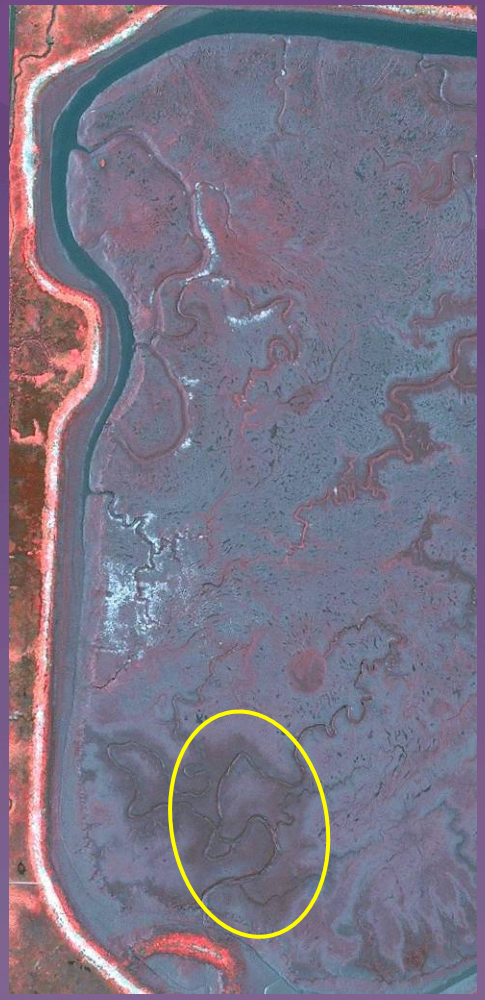
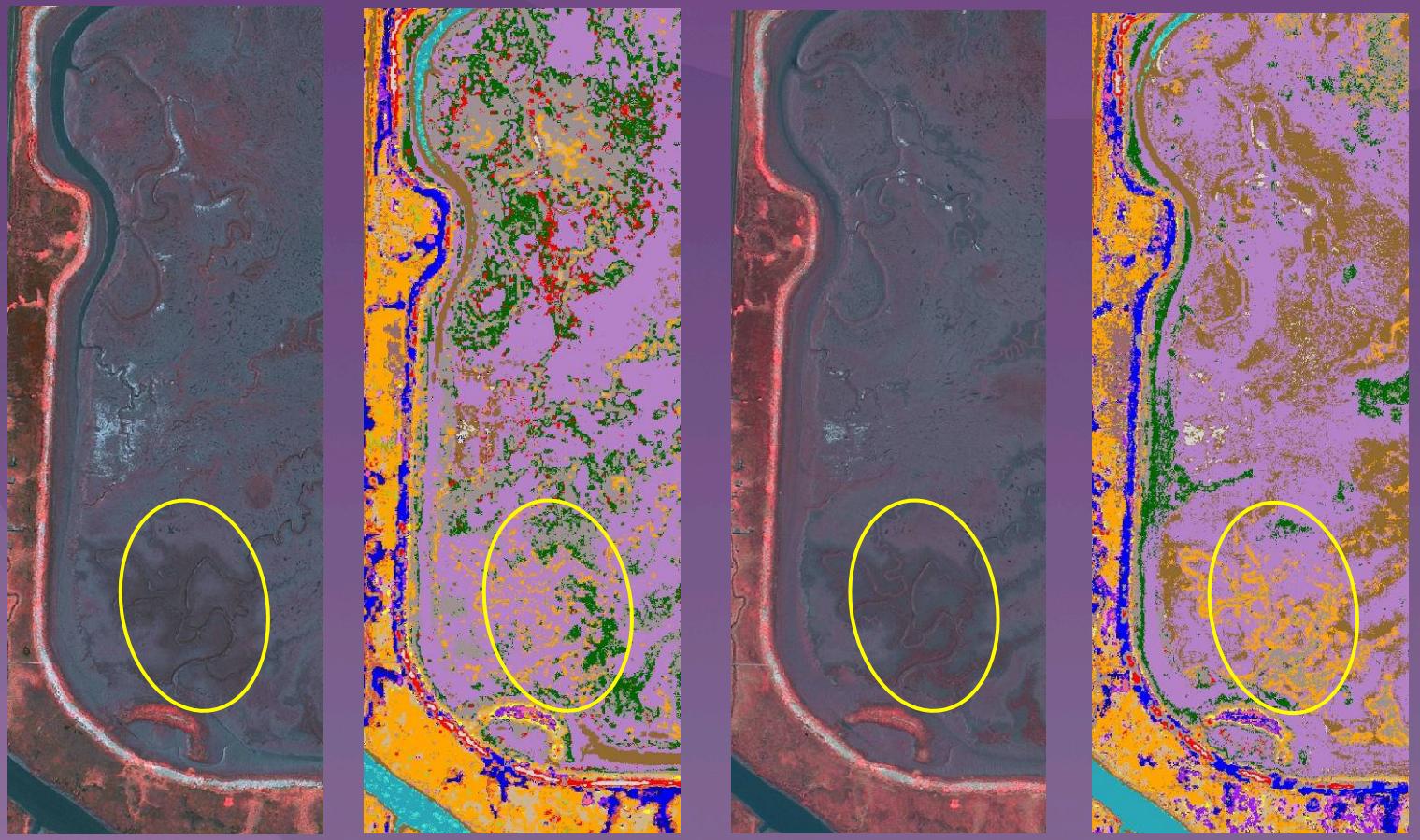


Photo Credit: Prof. Cris Benton, UC Berkeley

RE-RUN HABITAT CLASSFICATIONS

Pond A21 (breached in 2006) Improved Results

2009 IMAGE MODEL D 2010 IMAGE MODEL D

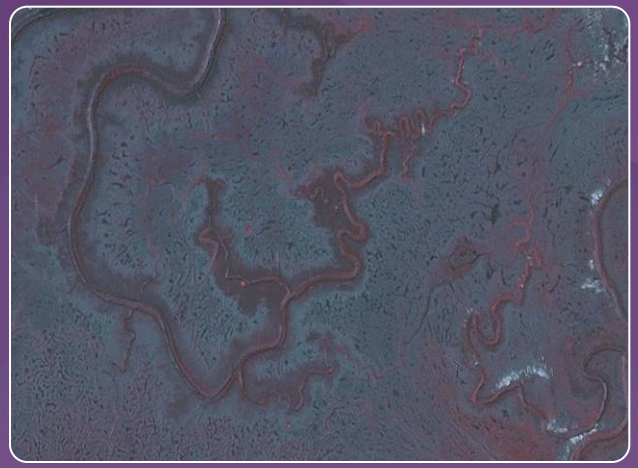


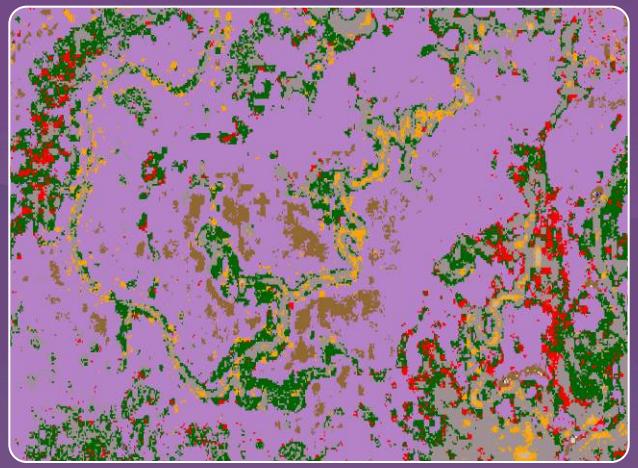
RESULTS (09-10) PICKLEWEED GROWTH ALONG CHANNELS IN A21

IKONOS FALSE

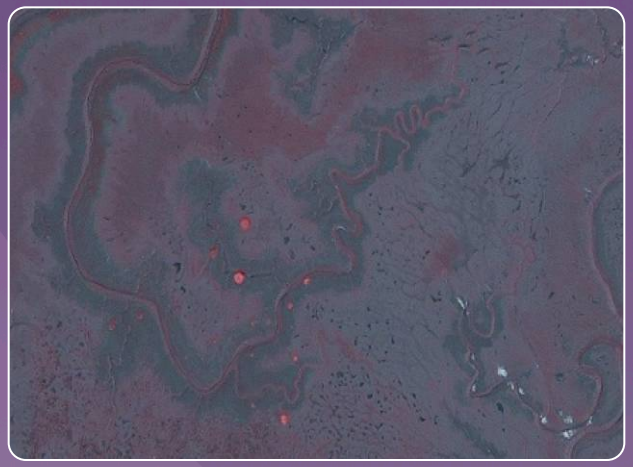
MODEL D

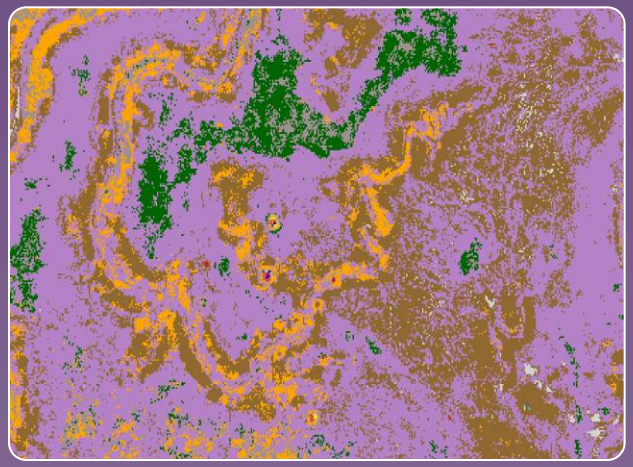
2009





2010





RESULTS (09-10) PICKLEWEED GROWTH ALONG CHANNELS IN A21

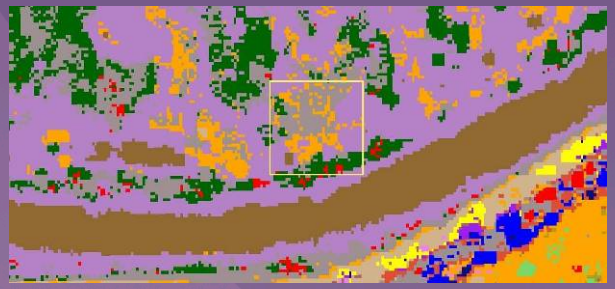
Photo Credit: Prof. Cris Benton, UC Berkeley

APRIL 2008 | SEPT 2009 | MAY 2010 | OCT 2010

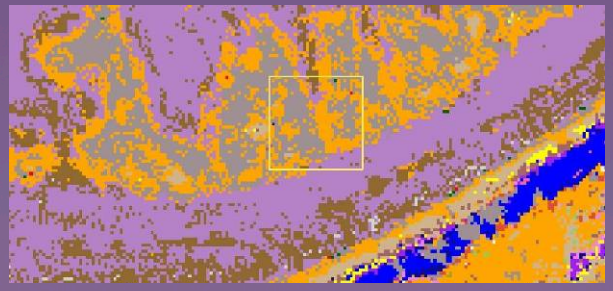
2009 IKONOS

2010 IKONOS

2009 MODEL D



2010 MODEL D

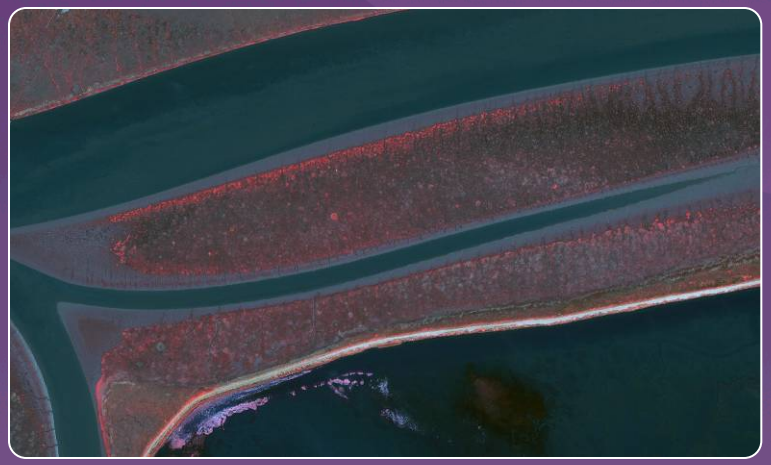


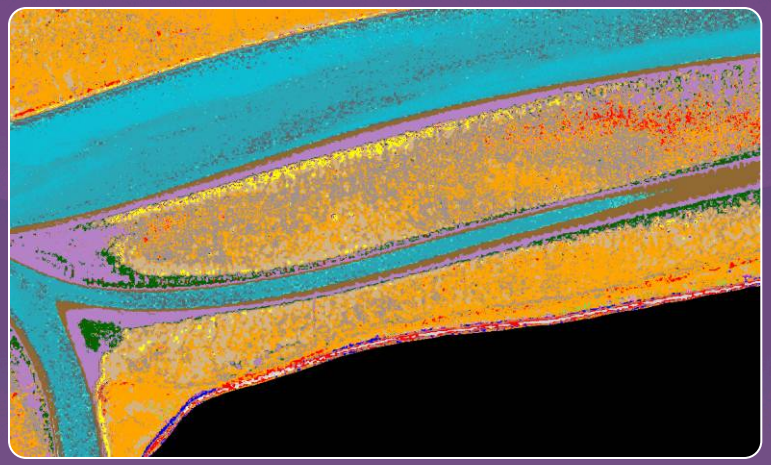
RESULTS (09-10) – "MUD ISLAND"

IKONOS FALSE

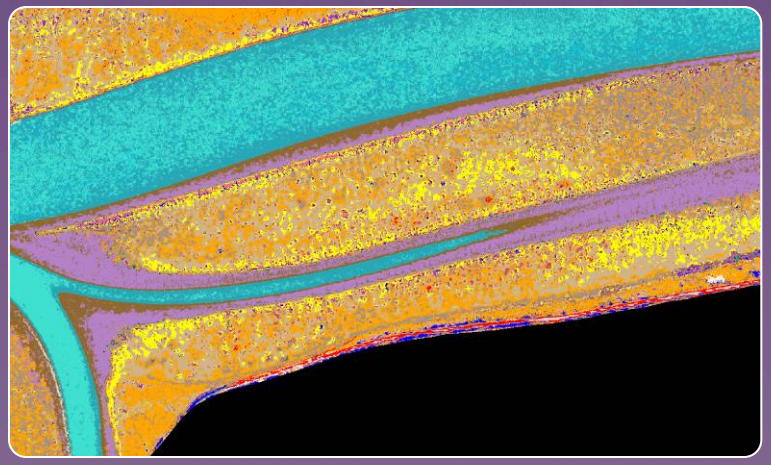
MODEL D

2009





2010

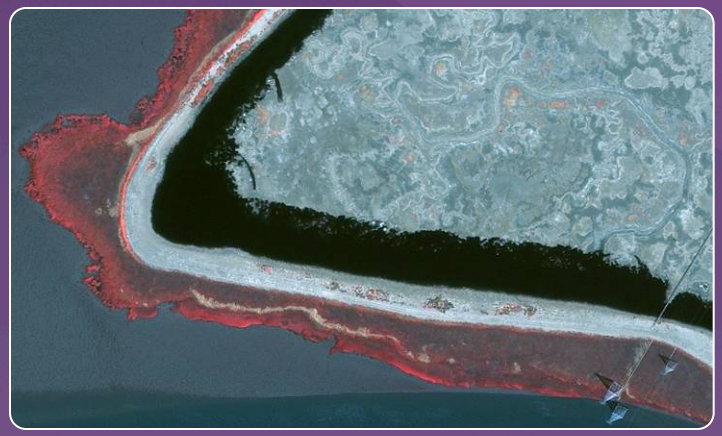


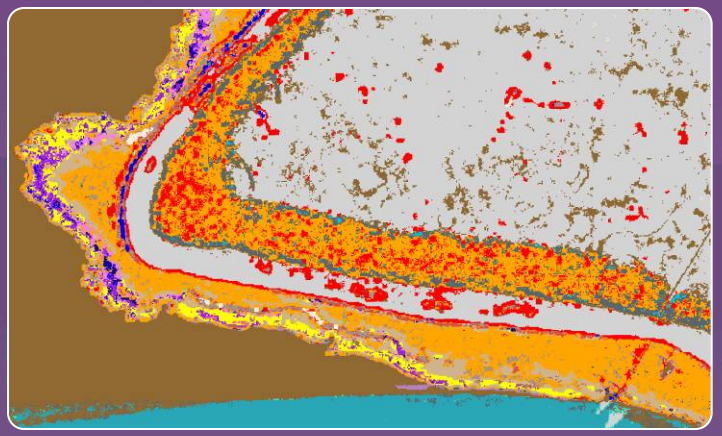
RESULTS (09-10) – SW A6

IKONOS FALSE

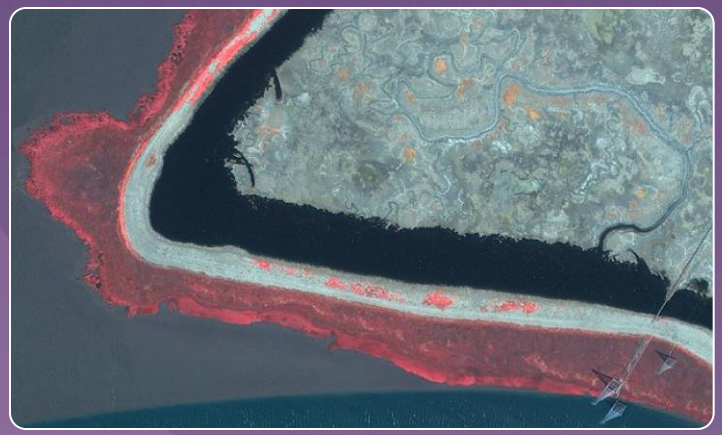
MODEL D

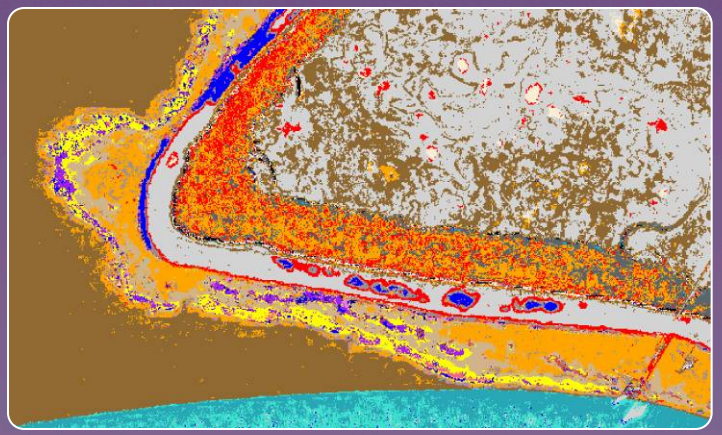
2009





2010



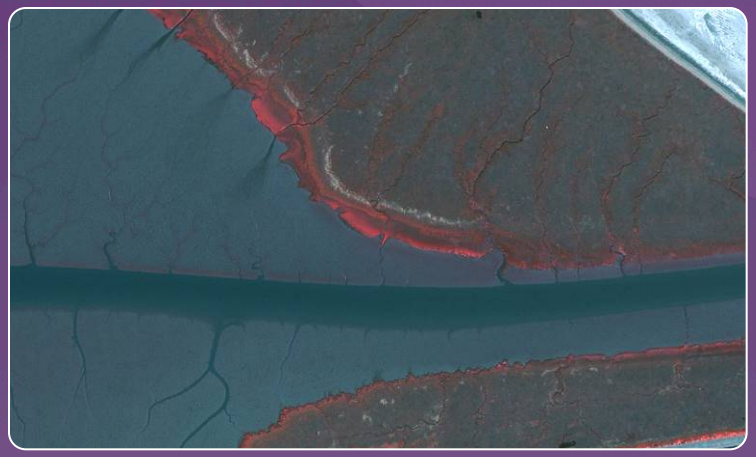


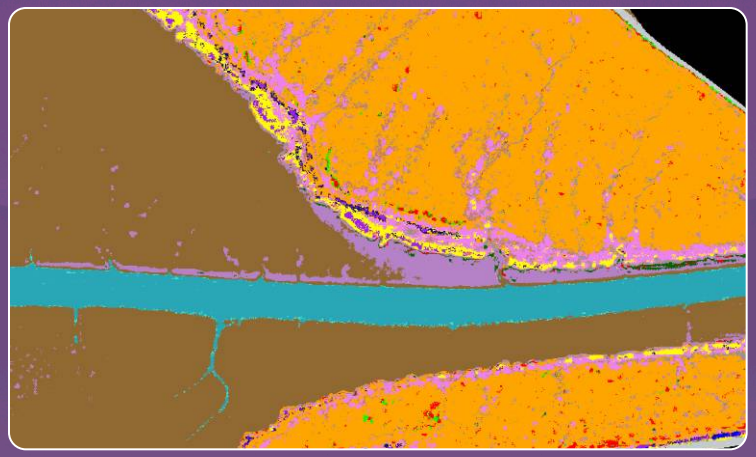
RESULTS (09-10) -- MOUTH OF MOWRY SLOUGH

IKONOS FALSE

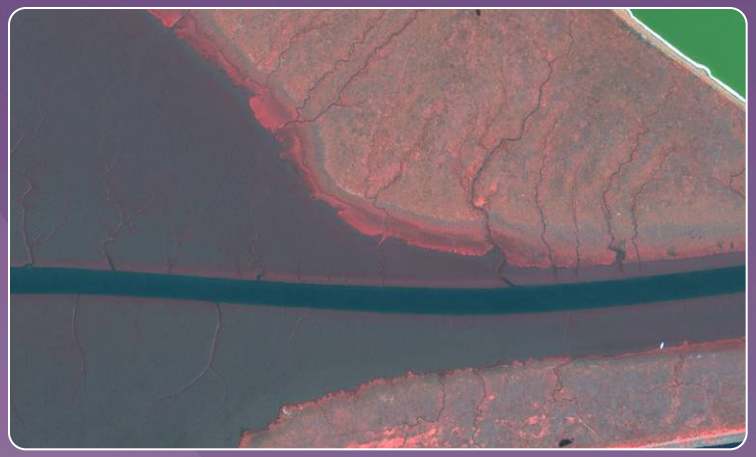
MODEL B

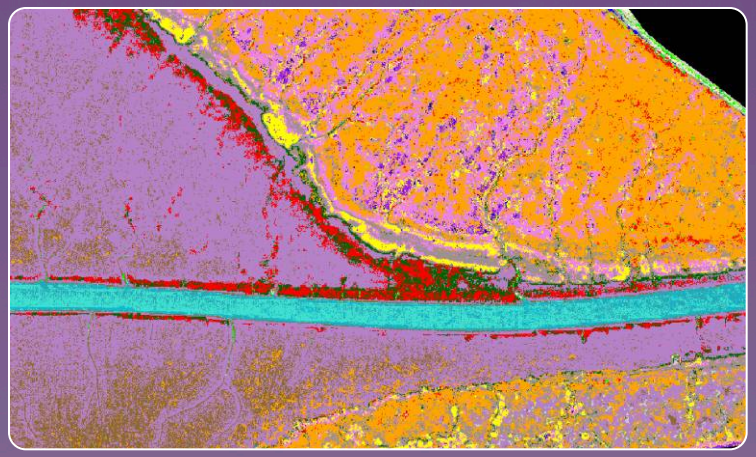
2009





2010



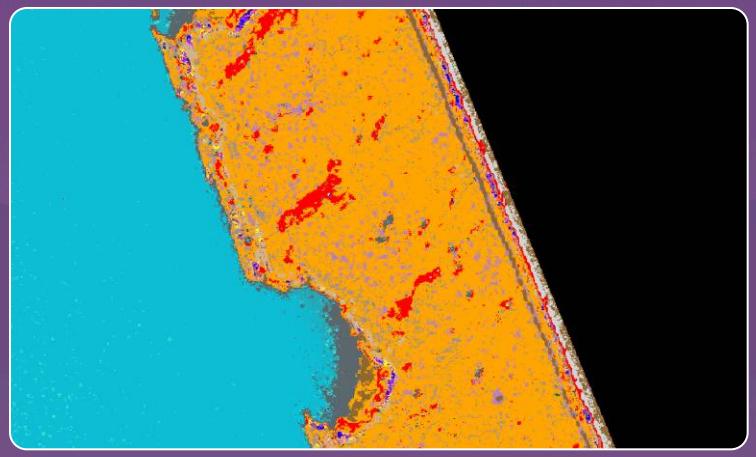


RESULTS (09-10)– WEST N5 (Variation in Plant Phenology)

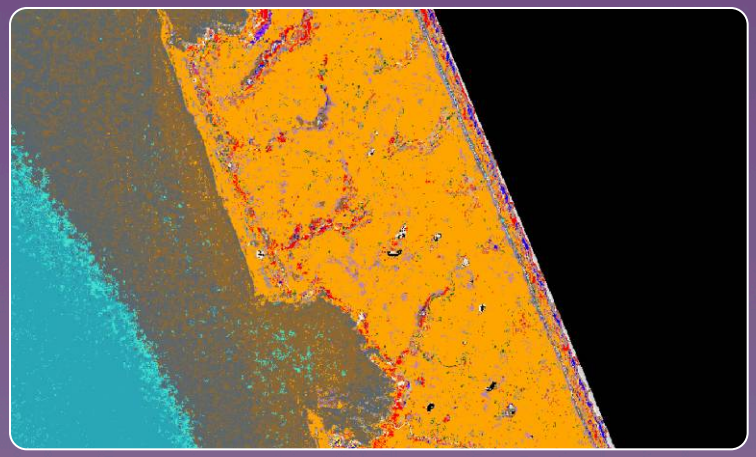
IKONOS FALSE

MODEL D

2009



2010

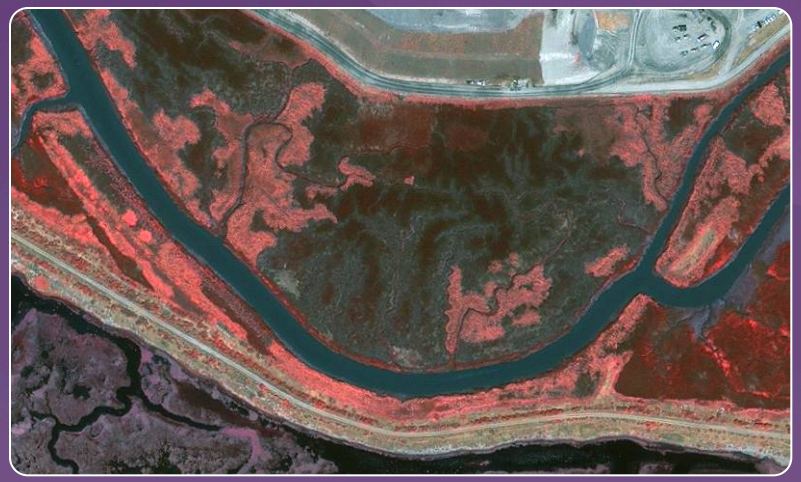


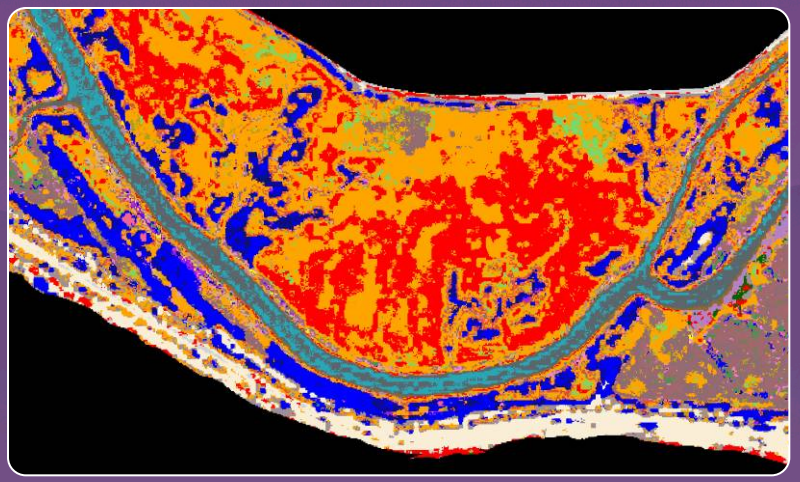
RESULTS (09-10) - E. ALVISO (VARIATION IN PLANT PHENOLOGY)

IKONOS FALSE

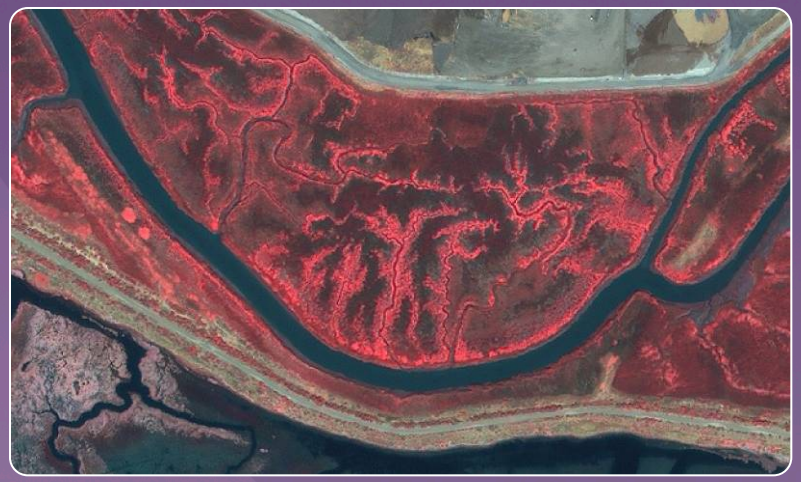
MODEL D

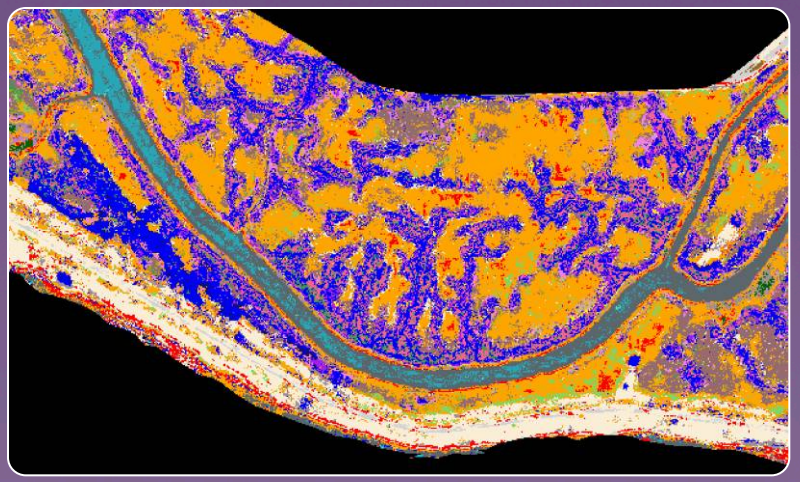
2009





2010



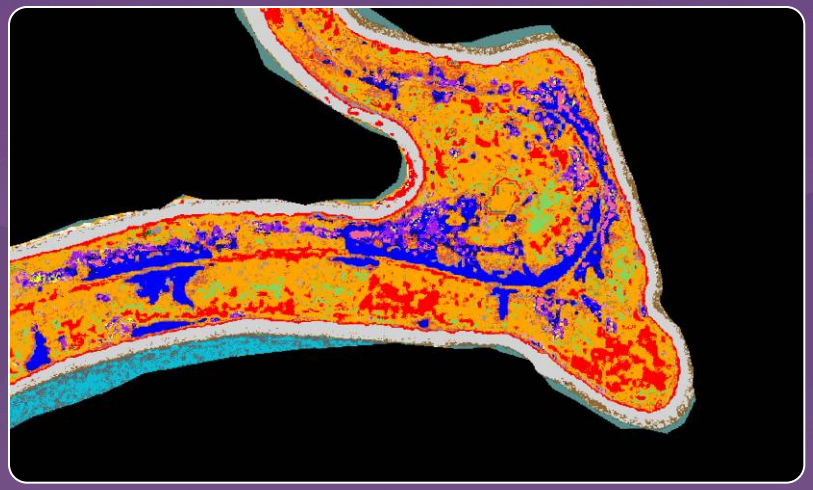


RESULTS (09-10) – N. ALVISO (VARIATION IN PLANT PHENOLOGY)

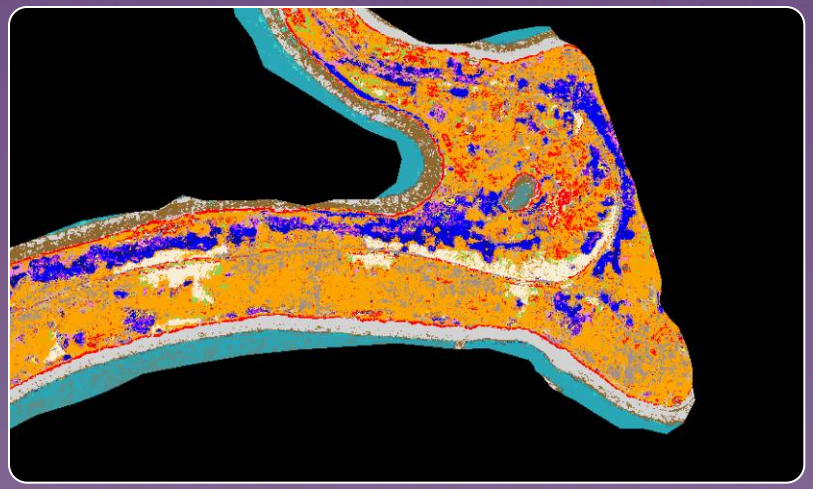
IKONOS FALSE

MODEL D

2009



2010



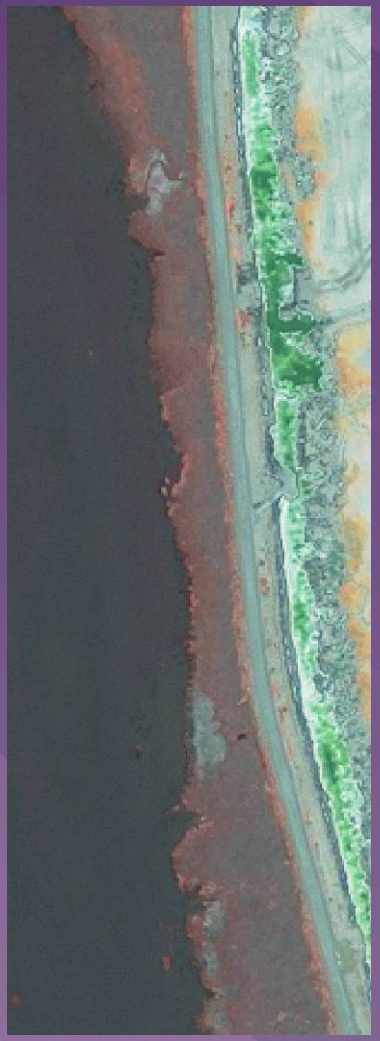
RESULTS (10)– EAST SF2 (PICKLEWEED)

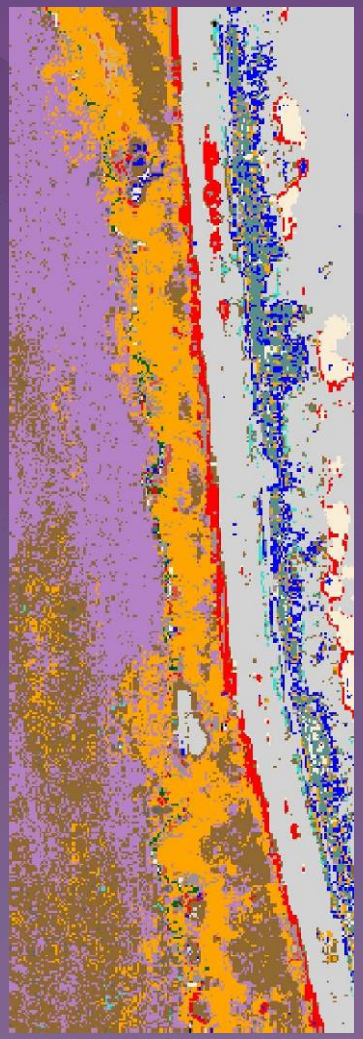
IKONOS FALSE

MODEL D

KITE PHOTO

2010





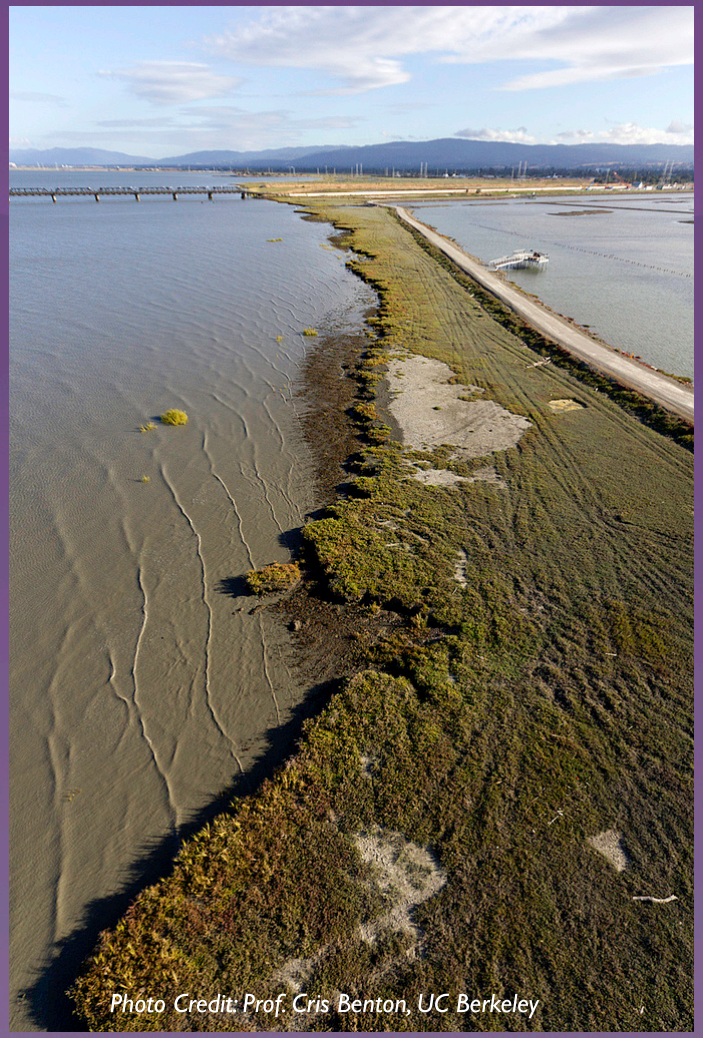


Photo Credit: Prof. Cris Benton, UC Berkeley

RESULTS (09) – NEWARK SLOUGH (MID MARSH & HIGH MARSH)

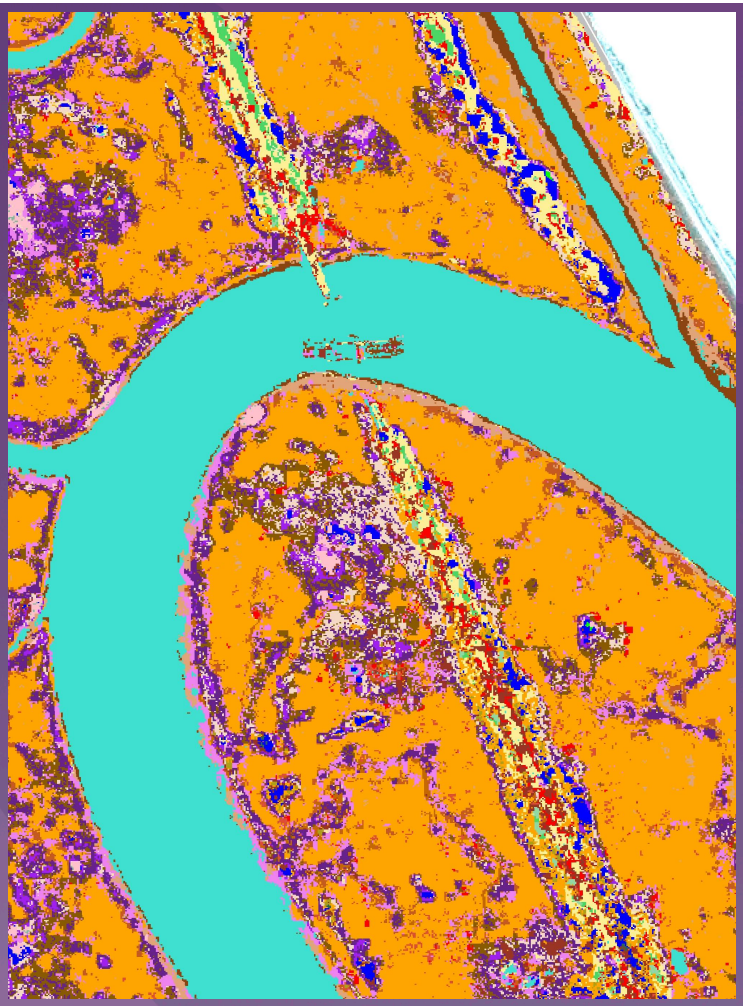


Photo Credit: Prof. Cris Benton, UC Berkeley

RESULTS (09-10) – NEWARK SLOUGH (GUMPLANT REPRESETING HIGH MARSH)

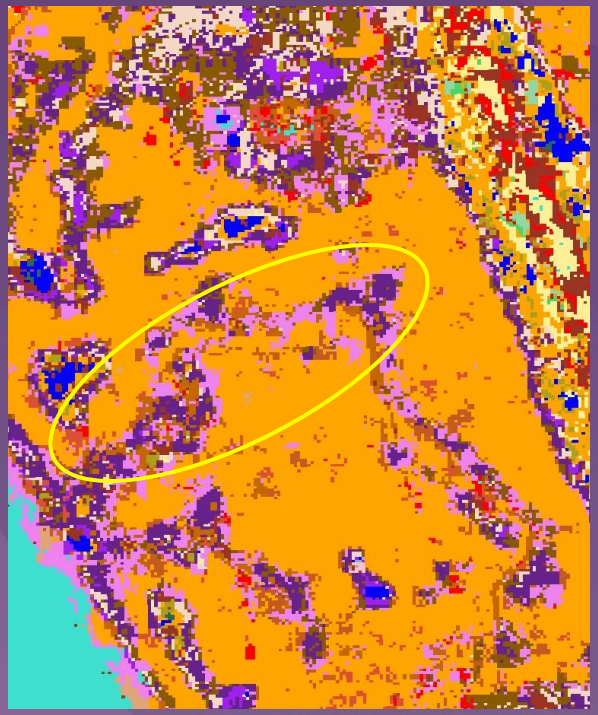


Image from Bing Maps

RESULTS (09) – "DRAWBRIDGE" (PEPPERWEED)

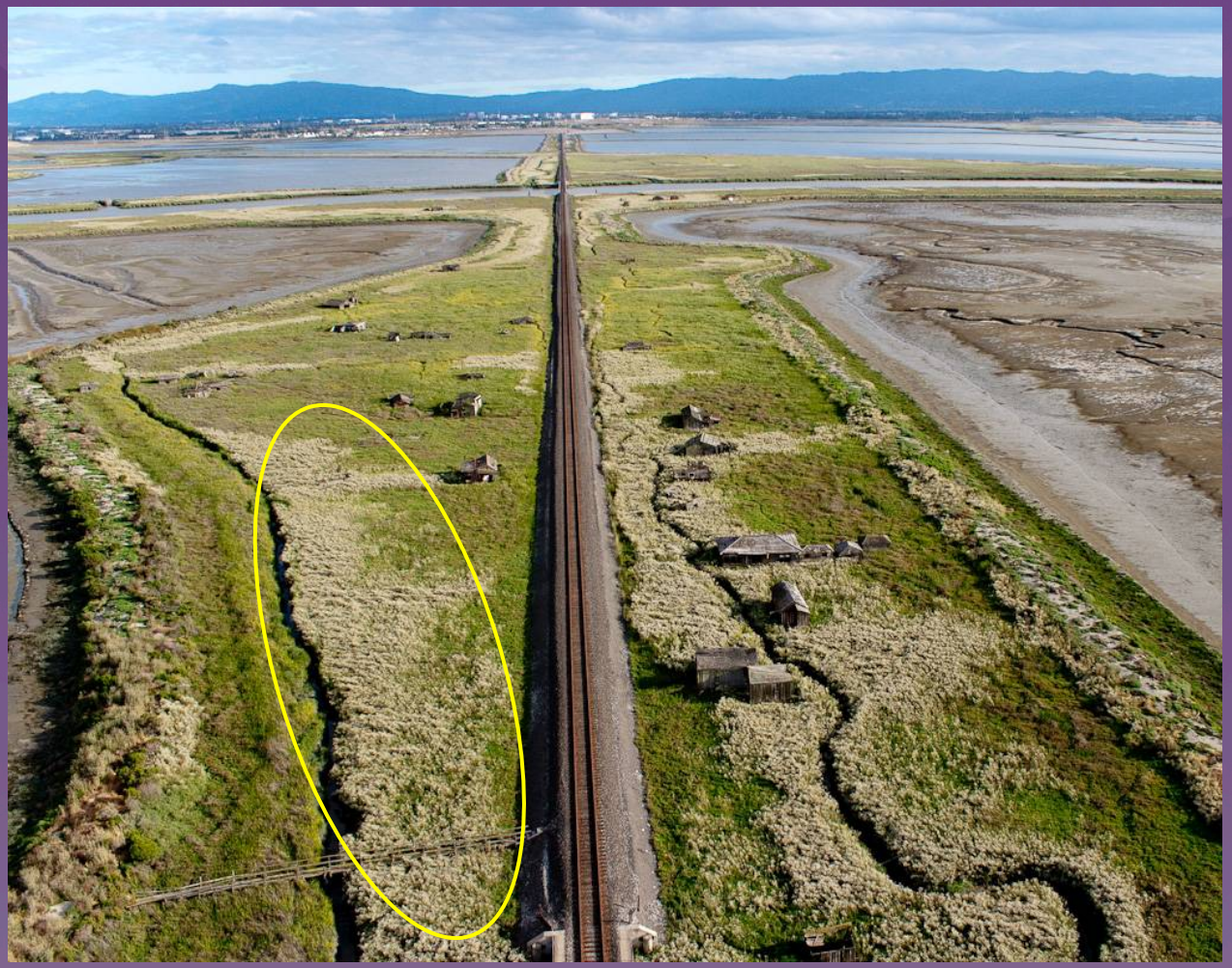
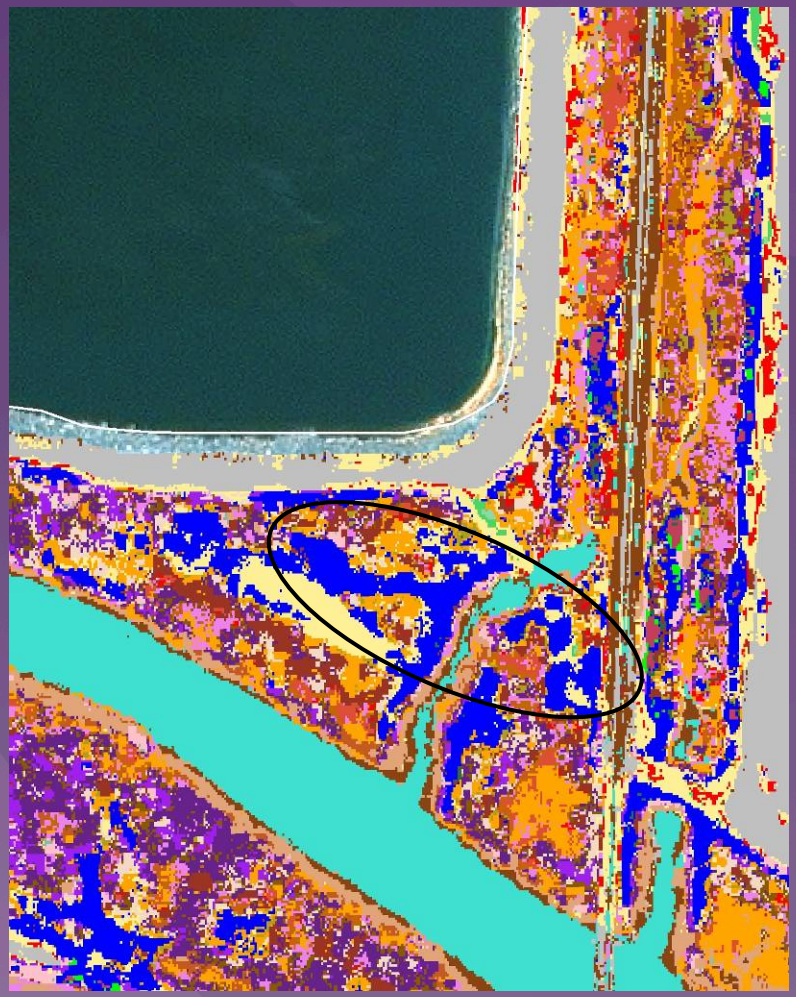


Photo Credit: Prof. Cris Benton, UC Berkeley

RESULTS (09) – "DRAWBRIDGE" (PEPPERWEED)



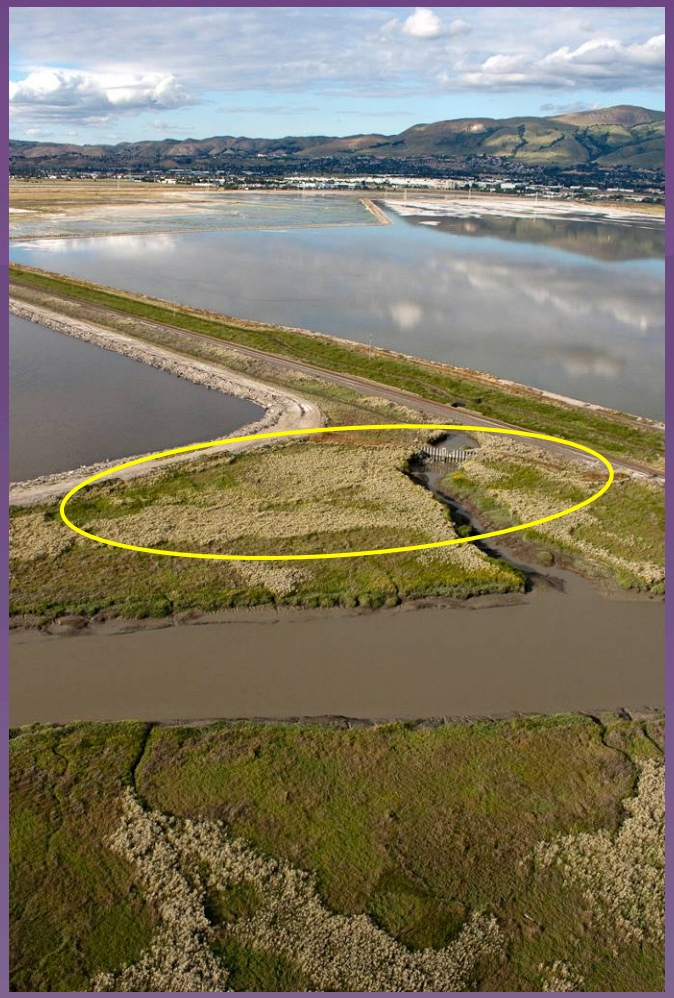
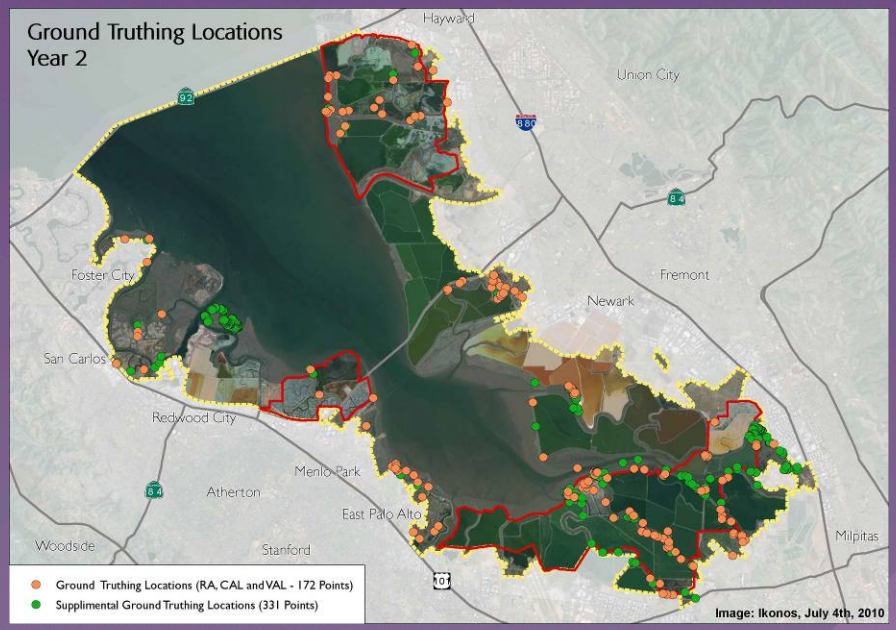


Photo Credit: Prof. Cris Benton, UC Berkeley

Step #4: MODEL VALIDATION

- Already collected validation data in the field for Year One and Year Two
- Currently running validation on final habitat classification



METHOD LIMITATIONS AND ISSUES

1. Complex Levee Communities
2. Spectral Mixing & MMU
3. Phenology
4. Image Normalization

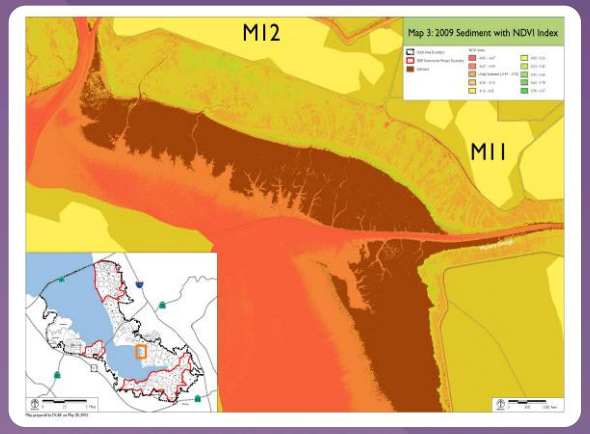
Slender-leaf Iceplant

Saltwort

SEDIMENT MAPPING ISSUES WITH SATELLITE IMAGE

- Time window for matching Ikonos acquisition time (~Noon) with optimal tides (MLLW) is difficult!
  - 2009 (mean tide)
  - 2010 (MLLW)
- NDVI index image (2009) captures mud beneath water

NDVI 2009

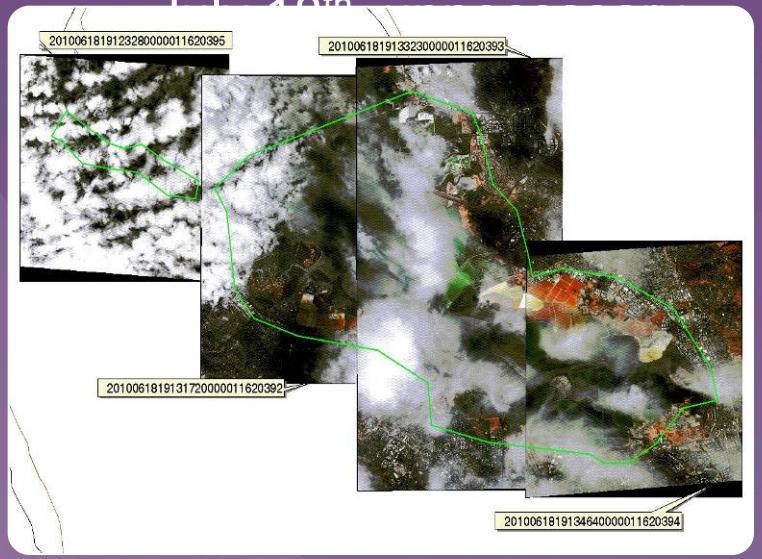


IKONOS TRUE 2009

IKONOS TRUE 2010

SATELLITE AQUISITION ISSUES FOR YEAR 2

- Only 3 attempts at low tide (MLLW) with noon lighting
  - June 18th, optimal tide (Failed—too much cloud cover—EX below)
  - July 4th, good tide (Success—see EX below)



YEAR TWO UPDATE

- **Fine tuning *training sites* for *final habitat classification***
- **Running *validation* [accuracy assessment and Root Mean Square (RMS) error] on *final habitat classification***
- **Preparing for Year Three:**
  - **Additional improvements to high marsh and biofilm**
  - **Improve image normalization**
  - **Incorporate Tidal Datum interpolations by Gavin Archbald (SFSU)**
  - **Consider use of GeoEye (.5**

Panne with surrounding diverse vegetation near Bair Island *Dec 2011*

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DESIGN, COMMUNITY & ENVIRONMENT

SOUTH BAY SALT POND RESTORATION PROJECT

Habitat Evolution Mapping Project

Questions?

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