TECHNICAL MEMORANDUM

DEPARTMENT OF PUBLIC WORKS
FLOOD CONTROL ENGINEERING DESIGN GROUP

LOWER LAS GALLINAS CREEK DREDGE CHANNEL
CONCEPTUAL DESIGN STUDY
FINAL DRAFT
MARIN COUNTY, CALIFORNIA

MARCH 18, 2015

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DATE: March 20, 2015

TO: Las Gallinas Watershed Group File – CSA 6

FROM: Roger Leventhal, P.E.

RE: Lower Las Gallinas Creek Geomorphic Dredge Channel Conceptual Design Study, Marin County, California

1.0 INTRODUCTION AND BACKGROUND

1.1 Introduction

For the past **40** years, local dredging efforts have provided recreational and aesthetic benefits to the Santa Venetia community. Costs to continue this work have risen faster than the funds to pay for it. This technical memorandum describes the study results that strive to identify a new type of dredge that creates a creek with dimensions closer to what would be naturally occurring; aka a geomorphic dredge. The anticipated advantage of a geomorphic dredge is that it is more cost-effective and less environmentally impactful. The geomorphic dredge will be added to the list of possible dredge options to be considered by the community as we move forward.

County Service Area No. 6 - Gallinas Creek (CSA 6) is a local taxing authority of property owners located adjacent to the Lower Las Gallinas Creek waterway. Members of CSA 6 have an interest in maintaining recreational boating access within a reach of the South Fork of Lower Las Gallinas Creek of approximately 14,000 linear feet and have historically worked with the Marin County Department of Public Works (County) to maintain channel depths in the creek by dredging. The lower channel is subject to siltation due to a variety of factors discussed below, which have resulted in the buildup of sediment in the creek channel and a loss of both width and depth. Marin Lagoon community members have also stated an interest in achieving an increased natural flow to improve flushing and water quality within the creek and lagoon.

In the past, our understanding is the creek has been dredged to uniform specifications for depth and width both downstream and upstream of Santa Margarita Island; i.e., a constant bottom elevation was specified for the channel invert (lowest elevation in the channel) along with uniform channel widths for each dredging event. Our understanding is that all previous dredging events were performed with a hydraulic dredge pumping to disposal locations primarily at the McInnis Park area, and once to what is now the Marin Lagoon area.

The creek channel begins to silt up again following dredging events. Based on anecdotal information, it appears that the channel silts in to unacceptable levels within three to seven years following dredging events; although not enough channel surveys have been performed for us to calculate the siltation rate to any degree of accuracy. However, based upon personal communications with community members since the last dredging event in 1992/94, it appears that the channel silted in to a level that impeded boat usage within a few years of the dredge, especially in the upper sections of the channel towards Santa Margarita Island.

The Conceptual Geomorphic Design

This memo develops a conceptual design layout and template for a channel dredging event for Lower Las Gallinas Creek through the CSA 6 reach based on a geomorphic design approach. The geomorphic approach uses available natural processes (in this case the tidal flushing flows) that maintain the channel's form for the dredge template design. The goal of using this geomorphic based approach is to develop a channel dredging template design that is potentially more self-maintaining over time since it is based on the available channel-maintaining flows (i.e., tidal prism as explained below) that exist in the lower creek watershed. In addition, we believe this approach will be more acceptable to the permitting agencies since it is derived from data obtained from natural marsh systems.

As described in more detail below, this geomorphic approach is based on empirical (in the field) measurements of natural tidal channel dimensions (i.e., width and depth) taken in numerous natural tidal marshes around the Bay Area. Those measurements are then plotted against (i.e., correlated to) calculated estimates of tidal water volume measured from the mean higher high water (MHHW) tide elevation down to either the channel bottom or the mean lower low water (MLLW) elevation, whichever is higher in elevation at the location of the field channel measurements. This calculated volume of water on the MHHW tide is known as the "tidal prism" and is measured in acre-feet. The overall term for this approach of correlating tidal prism to channel measurements is "tidal hydraulic geometry." Tidal hydraulic geometry should provide a more sustainable dredge channel template in line with the available tidal prism and forms the basis of the geomorphic approach to the dredge design for Lower Las Gallinas Creek.

The approach taken in this study acknowledges the natural variability of results within a reasonable "geomorphic" range and uses values within that range (to one standard deviation) to lay out a geomorphic channel along Las Gallinas Creek.

Note that no guarantees are provided that the geomorphic channel will be completely self-sustaining. The inherent variability of natural systems, the altered state of the existing Las Gallinas Creek system (especially the split flow around the Island), and changing bay tides and sediment loads mean that a fully natural and sustainable channel may not be possible. However, we believe the approach taken here has the highest likelihood of at least partial success because it attempts to respect the natural creek processes to the extent possible. It also recognizes the limitations imposed by the loss of tidal prism due to development.

1.2 Scope of This Study

The specific tasks for this study were as follows:

- Assemble and organize relevant data plots of Bay Area tidal hydraulic geometry from various sources to assess which are the most relevant to the Lower Las Gallinas Creek study area

- Develop input parameters for the geomorphic channel assessment based on current and historic maps

- Work with Watershed Sciences of Berkeley, California to prepare a focused historic ecology assessment for the lower watershed

- Perform a first-cut assessment of equilibrium tidal channel dimensions based on the current tidal prism and develop a geomorphic dredge channel template that adjusts to the available tidal prism

- Lay the geomorphic template onto the creek cross-sections and iterate a design solution that meets the various engineering constraints described within this memorandum

- Calculate dredge earthwork estimates and preliminary cost estimates for dredging and disposal comparing geomorphic cross-sections to the 2010 Winzler & Kelly[1] cross sections. Costs were developed using unit costs developed by Winzler & Kelly (2010) and updated with new information available to the County.

- Develop a list of next steps and recommendations for future studies

This memo provides a first-cut estimate of a dredge template along with dredging volume and cost implications. The purpose of this memo is to provide the CSA 6 Adviosry Board and residents with the preliminary results to help decide if further design and permitting are warranted. As described under Conclusions and Recommendations, Section 11, several additional efforts will be required prior to dredging, including an updated creek bathymetric survey and preliminary and final engineering design reports that evaluate disposal options in more detail. Finally, plans and specifications for dredging will need to be prepared.

1.3 Description of Dredging Issues

CSA 6 is a local tax assessment community developed to fund dredging and maintenance of Lower Las Gallinas Creek for recreational purposes such as boat access and for flood control purposes (Figures 1 and 2). The channel is prone to sediment buildup that reduces its navigational capacity, so it must be dredged regularly. The creek has been dredged four times since 1966; most recently in 1994. However, dredging is costly and has environmental impacts that can trigger regulatory scrutiny. Regulatory and permitting issues and costs have increased greatly in the 20 years since the last dredge; more mitigation is now required for impacts to marsh vegetation.

[1] Project Study Report, Channel Maintenance Dredging, Las Gallinas Creek, prepared by Winzler & Kelly (now GHD) February 26, 2010

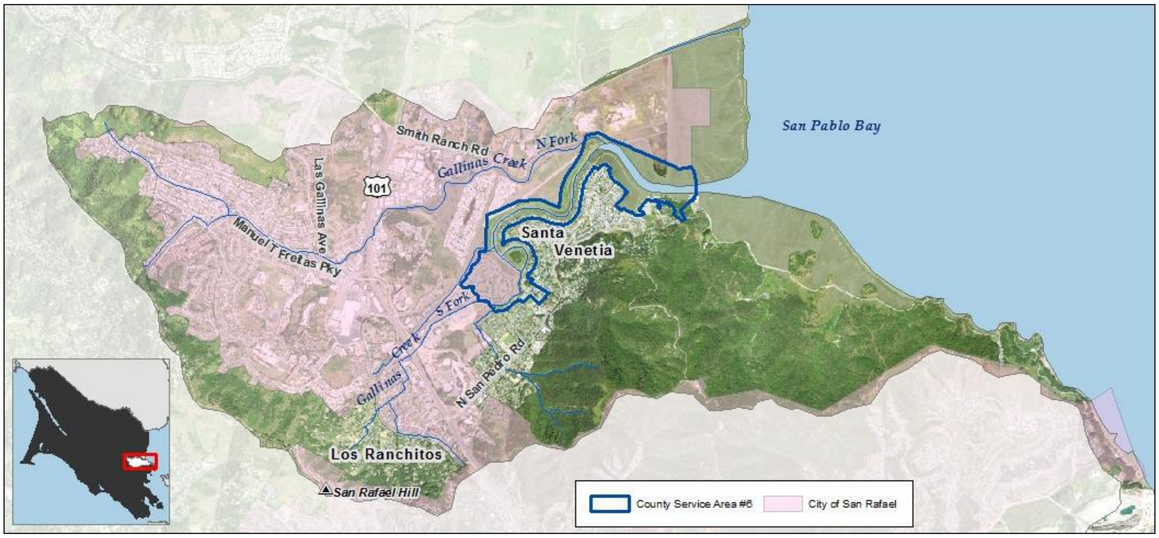

Figure 1: Location map

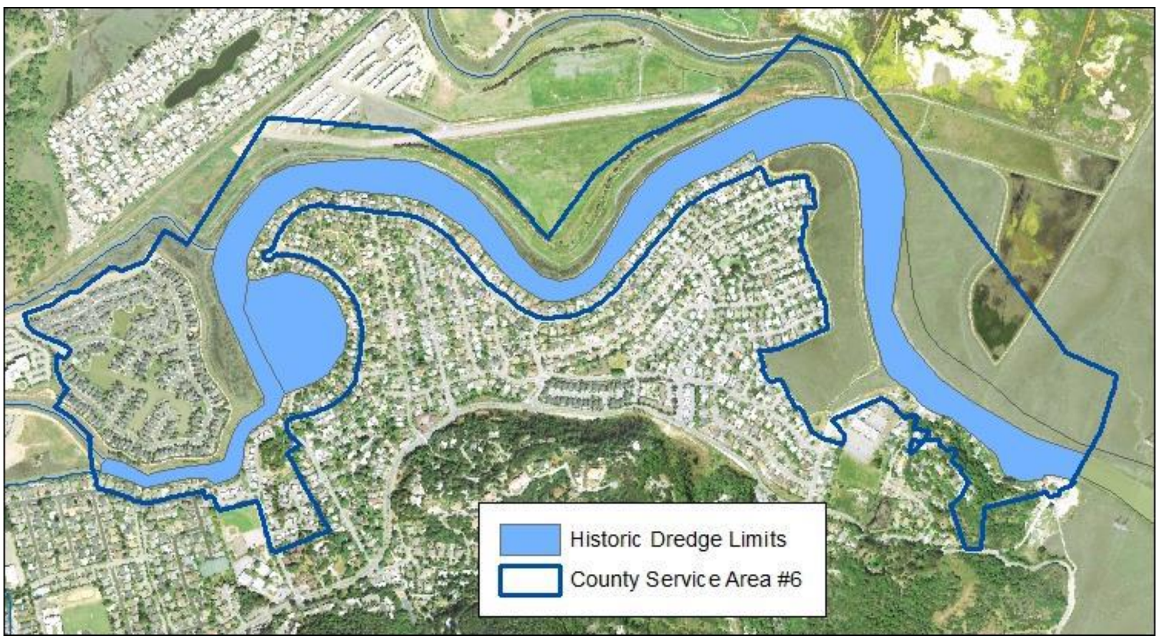

Figure 2: CSA#6 extents and limits of previous dredge episodes

In addition, CSA 6 members have expressed concern that continued channel siltation may lead to a buildup of sediment that allows marsh vegetation to colonize the channel, blocking boating access and recreation. Evaluation of sediment buildup (accretion) rates is beyond the scope of this study.

These concerns and community members' desires to improve water quality have prompted this evaluation of a more sustainable dredging template.

1.4 Study Goals

The primary goal of this study is to develop a dredge template that is more sustainable than the current regime and that will require fewer maintenance dredging episodes in the long-term. This approach—of designing the dredge channel dimensions to the available tidal prism—could thus lower dredging costs in both the short and long term. The cost of dredging has risen over time due to inflation and increasing environmental and permitting regulation. We believe that the approach described in this memo will be viewed more favorably by the regulatory agencies and possibly result in reduced mitigation requirements and associated cost.

However, the tradeoff is that given the loss of historic tidal prism, sustainable creek channel dimensions will be narrower and shallower then in previous dredging events and thus will restrict access up the creek by larger boats on lower tides. The implications of this approach are described in more detail below.

1.5 Study Limitations

As described in detail below, the geomorphic design approach uses plots of measured channel dimensions from a number of marshes around San Francisco Bay. This approach is subject to errors and uncertainties, including potential measurement errors as well as statistical uncertainty from making inferences about scatter plot data and best-fit regression lines using a linear least square regression approximations fit to field data. The natural variability inherent in tidal marsh systems also contributes to uncertainties. Plus, the Lower Las Gallinas system is no longer in a natural condition and the plots used from natural marshes around the bay do not necessarily address altered conditions such as the split flow around Santa Margarita Island.

As a result, the dredge channel dimensions developed from this study are preliminary and subject to the limits and uncertainties of the underlying data and analysis methods. We recommend that any dredge template also be evaluated using physically based hydrodynamic modeling of the channel in order to develop estimates of velocities and shear forces in the channel, and that those estimates then be adjusted for maximum sediment transport. Together, these approaches can offer a more comprehensive analysis of and approach to a dredge channel design for the creek. These limitations, plus local site constraints (i.e., split flow around Santa Margarita Island), mean that the design channel dimensions may not be self-sustaining and may still aggrade with sediment over time, but likely at a much lower rate than under previous dredge plans.

In addition, this geomorphic design study is based on a single creek survey from 2009, which did not extend down to Bucks Landing. An updated survey should be performed prior to final design to update the quantities and costs developed in this study. This study does not evaluate the geotechnical stability of levee slopes and makes no guarantee about the stability of existing levee slopes to the dredge footprint. We tried to follow Winzler & Kelly's recommendations to stay 50 feet off the toe of levees wherever possible, but we did not achieve a 50-foot offset in many locations, especially around Santa Margarita Island. The Winzler & Kelly report was careful to note that this 50-foot estimate was not based on any engineering design criteria, however, and they recommended that additional geotechnical studies be conducted to assess slope stability. The existing channel does not meet this 50-foot offset in many locations either. The geomorphic dredging template developed in this study may require modification to meet any required geotechnical offset developed during subsequent design phases.

1.6 Previous Studies Reviewed for This Memo

We reviewed the following studies of sedimentation in the Lower Las Gallinas Creek watershed:

- *Project Study Report, Channel Maintenance Dredging, Las Gallinas Creek prepared by Winzler & Kelly (now GHD) February 26, 2010*

- *Draft Report, Las Gallinas Creek Hydrologic, Hydraulic and Coastal Analysis, Noble Consultants, September 30, 2011 [This report was subsequently incorporated into the final USACE design report]*

Neither report presents nor discusses a geomorphic approach to developing a dredge template; so this memo is intended to provide such an alternative design approach to the historic dredging template. Together, these studies provide a range of engineering approaches and costs for developing a dredging plan for Lower Las Gallinas Creek.

2.0 BACKGROUND TO THE GEOMORPHIC ANALYSIS APPROACH

Geomorphologic analysis of tidal marsh systems is a large and complex area of science and engineering. This section presents the basic science behind the geomorphic design approach to dredging.

2.1 Tidal Hydraulic Geometry and Effective Tidal Prism

This section provides the technical background behind the theory and use of tidal hydraulic geometry to estimate equilibrium or “stable” channel dimensions. A full technical background is beyond the scope of this memo but can be found in numerous journal articles on the topic.

Tidal hydraulic geometry is an applied scientific theory that relates the physical form of a tidal channel (i.e., its width and depth and, thus, its flow area) to the “effective tidal prism,” or the volume of tidal water that flows in and out of a site measured from the MHHW (mean higher high water) tide level to the channel bottom or MLLW (mean lower low water), whichever is higher in elevation. The theory is based on the assumption that the effective tidal prism is the process that does the most to form the “equilibrium” or stable tidal channel dimensions over time. In theory, an equilibrium channel requires less dredging to maintain width and depth over time under natural conditions.

In applying this theory, we made use of empirical (i.e., field-based) observations and measurements of tidal channel dimensions at many different marshes around the San Francisco Bay Area . Tidal hydraulic geometry is a field-based approach developed over time based on data from numerous researchers. Researchers study marshes that are geomorphically “stable,” meaning that the tidal channels are functioning to connect tidal flows from the marsh to the bay. Researchers measure tidal channel widths and depths at various locations and calculate the upstream tidal prism from those locations. They then plot these width and depth measurements along the x-axis (horizontal) and the calculated volume of water in the system measured from the MHHW elevation (i.e., the “active tidal prism”) on the y-axis (vertical).

Channel stability in a complex natural system like a tidal marsh is a function of more than just one factor, but in general, tidal prism is a useful and easily measurable surrogate for the tidal channel-forming flows that maintain width and depth. Field-based datasets of stable channel sizes are typically plotted on log-log plots. An example of a hydraulic geometry plot for tidal marsh width as a function of tidal prism is shown in Figure 3 below. There are similar plots for marsh depth from MHHW and area.

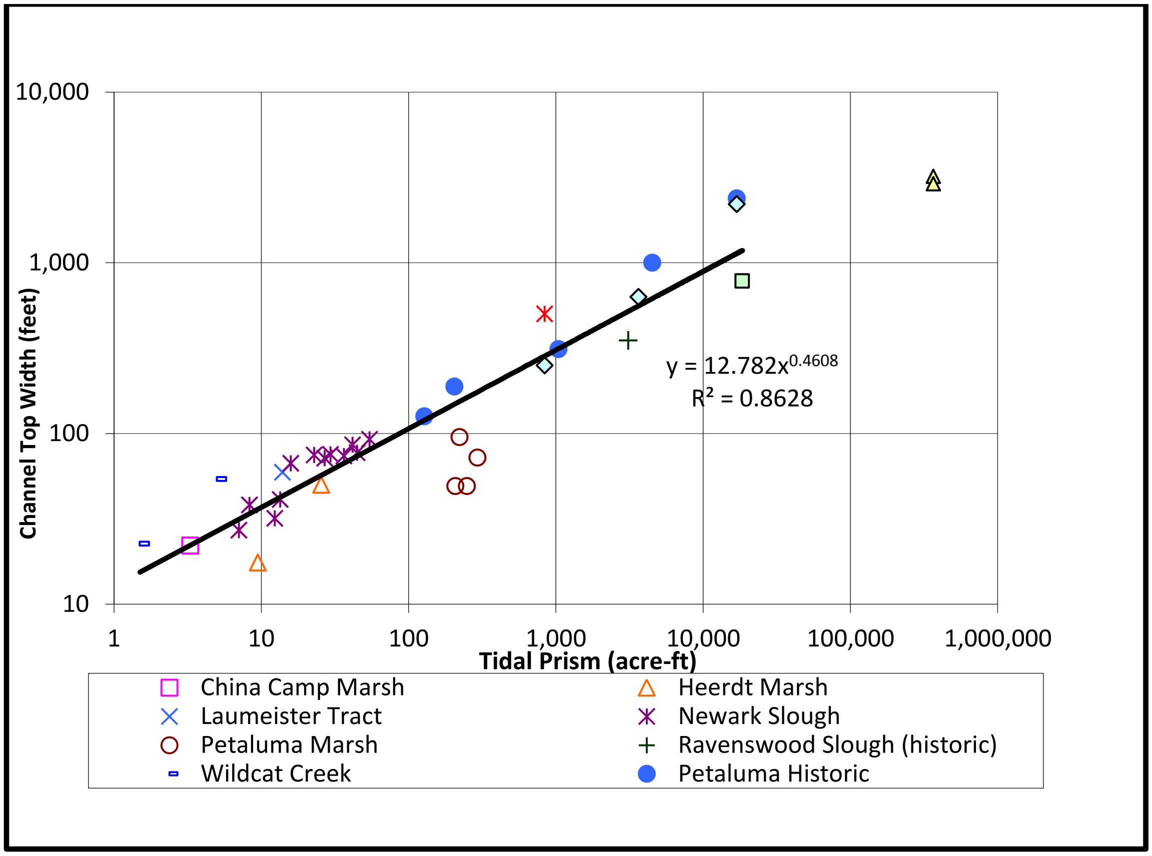

Figure 3: Example plot of tidal hydraulic geometry: tidal channel width plotted against tidal prism

The field data plots are then fitted with a best-fit line using standard linear regression methods so that one can use measured values of tidal prism to estimate the "geomorphic" channel width and depths with the line and equation shown above. We used this approach for estimating the geomorphically "stable" channel dimensions in this analysis that vary with the decreasing tidal prism up the channel.

Daily tides are the engine that drives the primary flow of water and sediment into and out of the tidal marsh system. In particular, the faster ebb tides have the greatest potential to mobilize the fine-grained bay sediments to maintain "stable" channel dimensions. Of course, in natural systems there are many other factors that may impact channel stability, but effective tidal prism level is commonly accepted to be a primary control on channel stability.

2.1.1 Effective Diurnal Tidal Prism

In this study, we calculated the "effective diurnal tidal prism," defined as the volume of tidal water that flows in and out of a site daily, measured from the MHHW tide level down to the channel invert or marshplain surface or MLLW, whichever is higher in elevation.

This is a common measurement of effective daily tidal prism used for hydraulic geometry relationships. Note that these areas must be actively inundated by the natural inflow and outflow of the tides on a daily basis. Areas that used to be tidal marsh but have been diked off for development no longer have an active tidal prism and thus do not move sediment either in or out of the system.

2.2 San Francisco Bay Area Relationships of Tidal Hydraulic Geometry

Hydraulic geometry plots have been produced for numerous marshes in California and around the country. However, given the unique dynamics of San Francisco Bay, we only used available data from San Francisco Bay Area marshes in this analysis.

In 2002, a San Francisco Bay Area regional curve of hydraulic geometry was published (PWA 2002)[2] that included data from all marsh types in San Francisco Bay plotted on the same graph. Given the variety of marsh sizes and level of maturity, a single plot is not a good guide to stable channel dimensions; therefore, the data was subsequently segregated by marsh size (small and large based on an area criteria of 50 acres) and degree of maturity (i.e., mature and immature marshes based on the history of the marsh). That data was subsequently summarized in a design memo as part of the Hamilton Wetland project design (PWA 2007)[3].

In this analysis, the plots for small, mature marshes were used to estimate stable channel dimensions under existing and proposed conditions. This plot is shown below as Figure 4.

As in most empirically (field-based) derived datasets, there is scatter and variation in the data. Nature is rarely uniform and consistent—and consistency and uniformity are even rarer when looking at geomorphic landscape scale data like tidal channel widths and depths. Also, there may be controls and parameters that impact channel width and depth other than tidal prism, so these plots should be understood to be approximate, with uncertainty, and not necessarily definitive.

In particular, there is scatter in the data that is folded into the r^2 value for the best-fit line. In other words, for the same value of tidal prism, there is natural variation—or perhaps measurement variation—in the channel width and depth for different marshes. This variation (the standard deviation of the dataset) can be used to develop confidence intervals for the plots based on basic statistical methods. Figure 4 shows an example data plot for channel depth from MHHW for small, mature marshes from San Francisco Bay with the 68% and 95% confidence intervals (PWA 2007). There are similar plots of channel width and area.

The values for small, mature marshes were used in this analysis because they had the best average fit to the available data. The r^2 value, which assesses how good of a fit to a linear regression the data is, was 0.792, which is considered a reasonably good fit.

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[2] Williams, et al. 2002. Hydraulic Geometry: A Geomorphic Design Tool for Tidal Marsh Channel Evolution in Wetland Restoration Projects, *Restoration Ecology* 10:3

[3] "Future Tidal Channel Predictive Information," Phillip Williams Associates for the USACE part of the Hamilton Wetlands project

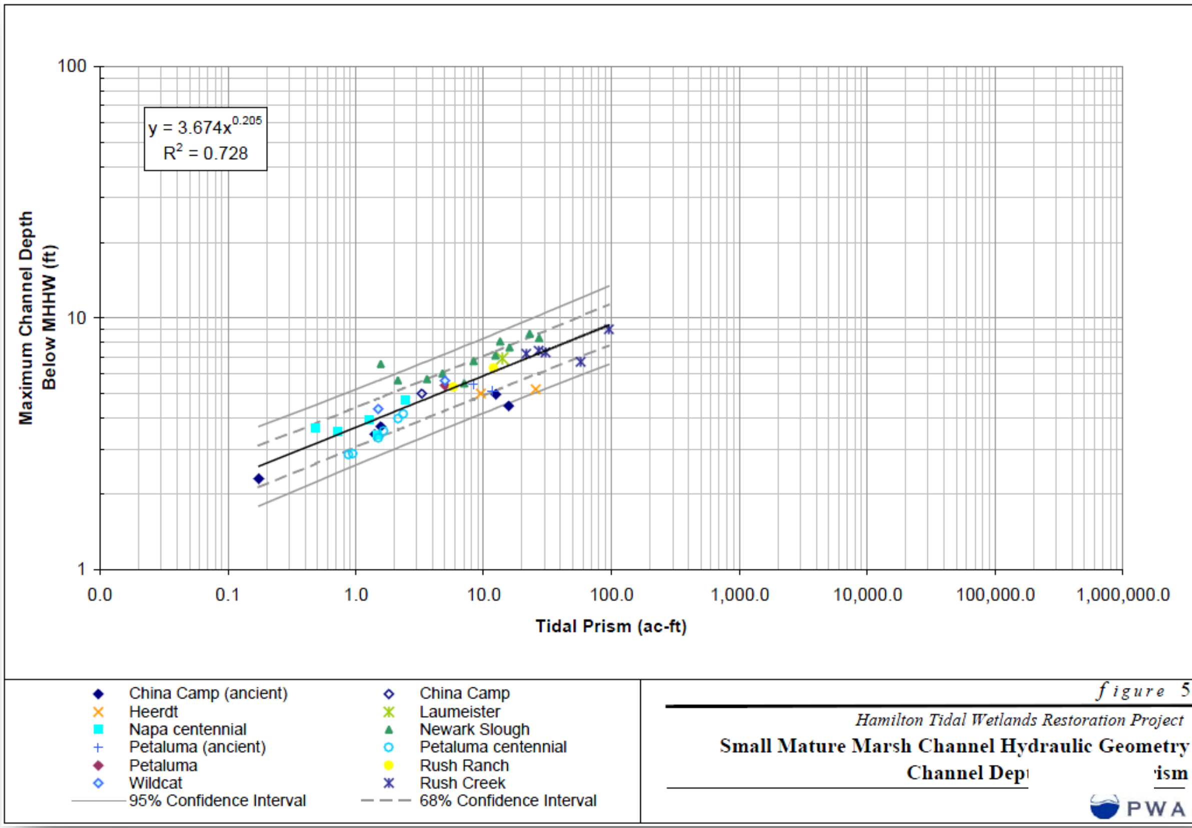

Figure 4: Hydraulic geometry plot for small, mature marshes showing confidence intervals

3.0 PROJECT BACKGROUND AND SETTING

3.1 Background

This section provides some limited background information from previous reports. For a more complete listing of past studies and reports, see the library section at www.marinwatersheds.org.

3.1.1 Historical Ecology

Much of the study area was once comprised of tidal marsh and mudflats. The daily rise and fall of the tides—especially during the astronomical extreme tide events and storms—worked to transport sediments from the channel into the bay. In conjunction with the preparation of this memo, Watershed Sciences (WS) conducted a focused historical ecology assessment of the Lower Las Gallinas watershed, which will be posted as a Powerpoint presentation at http://www.marinwatersheds.org when completed.

Although we focus on current, not historical, conditions in this analysis, the diking off of marshlands for development that began in the mid-nineteenth century has reduced the tidal prism and impacted the channel. The main impacts from development in the lower watershed with regard to loss of wetland acres and tidal prism are as follows:

- Previous estimates of tidal marsh areas and types (San Francisco Estuary Institute (SFEI) Bay Area Aquatic Resource Inventory (BAARI) maps) indicate that approximately 1,162 acres of tidal marsh were present in the lower watershed in the year 1850 prior to extensive diking off of the marshes. In 2010 existing marsh was estimated to be approximately 210 acres (Figures 5 and 6), representing a loss of approximately 80 percent since 1850.

- Due to the loss of tidal marsh, the tidal prism has been reduced from an estimated 1,100 acre-ft in the year 1850 down to the current (2010) estimate of 420 acre-ft. Note that historical tidal prism estimates are very approximate because no depth sounds are available. Therefore, depths (and hence tidal prism volumes) are based upon assumptions of ground elevations based on marsh type. Current estimates of tidal prism were made using AutoCAD Civil 3D to calculate volumes.

- WS has also measured historic channel widths and documented a reduction in channel width, which represents a natural progression as the channel narrows due to loss of tidal prism.

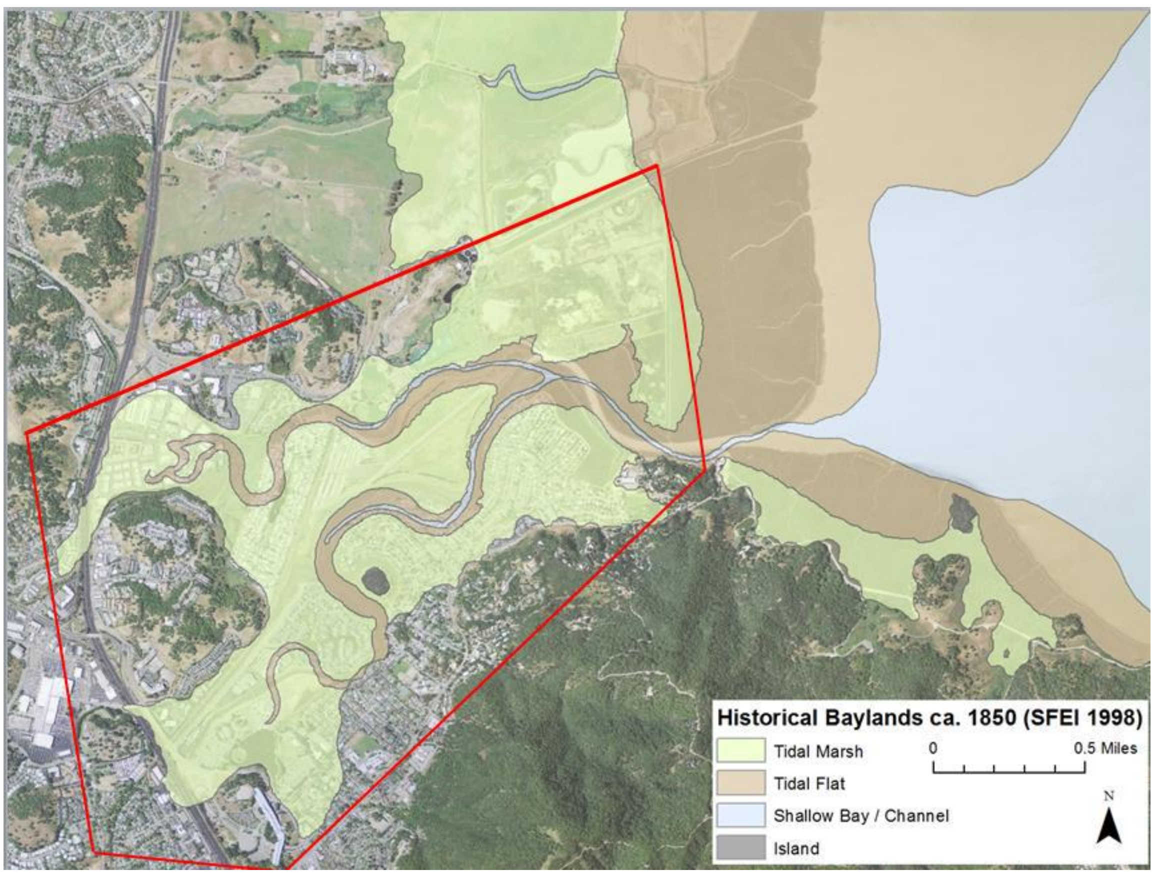

Figure 5: Historic wetlands circa 1850

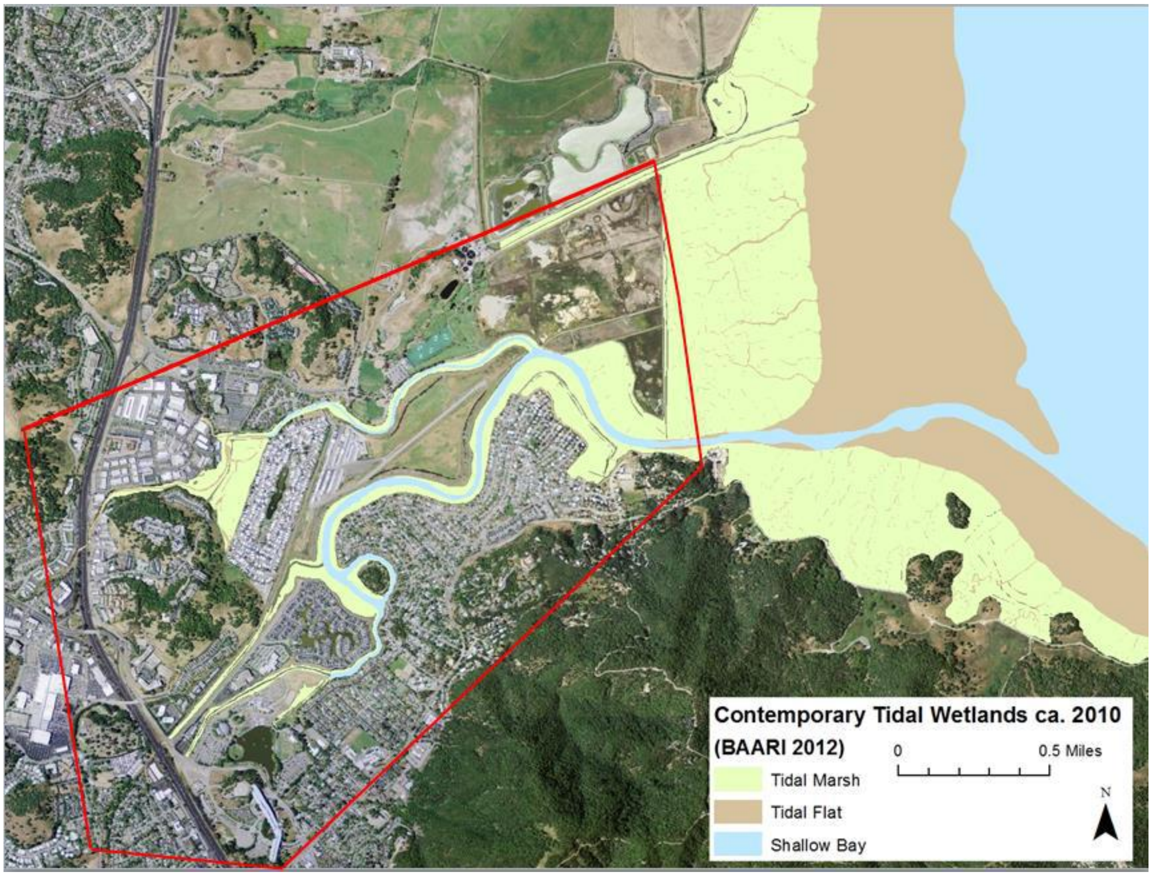

Figure 6: Wetlands, Lower Las Gallinas Creek, 2010

3.1.2 Channel Condition Survey (Based on 2009 GBA Survey) and Updated DEM

In 2009, Gahagan-Bryant Associates (GBA) (under contract to Winzler & Kelly) conducted a hydrographic survey of the creek channel. The survey was terminated at the downstream end of the previous dredging event (approximately station 11+00 on the Noble station line and 00+00 on the GBA station line) and did not extend into the deeper waters of San Pablo Bay. In 2011, Noble Consultants used this survey data for their modeling work for the U.S. Army Corps of Engineers (USACE). Noble then artificially created additional channel cross-sections into the bay for their work for USACE and extended the station line by approximately 1,100 feet. No new surveying was conducted for these extended sections. This extension means that the 0+00 station location for the Noble survey is different than the 0+00 station location used by Winzler & Kelly in their 2010 report. The difference between zero stations is approximately 1,100 feet; i.e., for the GBA survey (in the Winzler & Kelly report) the 00+00 station is located at station 11+00 (approximate) of the Noble stationing line. For this study, the longer Noble station line was used; but readers should be aware that the 2010 Winzler & Kelly report uses the GBA station line, and that there is a difference in the two station 00+00 locations. For this memo, all station numbers were taken from the Noble stationing line. Figure 7 shows the station numbering from the Noble study with station 00+00 at the downstream end and 157+28 at the upstream end.

Figure 7: Las Gallinas Creek station line (from Noble, 2011)

As part of their work for USACE, Noble merged the 2009 GBA bathymetric survey data into the County supplied watershed Digital Elevation Model (DEM—a 3d model of the land surface) and created a revised DEM that connects to the County DEM for the overbanks and levees. We used this revised DEM (as provided by Noble) to generate cross-sections and earthwork volumes.

A creek profile is a useful plot that shows elevations of various creek features (i.e., channel bottom, dredge elevations) along the creek channel as it extends from the lower parts of the creek to the upper end. Figure 8 is a profile for Las Gallinas Creek that extends from just downstream of the Bucks Landing boat dock upstream to Mark Twain Street at the upper end of the project boundary.

Figure 8 shows the following features (all elevations are in the NAVD88 datum). Note that the scale for the horizontal distance up the creek is different than the elevation (vertical scale); so the profile is what is known as "exaggerated," meaning that the horizontal and vertical scales are different. Vertical exaggeration is commonly done to better show the vertical features along a long horizontal length.

- The elevation along the deepest part of the creek channel (called the "thalweg") (elevation in the NAVD88 datum) based on the 2009 GBA survey from the bottom to the upstream end of the project.

- The channel bottom (thalweg) profile. (Some localized shoaling and scour of the channel is evident for the first 3,000 to 4,000 feet from Station 00+00 at the most downstream end of the station line just downstream of Bucks Landing.)
- The MHHW and MLLW tide elevations as dashed lines.
- The historic dredging line to –7 ft NAVD (-4.3 ft NAVD88) to –6 ft NAVD (-3.3 ft NAVD88). Note these are also the proposed dredging bottom (invert) elevations proposed by W-K in their 2010 report.
- The current water depths in the channel at a MLLW tide. Channel depths from MLLW are a good indicator of the available water depth for boat access at low tide, and larger boats require more depth to avoid being grounded in the mud. This profile shows that the existing channel depths (important for the hydraulic geometry relationships) range from -4 f NAVD88 at the lower reaches of the channel to approximate elevation 0 feet NAVD88 at the upper reaches of the channel. Note that the channel invert elevation rises up to an elevation higher than +2 ft NAVD88 at the inner arm of Santa Margarita Island due to the split flow regime.

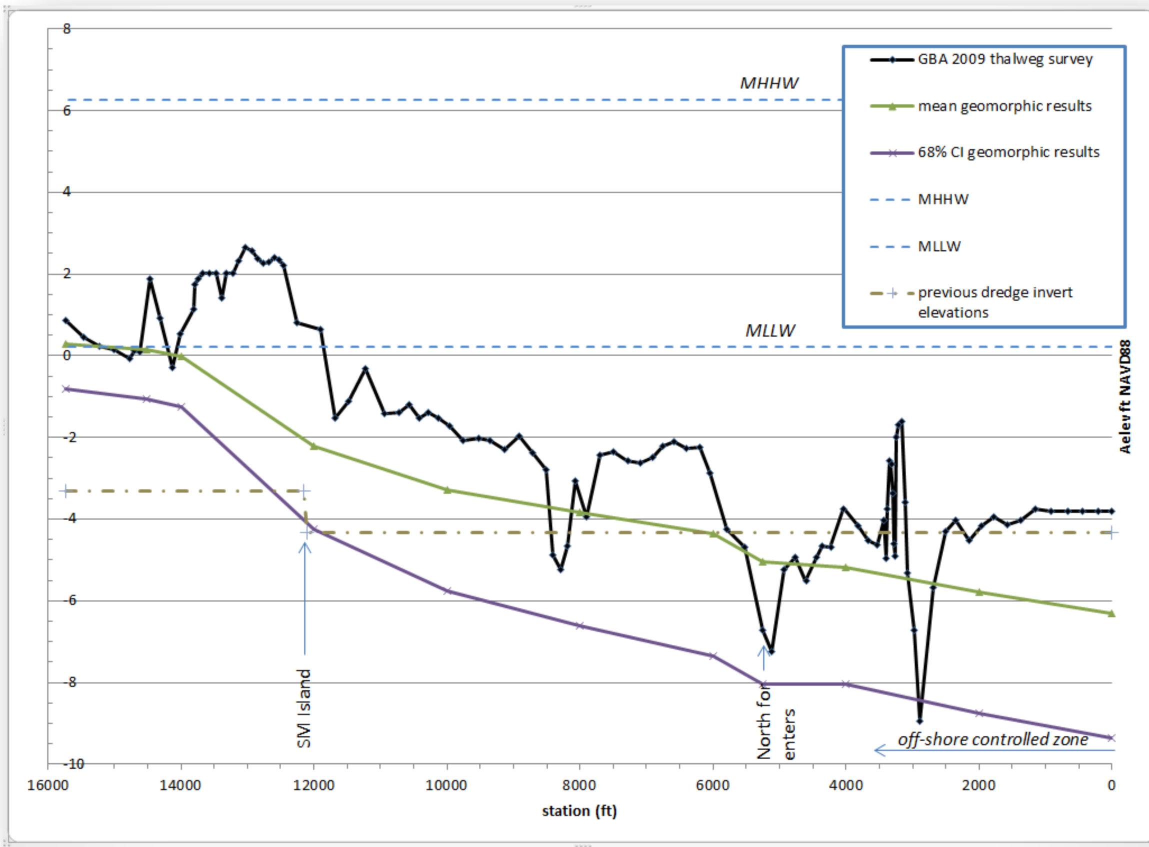

Figure 8: Creek profile showing the existing creek thalweg (black line) along with the previous dredging invert elevations from 1994 (dashed dot line) and the mean and 68% confidence interval geomorphic dredge results (green and blue lines)

3.1.3 Previous Dredge Episodes

The channel has been dredged at least four times by the County on behalf of CSA 6. It is our understanding that during previous dredging events, the sediment was hydraulically pumped and placed at a local disposal location, usually McInnis Park. Permitting requirements and disposal costs have greatly increased since the last dredging event in 1994. Dredging and dredge sediment disposal are now more difficult to permit and construct, especially in locations like Las Gallinas with wetlands adjacent to the dredge site. Impacts to wetlands will typically trigger permitting and mitigation requirements that can be significant. The approach in this study was used partly in response to these more stringent permitting requirements and associated costs as well as to CSA 6 Advisory Board members' concerns that the proposed dredge design (Winzler & Kelly 2010) is unaffordable.

Table 1. Summary of previous dredge episodes showing dredge invert elevations, channel widths, and side slopes

Year dredged	Invert elevation NGVD (NAVD) + overdepth (ft) to Invert Elev at Santa Margarita Island (ft NGVD (NAVD)	Bottom width at invert (ft) upstream (>) and downstream (<) Santa Margarita Island	Side slopes	Reported dredge quantity from plans (cy)	Dredge type and disposal location
1966	-9 ft (-6.3NAVD) + 1 ft OD	75' < Santa Margarita Island to 25' > Santa Margarita Island	3:1 to 5:1	460,000	Hydraulic to McInnis Park area
1973	-9 ft (-6.3NAVD) + 0 ft OD	<75' to >50'	5:1	114,200	Hydraulic to McInnis Park area
1981	-7 ft (-4.3 NAVD) + 0 OD to -6 (-3.3) at Santa Margarita Island	<50' to >20'	5:1	70,440	Hydraulic to McInnis Park area
1992/94	-7 ft (-4.3 NAVD) + 0 OD to -6 (-3.3) at Santa Margarita Island	<50' to >20'	5:1	138,348	Hydraulic to McInnis Park area and airport

3.1.4 Winzler &- Kelly 2010 Dredge Design

In 2010, under contract to the County of Marin, Winzler & Kelly prepared their report presenting a dredge design similar to the previous dredging events in that it specified a uniform invert elevation of -7 ft NGVD (-4.3 ft NAVD88) up to Santa Margarita Island and then -6 ft NGVD (-3.3 ft NAVD88) above the island. Winzler & Kelly also proposed relocating the creek thalweg adjacent to the docks for boating access, but did not evaluate long-term sustainability of such a relocation. Their preferred dredge sediment disposal location was SF-10 (the San Pablo Bay disposal location).

Note that the W&K 2010 dredge template and cost estimates did not directly account for impacts to existing wetlands and associated mitigation and permitting costs. As discussed in more detail in Section 8 below, the recommended plan to dig and haul by barge to SF-10 would have been very difficult and likely much more expensive than originally projected to implement north of Station 120+61, where the creek narrows around Santa Margarita Island. This issue is discussed in more detail below, but the revised dredging approach in this study was developed to account for these constructability and permitting issues and costs.

3.2 Flow and Sediment Dynamics

This section describes the general flow and sediment dynamics in this part of San Pablo Bay and locally in Lower Las Gallinas Creek. San Pablo Bay has very complex flow and sediment dynamics; however, this report discusses only those that impact Lower Las Gallinas Creek directly.

3.2.1 Regional Setting - San Pablo Bay Tide and Sediment Dynamics

San Pablo Bay comprises the northern part of the San Francisco Bay Estuary. It is mostly very shallow: two-thirds is less than 6.5 feet deep (2 meters) at MLLW. A deep main channel in its southern extent connects Central San Francisco Bay in the west to Carquinez Straight in the east. This deepwater channel (on average 40 feet deep) is a remnant channel from previous ice ages when sea level was much lower and is an important control on San Pablo Bay's hydrodynamic regime (Jaffe et al. 2007).[4]

Flow and sediment patterns in the bay are complex, and there are seasonal patterns in flow and sediment dynamics. In particular, there is a reported clockwise "eddy" flow cell from Las Gallinas Creek up to the Petaluma River due to the strong delta outflow that flows from San Pablo Bay down to the main part of the Central Bay. This larger eddy then sets up a smaller flow gyre near the mouth of Las Gallinas Creek that may help maintain its flow depth, which appears to be somewhat lower in elevation then channel inlets and mudflat elevations farther north.

3.2.2 Local Setting

Historically, the lower Las Gallinas and Miller Creek watershed areas comprised primarily tidal marsh and mudflats. Much of this area has been diked off for development, resulting in a loss of tidal prism and increased channel siltation.

The hydrodynamics of Lower Las Gallinas Creek are dominated by the bay tides and are relatively unaffected by fluvial flows from the watershed. Hydraulic modeling work conducted by Noble Consultants for USACE (Noble 2011)[5] has shown a relatively small rise in after-surface elevation due to fluvial flooding, and that the bay tides and coastal processes dominate the creek processes, effectively making Las Gallinas Creek a tidal slough in the way it transports sediments. Therefore, we believe that for this analysis, the tidal relationships of channel size and tidal prism are appropriate.

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[4] Jaffe, et al. 2007. Anthropogenic influence on sedimentation and intertidal mudflat change in San Pablo Bay, California: 1856-1983. *Estuarine, Coastal and Shelf Science* 73, pp. 175-187

[5] "Las Gallinas H&H and Coastal Analysis," Noble Consultants, September 30, 2011

3.2.3 Implications of Offshore Bay Dynamics to Las Gallinas Creek Channel Sustainability

NOAA hydrographic mapping of the areas offshore of the Las Gallinas Creek outlet indicates that some higher elevation shoals exist between the creek mouth and the deeper parts of San Pablo Bay. The offshore data is somewhat unknown since the 2009 GBA survey terminated at the downstream end of the previous dredge in 1992/94 and did not extend into the deeper of San Pablo Bay. However, some shoaling areas may form a downstream control on grades, which would impact the ultimate sustainable depth of any dredging project. In general, though, the elevations at the mouth of Las Gallinas Creek are subtidal (i.e., below elevation 0 ft NAVD88), so there is usually some depth of water at MLLW and therefore some degree of deeper water connection to the bay. The creek channel to station 11+00 near the mouth appears to be relatively stable at an elevation of approximately -4.3 ft NAVD. However, this finding would need to be confirmed by conducting additional hydrographic surveys.

The stability of offshore shoals and potential impacts to sustainable dredging depths are unknown since no replicable survey data exist for this area. However, based on a review of historical imagery from Google Earth, it appears that a small outlet channel to the bay is sustainable. We recommend that a bathymetric survey be conducted prior to preparing final dredge designs; the current channel should be resurveyed and the survey extended to include offshore conditions into San Pablo Bay.

3.2.4 Local Tidal Datums

Local tidal datums were developed for the Noble study for the USACE (Table 2-2 of draft 2011 Noble report). Noble assumed tidal datums to be the same at the mouth of Las Gallinas Creek as the tidal datums developed by the Corps at the nearby Hamilton site, north of Las Gallinas. We used the tidal datums reported by Noble Consultants.

The two most important tidal datums for this study are shown in Table 2.

Table 2. Local tidal datums

Tidal statistics	*Value in ft NGVD29 datum*	*Value in ft NAVD88 datum*
MHHW	3.57	6.25
MHW	2.98	5.66
MLW	-1.38	1.3
MLLW	-2.47	0.21

3.3 Project Reach Conditions

The project reach for Las Gallinas Creek is over 14,000 feet long. The reach has been altered heavily in some locations by levee construction and the loss of historic tidal prism discussed above, including land development. In addition, other local conditions, notably the artificial channel around Santa Margarita Island, which splits the flow, lower velocities and enhance sediment buildup in the channel around the island.

Given the length of the channel, we have divided the creek into six geomorphic reaches based on conditions in the channel. These reaches are approximate, are based upon channel observations, and can serve as a guide to and basis for evaluating the channel in the design sections below.

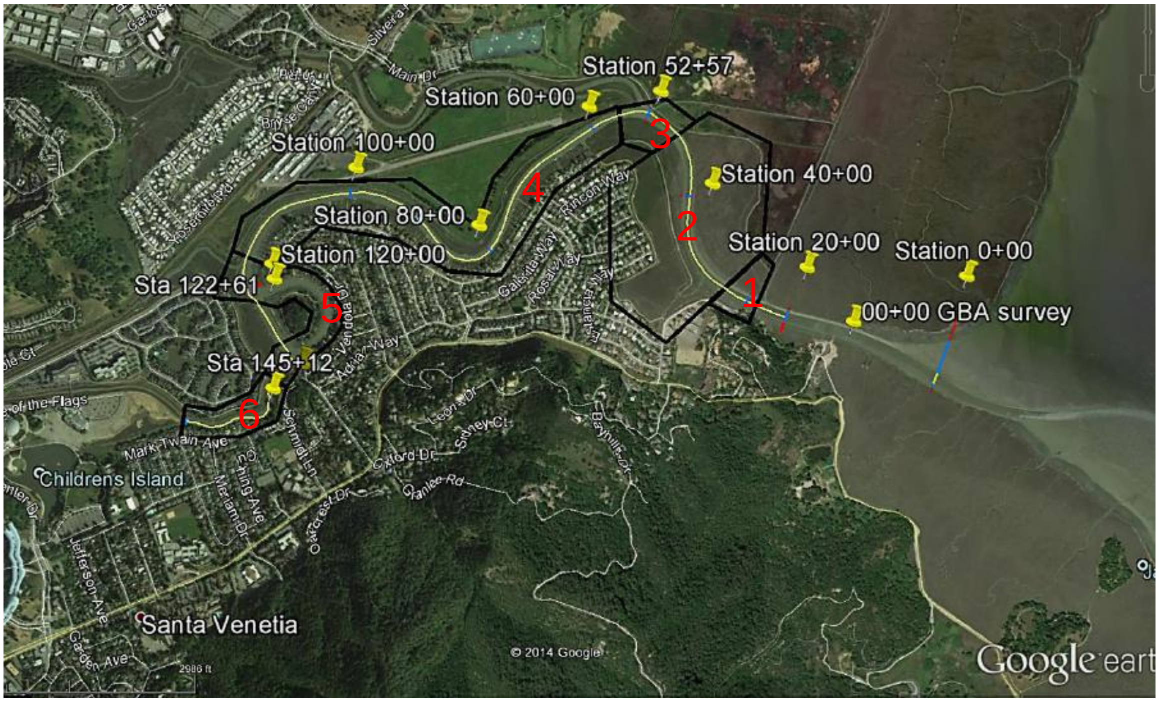

Figure 9. Lower Las Gallinas Creek reaches

Table 3. Summary of the six geomorphic study reaches

Reach number	*Approximate beginning and ending station numbers*	*Description*
1	23+84 to 28+20	Creek narrows as it flows into the bay
2	28+20 to 48+50	Expanded creek section with tidal marsh
3	48+50 to 56+08	Confluence reach where north fork enters the creek
4	56+08 to 115+83	Constrained reach as levees constrain the channel Boat docks start at around station 62+02
5	115+83 to 141+88	Split flow reach around Santa Margarita Island beings at around 121+61
6	141+88 to 157+30	Farthest upstream reach, with very limited tidal prism

In Section Table 9, representative cross-sections from each reach are evaluated and used to generate a first cut assessment of dredge volume.

3.4. Primary Causes of Channel Sedimentation

While a comprehensive assessment of channel sedimentation causes is beyond the scope of this study, we believe that the primary cause of creek sedimentation in the project area is likely the loss of tidal prism that has resulted from adjacent development that took place over time. The creek has adjusted to this loss of tidal prism by narrowing and, above Station 60+00, by reducing its depth. Downstream of Station 60+00, the creek invert appears to be predominately controlled by offshore processes in San Pablo Bay; in general it remains subtidal, although its width has likely narrowed.

In the upper reaches of the creek, confinement of the channel within levees has contributed to narrowing of the channel, while the loss of historic tidal prism has reduced the flushing effect of tidal flows. At Santa Margarita Island, the channel cut around the island has split the flow and increased sedimentation along both sides of the channel, particularly along the inner edge where the boat docks are located. Split tidal flows can lead to asymmetries in flow pathways that lead to sediment buildup.

4.0 GEOMORPHIC ANALYSIS RESULTS FROM HYDRAULIC GEOMETRY PLOTS

This section presents the results of the first-cut analysis of the geomorphic dredging template dimensions for the creek channel adjusted by the reduction in tidal prism moving up the channel. This section provides results of the analysis from the mean and the 68% confidence interval values from the empirical plots of marshes around the San Francisco Bay Area.

As described above, our approach is to develop an appropriate range of geomorphic widths and depths and then place this “geomorphic dredge template” cross-section within the current cross-section of the creek. At the same time, our design maintains some distance of geotechnical offset from existing levee toes, avoids impacts to existing marsh vegetation as much as possible, and provides access for construction equipment.

Section 5.0 describes the process of fitting the geomorphic template into the existing creek channel in more detail; this section provides results from the tidal hydraulic geometry plots.

4.1 Results of Measurements for Tidal Prism and Active Marsh Area

This section presents the results of estimated values of tidal prism and active tidal marsh areas. These estimates serve as the basis for developing stable channel dimensions using the curves of hydraulic geometry described above. All measurements are preliminary and based upon the available channel digital elevation model developed by Noble Consultants (2010).[6] Tidal prism was estimated at nine selected stations up the channel starting at Station 00+00 and moving upstream, by calculating the volume of water between MHHW and either MLLW or the channel invert, whichever is at the higher elevation

[6] “Las Gallinas H&H and Coastal Analysis,” Noble Consultants, September 30, 2011

4.1.1 Estimation of Areas and Tidal Prism (Historic and Current)

Table 4 presents the results of tidal prism and area calculations using AutoCAD Civil 3D based upon the creek elevation model (DEM) provided by Noble Consultants that merged the County DEM with the GBA Survey, 2009[7]. The results are consistent with previous estimates done by the County, in-house, using GIS analysis.

Table 4. Tidal prism and area results

Begin station	*End station*	*Cumulative tidal prism (acre-ft)*	*Cumulative area tidal marsh at MHHW (acres)*
00+00	20+00	405	193
20+00	40+00	328	170
40+00	60+00	256	112
60+00	80+00	177	67
80+00	100+00	139	56
100+00	120+00	105	45
120+00	140+00	59	25
140+00	145+12	12	7
145+12	157+28	4	---

Values in red are estimated (not calculated)

4.2 Geomorphic Values Developed from Hydraulic Geometry Regression Plots

This section develops the dredging template based on the results of the tidal prism analysis above. As discussed, this template varies by available tidal prism and distances up the channel. To facilitate the channel dredging layout, we developed tidal prism estimates at nine locations up the channel.

4.2.1 Data Scatter and Uncertainty

Since the data is based on field measurements, there is inherent scatter in the data plots due to natural variability in tidal marsh systems as well as differences in measurement technique. For this analysis, we have developed the 68% and 98% confidence interval values from the available data plots. In our engineering design summary (Section 5), we kept the range of allowable values for our geomorphic dredge template to values within the mean to the 68% values, and did not exceed this range, which is closer to the mean values than the larger confidence interval values.

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[7] *Project Study Report, Channel Maintenance Dredging, Las Gallinas Creek, prepared by Winzler & Kelly (now GHD) February 26, 2010*

4.2.2 Dredge Width at MHHW

Table 5. The hydraulic geometry curves provide the width at the MHHW elevation.

Station number	*Calculated tidal prism (acre-ft)*	*Channel width at MHHW (ft) – MEAN results*	*Channel width at MHHW (ft) – 68% results (low)*	*Notes*
0+00 (mouth)	405	174	109	
20+00	328	158	100	
40+00	256	142	92	
52+57	230	137	88	North fork confluence
60+00	177	120	75	
80+00	139	107	66	
100+00	105	94	60	
120+00	59	72	48	
140+00	14	37	25	
145+12	12	35	24	

Values in red are estimated (not calculated)

4.2.3 Dredge Depth from MHHW

Table 6. The regression plots provide the channel depth from the MHHW elevation.

Station number	*Calculated tidal prism (acre-ft)*	*Channel depth (ft) from MHHW – MEAN results*	*Channel depth (ft) from MHHW – 68% CI results (high)*	*Calculated channel bottom elevation (ft NGVD) from Noble RAS model for MEAN results*	*Calculated channel bottom elevation (ft NGVD)from Noble RAS model for 68% results*
0+00 (mouth)	405	12.6	15.6	-9.0	-12.0
20+00	328	12.0	15.0	-8.5	-11.4
40+00	256	11.4	14.3	-7.9	-10.7
52+57	230	11.3	14.3	-7.7	-10.7
60+00	177	10.6	13.6	-7.0	-10.0
80+00	139	10.1	12.9	-6.5	-9.3
100+00	105	9.5	12.0	-6.0	-8.4
120+00	59	8.5	10.5	-4.9	-6.9
140+00	14	6.3	7.5	-2.7	-3.9
145+12	12	6.1	7.3	-2.5	-3.7

Values in red are estimated (not calculated)

4.2.4 Cross-Sectional Area

Regression results for cross-sectional area are provided below. Note that these estimates are based upon an assumption that the channel is a trapezoidal cross-section with different side slopes above and below MLLW. This engineering design is further described in Section 5.

Table 7. Regression results for cross-sectional area

Station number	*Calculated tidal prism (acre-ft)*	*Channel area (ft) – MEAN results*	*Channel area (ft)- 68% CI results (low)*
0+00 (mouth)	405	909	580
20+00	328	803	475
40+00	256	696	400
52+57	230	669	380
60+00	177	560	350
80+00	139	486	290
100+00	105	413	250
120+00	59	294	190
140+00	14	125	75
157+28	12	116	70

Values in red are estimated (not calculated)

4.2.5 Width to Depth Ratio

This parameter describes the top width at MHHW to the depth from MHHW developed above. The channel width to depth ratio (w/d) is a useful measure of how channel shape adjusts in a tidal marsh system. As can be seen by the values below, w/d ratios tend to decrease (i.e., channel widths tend to narrow faster than channel depths become shallower) as one moves upstream in a tidal marsh system, i.e., the first order tidal channel (smaller channels) tend to be narrower and deeper than the channels lower in the system.

Table 8. Width to depth ratios

Station number	*Calculated tidal prism (acre-ft)*	*Channel width to depth ratio (ft) - MEAN results*	*Channel w/d ratio – 68% CI results (low)*
0+00 (mouth)	405	13.9	9.9
20+00	328	13.1	9.8
40+00	256	12.4	9.7
52+57	230	12.2	9.3
60+00	177	11.3	8.4
80+00	139	10.6	8.1
100+00	105	9.9	7.8
120+00	59	8.6	6.8
140+00	14	5.9	4.6
157+28	12	5.8	4.4

Values in red are estimated (not calculated)

5.0 ENGINEERING DESIGN CONSTRAINTS

The values presented in Section 4 above are channel dimensions developed from analyses of various marsh systems around San Francisco Bay. However, Las Gallinas is an altered systemand, therefore, these geomorphic parameters from other sites around the bay (width, depth, area, and w/d ratios) have to be overlain onto the actual cross-sections up and down the creek channel and adjusted (fit) to meet actual site constraints as described below. We attempted to adjust the dredge template sections to fall within the range of values from mean to the 68% limits, subject to the site constraints. We have noted where we could not meet these constraints.

5.1 Navigational Boat Requirements

Current boater usage up the channel appears to be primarily with small boats (10 to 12 feet wide), with drafts in the range of 3 to 5 feet. Since the width and depth requirements for boat usage are relatively small, we used a minimum channel design width at MLLW of 20 feet and water depths from MLLW, in accordance with the preferred dredge invert plan described in Section 6.3. If followed, these parameters will provide approximately 1 foot to 5 feet of water depth at MLLW tide in the thalweg, depending on distance up the creek channel from the bay. The shallowest depths are above Station 140+00 (equals 14,000 feet or approximately 3 miles up the channel from the bay), and the deeper reaches are at or below Station 60+00, or within a mile of the mouth. Note that these upper areas are currently dry at MLLW tides and, therefore, the proposed plan represents a small improvement in channel depth over the existing condition, but not enough to float most boats except for low draft kayaks. Note that above station 121+60 (SM Island) it is difficult to move more than small and very low draft boats (i.e., kayaks) at lower tides anyway.

5.2 Geomorphic Template Constraints

The dredge design template uses the geomorphic values for width and depth in the range of mean to the 68% confidence interval range developed in Section 4 above. Where the values needed to fall out of this range to meet other constraints, we noted the location on the summary table of results for representative cross-sections.

Another goal of the geomorphic template is to follow the existing thalweg to the extent possible. This deepest part of the channel may be expanded to meet geomorphic or construction access requirements, but, in general, we did not relocate the thalweg from its current location.

5.3 Allowable Dredge Cut Side Slopes

The dredged channel cut requires more gradual (flatter) side slopes than found in natural channels since, in natural marshes, channel slopes act primarily as depositional features and are not cut. The proposed side slopes from the Winzler & Kelly report are 2:1, but this is likely too steep to hold in typical bay muds and would likely result in excessive channel sloughing.

In this evaluation, we assumed a minimum 3:1 (horizontal to vertical) dredge slope above MLLW and a minimum 2:1 side slope below MLLW where the presence of standing tidal water helps maintain channel stability. Where possible, we used flatter slopes to help channel stability. Note that the older dredging events used an even flatter slope—often 5:1—so this issue should be re-assessed during subsequent geotechnical design studies. The upper side slopes may need to be increased to 4 to 5:1 during final design phases and constructability review.

5.4 Geotechnical Constraint – Offset from Toe of Existing Levees

This study focuses on a geomorphic dredge template and does not evaluate the geotechnical constraints and requirements for existing levees. In their 2010 report, Winzler & Kelly recommended a 50-foot offset from the base (toe) of any adjacent flood control levees. However, as described in the Winzler & Kelly report, this assumption was not based on site specific borings and geotechnical engineering analysis and may need to be confirmed by additional geotechnical engineering during subsequent design phases.

It is important to note that this 50-foot offset was not achievable in many locations, primarily in the inner bend around Santa Margarita Island where the channel narrows.

Note that in sections with geotechnical constraints, we identified the “assumed toe of levee” for levee offset distances based upon a visual inspection of the cross-section without review by a qualified geotechnical engineer. Therefore, the identified toe of the levee may be subject to change during the final design phase. The goal of this memo is a geomorphic channel assessment. If the project proceeds further, a focused geotechnical analysis should be performed and the levee toes and required offsets delineated.

Note that previous dredge episodes were to a lower invert elevation than the proposed geomorphic dredge. In many locations the “goal” of an offset of 50 feet from levee toes was not met, yet no geotechnical issues have been reported. This also means that the current mud invert elevations are from sediment aggradation: Because of that, the excavation in this design geomorphic dredge would not weaken the levee toe nearly as much as excavation of new sediment that never been removed before. In this first-cut assessment, we have noted where the 50 foot offset was not achieved and recommend that if there are levee stability concerns, an additional geotechnical study be performed to determine the allowable location for excavation adjacent to levees in the critical areas identified in this study. However, we have developed our sections even in locations where the geotechnical levee offset goal has not been achieved.

5.5 Preliminary Constructability Evaluation and Construction Equipment Access and Dewatering Constraints

Constructability is a significant issue for the design of the dredging event. This section provides a preliminary assessment of constructability and implementation of the dredging plans based on engineer experience and discussions with local dredgers. No site visits were conducted for this review, but should be conducted during the next phase of design activities. Previous dredge episodes in the creek from 1994 and earlier used a hydraulic dredge and pumped to local disposal areas. However, no local locations have been identified that can accept hydraulic dredge slurry as with the previous dredge episodes. In addition, permitting requirements for a hydraulic slurry dredging operation will likely be more stringent today than for the previous dredge episodes—and thus be more costly. It is possible that the McInnis Marsh restoration project, currently in the early stages of design by Marin County Parks, may be able to accept dredge slurry, but that project design will not be finalized until late 2015. Hydraulic dredging tends to be less expensive and to have smaller access requirements for the dredge than mechanical dredging operations. This makes hydraulic dredging preferable, but no viable location for dredge slurry has been identified.

Winzler & Kelly (2010) evaluated several different dredge disposal alternatives and determined that in-bay disposal at the SF-10 site in San Pablo Bay would be most cost-effective for the entire creek. Disposal at SF-10 is a dig and haul dredge operation that requires a barge-mounted excavator to dig and feed at least two dredge scows, with small tugboats moving the scows to the disposal site. Disposal at SF-10 (or SF-11) would require sufficient width and depth in the Las Gallinas channel for the excavator barge, sediment disposal scows, and tugboats. Timing the operation with the tides will be critical for success and may require unusual working hours to meet an accelerated schedule, which could significantly increase costs. The operation would probably need to take place over two years.

As described below, the available channel width and depth upstream of Santa Margarita Island—where the channel splits and becomes narrow and shallow—will not allow for cost-effective construction access for aquatic dredging and disposal at SF-10. Therefore, other alternatives for dredging those reaches are discussed below. Transporting scows loaded with dredged sediments requires water at least 5 feet deep, which would limit movement of barges and tugboats to higher tides. That limitation will lower dredge production rates and increase costs and schedule. The Winzler & Kelly uniform cost for dredge and disposal for the entire three miles of creek needs to be adjusted upward to reflect the realities of dredging construction access and costs.

Alternatives to Dig and Barge Operations to San Francisco-10/11 Above Station 121+61

The options for digging sediment, loading it onto barges, and using tugboats to bring the scows to SF-10/11 are very limited and impractical above Station 121+61. The creek becomes narrow and shallow, making alternative dredging approaches necessary for these reaches of the creek.

Hydraulic Dredging Options

The most cost-effective solution appears to be to use a small hydraulic dredge to dredge and pump the sediment to a local disposal site for decanting, and then send slurry water back into the creek as in the previous dredge episodes. However, no dredge sediment disposal sites have agreed or are permitted to accept hydraulic dredge slurry at the time of preparation of this memo. While hydraulic dredging is preferred due to the narrow width in the creek above 121+61, the permitting requirements for dredge decant water quality are much more stringent than in previous dredging events. This means that larger settling ponds and more monitoring may be required to meet permitting restrictions for return water from the dredge operation. Plus, an additional dredge to ensure adequate water depth for hydraulic dredging might have to be performed (in addition to the geomorphic dredging template). Any additional dredge cut needed for operating the hydraulic dredge would be evaluated during the next phase of project design.

Mechanical Dredging in the Dry—Dewater and Excavate in the Dry, Load onto Trucks for Off-Site Disposal

Another alternative approach to hydraulic dredging commonly used where appropriate is to dewater and excavate sediments in the “dry” and load the sediment onto trucks for off-site disposal. There are two different excavation approaches: dig from the banks using draglines or long reach excavators, or put small, low ground–pressure equipment into the creek and move the sediment to an excavator that loads trucks for off-site disposal. Marin County Flood Control District used the first approach (excavate from the banks) at the Novato and Coyote Creek projects.

However, the use of either technique to excavate sediments in the dewatered creek is very problematic in Las Gallinas Creek. The use of low ground-pressure equipment is unlikely to succeed due to the softness of the deposited muds. Initial discussions with local contractors confirm that this approach of placing equipment in the creek is unlikely to succeed. Although accessing and excavating the sediment from the adjacent levees has been used successfully at Novato Creek, this method presents a major problem in Lower Las Gallinas Creek particularly upstream of Santa Margarita Island for two reasons. For the most part, the creek banks are privately owned, making gaining access for construction equipment highly problematic. The other problem is that Santa Margarita Island is a nature preserve, and it will be very difficult to gain approval for access from the regulatory agencies. In other words, limitations on levee access to the creek make this approach very difficult. Given the width of the creek below Station 121+61 and the adjacent wetlands, installing a cofferdam across the creek for dewatering to allow for sediment excavation (and loading onto trucks) would be difficult and likely impractical. Therefore, this alternative was eliminated from further consideration.

Proposed Dredge Construction Access Requirements for Constraints Analysis

Given the known issues with each dredging option, we have made the following assumptions regarding equipment for this constructability constraints analysis based on communication with local dredgers and engineering experience:

<u>Stations Downstream of 121+61</u>: Construction constraints—mechanical dredging requirements with aquatic disposal at SF-10

Verbal and email communications with local dredgers have provided the following information:

- Typical barge width for a digging excavator is approximately 40 feet wide, and these barges draw 4 to 5 feet draft to move. At lower depths, the barges can dig, but they will be unable to move. The excavator can dig down about 5 feet under the water to dig the cut.

- The smallest scow that can transport spoils to *SF*-10 has capacity of approximately 300 cy. The typical width on a scow this size is approximately 35-40 feet and requires at least 5 to 6 feet of water depth when fully loaded. Note that smaller scows can be used for tight areas but would require double handling of sediment since smaller scows are loaded onto larger scows for transport to *SF*-10/11.

- A small tugboat is required to move the scow down the channel and to *SF*-10 and then to return the empty scow back to the creek.

- The bottom width at the invert elevation of any new dredge is designed at 10 feet.

Therefore, the minimum width at MLLW for barge access for digging and loading scows to *SF*-10 is assumed to be 35 to 45 feet. In order to meet this temporary requirement for construction, additional dredging may be necessary.

Stations Upstream of 121+61

As described above, neither of the mechanical dredging alternatives for the creek Station 121+61 appear to be feasible at this time, so we do not believe it feasible to complete the dredge for stations above 121+61 as described in the Winzler & Kelly 2010 report. For analysis and cost-estimating purposes, we assume that a local hydraulic dredge disposal site will be identified and permitted to make hydraulic dredging the most feasible alternative. The best outcome is that a local hydraulic dredge disposal site—like McInnis Park—will be found to accept the dredged sediments. Note that the final constructability issues will be addressed during the next phase of design activities.

Therefore, we have assumed no specific construction access constraints that impact the dredge template above Station 121+61. We have assumed that dewatering and in-channel work can dredge these narrower reaches and that the geomorphic template as developed will not require additional analysis for construction constraints.

If a suitable hydraulic dredge disposal site cannot be found and permitted or the banks cannot be accessed by long reach excavators, these reaches will have to remain undredged until a suitable hydraulic dredge disposal location is obtained and permitted. We have not confirmed that dredge in the dry is possible for the entire channel but this can be confirmed under future phases of work.

5.1.6 Impacts to Existing Marsh Vegetation

In order to evaluate potential on-the-ground impacts of any proposed dredging template, we developed two lines of existing marsh vegetation shown on the representative cross-sections in Appendix A. The locations of vegetation lines are approximate and based on tracing the vegetation outlines from Google Earth (GE) aerial photos from the last few years, or were taken from the County GIS system and transferred onto the AutoCAD base map for this analysis. These lines are approximations for this first-cut estimate of impacts and potential costs and should be field-delineated during subsequent design phases of the project.

Lower Limit of Marsh Vegetation - The first line closer to the creek channel (in lighter green) is the lower limit of marsh vegetation and represents the approximate location where marsh vegetation begins to appear on the channel sides. We believe that work that crosses this line will start to trigger permitting issues because of potential impacts to habitat. However, it should be noted that this line is drawn to the lower limit of any vegetation and as such represents the lower limit of habitat values and potential impacts.

Lower Limit of Dense Marsh Vegetation - The second line (in darker green) is the lower limit of denser marsh vegetation and represents the approximate location where impacts landward of this line would likely trigger more permitting issues and possible mitigation impacts and costs. We tried to avoid having the design template include work beyond this line to the extent possible. We measured the width of potential vegetation disturbance beyond each of the vegetation limit lines described above, and report the results below.

6.0 GEOMORPHIC CHANNEL ENGINEERING ANALYSIS RESULTS

This section provides the results of the geomorphic dredge channel analysis, a discussion of the engineering design issues, and rough cost estimates for construction.

This section is preliminary and intended to provide an order-of-magnitude estimate for feasibility evaluations. It should be developed further during the preliminary and final design phases of the project.

6.1 Design Layout Approach

Representative cross-sections were taken at several locations along the channel to allow for preliminary development of a dredge cut volume for comparing to previous dredge reports. These comparisons should help the CSA Advisory Board decide whether they recommend continuation of the geomorphic approach for the channel. The following steps describe the design approach to laying out the geomorphic dredge template for each cross-section. This approach is iterative at times and, as such, is more labor intensive then a single width or two taken to a constant elevation as is commonly done. We have developed approximately 20 cross-sections along the channel to develop the design layout parameters and quantities. A selection of eight representative cross-sections is contained in Appendix A.

Step 1 – Develop Geomorphic Widths at MHHW and MLLW at Each Section. Use the result for mean width at MHHW across the channel to assess how it fits in the channel and use this width to develop a width at MLLW for each section. Evaluate if these widths can fit without significant violation of the engineering constraints described above. The MLLW width is a better indicator of boat access at low tides. If the width is too large, use the width half-way between the mean and the 68% value, and if that doesn’t fit use the width at the 68% confidence interval value to fit the channel. We have adjusted the fit to try and avoid engineering and permitting issues.

Step 2 – Place Design Invert into Each Section. Lay the design invert (described in Section 6.3 below) into the design elevation and evaluate whether the channel fits within the constraints above. It is likely that the channel may require temporary widening for construction access, and this temporary impact would be tracked separately from the other impacts.

Step 3 – Evaluate Cross-Sectional Areas and Width/Depth Ratios. Perform a check on the cross-sectional area and w/d ratio to assess whether they are within the range of geomorphic variability for the system. Any areas or w/d ratios that fall outside of the desired range of values will be noted and the widths/depths adjusted iteratively to the extent possible.

Step 4 – Evaluate Constructability and Other Project Constraints. Evaluate and modified each cross-section for the various project constraints. While the final determination of dredge disposal options is beyond the scope of this study, we evaluate and make recommendations based upon the available cross-section templates, and constraints on constructability are noted as discussed in Section 5.1.4 above and in the summary results table (Table 9 below).

6.2 Dredge Channel Design Invert Results

Using the depths developed in Section 5, we have plotted the design invert elevations for the mean and the 68% confidence interval (CI) dredge plans.
Finally, we have added two lines in green and brown that show the calculated inverts of the geomorphic dredge channel for the mean and the 68% low results (green line is “mean geomorphic results,” and the orange line is the 68% CI line labeled as “68% geomorphic results”). These two lines bound the limits of what we are defining as the

"geomorphic dredge" for this project. One could define it more broadly and use the 98% line, but we have chosen to be somewhat more conservative and stay within this range of values.

Preferred Dredge Plan Invert Design

As shown in Figure 9, both geomorphic dredge lines are deeper than the actual creek invert for the first 6,000 feet of channel (stations 00+00 to 60+00). We believe that the channel invert elevation at these stations is controlled more by offshore bay coastal processes and that it would be geomorphically ineffective to dig much below the existing equilibrium elevation of approximately -4.3 ft NAVD. However, to provide some minor additional depth, we have proposed a small dredge in some locations to -4.3 ft NAVD for these reaches of the channel.

Starting at about Station 60+00 the channel invert elevation begins to rise, and at this point we chose to follow the mean geomorphic dredge elevation until about Station 120+00, where we modify the bottom profile to follow the 68% dredge invert line and provide some additional depth at MLLW for the residents at and above Santa Margarita island. Figure 10 shows the preferred dredge invert plan as a red dashed line that maintains a -7 ft NGVD invert elevation to approximately Station 60+00, where it rises to invert elevation -3.9 at approximate Station 150+00. This preferred dredge plan invert elevation falls between the mean and the 68% CI lines and, as such, represents a geomorphic template for the proposed project. We used this preferred plan dredge line to generate design templates as shown below. Note that the geomorphic dredge invert line adjusts its elevation in response to the available tidal prism and does not keep a constant bottom elevation as in previous dredging operation designs. While there may need to be some limited overdepth required for construction access in some locations, any over-digging for construction access would be temporary and not part of the geomorphic dredge template.

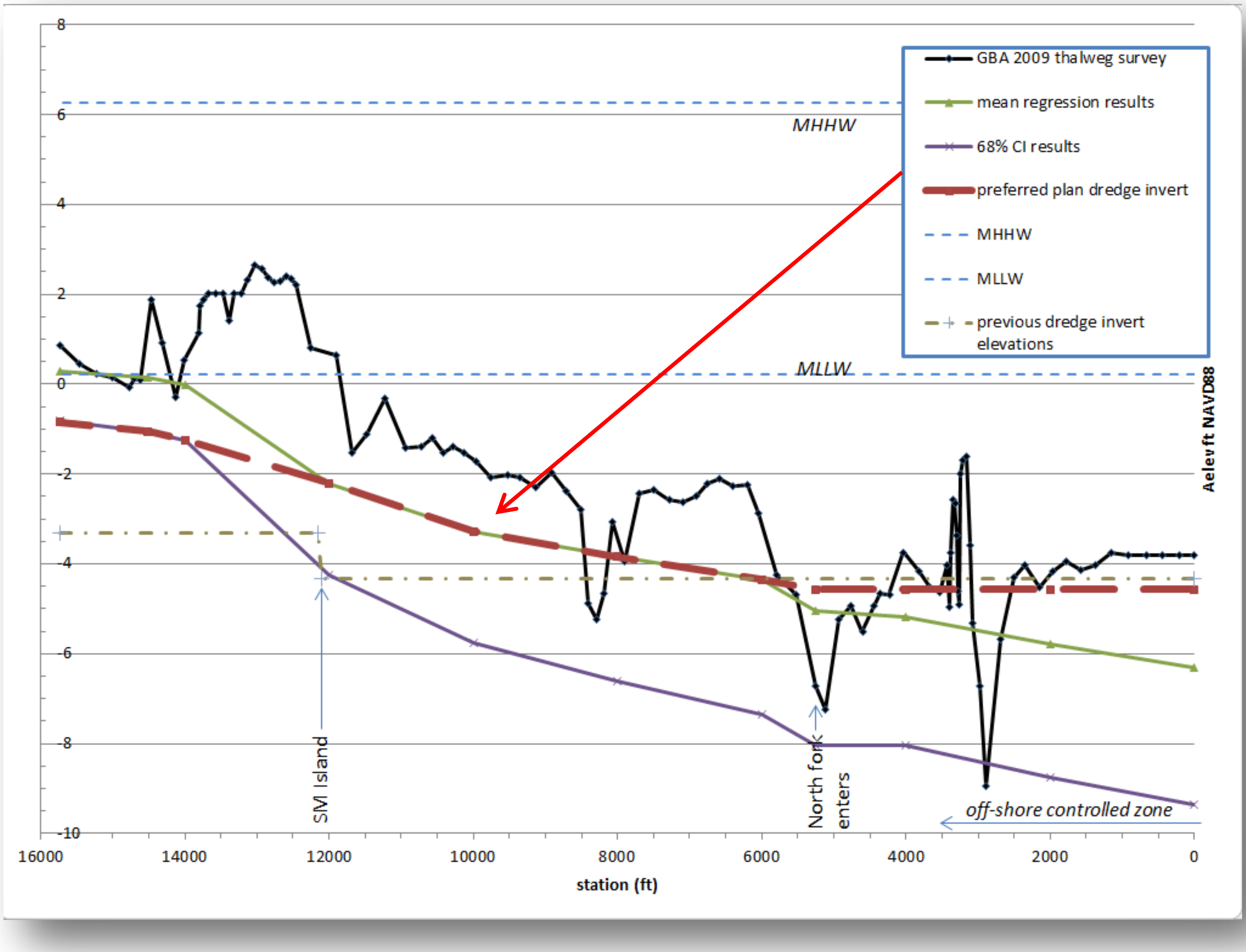

Figure 10: Creek profile showing preferred dredge plan (dashed red line)

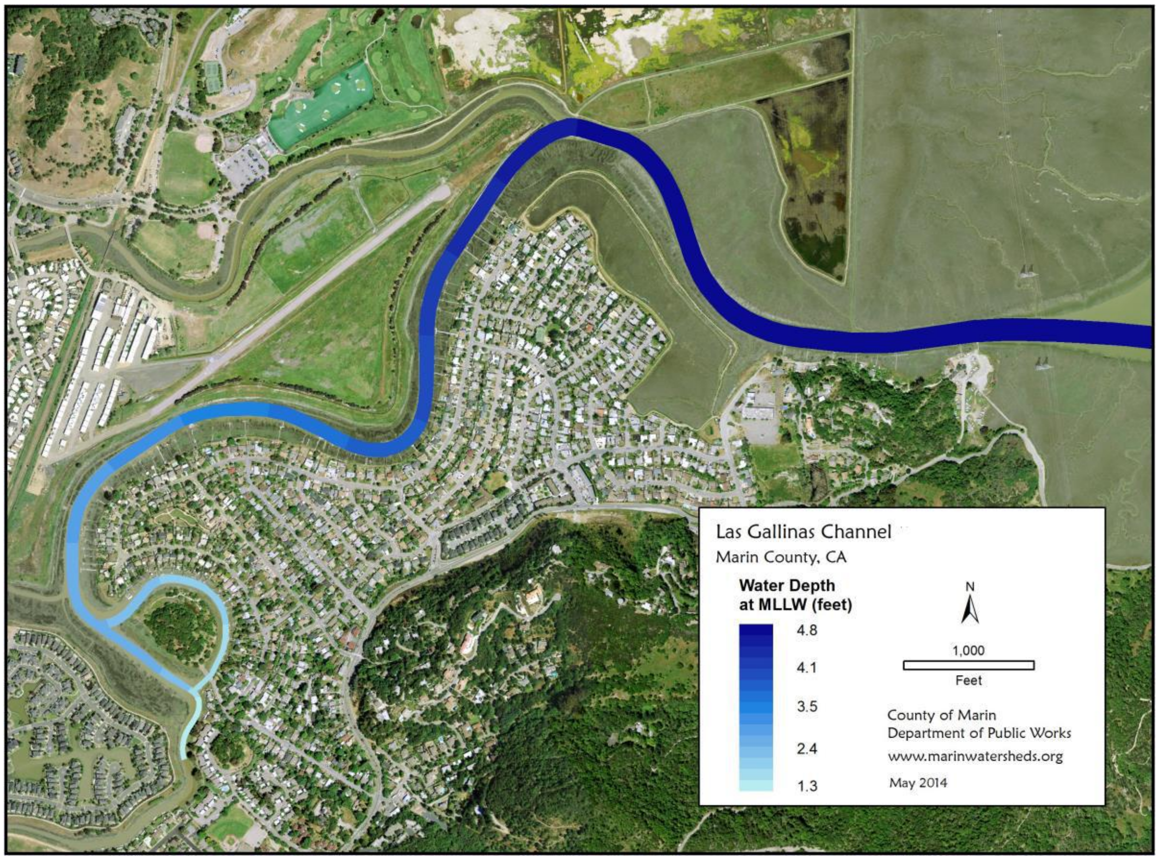

Figure 11: Plan view of water depths at MLLW for the geomorphic dredge plan

6.3 Geomorphic Dredge Template Cross-Section Layout Results

The Noble RAS model had more than 90 cross-sections. Here we present results for 18 cross-sections at various locations up the channel including sections within each geomorphic section identified above (Section 3.3 above and Table 9 below). Note that analysis of additional cross-sections may be required during subsequent design phases of the project to update and refine dredging volume calculations. Earthwork estimates were made by connecting the developed template at each of the 16 section locations and then linearly interpolating between sections in AutoCAD to match the form at the next specified upstream station. This approach introduces some margin of error that would be reduced by using additional cross-sections, which we recommend be done during the next phase of design.

Table 9 below shows the representative cross-sections used to estimate the geomorphic channel section and calculate earthwork volumes. We recommend that this work be expanded during the next stage of design once an updated creek survey has been accomplished. Example cross-sections are contained in Appendix A.

Table 9. Cross-sections used for analysis

Geomorphic segment number (stations)	*Representative cross-section(s) used for analysis*	*Average template section spacing*
GS 1 (23+84 to 28+20)	25+07	1 section in 436 feet
GS 2 (28+20 to 48+50)	28+94 and 40+00	1 section per 1,000 feet
GS 3 (48+50 to 56+08)	49+27 and 52+50	1 section per 380 feet
GS 4 (56+08 to 115+83)	60+41, 70+93, 80+00, 91+27, 100+00 and 110+00	1 section per 1,000 feet
GS 5 (115+83 to 141+88)	120+00, 125+00, 130+00, 135+00 and 140+00	1 section per 520 feet
GS 6 (141+88 to 157+30)	145+12 and 150+00	1 section per 771 feet

Appendix A contains the representative cross-sections with the results of the geomorphic template shown on each cross-section and adjusted to meet constraints as described above.

Table 10. Results of the geomorphic template for width at MLLW and depth from MHHW at each of the design cross-sections

Station	Nearest landmark (approx.)	Width at MLLW (ft)	Depth from MHHW (ft)
25+07	Upstream of Bucks Landing	108	4.5
28+94	DS of marsh outlet	100	9
40+00	Santa Venetia Marsh	120	4.8
49+27	Santa Venetia Marsh	80	5.7
52+50	DS of North fork confluence	80	5.8
60+41	Santa Venetia Marsh	70	4.5
70+93	Hacienda Way	70	4
80+00	La Pasada	60	4

91+27	Hawthorne	60	3.5
100+00	Mabry	55	3.6
110+00	Vendola	45	3
120+00	Downstream Santa Margarita Island	30	2.2
125+00	Vendola - Inner arm	20	2.2
130+00	Vendola – Inner arm	20	1.8
135+00	Vendola - Inner arm	20	1.8
140+00	Upstream Meadow Drive	20	1.3
145+00	Schmidt Lane	20	1.2
145+12	Schmidt Lane	20	1.2

6.4 Geomorphic Dredge Design Plan View Layout

The geomorphic dredge channel design attempts to follow the natural creek invert location to the extent possible. As shown on the representative cross-sections in Appendix A, we have not moved the thalweg from its current location except in limited locations to address other constraints.

6.5 Calculated Geomorphic Dredge Template Earthwork Volume

Dredge cut volumes were calculated using AutoCAD Civil 3D at the 18 representative design cross-sections developed for the channel layout calculations. Note that these volumes are first-cut approximations for comparison to the previous estimates and should be refined by laying out the dredge template at additional sections in the channel and recalculating the volumes. Therefore, the final estimate of dredge volume will change during final design and bidding. The geomorphic approach requires more extensive engineering analysis for each cross-section than a uniform dredge template (such as those used in previous dredging events) and so needs more refinement during final design. In addition, constructability factors that were not part of this study may require additional dredging to allow access for the hydraulic dredge.

Note that the volumes calculated below do not include additional dredge cut required for equipment access. It is possible, for example, that a hydraulic dredging alternative may require additional excavation to achieve depths for dredge access. These constructability cost will be assessed during the next phase of design.

Table 11. Calculated earthwork volumes for the proposed geomorphic dredge compared to previous earthwork volume estimates

Location	*2010* Winzler & Kelly *estimate (cy)*	*2014 Geomorphic dredge template (cy)*	*Notes*
Channel dredge (11+00 to 157+28)	182,173	30,000 to 48,000	Winzler & Kelly earthwork unclear – appears to show 145,000 cy up to station 121+00
Overdepth at toe	47,309	0	Overdepth not included in geomorphic dredge design
Overdepth at side slopes	66,010	0	Overdepth not included in geomorphic dredge design
Sub-totals:	295,492 cy	30,000 to 48,000 cy (*note 1*)	Does not include additional cut for dredge access

Note 1: Dredge quantities are to the geomorphic dredge template. Additional cut quantities may be needed for dredge equipment access and deeper water for dredge cut, which are not included in this table.

7.0 OTHER PROJECT CONSIDERATIONS

This section contains a description of additional projects related to, but not part of, the geomorphic dredge project work covered under this memo. We presented these additional projects to regional permitting agencies at the Marin Project Coordination Meeting in June 2014, and the preliminary results are discussed below. We believe that it may be possible to incorporate several of these additional items into an overall dredge plan for permitting by the agencies.

7.1 Additional Dredging for Low Tide Boat Dock Access

Many members of CSA 6 Advisory Board and the local community have expressed interest in extending the proposed geomorphic dredge to include low tide access to the existing boat docks. This would require widening the invert width of the dredge channel to include the boat docks. Currently, most of the boat docks are located along the inner bends where the channel naturally tends to form point bars and fill with sediment. It will be difficult to maintain those locations over time without frequent dredging. Therefore, the costs and benefits for this boat dock dredge need to be assessed by the local community, taking into account that any dredging benefit will likely be of short duration. However, to address this local request, we have developed the quantity and first-cut cost estimates for extending the proposed dredge episode to include the boat docks. Figure 12 shows an example of the additional dredge footprint at one location in the creek (note that the required dredge cut side slopes and any impacts to habitat are not shown). For this assessment, we have extended the geomorphic dredge design invert elevation to the boat docks to provide improved access at low tides. Appendix B shows the approximate additional dredge cut required at two representative cross-sections to provide this low tide access. Note that the dredge cut volumes calculated for this report were based on a similar template but were calculated using AutoCAD based on the project DEM. All volumes need to be recalculated with a new creek survey and project DEM.

The dredge design side slopes are a key element of the project design both in terms of dredge quantity and impacts. The 2010 Winzler & Kelly report assumed 2:1 (horizontal to vertical) side slopes. However, we do not believe 2:1 side slopes would be stable given the composition of the sediments (fairly unconsolidated bay muds). Note that all the earlier channel dredge operations typically used 5:1 side slopes (much flatter than 2:1). Therefore, we have selected 3:1 as our maximum design slope to balance the need to avoid excessive habitat impacts and costs while providing for slope stability. However, no warranty is provided as to the stability of the proposed dredge cut at this steepness.

Note that we have not deepened the channel access from the geomorphic dredge template invert elevation, so the boat access dredge depth will match the geomorphic dredge depth.

Table 12 below shows the estimated quantity for the boat-dredge access add-on dredge, which totals approximately 60,000 cy. As discussed in section 9.0 below, the regulatory agencies were not favorably inclined to permit this add-on project upon preliminary review, so it would likely require more extensive permitting and possible mitigation costs.

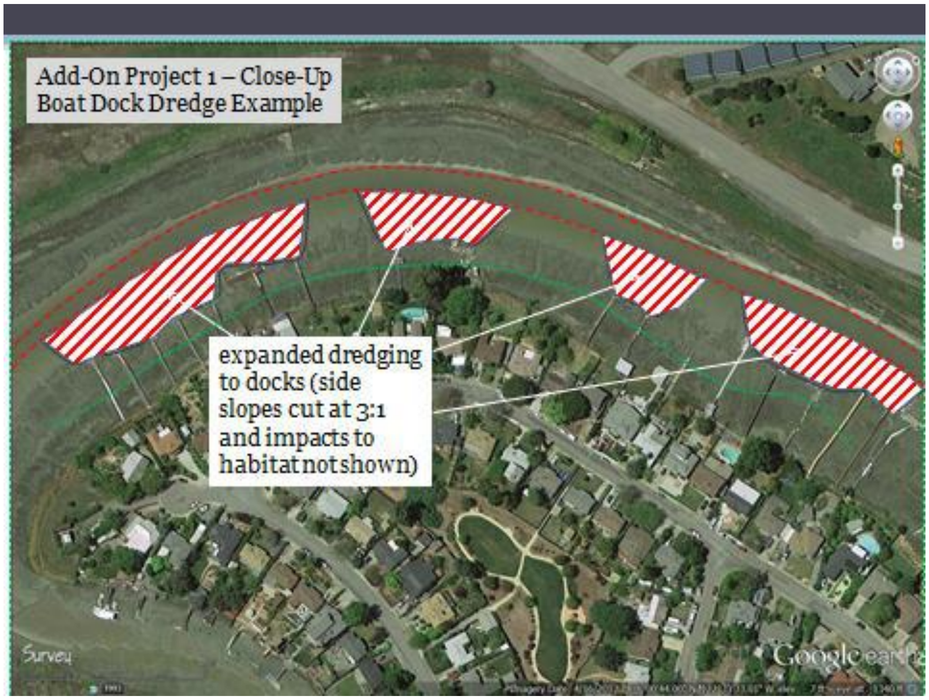

Figure 12: Example of dredge cut footprint to bring lower tide access to boat docks

7.2 Dredging a Pilot Channel to Connect to Deeper Water in San Pablo Bay

The farthest downstream extent (Station 11+00) for the previous Las Gallinas dredge is still approximately 3,000 to 4,000 feet west (i.e., upstream) of the deeper water channels in San Pablo Bay. A review of historical imagery from Google Earth shows that there is a persistent channel connection from the creek to deeper water in San Pablo Bay. However, the 2009 GBA creek bathymetric survey ended at Noble Station 11+00 (GBA station number 00+00) upstream of Bucks Landing, so the exact creek elevations into to San Pablo Bay are not known.

We recommend that during subsequent design phases, a bathymetric survey of the creek be extended out into the bay so that the connectivity of this channel to the bay can be assessed further. If existing depths are sufficient for the current navigational boat needs, then additional channel dredging into the bay may not be necessary. Some residents noted at public meetings that this channel connection to the bay is very broad and shallow, that boat access to the bay has to be timed carefully to avoid being stuck in the mud, and that they would like a deeper connection to be made. Evaluation of that deeper channel was beyond the scope of this analysis, and no additional costs for creating such a channel connection have been included.

We have estimated a pilot channel quantity using a simple linear measurement to the known deep water channel and assuming a uniform bottom elevation. The actual quantity estimate will require bathymetric survey data, so this quantity should be taken as a very initial estimate.

7.3 Eliminate Existing Split Flow Condition Around Santa Margarita Island to Improve Sediment Transport

The split channel flow around Santa Margarita Island reduces velocities and sets up backwater flows that increase sedimentation, which is particularly pronounced along the inner bend of the island. It appears that this split flow was probably made by man by dredging the inside channel where the existing homes and docks are located early in the last century. A potential engineering solution is to use natural materials (i.e., logs, also known as large woody debris or LWD) to block off one of the two channels and redirect all tidal flows through the other channel around the island. This will help increase velocities, focus the available tidal prism along the open channel, and improve sediment transport and better maintain channel depths. In Figure 13, we placed the channel blockage along the outer channel—the existing boat docks are along the inner channel—by adding the LWD at the downstream end, which will fill the area upstream with sediment. This sediment will form new tidal marsh wetlands, which are in short supply along the creek and will provide valuable habitat. Maintaining the existing split flow condition will likely result in accelerated filling of the channel with sediment and reduces the channel’s ability to be self-maintaining.

Initial feedback from the regulatory agencies on this idea was very positive as described in Section 9 below. The permitting and engineering impacts of this approach should be further investigated during the next phase of design activities. In particular, two significant concerns would need to be addressed during subsequent design phases:

1. Upstream boat usage would be limited by a boat’s ability to get under the existing bridge to Santa Margarita Island; otherwise, a new, higher bridge would need to be built. Boat access above Santa Margarita Island would likely be limited to kayaks or other low, shallow draft boats. Note that the dredge depths in the geomorphic plan are very shallow above the island; therefore, larger boats would be unable to travel farther up the channel under existing or proposed geomorphic dredge conditions.

2. Potential impacts to water intakes and outfalls from the Marin Lagoon would need to be investigated as well as water quality impacts to the lagoon community. A preliminary evaluation of the lagoon intakes indicates that they would not be impacted. However, during subsequent design phases, the outfall and intake locations should be mapped.

Figure 13: Concept for a low-flow blockage of outer channel at Santa Margarita Island, with wetlands forming upstream

7.4 Extending Private Docks or Creating Consolidated Community Boat Docks

The geomorphic dredge template does not allow for the relocation of the creek thalweg from its natural location along the outer edge of channel bends. Another add-on project considered was to either extend the existing private boat docks farther into the deeper water of the creek or creating larger community boat docks that extend to the deeper water areas of the creek. Recent discussions with the permitting agencies indicate that extensions to existing boat docks could trigger permitting issues and that construction would require use of "greener" materials, removal of creosote piles, and a dock design that maximizes light passage through the dock to improve plant growth. This issue was raised with the agencies during the informal monthly Marin County Permitting Meeting as discussed in Section 9 below.

Another approach to consider is to build fewer community boat docks in order to consolidate impacts from docks to fewer locations but allow for access to deeper water areas of the channel. This idea could be explored during subsequent design phases of the project.

8.0 EARTHWORK AND COST SUMMARY

This section contains a summary of the earthwork and preliminary cost numbers for the geomorphic dredge plus some of the project add-ons described above and compared to the 2010 Winzler & Kelly study report.

Table 12. Dredging summary

Project	*2014 Geomorphic dredge template (cy)*	*Other Dredge design project considerations (cy)*	*Comments*
Channel dredge 11+00 to 121+00	17,300 (L) to 24,450 (H)	----	No overdepth included or additional cut for equipment access or operation
Channel dredge 121+00 to 157+28	15,700 (L) to 23,555 (H)	----	No overdepth included or additional cut for equipment access or operation
Additional dredge for boat dock access at low tides	---	60,000	Approximate estimate by extending 10-ft wide channel 5500 lf with 3-ft cut
Pilot channel to SP Bay	---	~6,000+	Approximate calculation using AEA method for 900 ft of outer arm to elev 5.7 ft NAVD

8.5 Dredge Sediment Disposal Locations and Costs

8.5.1 Winzler & Kelly 2010 Costs

Winzler & Kelly (2010) evaluated several options for disposal of dredged sediments. This section builds upon that previous work and updates dredge disposal locations and costs based on current information from Flood Control District dredging projects. However, the focus of this study is the geomorphic dredge assessment and not disposal costs; therefore, all costs and options described herein need to be updated and confirmed during subsequent design phases of the project.

1. *SF-10 and SF-11* - The preferred option from the 2010 Winzler & Kelly report is in-bay disposal at SF-10. Winzler & Kelly put the cost for disposal at *SF*-10 at $13 to $18 per cubic yard and used a cost of $15.50 per cubic yards for all 15,000 linear feet of Las Gallinas Creek in their table “Preliminary Opinion of Probable Cost, *SF*-10 Disposal Site” (Table 9.1 2010 report). *SF*-11 was also identified as an option, depending on availability. Both sites have a disposal limit on cubic yards per year. Note that this cost is considered low and appears to be

based on unit costs for marinas and ports with easy access for loading and disposal to *SF*-10. The south fork of Lower Las Gallinas is a creek dredge, requiring a tugboat to transport sediment from its upper end three miles to the mouth of the creek plus the distance to *SF*-10/11. This would likely result in a significantly higher unit cost for dredging and disposal at these in-bay sites. As described below our study uses much higher unit costs to account for these factors.

2. *Discontinued Upland Sites - Carneros River Ranch and Hamilton Air Field Project* – Winzler & Kelly 2010 evaluated two upland disposal sites at Carneros Ranch and the Hamilton AFB project. Unfortunately, these sites are no longer available for disposal.

3. *San Rafael Airport* – A portion of the property at San Rafael Airport was identified and evaluated as a potential disposal site. This site is not permitted to accept dredge sediment at this time. Winzler & Kelly estimated costs for disposal at SR Airport at $19/cy.

4. *Las Gallinas Valley Sanitary District Disposal Site* – The Las Gallinas Sanitary disposal pond site was identified as a possible location at a unit cost estimate of $19 to $24/cy. However, as noted, this site is not permitted either, and it is unclear if it can be utilized.

5. *McInnis Marsh Restoration* - McInnis Marsh at the mouth of Las Gallinas Creek was the historic disposal site for most of the previous creek dredging events. This site is owned by Marin Parks and is currently in the early stages of restoration design. Project managers are evaluating the use of dredged sediment as part of the site restoration design. Winzler & Kelly estimated a unit cost of $13 to $18/cy.

6. *Redwood Landfill* - Redwood Landfill can accept dredge sediment as landfill sediments. The Winzler & Kelly estimated cost was $25 to $30 per cubic yard.

8.5.2 Updated Disposal Locations and Costs Based on County Knowledge as of 2014

This section presents a brief survey of recent dredge disposal locations and costs.

<u>McInnis Marsh Restoration Project</u>

McInnis Marsh at the mouth of Las Gallinas Creek was the historic disposal site for prior dredging events. It will not be known until sometime in 2015 if the preferred alternative will identify the utilization of dredged sediments from Las Gallinas Creek as part of the site design. The Marin County Department of Public Works is a partner with Parks on this project and will work to assess whether the proposed restoration design can incorporate dredged sediments. Initial discussions with the design consultant have been positive; however, no final decision has been made. There could be challenges in coordinating the timing of sediment acceptance since the McInnis Park project construction is not yet funded.

<u>In-Bay Disposal at SF-10/11</u>

The County has some updated costs for dredging and disposal at <u>SF</u>-10 that show a higher range of dredging and disposal costs than Winzler & Kelly described in their 2010 report. The results from a recent County bid and a local dredging association varied substantially. However, both of those dredging sites are marinas located in San Francisco Bay proper and would be expected to cost substantially less to dredge than the upper reaches of Las Gallinas Creek.

Updated Redwood Landfill Costs

Recent costs for disposal at Redwood Landfill are $35/cy for muds plus a per load fee of $14. Note that dredging, dewatering, and trucking costs are not included in this landfill disposal fee. Redwood Landfill is a 30 to 40 minute drive from Las Gallinas Creek, and loading and dewatering time would need to be factored into the cost as well. We estimate that landfill disposal could run as high as $50/cy. Note that trucking of sediment may require a large temporary storage location for drying the sediment prior to placing it onto trucks for off-site disposal. It is unclear if a suitable site for dewatering of sediment is available, but if a suitable location can be found, this option is more viable.

Dredge Costs

Below is a summary of recent, known project bids or construction costs for several dredging and disposal projects. This list is not necessarily complete, but provides some information on dredging and disposal costs around the bay. Note that dredging is a very particular construction item, and that all projects have their own set of constraints that can significantly impact costs, making comparison problematic.

Bel Marin Keys Community Service District (BMKCSD) Hydraulic Dredging and Disposal Bid Costs (2005 and 2006)

In 2005, the BMKCSD dredged approximately 60,000 cubic yards of sediment hydraulically onto a site they owned and operated. The cost for this local operation was approximately $21/cy. In 2006, the BMKCSD received bids to pump sediment to Hamilton Air Field; the winning bid for pumping approximately 160,000 cubic yards of sediment was about $20/cy. Note that both of these sites represent relatively close proximity hydraulic disposal sites. Using a disposal site near the dredging operation is likely going to be the most cost-effective option for all dredging alternatives.

Note that the BMKCSD costs include dredge water management but not dredge disposal site preparation (i.e., construction of ponds and weirs), water quality monitoring and reporting, or road crossings and pipelines.

Costs for Aquatic Dig and Haul to In-Bay Sites SF-10/11

We know of three recent (2014) dredge project bid costs. Each of these dredge episodes disposed of sediment in-bay to the USACE aquatic disposal sites known as SF-10 and SF-11. The range of costs for this disposal option reflects the unique characteristics of each dredging event.

Paradise Cay Dredge Episode, Marin County

Paradise Cay is a marina located right on the bay, making it an easier dredge and transport project than Las Gallinas Creek. In 2014, dredging from Paradise Cay was bid for 28,5050 cubic yards. The bids received were $648,169.50 ($24.45/cy) and $917,246 ($34.60/cy), representing a marked increase over previous bids in the $10-11/cy range. This increase may reflect increases in fuel costs, lack of competition, and the thin cut of the dredging.

Strawberry Recreation Center Dredge, Marin County

The Strawberry Recreation Center reportedly got a much lower unit cost of approximately $11/cy for their dredge to in-bay disposal. The difference in cost may be due to the thickness of the dredge cut and increased production rate.

Costs for Aquatic Dig and Haul to Uplands Beneficial Reuse

Port of Oakland Maintenance Dredge Contract, Oakland, CA, 2014

The Port of Oakland just awarded a contract for dredging 142,500 cubic yards of maintenance sediment for uplands beneficial reuse at a cost of $4,535,000 or a unit cost of $31.80/cy. However, this port dredge is very different than a river dredge in terms of depth, has a more direct route to the disposal site, and can use larger equipment, so the comparison to Las Gallinas is indirect.

Costs for Dewatering Creeks, Digging from Top of Levee Banks, Loading onto Trucks, and Hauling Off-Site for Disposal

Novato Creek, Marin County

The Marin County Flood Control District dredged Novato Creek in 2012 by installing a cofferdam system, dewatering the creek for one month (allowing the sediment to dry out somewhat in place), and then excavating the sediment from the bank and loading it directly into trucks for hauling to Gnoss Field (no disposal charges) for disposal. The cost for this event was approximately $17/cy of sediment and about $25/cy for vegetation (Gnoss Field managers did not want vegetation since they planned to reuse the sediment for levee construction).

Note that the Novato project has several cost advantages over the Las Gallinas project:

- Novato Creek can be accessed easily from the creek levees for dredging with a long-reach excavator and loading into trucks without double handling of sediment. This levee access is not available at Las Gallinas Creek and is a significant factor in the bid cost for the project.

- The Novato Creek project used a no-cost disposal site; we have not yet identified such a site for Las Gallinas.

Because of these factors, the Novato Creek estimate is not directly applicable to Las Gallinas.

Preliminary Feedback from Local Dredger on Las Gallinas Dredging Costs

Preliminary feedback from a local dredging company (Salt River) that has worked in Marin County was obtained on the constructability issues and cost associated with the proposed dredging plan (R. Leventhal, personal email communication with Salt River Dredging 6/16/14). This information is solely based on emails and no field visits, and should not be taken to represent biddable costs or a constructible approach, but does provide updated costs. Salt River recommends that the dredge be budgeted at $39/cy below Santa Margarita Island, and suggested that if the reaches above Santa Margarita Island have to be dredged and hauled to SF-10 per the 2010 Winzler & Kelly report, double handling of sediment would be needed (i.e., transferring from smaller to larger barges). Salt River estimated the cost of that dredge/haul at $70/cy. We have not requested site visits by potential dredgers to confirm access requirements and dredging operational requirements. Site-specific constructability will be addressed during the next phase of the project.

Summary of Results

The tables below summarize sediment disposal locations and cost estimates.

Table 13. Status and costs of previously identified dredge disposal sites (2010 and 2014, updated)

SF-10 or SF-11 (in-bay)	$13-$18 (SF10) $18 (SF11) Used $15.50 for final estimate	$25-40 below station 121+00 and >$70 above station 121+00)	Updated to represent recent estimates from County dredge projects. Costs are to Station 121+00. Above this station will require double handling – estimate $70/cy.
San Rafael Airport	$19 - $24	Unknown for local hydraulic dredge operation use $25/cy plus set-up costs	No site is identified or permitted for sediment placement.
Hamilton AFB and Carneros Ranch	$33.50 - $38.50 (Carneros) and $17-$22 (HAFB)	N/A	Neither site is available.
McInnis Marsh Project	$13-$18	Assume local hydraulic dredge costs - use $25/cy plus set-up costs	Project in design phase – not yet determined if dredge sediment will be used.
LGVSD	$13-$18	Assume local hydraulic dredge costs - use $25/cy plus site prep and monitoring costs	No site is identified or permitted for sediment placement.
Redwood Landfill	$25-$30	$35+/cy not including digging, dewatering, trucking costs – use $50 to $60/cy	Costs for landfill disposal have increased.

Table 14. Summary of dredge disposal options using updated 2014 costs for available sites and adjusted for increased costs for dredging upstream of Station 121+60

Station	Dig and haul SF-10	Local hydraulic disposal Ssite (1)	Dewater, dig, and haul to local disposal site or landfill	Comments
00+00 to 121+00	$28 to $40/cy	$24 -$30/cy	Note 2	Local hydraulic disposal site likely most cost-effective option
121+00 to 157+47	$60 to $75/cy	$25 - $30/cy	Note 2	Dredging > station 121+00 problematic without hydraulic dredge option; additional depth may be required for dredge access and operation

Notes:
(1) Assumes hydraulic disposal at the McInnis Marsh project. Mechanical placement at Airport may cost more.
(2) Requires land based excavation from the top of the levee, which is currently not possible due to access restrictions.

Table 15. Range of probable costs for geomorphic dredge template with assumptions

Station	Quantity (low to high)	Unit costs $/cy (low to high) (cy)	Estimate of probable cost ($) (low to high)	Notes
11+00 to 121+00	17,300 (L) to 24,450 (H)	$24 (local hyd) (L) $40 (SF-10) (H)	$415,000 (LL) $692,000 (LH) $587,000 (HL) $980,000MD (HH)	Costs for local hydraulic (low) to SF-10 (high)
121+00 to 157+28	15,700 (L) to 23,550 (H)	$25 (local hyd) (L) $75 (SF10) (H)	$392,500 (LL) to $1.2MD (LH) $600,000 (HL) to $1.77MD (HH)	Another possibility not included is in-channel placement within the outer arm of Santa Margarita Island

L = low estimate (either quantity or unit cost)
H = high estimate (either quantity or unit cost)
LL = low quantity estimate times low unit cost estimate
LH = low quantity estimate times high unit cost estimate

HL = high quantity estimate times low unit cost estimate
HH = high quantity estimate times high unit cost estimate

Note: Costs are for construction of geomorphic dredge template only (no dock access). Costs for survey, design, permitting, mitigation, construction monitoring, and post-monitoring costs not included. Additional costs for dredge equipment access or operation are not included but may be significant above Station 121+00.

Finally, we prepared a summary table for the entire project both assuming an available local dredge site and not. This table is for the basic geomorphic dredge template quantities and does not include additional cost for equipment access or operations, which may be significant above station 121+00.

Table 15. Costs for entire project

Stationing	Disposal location	Costs to dredge and dispose (low end)	Costs to dredge and dispose (high end)	Total cost ($) range (note 1)
Entire Project (11+00 to 157+67)	Either SF-10 (H) or local hydraulic dredge site available (L)	$810,000	$2,760,000	$1.2MD to $4.1MD
Entire Project (11+00 to 157+67)	Assumes local hydraulic dredge site is used	$810,000	$1,300,000	$1.2MD to $1.95MD

Notes:

(1) Total design and permitting costs estimated at 50% of construction cost and added into total. These include approximate costs for survey, preliminary design, final design, plans and specs, permitting (no EIR), and construction monitoring.

(2) Costs are for construction of geomorphic dredge template only (no dock access). Costs for survey, design, permitting, mitigation, construction monitoring, and post-monitoring not included. Additional costs for dredge equipment access or operation are not included but may be significant above Station 121+00.

9.0 PERMITTING CONSTRAINTS

The 2010 Winzler & Kelly report contains a summary of the permitting requirements for the project. We highlight two points of particular concern from their discussion.

Winzler & Kelly did not account for mitigation costs associated with any dredge cuts into either line of channel vegetation (i.e., either the lower limit of marsh vegetation or the limit of dense marsh vegetation). Depending on the extent of impact to existing marsh vegetation and density, mitigation costs could be significant.

Winzler & Kelly also noted in their 2010 report—and we repeat here for emphasis—that moving the channel thalweg from its natural and current location may be considered new dredging by the Dredge Material Management Office (DMMO), making it ineligible for in-bay disposal at SF-10, which was the preferred disposal location. Moving the channel thalweg would have significant cost impacts for this disposal location but not for other locations such as McInnis Park or the San Rafael Airport. As described in section 5.1.2 above, the approach taken here does not relocate the thalweg from its geomorphic location except for any add-on dredging for boat dock access.

Preliminary Discussions with Permitting Agencies

On June 18, 2014, we presented the geomorphic dredge design approach and preliminary results to the permitting agencies that attend the Marin monthly permitting meeting. These agencies include the primary agencies that would be involved in permitting a dredge project in the creek, including the San Francisco Bay Regional Water Quality Control Board, the U.S. Army Corps of Engineers, and the California Department of Fish and Wildlife. The meeting provided an informal forum for vetting the geomorphic dredge design and gaining initial feedback (presented below) from the agencies on how they might view the proposed application if the project proceeds. All of the agencies reserve the right to modify their comments during actual permitting consultations.

1. Geomorphic Dredge Approach – Received very positive feedback and strong support.

2. Additional Dredge to Boat Docks – The feedback was not positive. This dredge would likely require trigger permitting and mitigation requirements and would tend to fill in quickly after the dredge episode.

3. Block the Outer Reach of Santa Margarita Island – Received very positive initial feedback. The agencies discussed using this project as mitigation for the other dredging impacts and as a sediment disposal location. Considered a very viable option to bring forward. However, there may be local opposition, plus the agencies could reconsider their initial positive feedback and require mitigation.

4. Pilot Channel into Deeper Water – Initial agency feedback was that this would not be sustainable and that the benefits were unclear. This project would require additional analysis of impacts for permitting and possible mitigation requirements.

5. Extend Existing Boat Docks or Community Boat Docks –The agencies preferred the approach of establishing community boat docks but would consider individual extensions, with requirements for “green” construction methods and materials:

minimal dock areas, opening up the docks to as much light passage through the structures as possible; and removal of all existing creosote piles.

Not all of the agencies with regulatory authority over habitat, threatened and endangered (T&E) species, and dredging and channel navigation requirements were present at the meeting; they may have permitting requirements that have not yet been identified or addressed. These agencies will be contacted and their permit requirements determined during subsequent design phases of the project as described below.

Those agencies may include--but are not limited to—the following four agencies:

1. State Lands Commission – Besides the property ownership issues, State Lands sometimes has additional requirements for work in tidal baylands.

2. USACE Dredge Material Management Office (DMMO) – Ultimately, a permit from the U.S. Army Corps of Engineers (USACE) will require a permit from the DMMO since it is concerns dredging and disposal. The DMMO reviews sediment quality testing and approves its disposal location. The level of testing required depends on the disposal location. For reuse in a marsh project like McInnis, a higher level of testing will be needed to ensure that there are no impacts to the aquatic environment.

3. U.S. Fish and Wildlife Service (FWS) – Las Gallinas Creek is known habitat for listed threatened and endangered species, especially the Ridgeway Rail (formerly the California Clapper Rail) and potentially the Salt Marsh Harvest Mouse. Any dredging operation that may impact these species will be subject to regulatory review and permitting. This is one reason we have tried to develop the geomorphic dredge template to avoid impacts to vegetation, but there may nonetheless be impacts from hydraulic pipeline placement, or other impacts. FWS is usually brought in by the USACE during their permitting consultation. Depending on the FWS analysis of impacts, a biological opinion (BO) may be required, which could delay permits for the project.

4. USACE and Coast Guard –The lower reaches of Gallinas Creek are considered a navigable channel for some distance up the creek. The extent of navigability needs to be determined through consultations with the USACE and the Coast Guard.

10.0 OTHER OUTSTANDING ISSUES

Boundary Survey and Property Ownership Issues

The boundaries and ownership of the creek and banks are unknown, and a survey is needed to establish final boundaries. State Lands has said it will take nine months at a minimum to complete the survey work, which has not yet begun. Even if they start soon, it is likely that this survey will not be completed until late 2015, with boundary amendments made afterwards.

Discussions with San Rafael Airport Staff

On Tuesday October 14, 2014, County staff met with representatives of the San Rafael Airport to discuss a range of issues, including those related to the dredging. In general, Airport staff stated that the airport supports creek dredging as part of a cohesive flood control program for Gallinas Creek that includes long term levee maintenance agreements between the County and the impacted property owners, including San Rafael Airport. Airport staff specifically stated that prior to dredging, a geotechnical slope stability analysis must demonstrate that the dredging will not de-stabilize the north bank levees that protect San Rafael Airport, the SMART railway, and Contempo Marin Mobile Home Park.

Airport staff are also willing to resolve the issue of private dock extensions as part of an overall agreement. In the meantime, the Airport would consider offering a lease to make dock improvements, modifications, or extensions on a case-by-case basis. Interested property owners should contact the Airport directly.

11.0 CONCLUSIONS AND RECOMMENDATIONS

We have developed a conceptual design for dredging the south fork of Las Gallinas Creek using a geomorphic design that adjusts the dredging dimensions based on the available tidal prism. The design template was analyzed for its ability to pass small boats as well as by a variety of other criteria including geomorphic, geotechnical, access, and permitting issues.

This analysis is conceptual, but is intended to present a design with a level of detail sufficient for the CSA 6 Advisory Board to provide a recommendation concerning the next steps and additional studies that are needed to proceed with a dredging episode. In particular, a constructability review needs to be done to confirm the operation's size and depth requirements for any hydraulic or mechanical dredging operations.

Our recommendations for the next steps in the design and construction process include the following:

Confirm Feasibility and Preliminary Design – Duration 12 Months

- Maintain involvement in the McInnis Marsh restoration design process to promote the reuse of dredge sediments to the extent possible.

- Perform a dredge operations constructability review to evaluate field conditions with dredging contractor(s) in greater detail and adjust the dredging template to reflect access and operational requirements. Incorporate any changes in costs into the final design basis report described below.

- Confirm feasibility of potential dredge placement sites. Retain a firm to prepare preliminary dredge sediment placement designs at the airport, the McInnis Park site, or another nearby site. We anticipate a preliminary decision on the reuse of creek-dredged sediment at McInnis Marsh by Marin Parks in early to mid-2015. We would then prepare an RFP and seek bids from qualified consultants to evaluate disposal logistics and costs and make a recommendation for the most cost-effective disposal site—either the McInnis site or the airport (or a combination of both). We would then prepare concept designs that can be folded into the design documents for the selected disposal site(s) described below.

- Assist State Lands to finalize the boundary property survey and work on the property line amendments. Note that property line amendments are complex, and the date for completion of amendments is unknown.

- Prepare the Final Geomorphic Design Basis Report that updates this Conceptual Design Study with the results of any of the new studies. The final report will incorporate the results of the design and constructability reviews and disposal site evaluations, investigate right-of-way acquisition costs, finalize the permitting requirements, develop schedules for implementation, and prepare updated cost estimates.

Final Design and Permits/CEQA – Duration 21 to 24 Months

- Prepare RFP for a final design and permitting consulting firm to finalize the project design and construction details, prepare plans and specifications for construction and permit applications, and perform a CEQA analysis. This contract will include the following technical studies and activities:

    - Perform a geotechnical levee stability evaluation of the proposed dredge plan in areas of concern. We anticipate that the geotechnical consulting firm will be able to leverage previous boring information, but the requirement for additional field data will be determined during the bidding and consultant selection process.

    - Perform an updated bathymetric survey of the creek. This concept design memo is based upon a single creek bathymetric survey from 2009. We recommend that the creek be resurveyed to confirm results and check the proposed dredge template. An updated survey would be incorporated into the final design and plans and specifications for dredging and disposal. We would also extend the survey farther into the bay to address concerns over low tide access to the deeper areas of San Pablo Bay.

    - Perform any required biological studies. The design team would perform the biological field studies required for permitting and for construction access. The surveys typically consist of field surveys for threatened and endangered species and would be coordinated with our construction requirements to identify acceptable pipeline routes or locations for equipment access that minimize impacts (and hence mitigation costs) to the wetland areas.

    - Collect samples for sediment quality analyses for review and approval by DMMO prior to permitting the dredge. These results are only good for a set period of time, so they should not be collected too far in advance of the dredge.

    - Prepare and submit permit applications and perform CEQA analysis.

Bidding and Construction – Duration 6 to 18 Months (one or two seasons)

Depending on the final dredging plan and volumes, we anticipate that the dredging could be completed over one or two construction seasons. Regulatory agencies have various “work windows” designed to protect species of concern, which can impact the timing of dredging.