

Delta Slough Investigation

My name is Donald Moore. I am a registered geologist and certified hydrogeologist in the State of California. As a licensed commercial pilot, I am also the owner of Geoimagery, an aerial photography and remote sensing company. I own and fly my own aircraft that has been specifically modified to take vertical digital imagery. I have been a practicing geologist and aerial photographer since 1983.

In my work as a consulting geologist and aerial photographer I have worked throughout northern California, including extensive work in the Sacramento and San Joaquin River basins. My work has required that I adapt commercially available computer software, such as Adobe Photoshop, ESRI ARCView, Global Mapper, and OrthoMapper for use in enhancing and improving the quality of digital, conventional and historic aerial photographs for use in interpreting geologic, geomorphic and fluvial features. My work has also included comparing physical features shown on historic maps with current or recent geomorphic or fluvial landforms and stream channels. This process often requires rectifying old maps and aerial photographs so that they can be accurately represented on the same map base for use in measurements and interpretations.

My work in fluvial geomorphology has included identifying abandoned and existing water courses in the Sacramento-San Joaquin River Delta, applying aerial photographic and computer enhancement techniques to map suitable gravel salmonids spawning beds, migrating gravel bars, stream bank erosion and the use of historic maps, historic aerial photographs and newly acquired digital photographs to establish the location of historic and current water courses including sloughs, streams, rivers and flood channels.

My testimony consists of three parts. First, a brief overview of some standard computer software now commercially available to enhance land forms and water features from aerial photographs, and how various maps and aerial photographs of different ages and scales can be accurately rectified to present a contiguous history. Second, I will discuss how these techniques have been applied to historic and current data sets available in the Sacramento-San Joaquin River Delta. Finally, I will discuss how computer techniques, geologic interpretations and fluvial geomorphic histories have lead me to conclusions on specific parcels in San Joaquin County.

1. COMPUTER SOFTWARE

My first step to begin a detailed aerial photographic analysis of geomorphic features is applying computer enhancement techniques. In the case of the San Joaquin County analysis, I used Adobe Photoshop CS4 software. Adobe Photoshop is recognized as the leading image enhancement software for normal photographs covering the wavelengths of light in the ultra-violet, visible range, and the non-visible near infrared spectrum. Adobe Photoshop uses most or all of the features for basic image enhancement that sophisticated satellite image analysis software uses and some features that the satellite software does not have. The fundamental procedures of image analysis: tone & color, size, shape, texture, patterns, shadow enhancement, and site association are effectively enhanced with Photoshop. The features Adobe Photoshop lacks are primarily those which cover wavelengths of light and energy beyond the sensitivity range of film and digital sensors, such as radar and microwave, and are not available in the

normal visible wavelength photography used for the images in this analysis. Using Adobe Photoshop and its advanced techniques, which was not available when previous fluvial geomorphic studies were performed, allowed the identification of complex surface detail from historic photographs.

The fundamental Photoshop functions and their comparable remote sensing functions are:

- Photoshop Levels-contrast enhancement, comparable to linear and non-linear contrast stretch
- Photoshop Curves- contrast enhancement, with more control to enhance select spectral ranges.
- Photoshop Hue/Saturation-intensify color and brightness, comparable to HIS-Intensity, Hue, Saturation
- Channel separation/layer blending-enhance specific spectral ranges comparable to Density Slicing
- Edge Enhancement-intensifies the contrast between areas of varying brightness, particularly useful for linear features. Several algorithms are available: find edges, gradient overlays, bevel-emboss, and trace contour

2. COMPUTER TECHNIQUES APPLIED TO HISTORICAL AERIAL PHOTOGRAPHY

Historic black and white aerial photographs taken in 1937 and 1940, and current color photographs acquired in 2005 provide the basis for the photographic analysis. Historic records include early 1913 USGS topographic maps, San Joaquin County assessor parcel maps, and written historic records dating back to 1850. Geologic and soil investigations prepared in the 1950's through the 1970's by the United States Geologic Survey provided a scientific basis for the analysis. The historic geomorphic analysis was expanded using the modern computer technology that enabled photograph enhancement and geographic positioning that was not available at the time of earlier investigations. This resulted in identification of many features that were not available to earlier researchers.

Typically aerial photographs of various ages differ in quality and resolution. The aerial photography acquisition dates of 1937 and 1940 generally implies aerial photographic equipment from cameras to film and photographic processing are of considerably lower quality than modern color photographic and digital images. Black and white film captures much less visual data than modern color film and producing multiple photographic copies combined with the use of older film, further degrades the quality of historic aerial photographs. Despite this lower quality, a large percentage of the sloughs and other fluvial features are still clearly visible on older black and white aerial photographs. The clear presence of these fluvial and riparian features on older aerial photographs and the same identifiable fluvial and riparian features on current high quality aerial photographs provides significant evidence that allows for correlation between historic and present day fluvial and riparian features.

When a potential historic or existing fluvial or riparian feature is identified on an aerial photograph near a subject parcel a detailed photographic and geomorphic analysis is initiated to further characterize the feature's history. I typically used a procedure that progressively "zoomed in" on the suspected feature.. The first step is to trace the location of the feature over a large area to find a potential up-gradient water source, establish natural flow behavior, and identify any alteration to natural geomorphic conditions.

To optimize the unique qualities of each historic aerial photograph and successfully enhance each fluvial and riparian feature, each subject parcel is analyzed using various computer enhancement techniques before selecting the most appropriate for a specific site. Additionally, because Adobe Photoshop enhancement techniques will slightly degrade the final image quality, two fundamental procedures are used to minimize or eliminate the degradation. The first is to work on duplicate copies of the aerial photograph.

When an image is opened on the computer, I make an exact copy. One original is left unaltered and the computer enhancements are performed on the duplicate. Initial computer analysis is conducted on the non-altered photographic image. The enhancements are conducted on the duplicate using adjustment layers, a system unique to Adobe Photoshop. Adjustment layers allow multiple and repeated enhancements of the image without any degradation. This allows experimentation to select the best procedure(s). When the original and enhanced photographic image are viewed simultaneously and the best enhancement techniques are selected, subtle geomorphic features such as abandoned channels and levee breach deposits are enhanced, analyzed for their likelihood as potential riparian conditions, and the features are plotted on the original version. These operations are performed on the historic black and white photographs and the recent color photographs. After the fluvial features are plotted on the base image, the various enhancement layers are flattened to one layer for illustrational use. The procedure of flattening the layers will introduce some degradation of the photograph however, the effect is minimal and the critical features are plotted prior to any degradation.

After completing the analysis of a fluvial or riparian feature, its location is plotted on the appropriate parcel map. Plotting a fluvial or riparian feature involves two functions: First the feature is located relative to landmarks on or near the subject parcel. Second, the feature is located relative to the same landmarks on historic photographs and maps from different time periods. Most current and historic fluvial and riparian feature locations were relatively easy to identify relative to the subject parcel.

Many fluvial and riparian features are readily apparent on the current aerial photographs. Likewise the 1940 era aerial photographs and in many cases, historic maps, show the same features that are readily apparent on current aerial photographs. To further characterize the history of a fluvial or riparian feature, the aerial photographs and maps indicating the location of a feature are scaled and rectified to achieve a close fit to the maps and photographs of differing ages. This enabled computer me to compile data overlays from different times with landmarks as registration. The comparison of fluvial and riparian feature locations allowed me to determine how channels had migrated and how those migration deposits indicate fluctuations relative to changing levels of water flow. When channel migration is evident from changing bank

locations, and meander deposit patterns supported evidence of channel movement, I have a high level of confidence to confirm the historical presence of a channel. Channel migration is a natural occurrence in fluvial geomorphology. Using historic aerial photographs allows me to compare seventy years of fluvial history. By using and comparing the historic 1913 topographic maps (surveyed in 1911) allow me one-hundred years of comparison. The historic written record, allows me to confirm the relative location and movement fluvial features. When registered overlays indicate channel migration, the correlation of variations such as meander scrolls confirm the migration direction and allow confident age determination of the sloughs.

The registration/matching of the various data sets is a function of Geographic Information Systems (GIS). Three programs are used: First, for relatively flat, featureless areas the computer software ESRI ArcView and Global Mapper are used. These software programs allow the registration of two maps or photographs by user input which have identified identical landmarks in each map. Second, with sufficient, identical, landmark points, such as buildings and roads, identified on each map or photograph, the software re-scales, rotates, and closely matches the two maps or photographs. The third software used for more complex areas is a photogrammetric program, Orthomapper. This software works in a similar manner to the GIS software but adds the feature of using digital elevation models (DEM) for more accurate registration over the entire photograph. Additionally, this software has special functions for the registration of cultural change and maps of low levels of accuracy.

The software programs produce accuracy levels that are more than sufficient for geomorphic analysis. The location of a channel and the historical locations of the channel can be identified relative to landmarks which will clearly place the fluvial or riparian feature on or off of a subject parcel. Absolute accuracy is not attainable at this time for a number of reasons:

- No ground survey is used. Surveyed ground control is necessary for the highest order of accuracy
- The age of the maps and photos. Many of the maps were produced before the first standardized survey datum in 1927 was established and variation in survey methods and quality of equipment led to errors
- No camera data or ground control was available for the historic photos

Despite the lack of precise accuracy, the technique of overlaying identical geographic landmarks allows location and analysis of channel features relative to a given property with more than adequate accuracy to establish the presence of the channel on that property.

3. SPECIFIC PROPERTY ANALYSIS

I conducted detailed analysis of the two following parcels using the 1940 black and white aerial photographs, the 2005 color photographs and in consultation with Mr. Lajoie. I performed detailed photo analysis utilizing enhancement techniques of the 1940 aerial photographs. For my analysis I chose to use only the non-altered photographs. After confirming the presence of the major riparian features, I used only the most basic, non-destructive, contrast enhancement of the photographs to identify minor, related features. The unaltered photographs revealed enough data to establish the presence of riparian features on each of the parcels. The technique of identifying the riparian features on the original photographs, the registered overlays of the historical data, and the drainage history of the region confirms my opinion that the subject parcels are riparian to Duck Slough.

- 3a) Parcel 131-170-03 (Mussi). This 70.18 acre parcel borders Duck Slough which parallels Inland Drive in the western portion of section 27, Township 1N, Range 5E M.D.B.&M. The photo analysis of current and historic photographs indicate Duck Slough has a natural levee. Sea level elevation is indicated just west of the property and Inland Drive. An elevation of three feet below sea level is indicated just east of the property. Riparian features, approximately paralleling the levee, are clearly indicated on both the non-altered 2005 color photo and the 1940 photo ABD 334-35. A channel break, or blow-out is evident on the adjacent-west parcel beginning from the Duck Slough and proceeding northwest from the center of the subject property into the adjacent property. Basic Photoshop enhancement using histogram equalization boosted the contrast and indicated additional features sub-parallel to the dominant features. This series of parallel/sub-parallel features indicate fluvial deposition from rising and falling waters that resulted in meander scrolls of deposited material that have been left over the ages from channel migration. These meander scrolls east of Duck Slough and the blow-outs and possible channels west of Duck Slough establish the presence of a major slough.
- 3b) Parcel 131-180-07 (Pak and Young). This 40.0 acre parcel borders Duck Slough/Inland Drive in the south portion of section of 22 and north portion of section of 27, Township 1N, Range 5 E, M.D.B.& M. The natural levee of Duck Slough/Inland Drive is the east border of the property. The 1940 aerial photograph ABD 333-68 clearly indicates a riparian feature trending west from Duck Slough through the central area of the subject property. Enhancement of the 2005 color photographs indicates altered areas that correlate with the location on the 1940 photograph. The connection to Duck Slough and sediment deposits along the channel indicates a possible levee break or blow-out.

In the northeast portion of this parcel a more pronounced riparian feature is evident. This feature indicates more characteristics of a natural channel. The feature is wider, appears to be deeper, and appears to connect to apparent channels in the property adjacent-north of 07. Similar features are evident on other properties along the length of Duck Slough. All of these features trend west and north of the Slough. South and east (or opposite side) of the Slough these features are not noted. The east side of the Slough

does show evidence of curving, parallel features that are likely meander scars. The meander scars dominate the fluvial features on the east side of Duck Slough and the channels and blow-outs dominate the fluvial features on the west side of Duck Slough. This evidence suggests strongly Duck Slough was a major water course. The presence of possible levee blow-outs and apparent natural riparian channels that are obvious on both historical and current photos of the subject property combine with the natural history of Duck Slough to confirm my opinion that the subject parcel is riparian to Duck Slough.

My conclusions that the two subject parcels are riparian to Duck Slough are supported by the following data:

1. County Assessor parcel maps dated 1876 and 1881-82 indicate a blue line that represents Duck Slough;
2. The U.S. Geological Survey Quadrangle (Holt), surveyed in 1911 and published in 1913 indicates a blue line that denotes water in Duck Slough;
3. Maps from the early 1900's shows homes and farmsteads along the high banks of sloughs, including Duck Slough that lead to the conclusion that farmers would build next to water;
4. Based on previous mapping by qualified geologists and hydrologic data shown on the Holt Quadrangle, I evaluated the historic topographic elevations and known tidal ranges to arrive at the conclusion that tidally controlled water would be present in Duck Slough prior to 1881.