



# Levee Assessment via Remote Sensing

## Levee Assessment Tool

### Prototype Design & Implementation

User-Friendly Map Viewer  
Novel Tab-GIS Interface  
Extensible GIS Framework  
Pluggable Tools & Classifiers

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By  
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## LEVEE ASSESSMENT TOOL

As part of the DHS SERRI project, “Screening of Levees by Synthetic Aperture Radar” prototype mapping software called the *Levee Assessment Tool* (LAT) was developed to enable visual depiction and manipulation of geodata layers and images utilized and developed in the project. In addition to capabilities to visualize standard geodata layers and remote sensing inputs, the LAT demonstrates capabilities to manipulate and load complex SAR datasets and the capabilities to integrate selected feature detection and classification algorithms implemented as MatLab executables developed by the team.

The LAT incorporates a user-friendly interface that provides general capabilities to open, save, and close LAT projects (.lat extension files), zoom and view controls, data layer controls, and viewer tab controls. The LAT was designed and built upon open-source tool to provide an open geospatial platform that is highly interoperable with other mapping products and extensible to future enhancements and extensibility. The software development team prototyped and tested basic data handling capabilities, data manipulation utilities, and the integration of feature detection software which is built into the final package.

The prototype tool builds on the MapWinGIS open source geospatial software library, integrates OSGeo and GDAL, and embeds MatLab functions for anomaly detection and feature classification of the SAR input data. This powerful combination enabled the team to develop a tool which implement familiar GIS functionality and advanced classification capabilities without requiring the end user to purchase a commercial GIS license. MapWinGIS, itself developed through NSF sponsored research and development, has been used extensively as part of the Nation Science Foundation sponsored Consortium of Universities for the Advancement of Hydrologic Sciences, Inc (CUASHI) by the Universities Allied for Water Research and forms the basis for the hydrologic information system tool, HydroDesktop.



**Open-source component technologies incorporated in the Levee Assessment Tool as well as the example HydroDesktop tools which are built on the same open-source components.**

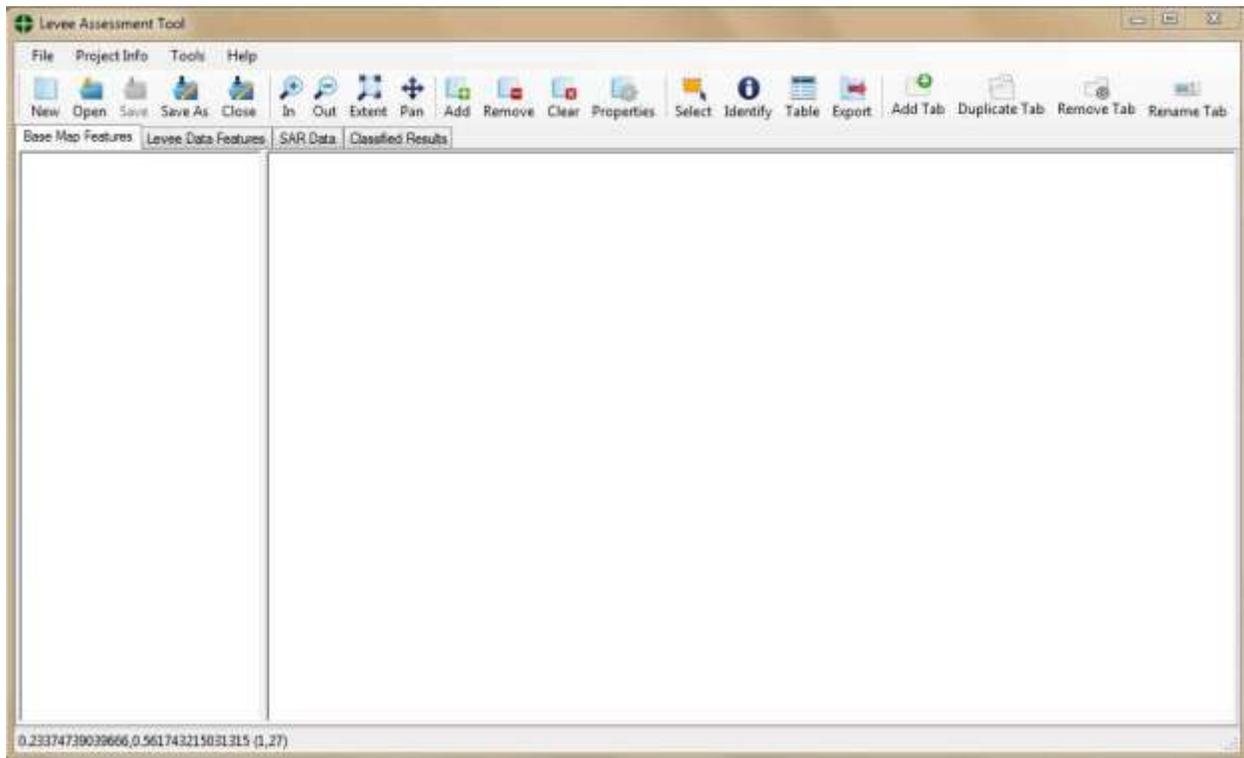
## 1.0 MULTI-TAB LEVEE ASSESSMENT TOOL

The unique multi-tab GIS mapping interface concept, similar to modern web browser interfaces, arose from early requirements discussions among research team members regarding the need to organize, identify, and manage a variety of basemap geospatial data themes, levee information data layers, SAR data inputs, data products, and decision results.

The multi-tab interface was formalized as a requirement in the software design to provide a highly flexible and configurable set of separate map frames, each providing a clear depiction of data organized to provide a desired view, to present data for a specific workflow, or to show data organized by thematic categories. In discussing these requirements with USACE and project partners, the needs assessment and discussion led to ideas and designs for the browser-like multi-tab design for the GIS tool. The requirements were distilled into a group of high-level capabilities as follows:

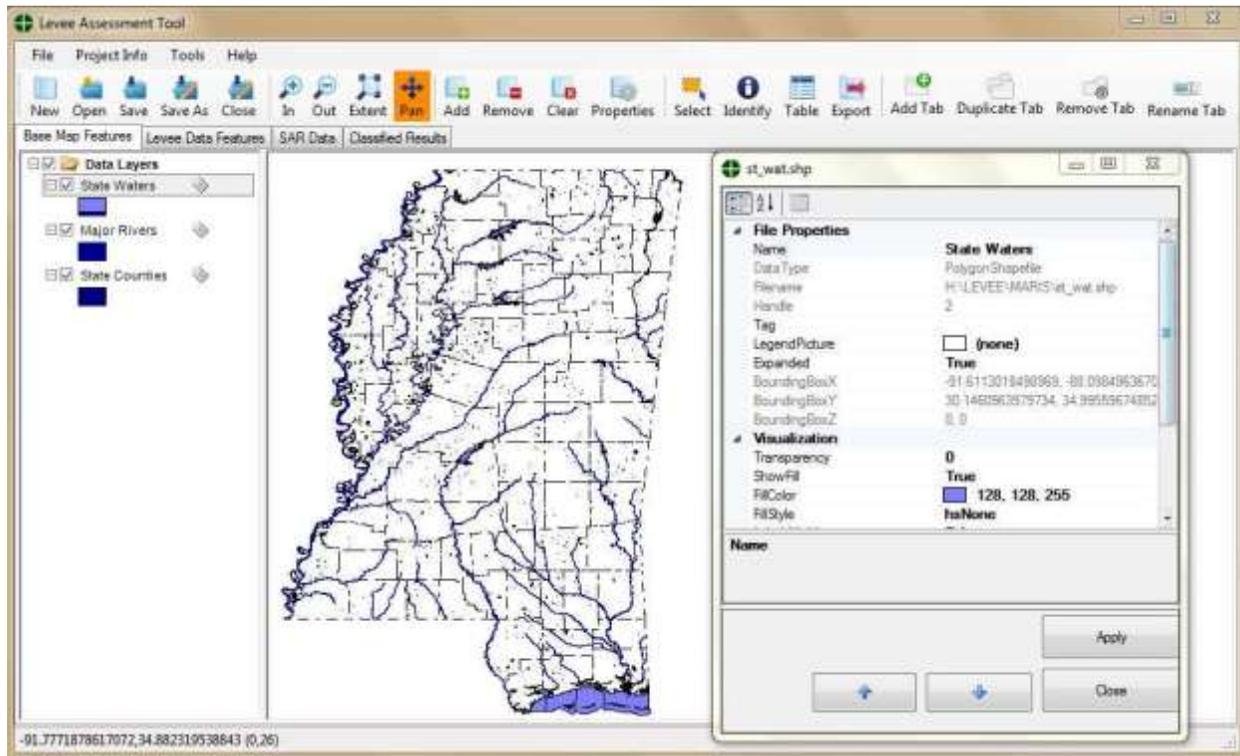
- A GIS interface will enable using and managing separate tabs with data and legend views;
- Main menu and interface tools may be used based on the active tab and data set(s);
- The separate tabs, their names, contents and ordering may be easily manipulated;
- The map information contents of each tabs may be listed separate or as part of groups; and
- The individual data layers or groups may be easily copied or moved between tabs as desired.

The multi-tab concept, requirements, and capabilities were followed in developing the working prototype Levee Assessment Tool (LAT) interface, shown in Figures 1 and 2.



**Figure 1. The Levee Assessment Tool interface with multi-tab interface design. Tabs may be added, named, and manipulated to present and organize data as desired.**

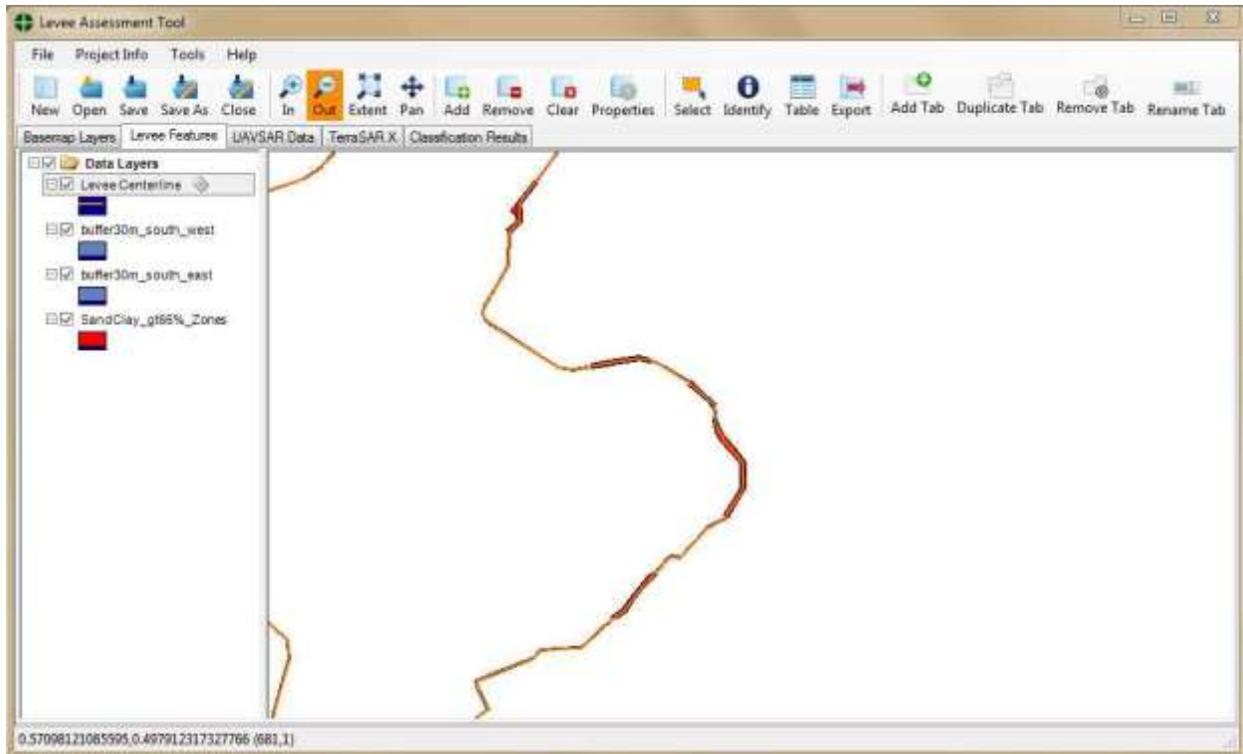
As shown in the project view in figure 2, tabs have been created for Base Map Layers, Levee Data Features, SAR Data, and Classified Results. The view below shows basemap layers added for the state of Mississippi, water bodies, and streams. For individual layers, the names of the shapefiles shown in the legend may be changed, symbologies may be manipulated, and data displayed as desired by the user through a simple properties interface.



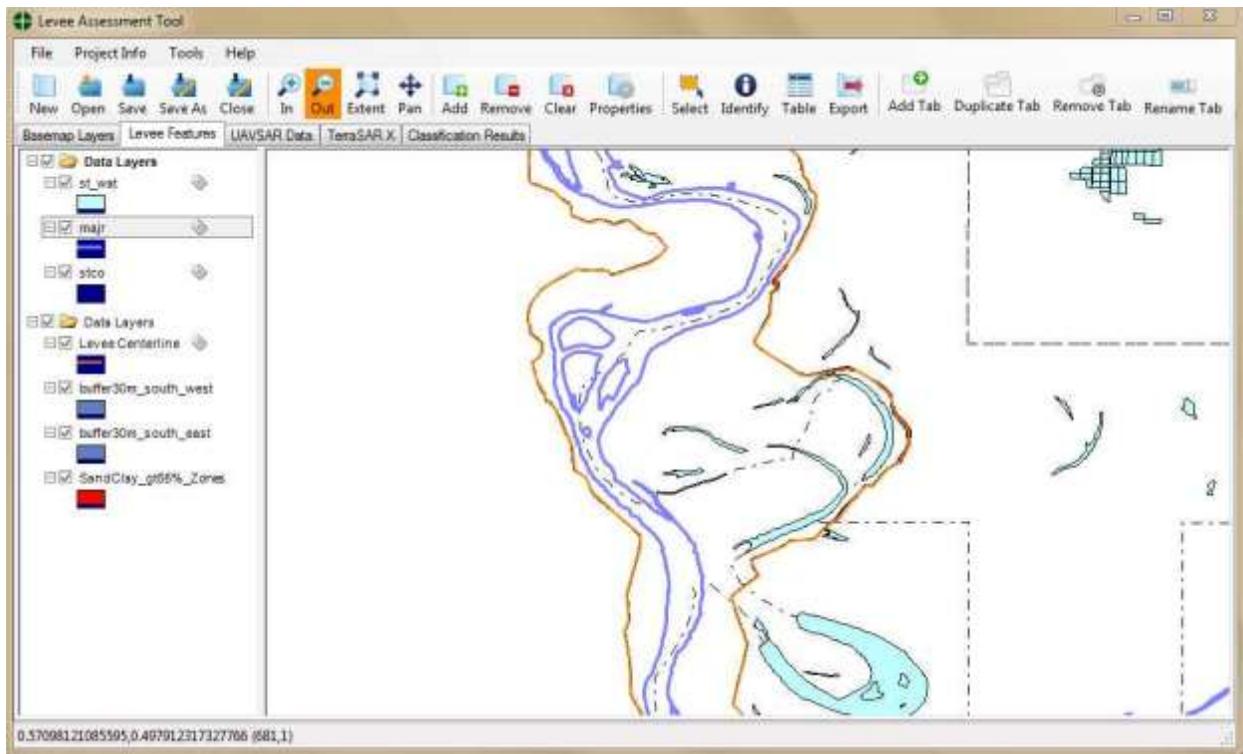
**Figure 2. The LAT interface with Base Map Layers populated. The properties for each layer may be accessed and set for line color, fill, transparency, and point symbol, color, and size. In this case, properties are shown accessed for the shapefile st\_wat.shp which has been renamed as State Waters and given a light blue line color.**

A wide variety of data files were used in the project to analyze levees and their context. Layers such as levee centerline files, buffered levee lines, locations of historic levee slides, and locations of sand boils in the vicinity of levees were employed. In addition, to evaluate the content of areas around levees, features such as soils, geomorphology, and geologic features were utilized in the project. Assessments were conducted to analyze the composition of soils in terms of sand, silt, and clay fraction as well as geologic features with respect to the location of slides and sand boils to gain insight as to the occurrence of these faults and to attempt to quantify and correlate the occurrence of faults with material properties.

In preparing data files for use in the application, since the UAVSAR data were provided in geographic coordinates and other location information was largely collected in geographic coordinates, it was decided that all data for the LAT would be in geographic coordinates with WGS84 defined as the common datum for data to be utilized. This standardization alleviated the software development team from the requirement to have to support automated ‘project on the fly’ capabilities which could have been integrated, but would have required that all geodata sets utilized be fully defined in terms of the spatial reference systems (SRS), geographic coordinate system (GCS), projected coordinate system (PCS), and datum for each data set. In addition, reprojection and ‘project on the fly’ would have required the tool to take a major performance hit in operation to handling raster reprojection of large SAR files.



**Figure 3. Levee Features tab with data depicted for the levee centerline and buffered segments on either side of the levee. Areas with vulnerable soils are depicted by red segments along the levee.**



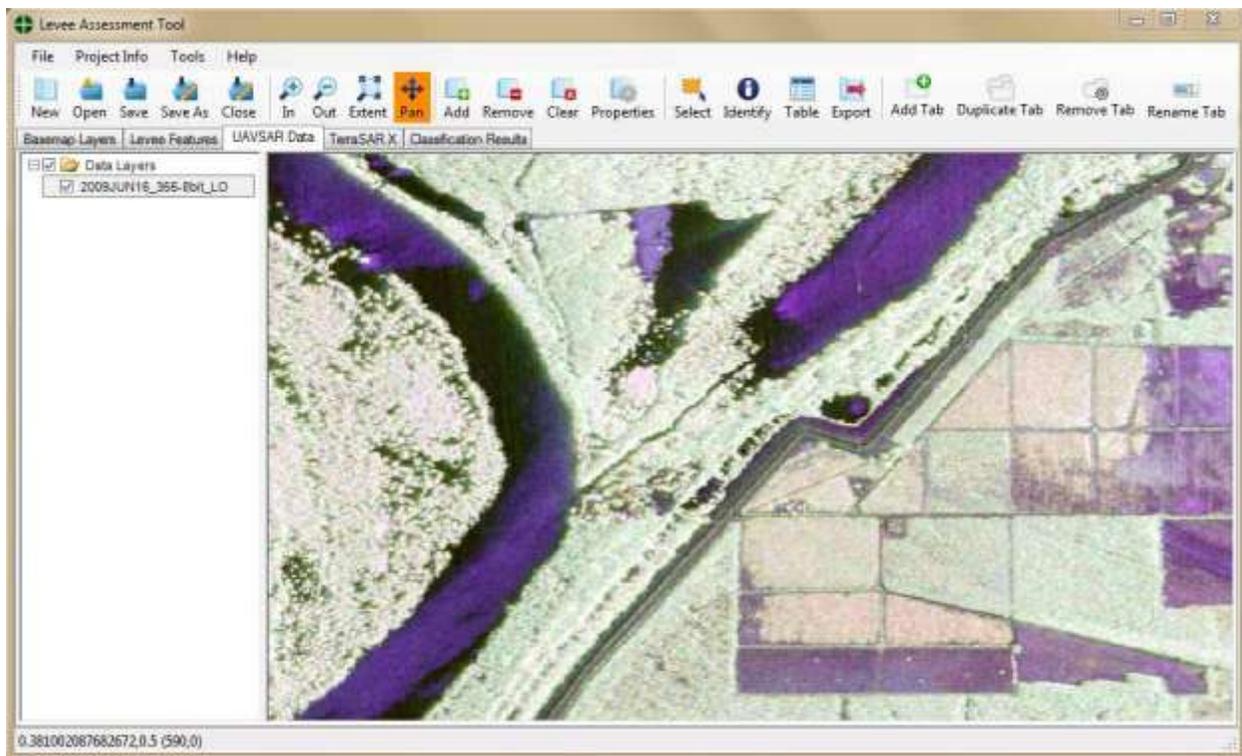
**Figure 4. Data from the Basemap Layers group copied as a group into the Levee Features tab interface illustrating the ease of moving data between tabs to enhance context understanding.**

## 2.0 SAR DATA HANDLING

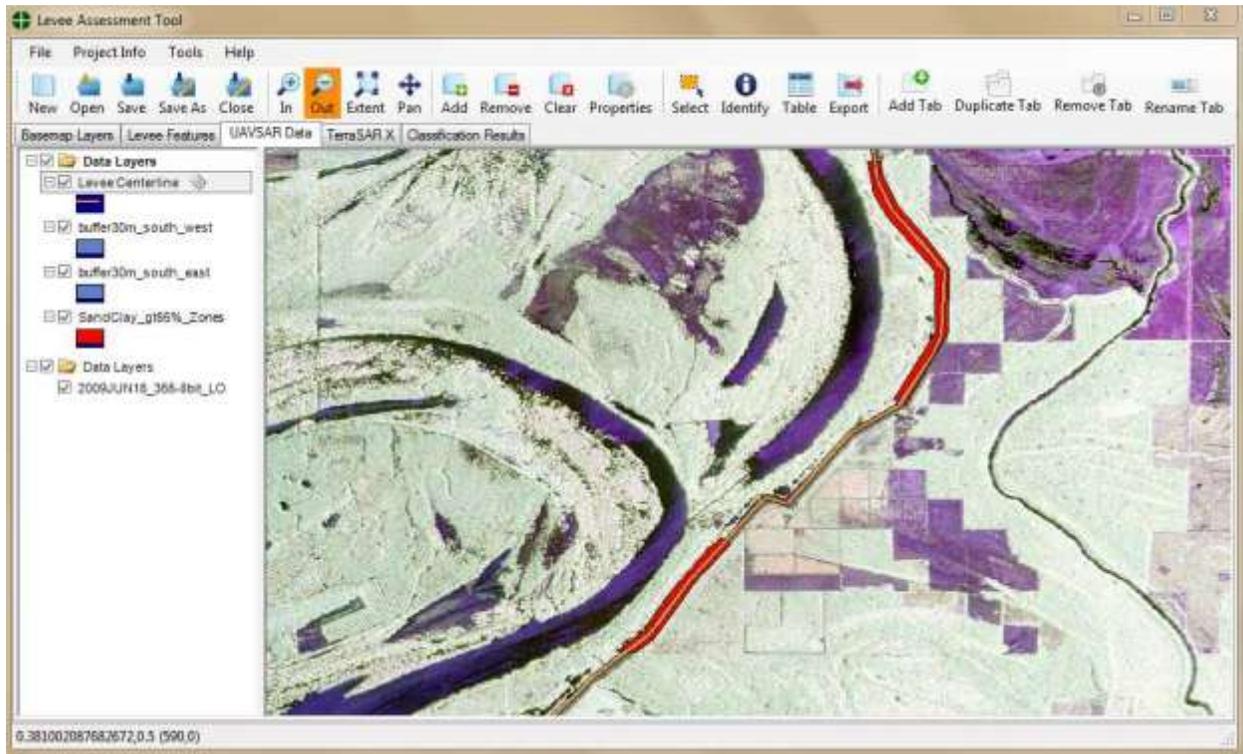
Synthetic Aperture Radar (SAR) data layers may be loaded and viewed in the application. Specific viewing capabilities were developed by the team to enable effective viewing of UAVSAR data as well as TerraSar X data files. For UAVSAR data files, one aspect included in the development of the tool was support of capabilities to perform data manipulation, transformation, and analysis of the radar data products to be used. Fundamental needs to automate frequently repeated tasks required that the software development team consider such tasks as the following:

- generating georeferenced image header files,
- performing statistical analyses and generating histograms,
- performing log/data transformations,
- converting data to standard GeoTIFF format, and
- bandstacking to deliver three-band viewable data.

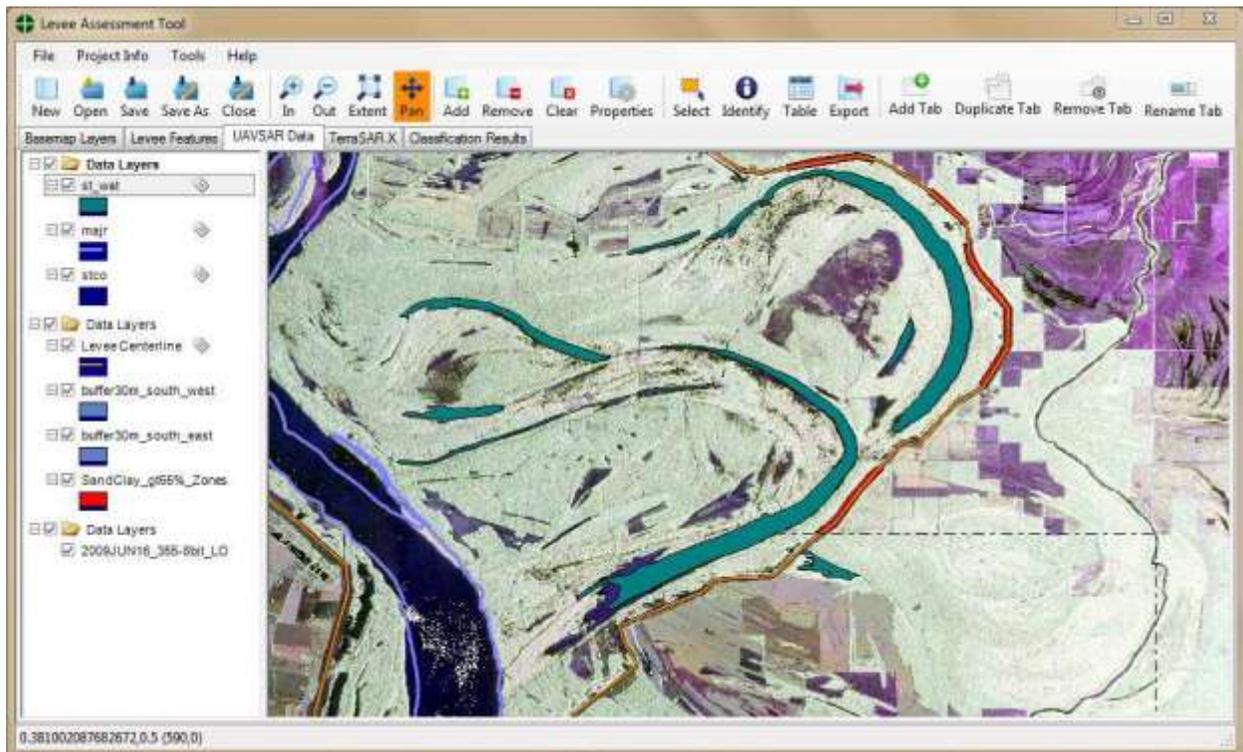
Results of a typical georeferencing; transformation; and bandstack of HH, HV, and VV bands into three-band data for RGB viewing of data are shown in figure 14.



5(a)



5(b)



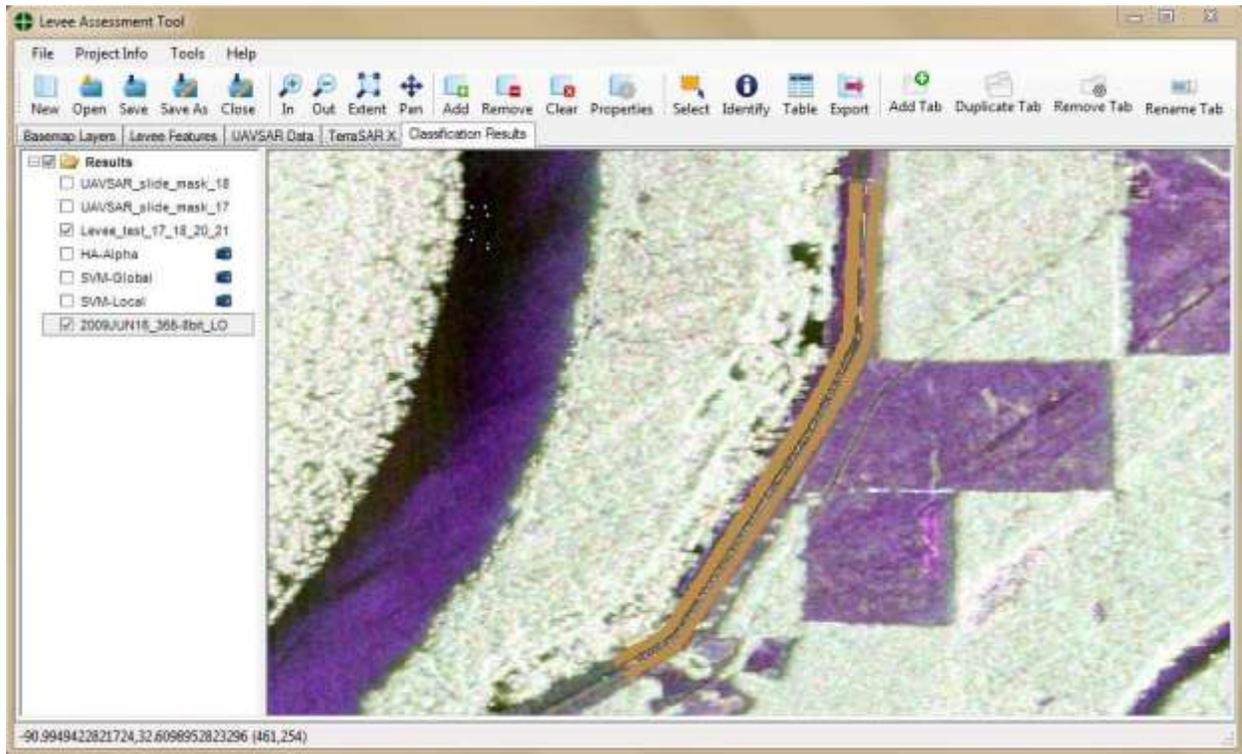
5(c)

**Figure 5. Flight line of UAVSAR data transformed and bandstacked for viewing, 5(a) includes only UAVSAR, 5(b) includes levee features, and 5(c) includes basemap layers.**

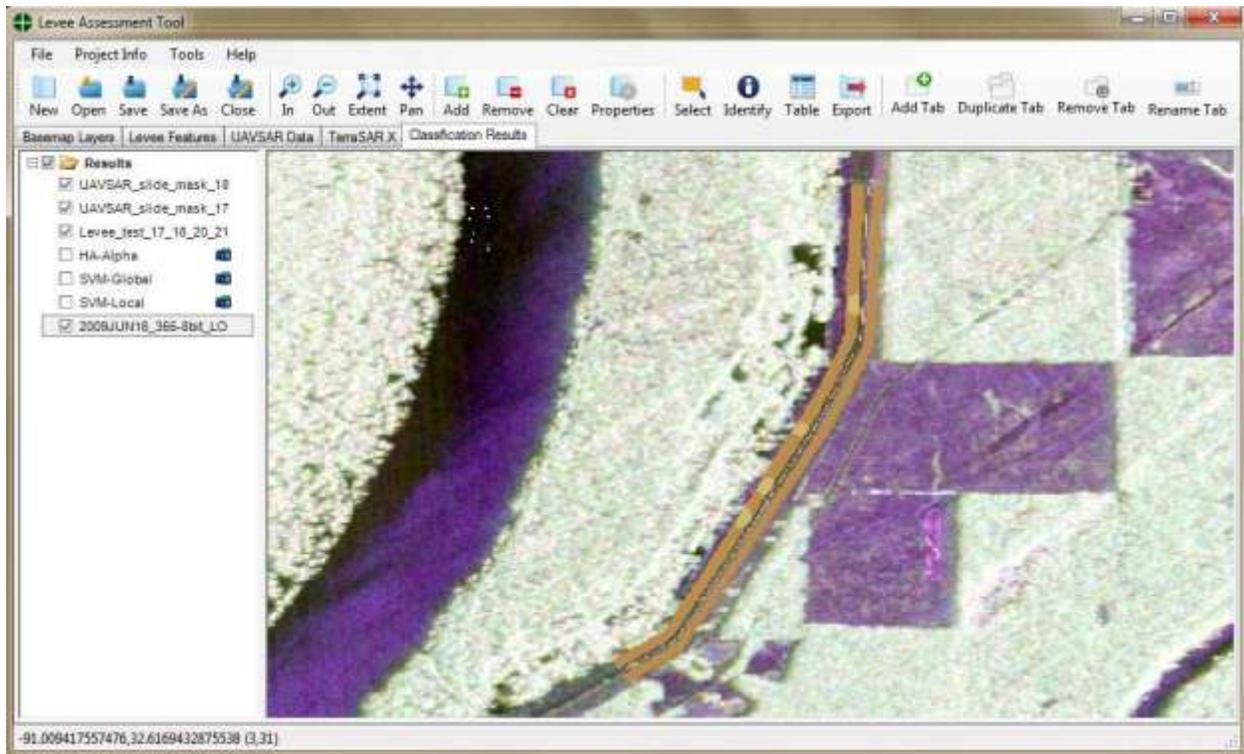
The images in 5(a), (b), and (c) show incremental zoom steps into a levee region in which segments are actively being studied by the levee assessment project team for historical, current, and possible future slide events. Note that the buffered levee layer is shown with respect to the UAVSAR image and data groups have been copied into the view from the Base Map Layers and the Levee Features tabs.

## 2.1 Classification Results Display

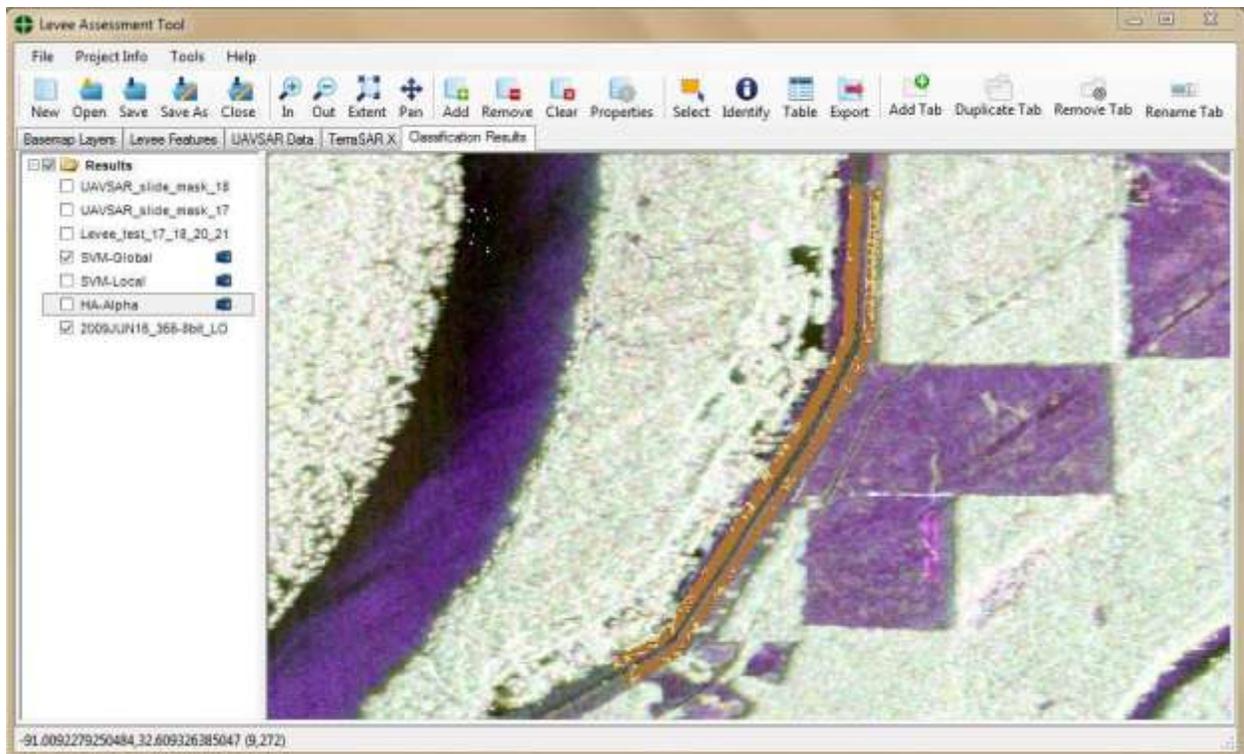
Figures 6(a)–(d) show areas of slide occurrence for slides 17, 18, 20, and 21. Masks of areas where slides occurred were compiled and the figures show slide feature detection results for the segment of interest using a cross-section of feature detection and classification methods. The levee has been segmented based on orientation changes and overall length between changes. Thus, for levee areas with frequent changes in orientation there are numerous segments, each containing a segment with nearly consistent orientation. These segments were created to be used along with levee data and geology, soils, and historical information to assess the prior probability of risk based on physical characteristics and the overall risk characteristics based on historical slides or possible current slides. The levee segments and aggregated results for the area are shown in figure 6, with risk indicated by color as presented in Table 8.



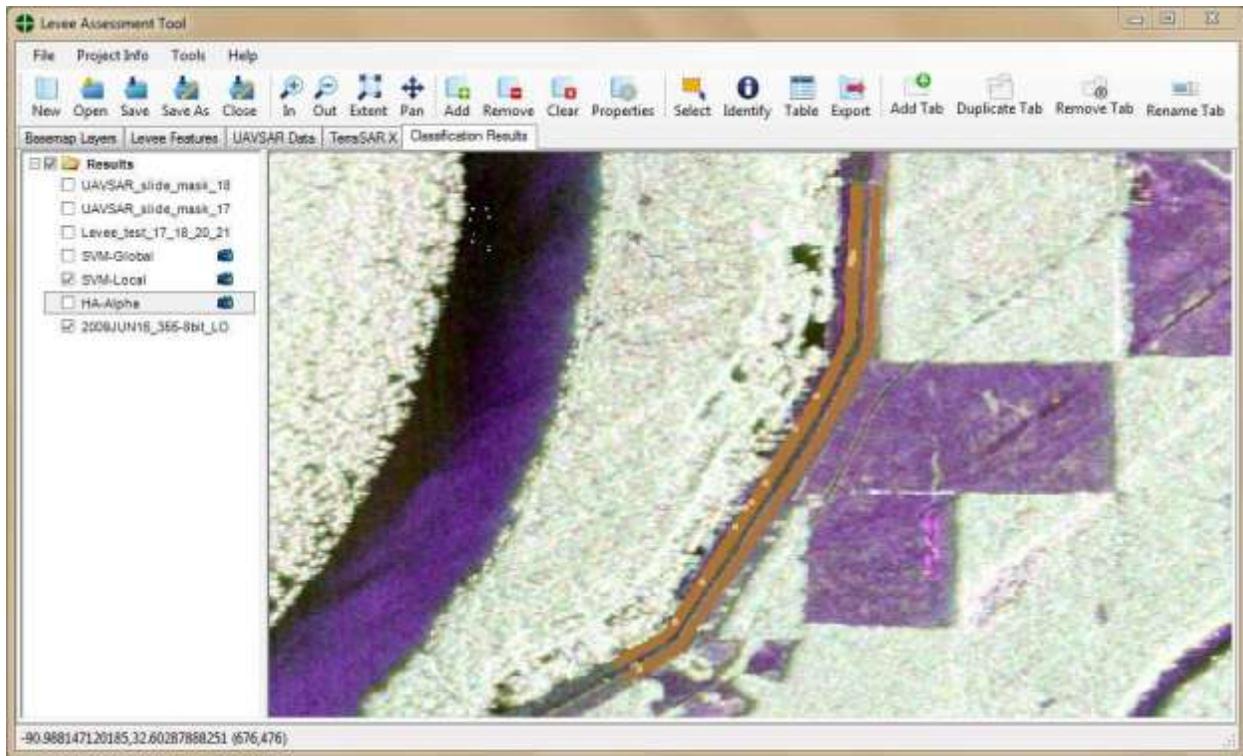
6(a) Slide area for slides 17, 18, 20, and 21 showing levee and road mask.



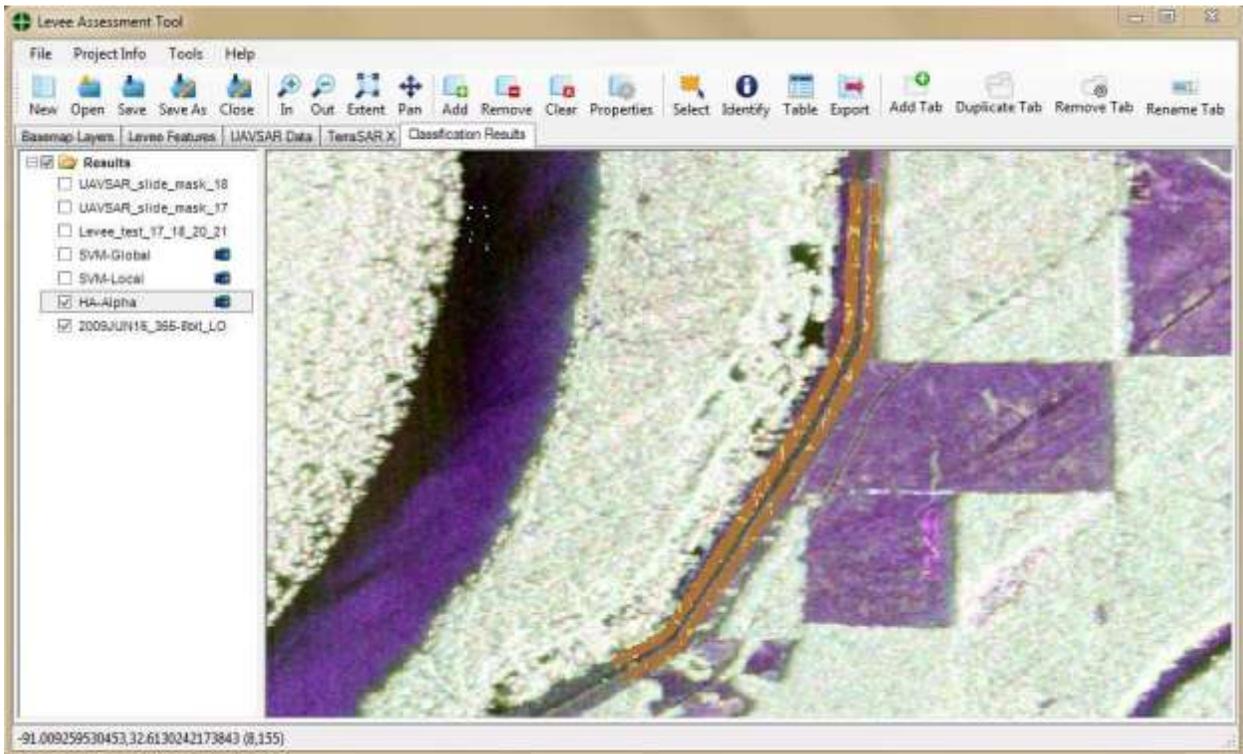
6(b) Slide area for slides 17, 18, 20, and 21 showing locations of current and past slides



6(c) Preliminary classification results using raw backscatter and global data normalization



**6(d) Preliminary classification results using raw backscatter, local normalization, and feature dilation.**

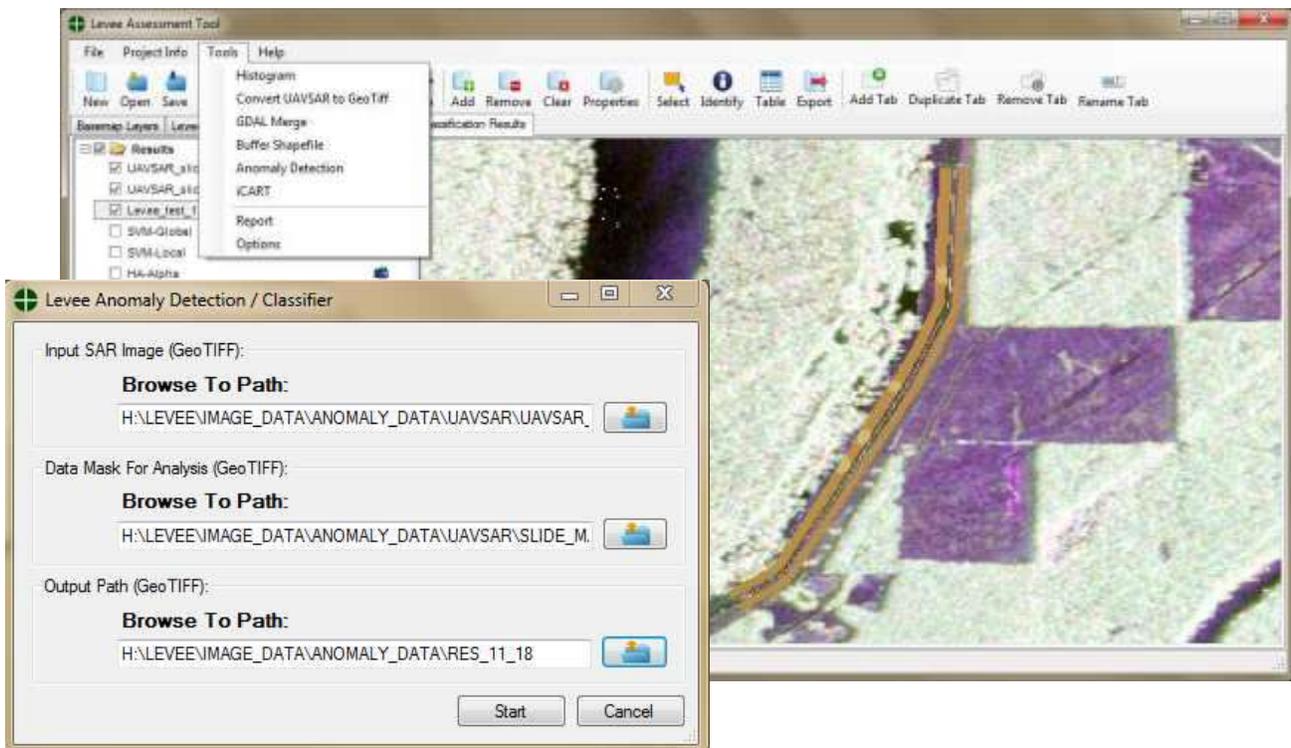


**Figure 6. Images of masks for areas and features of interest [(a) and (b)] and preliminary results of classification [(c) and (d)] and above. Brown depicts analysis areas while tan areas depict features or classification results.**

## 2.2 Integrated MatLab Classifier Operation

The classification results shown in figure 6 present visual results for feature detection and classification results conducted by the research team using methods external from the LAT. The feature detection and classification methods were developed in MatLab and were typically performed on SAR data for small areas wherein levee slides had been identified by the USACE, identified by the project team, and tested in a SAR data set acquired contemporaneous with the slide. Many methods were evaluated and utilized in testing feature detection and classification by the research team. Two methods requiring no training data were selected by the team to incorporate into the LAT. These methods were RX Anomaly Detection and K-Means clustering.

The MatLab codes to conduct the anomaly detection and K-Means clustering were configured for use as executable code that could be called and run from within the LAT. The methods are called from within the interface using the “Tools” menu as shown in figure 7.



**Figure 7. LAT menu interface with Tools menu accessed to enable access to the Anomaly Detection interface which opens the form for specifying image data, data mask, and output folder which are the parameters needed by the embedded executables.**

When the Anomaly Detection / Classifier tool is used, the MatLab executable runs in the background, performs the analysis, and creates the output in the directory designated. Outputs are automatically created for the RX Anomaly Detection method as well as for the K-Means Clustering method which has been configured to create 6 classes by default. The RX Anomaly Detection method recodes each pixel into a floating point value from 0 to 1; whereas, the K-Means Clustering method recodes each pixel into integer values from 1 to 6. In either case, there is a need to examine the anomaly detection and classification output to ascertain which values actually may indicate potential anomalies on the levee or point to the location of a current or past slide.

## 2.3 Image Classification Analysis and Recode Tool (iCART)

To view and analyze the outputs the image Classification Analysis and Recode Tool (iCART) may be used to view data, recode values, and capture statistics for the approximate quantity of pixels that are anomalies. The iCART application is also called from the tool menu and provides capabilities to interactively select data ranges of interest using a set of slider bars that allow the user to bracket the values that correspond to anomalies.

The iCART tool enables images to be loaded, colors to be selected for three (3) or two (2) possible classes of interest, and slides shown at the bottom of the page are used to set the breaks for the data values of interest. In the case shown below for the segment of interest, values below .05 are included in Class 1 comprising 91.209% of the image, values above .05 and lower than .39 are included in Class 2 comprising about 8% of the image, and values of .39 and higher are included in Class 3 which is less than 1%.

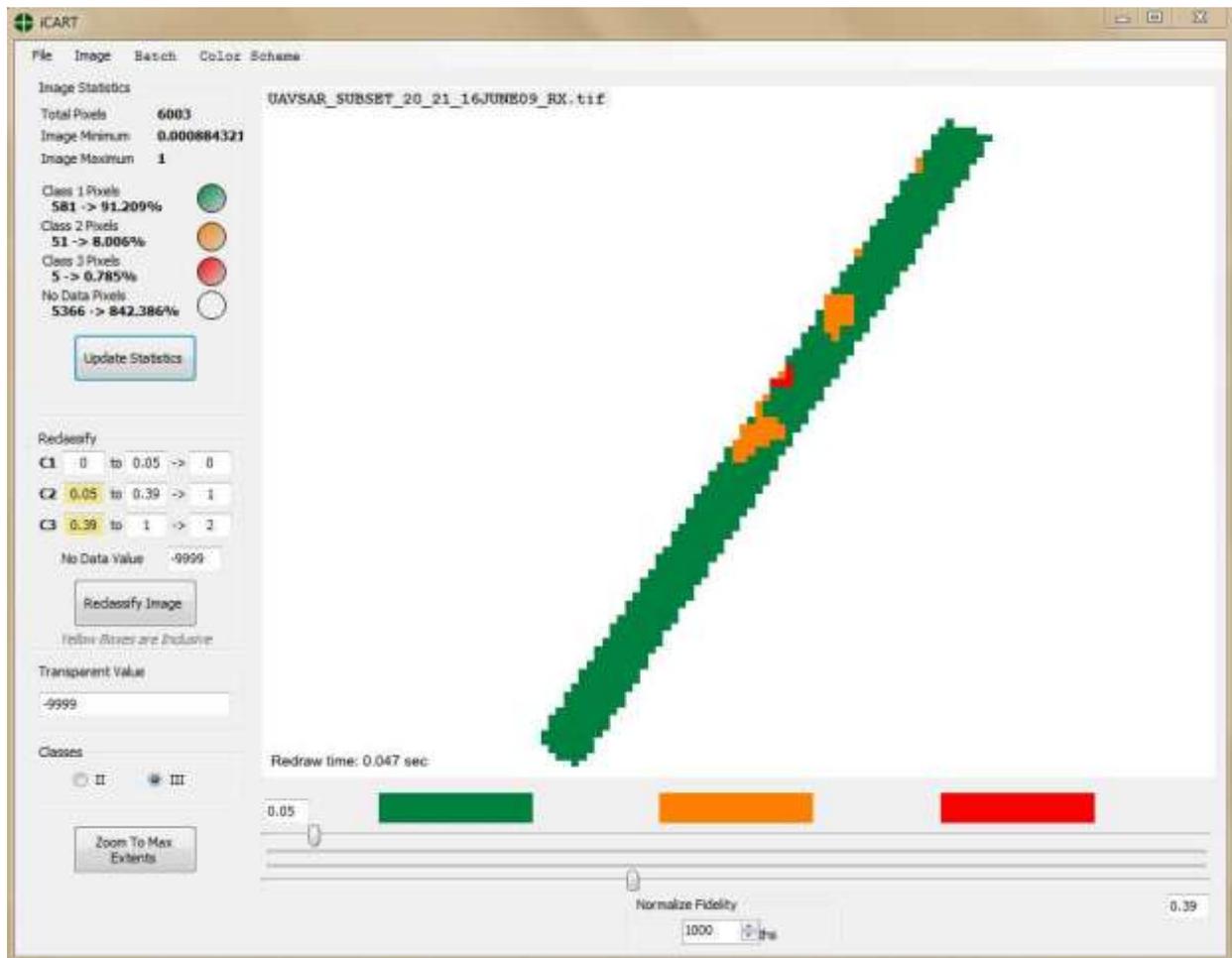


Figure 8. The LAT iCART interface with RX Anomaly Detect Results shown for UAVSAR data collected 16 June 2009. During this time period slides 20 and 21 were active on the segment of interest. The areas shown in orange (Class 2) appear to correspond exactly with slide areas, while areas in red (Class 3) seem to be edge effects that may be associated with the adjacent active slides. After slider values are set, the value ranges may be exported as a reclassified image which in this case recoded all values below .05 to 0 for ease of interpretation.

The combination of Anomaly Detection / Classification and the iCART tool demonstrates the capability to detect anomalies of interest and estimate their abundance within a levee segment. The recorded result image may be readily added back into the interface. Assuming that transparency and data values have been properly established, the results should overlap data such as images and masks to show how well the results performed as shown in figure 9 below.

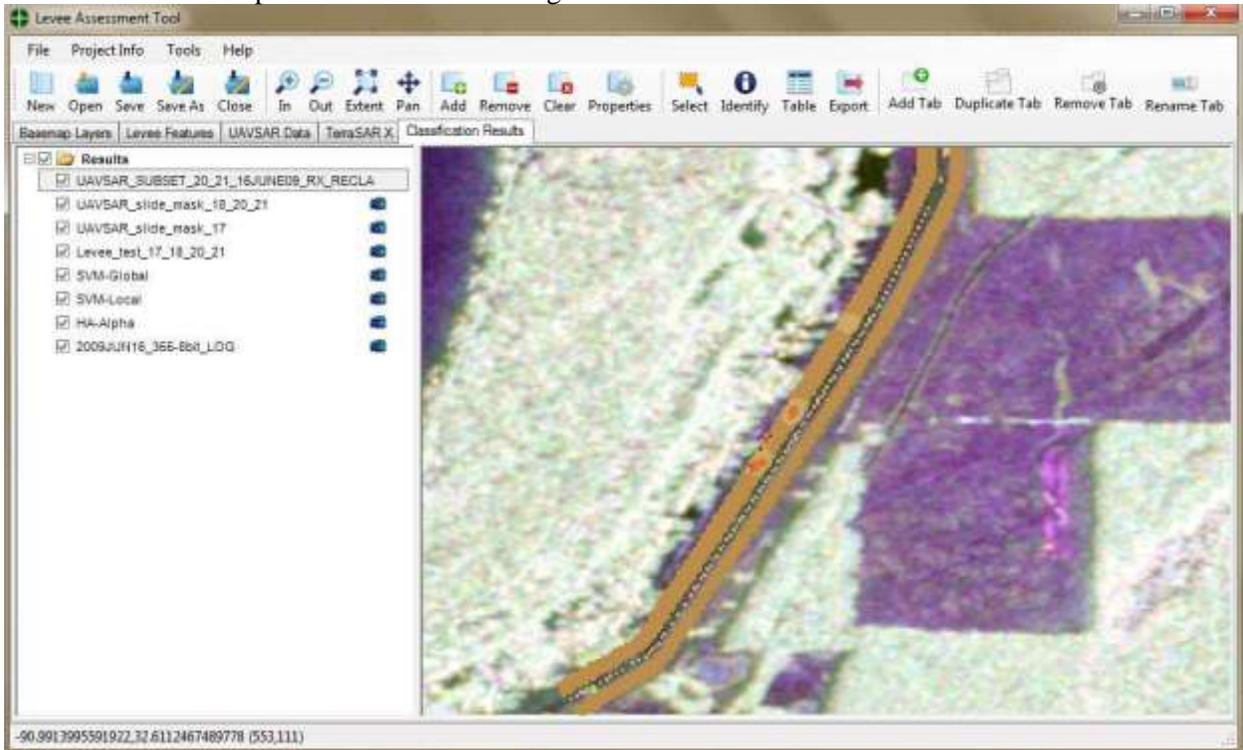


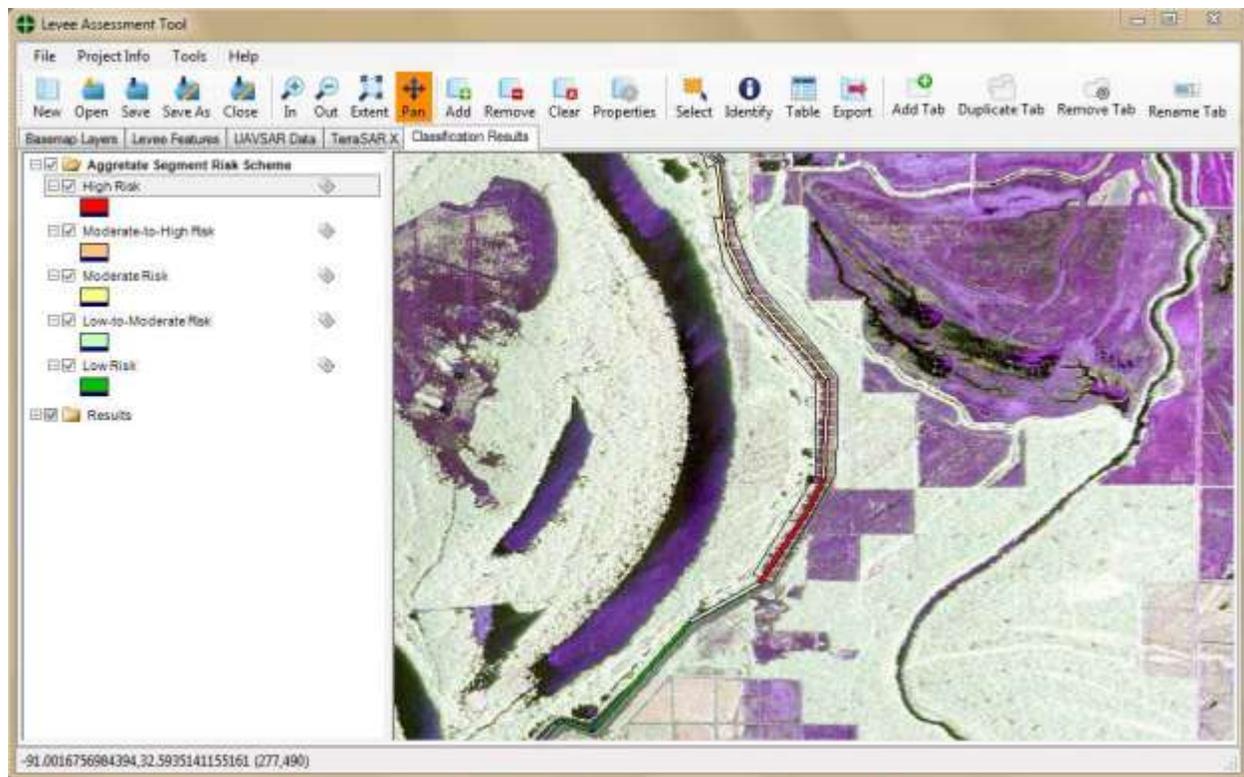
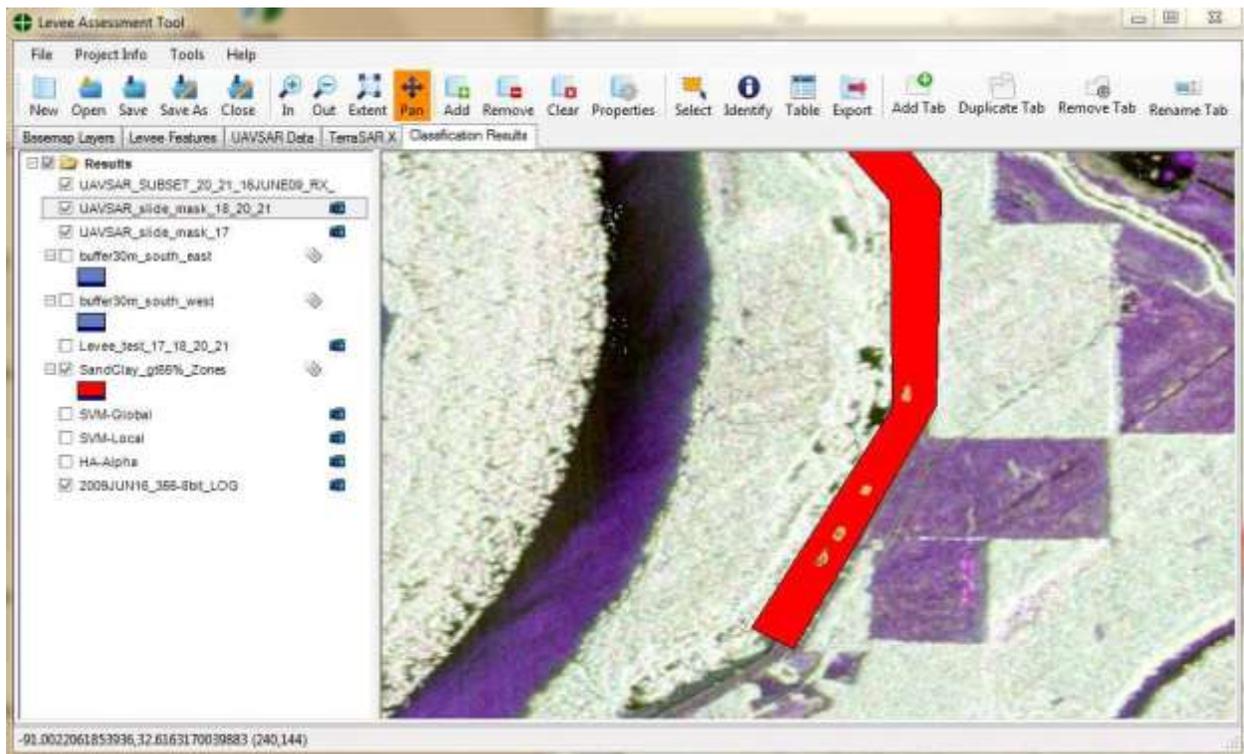
Figure 9. Results from the classified and recoded image performed in iCART have been added back to the Classification Results tab in the interface. The analysis mask for the area is shown in brown, tan areas are shown depicting areas masked as being where levee slides were known to exist. The orange area on top of the tan areas are the pixels recoded as anomalies and labeled as 1 or 2 within iCART. These areas correspond to masked areas of the slides with the exception of border pixels influenced by healthy levee areas.

### 3.0 CONCEPTUAL LEVEE AGGREGATE RISK CLASSIFICATION

The methods presented to evaluate levee segments of given orientation, to consider the levee’s contextual association with subadjacent soils and geology, and to consider the presence of current or past anomalies provides a conceptual framework for performing aggregate risk classification of levee segments. This aggregate risk classification could consider the soils, the history of the segment, and the current conditions as shown on table 1 and illustrated in figure 10 .

Table 1. Levee segment risk

Geology/Soils	History	Slide features	Risk rank	Risk description
Good	Absent	Absent	1 (Green)	Low
Poor	Absent	Absent	2 (Lt Green)	Low-to-Moderate
Good	Present	Absent	3 (Yellow)	Moderate
Poor	Present	Absent	4 (Orange)	Moderate-to-High
Either	Either	Present	5 (Red)	High



**Figure 10.** The upper map presents areas of high soil zone risk (sand fraction greater than 65%) in red, shows historical or present slide areas in tan, and shows the detected slide anomalies in brown on top of the tan masks. The lower map depicts segments overlying red soil areas as having poor substrate with historical or current slides. These levee segments for these areas are shown from yellow to red. Areas south of the area of interest with no slides and better soils and substrate would be symbolized in light green or green.

## 4.0 NEXT STEPS

Prototyping efforts have led to a working demonstration software package called the Levee Assessment Tool (LAT) which is implemented as standalone mapping software in the form of a highly flexible and potentially powerful multi-tab GIS data management and analysis application. Capabilities to manipulate, transform, and manage SAR and other geospatial data add further capabilities to the application. The LAT provides a general, open source mapping tool which demonstrates prototype capabilities to use SAR data and derived products in a GIS. The novel multi-tab capabilities presented in the LAT provide an entirely new paradigm for easy map data handling, organization, and manipulation of geodata as well as workflow products. Capabilities which have been added to enable easy copying of layers and groups between tabs, assigning colors and symbols for layers, and specifying transparency for rasters and layers provide powerful capabilities that may be readily enhanced and extended.

Capabilities to integrate custom classifiers and process SAR data to extract possible problem areas have been completed as have capabilities to analyze and reclassify and feature detection results. These reclassified results identify features or classes of actual interest to the user and quantify what proportion of areas within a segment that the features of interest constitute. These identified features may be saved as output and added back to the map interface which supports the capability to perform aggregate risk analysis on segments of interest.

Expanding this capability to consider larger areas will require that soil conditions, geologic materials, historical slide and sand boil occurrences, and other factors of interest are fully captured as geodata layers so that they may be populated within the interface. Additional steps are needed to scale the application for more fully automating the aggregate risk assignment of all levee segments within an area or reach of interest. Furthermore, capabilities to extract larger image areas of interest and perform rapid anomaly detection and monitoring of levee conditions over time would be an obvious next step for enhancing the applications.

Finally, the free and extensible and easy-to-use tool may provide an ideal platform to build an end-user application that may be provided to levee operators and inspectors to provide reporting and data management capabilities. Delivering a tool for broader use as well as field operation would likely involve addressing the following modest and readily accomplished list of capabilities which could be added to the open-source LAT platform:

- Levee inspection data entry forms and output reports.
- Map markup, redline, and comment capabilities for easy and flexible user input.
- Map data projection control and “project-on-the-fly” capabilities.
- Measuring, interactive query, and heads up digitizing tools.
- Expanded tools and utilities for data manipulation and analysis.
- Operations on a Windows Tablet with Stylus or Touch Interface.
- Ease of use with field GPS.
- Automated connectivity to OGC and other on-line data sources.
- Menus and inputs for field inspections and easy upload capabilities.
- Enhanced stability of operations and error trapping for full functioning operations.