

Appendix B: Groundwater Levels, Borehole Lithological Data, and Thickness of Organic Soils and Mud Deposits

Steven J. Deverel^{*1}, Christina E. Lucero¹, and Sandra Bachand²

Volume 13, Issue 2 | June 2015

- * Corresponding author: *sdeverel@hydrofocus.com*
- 1 Hydrofocus, Inc., 2827 Spafford Street, Davis, CA 95618 USA
- 2 Tetratech, Inc., 509 Fourth Street, Suite D, Davis, CA 95616 USA

Article doi: http://dx.doi.org/10.15447/sfews.2015v13iss2art4

METHODS

Groundwater Levels

To assess groundwater levels, we used the Delta Wetlands Project groundwater level data collected from 1989-1995 for wells located on or near the levees throughout the Delta (Harding Lawson Associates 1991; Hultgren-Tillis 1995). We used these data and groundwater-level measuring point elevations reported in the Delta Wetland Project documentation (relative to the NGVD-29 datum) to calculate groundwater elevations. We also obtained groundwater level data measured by transducers every 15 minutes during 2004 and 2005 as part of the Upper Jones Tract flood monitoring (Hultgren-Tillis 2005). We converted all groundwater-level measuring point elevations to NAVD-88 using VERTCON (http://www.nqs.noaa.gov/TOOLS/Vertcon/vertcon. *html*) and calculated the groundwater elevations by subtracting the depth to water from the measuringpoint elevations.

We also used 2011 and 2012 data for wells from the Dutch Slough groundwater monitoring project (HydroFocus, Inc. 2012) where water-level data was recorded every 15 minutes using transducers. Also, Twitchell Island manual groundwater level measurements collected by HydroFocus, Inc. from 2001 to 2012 were used. We retrieved water level data from a 57-foot deep USGS well on Medford Island with data from 1983 through 1987 (*http://nwis.waterdata. usgs.gov/nwis/*). We also used groundwater level data collected on Jersey Island by HydroFocus personnel from 2006 to 2008. Surveyed measuring point elevations were reported for all these wells, which we used to calculate the groundwater elevations relative to NAVD-88.

Borehole Lithological Data and Thickness of Organic Soils and Mud Deposits

We obtained well and bore-hole logs from the Delta Wetlands Project (Harding Lawson Associates 1991; Hultgren-Tillis 1995), the 2004 Jones Tract Flood Report (Hultgren-Tillis 2005) and from CDWR (2012 data transfer set to Christina Lucero from Joel Dudas, unreferenced, see "Notes"). These data and data presented in Atwater (1982) were used to define the bottom elevation of the organic and mud deposits. Using logs available from CDWR, Atwater (1982) posted 1,081 useable values for the bottom elevation of the organic soils and 562 useable values for the bottom elevation of the tidal mud deposits on 24-min U.S. Geological Survey (USGS) quadrangle maps. We also extracted the organic-soil- and mud-bottom elevations from well logs obtained from CDWR and pub-

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lished in the Delta Wetland Project reports from other projects throughout the Delta.

Information sources included: the Alternative Delta Facilities Special Studies (1976), West Delta Temporary Barriers (1977), Hotchkiss Tract Sewage Collection System (1977), Evaluation of Levees at Aqueduct Crossing (1981), Woodward Island Supplementary Engineering Studies (1981), McDonald Island Piezometer Installation Report (1984), Brannan Levee Project (1987), Sherman Island Pipeline 131 Levee Stability Study (1987), Delta Wetlands Project (1988), Hotchkiss Tract Treatment Plant Ponds (1988), Hotchkiss Tract PG&E Pipeline Crossing (1990), North Fork Mokelumne River Setback Levees (1992), Webb Tract Levee Improvements 2000-2001 (2001), Jersey Island Triple Decker Project (2003), Bethel Island Liquidation Investigation Delta Coves (2003), Jersey Island Geotechnical Data (2004), Groundwater Monitoring Jones Tract Flood (2005), Webb Tract Geotechnical Investigation Stations 317 & 435 (2007), Holland Tract Levee Rehab Station 55 to 250 (2008), Sherman Island Landslide Setback Habitat Project (2008), and Bethel Island Horseshoe Bend (2011).

Using the Atwater definitions for organic soil and mud bottoms, we extracted 134 organic-soil bottom elevation points and 86 mud bottom elevation points from these sources, for dates ranging from the 1970s to 2011. The land surface elevation datum was either listed on the log or assumed to be NGVD-29. We incorporated the locations and elevations of all data points into a GIS database, resulting in 1,215 organic-soil bottom elevation points and 648 mud-bottom elevation points. Finally, we converted all points to the vertical datum NAVD-88 using VERTCON.

To characterize the spatial distribution of the organic-soil-bottom and mud-bottom elevations and thickness, as related to geomorphic processes and the WNMF areas, we used the theory of regionalized variables or geostatistics and Geostatistical Analyst within ArcGIS to create mud bottom and organic-soil bottom elevation grids. The theory of regionalized variables as described by Matheron (1963), Journel and Huijbregts (1978), David (1977) and others relies on the description of data collected in geographic areas as randomly distributed. "Kriging," the process of interpolation from measured values of some variable *z* measured at *n* locations relies on the determination of the spatial covariance or semivariogram of the variable at points x_i . The semivariogram (γ) is defined as:

$$\gamma(h) \frac{\text{variance } z(x_i) \quad z(x_j)}{2} \tag{B-1}$$

where;

h is the lag or average distance between data points, and

z is the elevation of the organic soil or mud bottom.

We therefore calculated the semivariogram to estimate the spatial covariance in the area shown in Figure 9 (See page 17 in the paper, *http://escholarship.org/uc/item/5nv2698k*). We then interpolated with kriging which uses a linear combination of weighting factors and measured values of that minimizes the estimation variance.

We calculated and plotted directional semivariograms to determine anisotropy. The west to east directional semivariogram showed the most drift, especially at greater distances. In contrast, the north to south direction showed the least drift. The greater trend or drift in the east–west direction reflected increasing mud and organic soil thickness from east to west, especially at the western edge of the Delta.

We attempted to model the semivariograms that best represented data for a large geographic area for organic-soil-bottom and mud-bottom elevations. The directional spherical and exponential semivariograms normal to the maximum drift (north-south direction) showed the lowest sill variance and were used for kriging for the organic-soil-bottom and mud-bottom elevations, respectively. The semivariogram models were iteratively verified and refined to minimize the estimation variance for both variables.

After creating a grid of estimated organic-soil-bottom and mud-bottom elevations by kriging, we created a mud thickness map by subtracting the mud-bottom elevation grid from the organic-soil-bottom elevation elevation grid from the organic-soil-bottom elevation grid in GIS. Similarly, we created an organic-soilbottom thickness map by subtracting the organicsoil-bottom elevation grid from the LiDAR (Light Detection and Ranging) land-surface elevation grid (CDWR 2007), which is reported in NAVD-88.

RESULTS

Groundwater Elevations

We examined groundwater elevations using available data for the aquifer underlying the organic deposits. Examination of hydrographs (Figure B1) for wells installed throughout the Delta generally demonstrated temporally stable groundwater elevations during the last 20 years. There are three exceptions. First, there was a slight downward trend in groundwater elevations for well WO-26 on Woodward Island. However, data collected during 2003 and 2004 indicate stable groundwater elevations from 1995 to 2004. Second. data collected in wells MC-13 and MC-14 on McDonald Island indicate precipitous declines and recovery during 1990 and 1991 when groundwater levels returned to close to previous levels. Third, there was an apparent downward trend on Medford Island. Recent data for wells on Upper Jones and Palm Tract demonstrate a lack of significant water-level change during the longer term from 1989 to 2004. The hydrograph for Upper Jones Tract shows the effect of the levee breach in 2004 and then a return to groundwater levels similar to those measured in the 1990s. Also, the Twitchell Island data shows no multi-year trend from 2001 to 2013.

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NOTES

Dudas J. 2012. Soil test data folder. Data transfer to Christina Lucerro containing borehole logs and shapefiles of locations in the Sacramento-San Joaquin Delta. Located on server at Hydrofocus, Inc., 2827 Spafford Street, Davis, CA 95618.



Figure B1 Map with groundwater hydrographs in the aquifer underlying organic deposits