The Geomorphic Dredge Approach
Using Tidal Hydraulic Geometry to Design a Dredge Project

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Marin County Flood Control

FMA 2016
Gallinas Creek

>3 mile creek – tidally dominated

Local CSA self-taxing for dredge

Last dredged 1992/1994
Creek Stationing
# Previous Dredge Events

<table>
<thead>
<tr>
<th>Year dredged</th>
<th>Invert elevation NGVD and (NAVD88)</th>
<th>Bottom width (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td>-9 ft (-6.3)</td>
<td>75 to 25</td>
</tr>
<tr>
<td>1973</td>
<td>-9 ft</td>
<td>75 to 50</td>
</tr>
<tr>
<td>1981</td>
<td>-7 ft (-4.3)</td>
<td>50 to 20</td>
</tr>
<tr>
<td>1992/94</td>
<td>-7 ft</td>
<td>50 to 20</td>
</tr>
</tbody>
</table>

**2010 design estimate**
- 182,173 cy dredge cut
- 114,000 cy overdepth
= 295,500 cy total (@$15/cy – too low)
One sentence summary of “geomorphic” dredge channel approach

The channel shape that would be expected to form in equilibrium and thus maintain its shape (width and depth) with the available daily tidal volume (the “tidal prism”)

Developed from studies of other natural marsh systems around the Bay (empirical field data).
Why take a geomorphic approach to dredge design?

1. Channel should be more self-sustaining and require less frequent dredging

2. Easier to permit and less mitigation costs

3. Less volume = less often = less costly

However the trade-off is less depth and width
6.25 ft NAVD = MHHW

Need to discuss navigational objectives

Channel bottom elevation from 2009 survey

sustainable dredge depth? - tbd

W-K design dredge depth = -4.3 (-7 NGVD)
What is tidal prism?

- Tidal prism is the volume of water between MHHW and the land surface on a tide cycle.

- Location matters – further upstream maintains channel depth.
## Calculated loss of historic tidal prism

<table>
<thead>
<tr>
<th>Description</th>
<th>Tidal Wetlands 1850 (acres and acre-ft)</th>
<th>Tidal Wetlands 2012 (acres and acre-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal marsh</td>
<td>951</td>
<td>185</td>
</tr>
<tr>
<td>Tidal flat</td>
<td>187</td>
<td>7</td>
</tr>
<tr>
<td>Shallow bay/deep channel</td>
<td>24</td>
<td>44</td>
</tr>
<tr>
<td><strong>SUB-TOTALS</strong></td>
<td><strong>1162 acres</strong></td>
<td><strong>237 acres</strong></td>
</tr>
<tr>
<td>Tidal prism to MHHW</td>
<td>~810 – 1142 acre-ft</td>
<td>~434 – 526 acre-ft</td>
</tr>
</tbody>
</table>

**Notes:**
(1) for historic tidal prism calcs assume the following elevations:
- Tidal marsh = MHW to MHHW
- Tidal flats = MLLW to MTL
- Channel = MLLW

(2) 2012 calcs based on County DEM using GIS; added 6 and 12 inches to account for LiDAR veg effects
**Tidal Prism Analysis**

**Q)** How do we use tidal prism numbers to evaluate and design stable tidal channels?

**A)** Use plots of field data of channel size plotted against calculated tidal prism at many marsh sites (= “hydraulic geometry” for tidal systems).

Empirical Data is
- Only as good as measurements
- Only good within measured range
- Can be uncertain
Empirical Analysis of Tidal prism

- Data is available for San Pablo Bay
- Issues - how to measure

![Figure 6](image)

\[ y = 12.782x^{0.4608} \]

\[ R^2 = 0.8628 \]
Close-up segregated data –
data ranges

\[y = 3.794x^{0.198}\]
\[R^2 = 0.837\]

range high

range low
<table>
<thead>
<tr>
<th>station</th>
<th>Widths</th>
<th>Regression Results - 95% high</th>
<th>percent above/below mean</th>
<th>Regression Results - 68% high</th>
<th>percent above/below mean</th>
<th>Results - mean (small mature)</th>
<th>percent above/below mean</th>
<th>Regression Results - 68% low</th>
<th>percent above/below mean</th>
<th>Regression Results - 95% low</th>
<th>percent above/below mean</th>
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</thead>
<tbody>
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<td>606</td>
<td>400.00</td>
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<td>43%</td>
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<td>158</td>
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<table>
<thead>
<tr>
<th>station</th>
<th>Width/depth ratios</th>
<th>Regression Results - 95% high</th>
<th>percent above/below mean</th>
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<th>percent above/below mean</th>
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<th>percent above/below mean</th>
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<tbody>
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<td>17.63</td>
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<td>4.63</td>
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<td>3.89</td>
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</table>
## Measured Channel Width/Depth Ratios

<table>
<thead>
<tr>
<th>condition</th>
<th>Width (ft)</th>
<th>Depth (ft)</th>
<th>W/D ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1854 T sheet (non-uniform channel)</td>
<td>80-85 ft (&lt;MLLW part)</td>
<td>est. ~12 ft</td>
<td>~7-8</td>
</tr>
<tr>
<td>1854 Hydraulic Geometry Curves for large mature marshes</td>
<td>250 ft (full width)</td>
<td>15-17 ft</td>
<td>14.7 - 16</td>
</tr>
<tr>
<td>2012 condition (upper end at 100+00)</td>
<td>110-130 ft</td>
<td>6 – 7 ft</td>
<td></td>
</tr>
<tr>
<td>2012 condition (lower end North and South forks)</td>
<td>170-174 ft</td>
<td>6 – 10 ft</td>
<td>18 - 28</td>
</tr>
<tr>
<td>Hydraulic Geometry Curves for large mature marshes 2012</td>
<td>171 ft</td>
<td>13 ft</td>
<td>13</td>
</tr>
</tbody>
</table>

Lower w/d ratio increases velocity/shear forces.
Results for dredging depth

- GBA 2009 thalweg survey
- Geomorphic dredge invert
- MHHW
- MLLW
- Previous dredge invert elevations

SM Island enters offshore controlled zone

Elevations:
- 1 ft
- 2 ft
- 3.5 ft
- 4 ft
No Dredge Required

MHHW

MLLW

Lower limit of dense marsh veg

Lower limit of marsh veg

South Fork/North Fork Confluence

Width at MLLW = 80 feet
Depth at MLLW = 5.5 feet

No Dredge Required
Dredge required for depth

Vendola Drive

Width at MLLW = 70 feet
Depth at MLLW = 4.2 feet

Dredge required for depth
Halfway around inner bend of Santa Margarita Island

Width at MLLW = 20 feet
Depth at MLLW = 1.8 feet

Dredge required for depth and width

gerotech off-set from toe (typ)
Add-On 3 - Santa Margarita Island – Split Flow

- Block outer arm allow wetlands form upstream
- Increase velocity maintain depth
- Helps geomorphic dredge
- Significant issues of boat access under bridge and blockage of intakes to be resolved
Gallinas Current Status

- RWQCB provided letter of support
- Redoing hydrographic survey and sampling
- Designing local hydraulic placement facility
- Goal is permitting and dredging by 2018
As the Crescendo approach to Corte Madera Creek, one of the tasks was to design the Geodredge. The creek is a large one with significant fluvial input. The question arises as to how many similar sites exist on the PWA curve. The majority of the creek is lined by fringing marshes. The question is whether these marshes function the same as natural tidal marshes?
More questions?

• Why isn’t the channel forming the equilibrium shape by itself?
• Can I just use PWA plots to design a dredge slot channel?
Channel filling in uniformly – would a slot dredge be sustainable?

Do we need a new curve for high order fluvial dominated systems?
tidal channel complexity

Channel order matters

Higher order tend to be flood dominated; lower are ebb dominated
More about tidal channel complexity

- Low order channels tend to gain x-sectional area by increased depth while higher order due to changes in width
- Higher order tend to be U shaped and lower order tend to be V shaped
- Higher order tend to be flood dominated; lower are ebb dominated
- Abrupt widening at transition
More About tidal channel complexity

- Higher order channels (the big ones we in FC care about) are antecedent channels that evolved on the predecessor mudflat - tend to gain area by width

- Lower order channels evolved with the marsh plain – tend to gain area by depth
Current Status and Lessons Learned

Therefore, higher order tidal channels do not follow same processes as lower order – antecedent (4th and 5th order) versus accretionary channels (1st through 3rd order)

Inherent issue with using empirical data – must understand date sources and processes

We in flood control really care most about big high order channels that we need to dredge for flood control and navigation
Current Status

Now neck deep into a quick study of high order, larger channels around the bay and how they respond to loss of tidal prism

- compiling dozens T-sheets and H-sheets (1850s – 1900s) to perform measurements of width and depth changes in larger channels
- Got an intern with GIS skills and a tidal sub helping with measurements

• Hope to have a new hydraulic geometry curve for high order fluvial and non-fluvial tidal channels by next FMA