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# Risk Analysis, GIS and Arc Schematics: California Delta Levees

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## Abstract

The Sacramento - San Joaquin Delta, California is defined by waterways confined by levees. Over 1,000 miles of levees were constructed for wetland conversion to agriculture in the late 1800's. Exposure of the rich organic soils has resulted in substantial land subsidence. There have been over 160 levee failures since 1900. The levee system is at increasing risk of failure from sea level rise or seismic activity. Information about the levees includes failure history, elevation, and material composition. Associated information includes geomorphology, soils and amount of subsidence of the enclosed islands. This can be viewed as a network system. There are individual networks of levees on the islands. Many of the island networks are separated by narrow channels or adjacent to islands of natural wetland and riparian vegetation which lack levees. GIS is used to integrate this information for risk analysis. Arc Schematics provides opportunities to effectively display and convey this information to decision makers.

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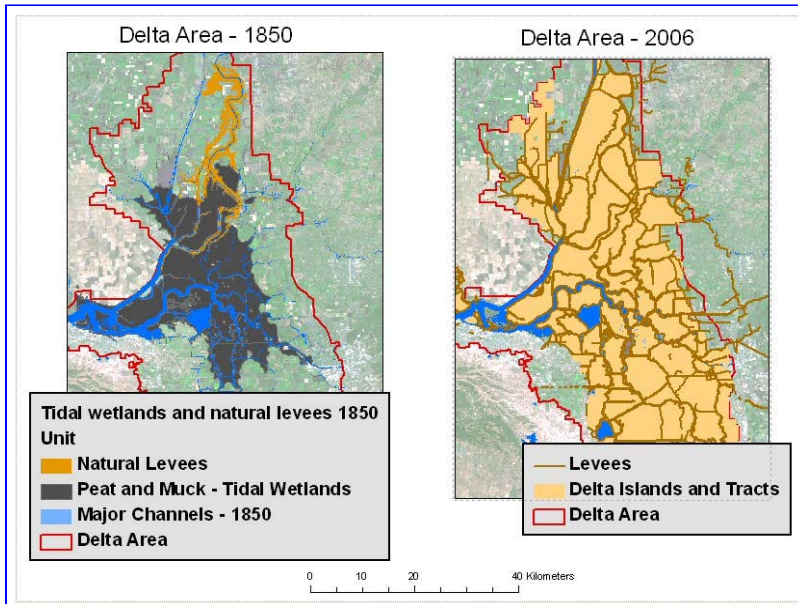
## Introduction

The California Delta and Suisun Marsh area are major components of San Francisco Bay Estuary. The system carries flows from the watersheds of the Central Valley. This includes the entire western slope of the Sierra Nevada.

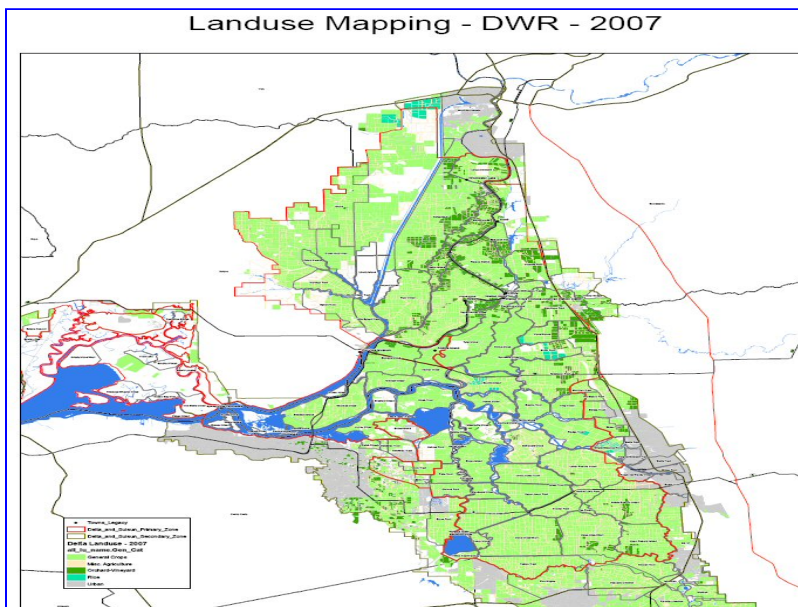
At the end of 2006, the Governor of the State of California appointed a Blue Ribbon Task Force to study and develop a strategic vision for the Delta. At the end of 2007, this task force issued the vision statement for the Delta. The major recommendation of the task force is *The Delta ecosystem and a reliable water supply for California are the primary, co-equal goals for sustainable management of the Delta*. The task force is now involved in the development of a strategic plan to implement this vision. GIS has played a role in the deliberation of the Blue Ribbon Task Force and supporting groups in the visioning process. This paper presents some of the information presented to this task force.

Water passing through the Delta is a source of water for a majority of the State's population and provides irrigation water for over 1.0 million hectares (2.5 million acres). It is a key component of Federal and State water projects. The Delta and adjacent Suisun Marsh are constrained to one outlet at Carquinez Strait by coastal mountains. Instead of migration of fluvial and tidal sediments seaward to the bay, tidal and fluvial sediments are stratified upstream as sea levels rise and fall (Atwater, 1982). Figure 1 shows the relative extent of tidal wetlands at about 1850 in the left panel. This also shows natural levee deposits along the stream channel for the Sacramento River at about the same time period (Atwater, 1982). Since 1850, these natural levees served as the basis for man-made levees which have been expanded throughout the Delta and portions of Suisun Marsh. There are over 1,600 kilometers (1000 miles) of levees at the present time (URS Corp., 2007). These levees are shown on the right side

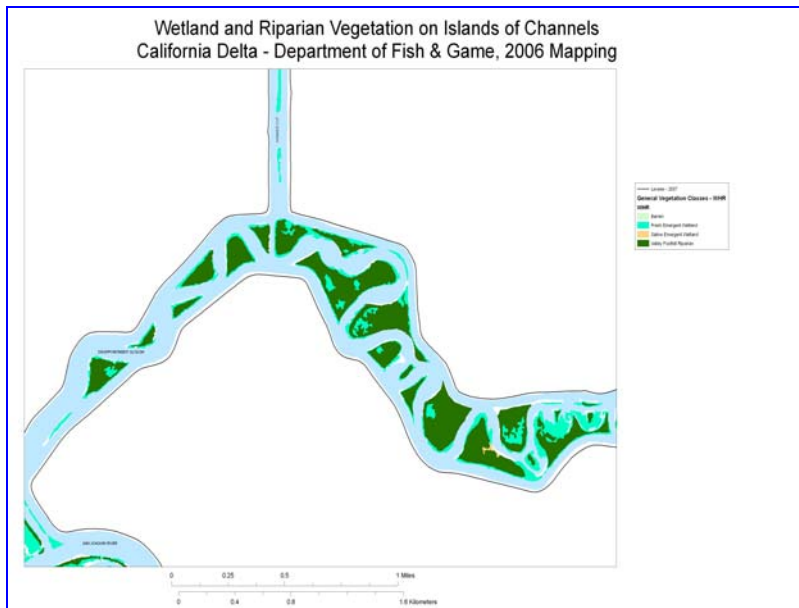
of Figure 1 for the Delta area.



In the Delta, agriculture developed since 1850 with the construction of levees and drainage of tidal wetlands. Presently over 202,000 hectares (500,000 acres) of Delta lands are in agricultural production. Figure 2 shows major land use (agriculture) within the Delta based on 2007 mapping by the California Department of Water Resources.



The complexes of wetland and riparian systems that existed prior to agricultural development exist only in remnants. Suisun Marsh is largely wetland. It and the remnant wetlands in the Delta represent about 10 percent of the existing wetland areas in California. The Delta remnant is now about 3,000 hectares (7,500 acres). Much of the remaining wetlands in the Delta are located on undeveloped natural islands in channels and sloughs. Figure 3 shows an area of remaining wetland and riparian vegetation on channel islands. This is based on detailed vegetation species level mapping by the California Department of Fish and Game in about 2006.



Drainage and conversion of the organic peat and muck soils to agricultural production have led to significant subsidence. Some areas of the Delta are over 7.5 meters (25 feet) below current mean sea level.

## Delta Levee Systems

Many of the levees were constructed from local materials on site including peat and muck. Levee failures have occurred not only during severe storm events. Since 1900, there have been 166 recorded levee failures (URS Corp, 2007). Only portions of this levee system near the cities of Stockton, West Sacramento, and Sacramento are considered adequate for flood protection. The Delta is in close proximity to major active faults in Northern California. It is expected that a severe seismic event would lead to catastrophic collapse of many levee systems. Sea level rise expected from climate change is expected to place an increasing amount of stress on an already risky levee system.

The levee systems are factors to be considered for both the environment and water supply. Levees define the stream channel network of the Delta. They define the land-water interface of islands and tracts. They restrict flows to remaining wetland habitats that are on the interior of islands. Public investment in habitat development within subsided portions of the Delta islands is discouraged because of the lack of stability in the levee system and the threat of sea level rise. Failure of key levees or a catastrophic collapse threatens the operation of key water supply systems for the state.

## Information on the Levee Systems

A considerable amount of information has been collected on the levee systems. This includes the historic record as well as extensive on-site investigations. Initially, this information was summarized on individual 100 foot levee segments. While information on individual levee segments can identify particular portions of a levee susceptible to failure, failure of any segment allows flooding of that island. It is more useful to examine the levee system as a whole for a particular island or tract. There are over 80 levee systems reported on in this summary. Among other characteristics, it ranks the value of levees on the following:

- Water export importance



defined for the feature classes participating in the schematic with ArcCatalog. In ArcMap, the features are symbolized for common display in both the data frame containing the features and the data frames for the generated schematics.

The levee system can then be displayed by various ranked values and costs as carried in the spread sheet. As can be seen in the figure, the levee systems are complex and the size of the islands and tracts protected by the system varies considerably. It is difficult to compare the length of one levee system to another. The extension, ArcGIS Schematics, permits display and analysis of both the components of a geometric network and its schematic representation. Simplification of a network into a schematic focuses attention on major network elements. The relative position and configuration of levee systems based on a selection of similarly ranked levee systems or individual systems can be displayed with the schematic.

Two sets of selected sets of levee systems are shown in the following figures. Figure 5 shows the set of levees ranked as critical for maintaining water conveyance through the Delta for the water supply systems.

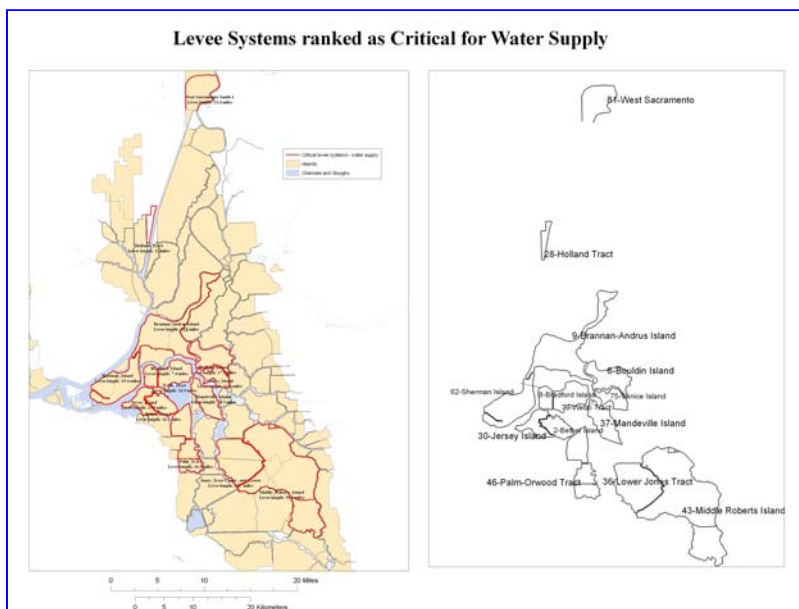
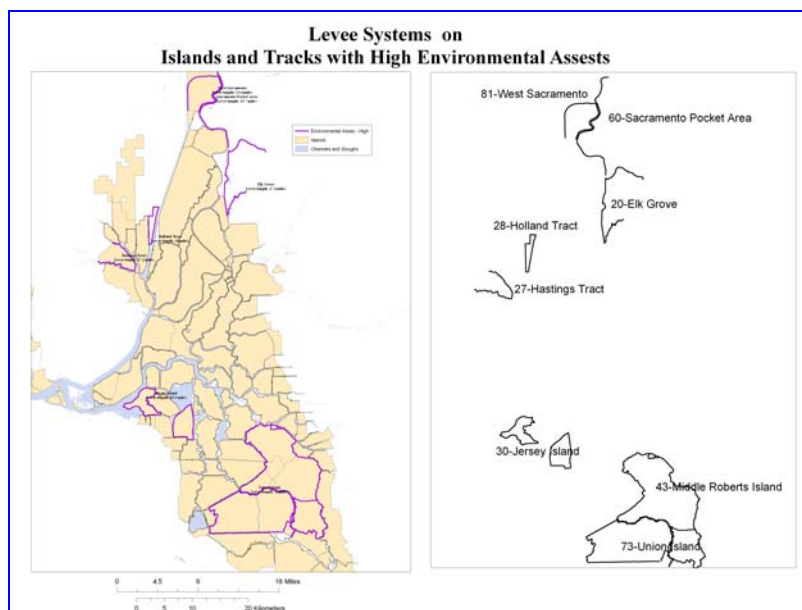


Figure 6 shows a set of levees that contain areas which are ranked high for environmental assets.



Both figures display the schematics in their initial geometric positions. This makes it easier to associate the diagram with the levee system configuration displayed in the map. Selections can be easily made between the tables of information on the levee systems. New schematics can be quickly generated as needed by the groups involved in the Delta Vision process.

## Summary

The extension, Arc schematics, is an effective tool for display and evaluation of networks. In this application, the extension was used to simplify the display and analysis of levee systems in the California Delta. Of major interest for this application is the query of ranked values developed for each of the levee systems and display of those systems in a simplified format. The State of California is in the midst of planning process for the Delta (Delta Vision, 2007). This process is examining the risks to the area from climate change, sea level rise, seismic events, urbanization, etc. to the area and services provided by the area. Schematics should be useful in this process.

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