Intensive Management of Dredged Material to Maximize Storage Capacity of a Confined Disposal Facility in Savannah Harbor, Georgia – A Success Story

K. Badu-Tweneboah, Ph.D., P.E. and R. G. Mijares, Ph.D., P.E.
Geosyntec Consultants, Inc., Jacksonville, FL, USA

K. W. Cargill, P.E.

KW Cargill, P.A., Punta Gorda, FL, USA
Presentation Outline

- Project Location and Background
- Dredging-Related Infrastructure at Elba Island
- Dredging and Disposal Challenges
- Prediction of DMCA’s Life
- Evaluation of Disposal Options
- Implementation of Intensive DMCA Management
- Conclusions & Recommendations
- Questions
Project Location

Elba Island

Savannah, GA
Elba Island - Historical Island in Savannah River, predominantly salt marsh

Converted to a dredge material disposal area post WWII

LNG Facility was established in 1978 and recommissioned in 2001

1 of 8 LNG delivery terminals in nation

0.3 billion m³ (11.2 billion ft³) of LNG storage

- July 2003 - Feb 2006: Elba II Expansion Construction and in Service
- Sep 2006 - 2010: Elba III Expansion Phase A Construction and in Service
- 2014 - 2015: Elba III Expansion Phase B – Cancelled
- 2013 - 2016: Elba Liquefaction Project – Design, FERC Permitting, Construction, and in Service
Elba Liquefaction Project
Dredging-Related Infrastructure

- **Turning Basin** – Approx. 13 ha (33 ac) conforming with U.S. Coast Guard minimum (FERC Recommendation)

- **Ship Slip** – Approx. 18 ha (44 ac), berths for 2 ships simultaneously

- **DMCA 1** – Approx. 52 ha (130 ac), dike last raised 2011, current dike elevation of 15.2 m (50 ft) MLW, being used for disposal

- **DMCA 2** – Approx. 48 ha (120 ac), dike last raised 2009, being intensively managed for drying and material harvesting since 2011, current dike elevation of 13.4 m (44 ft) MLW
Ship Slip and Turning Basin

Elba Island Aerial Photograph (August 2011)

Turning Basin
~ 33 ac

Ship Slip
~ 44 ac
Dual Ship Off-loading
Confined Disposal Facilities (DMCAs)

Elba Island Aerial Photograph
(August 2011)

DMCA 1
~ 130 ac

DMCA 2
~ 120 ac

Sedimentation Pond

Weir Outlet
Permit Requirements

- **Ship Slip**
  - -13.4 m (-44 ft) *min* to -14 m (-46 ft) *max*, MLW dredge depth
  - 0.6 m (2 ft) allowable overdredge
  - 344,000 m³ (450,000 yd³) annual dredge volume

- **Turning Basin**
  - -12.2 m (-40 ft) *min* to -12.8 m (-42 ft) *max*, MLW dredge depth
  - -0.6 m (2 ft) allowable overdredge
  - 612,000 m³ (800,000 ft³) annual dredge volume

- Hydraulic cutterhead dredge with upland disposal
2014 Dredging Permit
Hydraulic Cutterhead Dredge
Contractual Obligations

- Maintain required dredged depths year round
  - -11.6 m (-38 ft) MLW minimum
  - 0.15 m (0.5 ft) under keel clearance
- Post-Panamax vessels ($Q_{\text{max}}$ and $Q_{\text{flex}}$)
  - -12.2 m (-40 ft) MLW drafts
  - 0.6 m (2 ft) under keel clearance
- Typical 1-month notification of LNG Tanker ship coming
- With liquefaction, ships will leave more frequently
- Huge Financial Penalty if ship cannot come or dock
Historical Maintenance
Dredging Volumes

Combined Dredged Volumes

Volume Dredged (cubic yards)

Year


Turning Basin  Ship Slip
Disposal Challenges

- **Long-Term Dredged Material Management Plan (DMMP)**
  - Prediction of DMCAs Life using PSDDF Software Program by USACE

- **Impact of Increased Frequency of Dredging**
  - Rapid Filling of DMCAs
  - Less Time for Consolidation and Desiccation
  - Changes to Dike Raising Schedules

- **Dike Raising Constraints**
  - Maximum Dike Height of 18.9 to 20.7 m (62 to 68 ft) MLW
  - Stability Constraints (marginal FS at 20.7 m (68 ft) MLW)
  - Availability of Fill Material
Objective is to calculate how in-situ sediment volumes in river convert to in-situ dredged material volumes in DMCA over time

Need to know:

- Void ratios of sediment in river and dredged material after water decantation
- Desiccation Limit of dredged material
- Relationship between void ratio and hydraulic conductivity and between void ratio and effective stress for dredged material

Analyze dredging disposal and drying cycles using USACE model PSDDF (Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill)
Prediction of DMCA Life
Theoretical Background

- **Primary Consolidation: governing equation**
  
  \[
  \left( \frac{\gamma_s}{\gamma_w} - 1 \right) \frac{d}{de} \left[ \frac{k(e)}{1+e} \right] \frac{de}{dz} + \frac{\partial}{\partial z} \left[ \frac{k(e)}{\gamma_w(1+e)} \frac{de}{dz} \right] + \frac{de}{dt} = 0
  \]

  - \( k(e) \) is the coefficient of soil permeability as a function of void ratio \( e \)

- **Secondary Compression**
  
  \[ S_s = \frac{c\alpha}{(1+e_0)} (h) \log \left( \frac{t}{t_p} \right) \]

- **Desiccation Processes**
  
  \[ \Delta W' = CS - (C_E' \cdot EP) + (1 - C_D)RF \]

  - \( \Delta W' \) is the water lost during first-stage drying,
  - \( CS \) is water supplied from lower consolidating soil,
  - \( C_E' \) is the maximum evaporation efficiency,
  - \( EP \) is Class A pan evaporation,
  - \( C_D \) is the drainage efficiency, and \( RF \) is the rainfall

Void ratio distribution immediately after placement of new lift (Cargill 1985)
Measured Specific Gravity Values of Dredged Material from DMCAs

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Measured G_s</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comp. B</td>
<td>2.552</td>
<td>June, 2011, Composite sample near weir of Samples 5 &amp; 6</td>
</tr>
<tr>
<td>Comp. C</td>
<td>2.407</td>
<td>June, 2011, Composite sample from Pit 2 of Samples 8 &amp; 9</td>
</tr>
<tr>
<td>P41-06</td>
<td>2.631</td>
<td>April, 2012, Jar sample 6” below desiccated crust in DMCA 2</td>
</tr>
<tr>
<td>P41-12</td>
<td>2.583</td>
<td>April, 2012, Jar sample 12” below desiccated crust in DMCA 2</td>
</tr>
<tr>
<td>P42-06</td>
<td>2.641</td>
<td>April, 2012, Jar sample 6” below desiccated crust in DMCA 2</td>
</tr>
<tr>
<td>P42-12</td>
<td>2.609</td>
<td>April, 2012, Jar sample 12” below desiccated crust in DMCA 2</td>
</tr>
<tr>
<td>P43-06</td>
<td>2.619</td>
<td>April, 2012, Jar sample 6” below desiccated crust in DMCA 2</td>
</tr>
<tr>
<td>P43-12</td>
<td>2.585</td>
<td>April, 2012, Jar sample 12” below desiccated crust in DMCA 2</td>
</tr>
<tr>
<td>P44-06</td>
<td>2.599</td>
<td>April, 2012, Jar sample 6” below desiccated crust in DMCA 2</td>
</tr>
<tr>
<td>P44-12</td>
<td>2.657</td>
<td>April, 2012, Jar sample 12” below desiccated crust in DMCA 2</td>
</tr>
<tr>
<td>A2 @ 9 ft</td>
<td>2.552</td>
<td>December 2013, Tube sample at berm outside DMCA 2</td>
</tr>
<tr>
<td>A3 @ 9 ft</td>
<td>2.537</td>
<td>December 2013, Tube sample at berm outside DMCA 2</td>
</tr>
<tr>
<td>A5 @ 3 ft</td>
<td>2.572</td>
<td>December 2013, Tube sample at berm outside DMCA 2</td>
</tr>
</tbody>
</table>

Average of measured: \( G_s = 2.580 \)
### Calculated Void Ratios of Sediments and Dredged Material

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Measured w (%)</th>
<th>Calculated e</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>TB-01</td>
<td>228.6</td>
<td>5.9</td>
<td>2011 Tier II Sediment Investigation</td>
</tr>
<tr>
<td>TB-02</td>
<td>294.9</td>
<td>7.6</td>
<td>2011 Tier II Sediment Investigation</td>
</tr>
<tr>
<td>TB-03</td>
<td>279.9</td>
<td>7.2</td>
<td>2011 Tier II Sediment Investigation</td>
</tr>
<tr>
<td>TB-04</td>
<td>248.9</td>
<td>6.4</td>
<td>2011 Tier II Sediment Investigation</td>
</tr>
<tr>
<td>TB-05</td>
<td>231.8</td>
<td>6.0</td>
<td>2011 Tier II Sediment Investigation</td>
</tr>
<tr>
<td>SS-09</td>
<td>250.0</td>
<td>6.4</td>
<td>2011 Tier II Sediment Investigation</td>
</tr>
<tr>
<td>SS-10</td>
<td>265.0</td>
<td>6.8</td>
<td>2011 Tier II Sediment Investigation</td>
</tr>
<tr>
<td>SS-11</td>
<td>317.3</td>
<td>8.2</td>
<td>2011 Tier II Sediment Investigation</td>
</tr>
<tr>
<td>SS-12</td>
<td>331.5</td>
<td>8.6</td>
<td>2011 Tier II Sediment Investigation</td>
</tr>
<tr>
<td>L1D1</td>
<td>405.7</td>
<td>10.5</td>
<td>2013 Bed-Leveling Research</td>
</tr>
<tr>
<td>L1D2</td>
<td>415.2</td>
<td>10.7</td>
<td>2013 Bed-Leveling Research</td>
</tr>
<tr>
<td>L2D1</td>
<td>375.6</td>
<td>9.7</td>
<td>2013 Bed-Leveling Research</td>
</tr>
</tbody>
</table>

Average of calculated: $e = 7.8$

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Measured Water Content, w</th>
<th>Calculated, e</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weir-5</td>
<td>399.2</td>
<td>10.3</td>
<td>Sample near the weir end of DMCA 1</td>
</tr>
<tr>
<td>Weir-6</td>
<td>422.2</td>
<td>10.9</td>
<td>Sample near the weir end of DMCA 1</td>
</tr>
<tr>
<td>Pit 2-7</td>
<td>391.7</td>
<td>10.1</td>
<td>Sample ¼ DMCA length from dredge pipe</td>
</tr>
<tr>
<td>Pit 2-8</td>
<td>429.8</td>
<td>11.1</td>
<td>Sample ¼ DMCA length from dredge pipe</td>
</tr>
<tr>
<td>Pit 2-9</td>
<td>440.9</td>
<td>11.4</td>
<td>Sample ¼ DMCA length from dredge pipe</td>
</tr>
<tr>
<td>Pit 2-10</td>
<td>400.1</td>
<td>10.3</td>
<td>Sample ¼ DMCA length from dredge pipe</td>
</tr>
</tbody>
</table>

Average of calculated: $e = 10.7$
DMCAs Life Prediction Using PSDDF Model
### DMCAs Life Prediction Using PSDDF Model

<table>
<thead>
<tr>
<th>Cases</th>
<th>Comments</th>
<th>Dredging Event</th>
<th>Thickness Deposited (ft)</th>
<th>Estimated Life Expectancy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>DMCA 1</td>
<td>DMCA 2</td>
</tr>
<tr>
<td>Case 1</td>
<td>2 dredging events per year: SS and TB</td>
<td>1 April</td>
<td>3.94</td>
<td>4.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 October</td>
<td>3.94</td>
<td>4.22</td>
</tr>
<tr>
<td>Case 2</td>
<td>3 dredging events per year: SS and TB</td>
<td>1 March</td>
<td>2.63</td>
<td>2.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 July</td>
<td>2.63</td>
<td>2.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 November</td>
<td>2.63</td>
<td>2.82</td>
</tr>
<tr>
<td>Case 3</td>
<td>3 dredging events per year: SS</td>
<td>1 March</td>
<td>1.07</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 July</td>
<td>1.07</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 November</td>
<td>1.07</td>
<td>1.15</td>
</tr>
<tr>
<td>Case 4</td>
<td>3 dredging events per year: SS</td>
<td>1 March</td>
<td>3.4</td>
<td>3.65</td>
</tr>
<tr>
<td></td>
<td>2 dredging events per year: TB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 July</td>
<td>3.4</td>
<td>3.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 November</td>
<td>1.07</td>
<td>1.15</td>
</tr>
</tbody>
</table>

Notes: SS = Ship Slip; TB = Turning Basin
Evaluation of Disposal Options

- **Bed leveling (agitation dredging) in ship slip**
  - Research (NW 5) Permit issued in January 2012
  - Study Period: April 2012 thru May 2013
  - Allow more drying time in DMCA by increasing time between dredging events

- **Negotiations with USACE & GDOT**
  - Use of SC DMCAs for dredged material disposal
  - Ship Slip and Turning Basin are for a single user

- **Ocean Disposal**
  - **Intensive management of DMCA drainage and dredged material harvesting**
    - Concepts developed during last DMCA 1 dike raising in 2011
    - Concepts currently being implemented in DMCA 2 since 2011
    - Final objective is system steady state where volume capacity of DMCA is perpetually restored between dredging
Concept of Intensive DMCA Management

- Rapid removal of decanted water and constant removal of rainfall and drainage water
- Use of specialty equipment to remove dredged material at perimeter to promote more rapid development of interior desiccated crust
- Continued removal of desiccated crust within approximately 60 m (200 ft) DMCA perimeter
- Development of interior borrow pits for material mining as possible
- Hauling desiccated and consolidated material to stockpile areas outside DMCAs for further drying and processing
Construction Equipment Being Used

- Marsh (Swamp) Buggies – 2
- Long-Reach Excavators – 4
- Trackhoe Excavator – 1
- 25-ton Off-Road Trucks – 2 to 4
- Track Harrow (for diskimg) – 2
- Bulldozers – 2
Implementation – Decanted Water
Implementation – Marsh Buggy
Implementation – Long-Reach Excavators
Implementation – Marsh Buggy
Implementation – Marsh Buggy
Implementation – Marsh Buggy
Implementation – Dozer
Tracking Consolidation and Settlement
Tracking Consolidation and Settlement
On-going Settlement in DMCA 2

DMCA 2 CENTERLINE PROFILE

Elevation (ft)

Horizontal Distance (ft)

West End (Near the weir)  East End

Apr 2012 Mudline
Aug 2012 Mudline
May 2014 Mudline
Jul 2015 Mudline
Apr 2016 Mudline
May 2015 Aerial
Apr 2013 Aerial
Aug 2011 Aerial
Consolidation/Desiccation Settlement in DMCA 2
<table>
<thead>
<tr>
<th>Survey Date</th>
<th>DMCA 2 Capacity to EL 40 ft MLW (CY)</th>
<th>Net Capacity Increased (CY)</th>
<th>Cost</th>
<th>$/CY of Capacity Gained</th>
<th>Dike Raising Equivalent to Capacity Gained (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 2011</td>
<td>316,279</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>April 2013</td>
<td>1,285,361</td>
<td>969,082</td>
<td>$ 2,546,936</td>
<td>$ 2.63</td>
<td>4.8</td>
</tr>
<tr>
<td>May 2015</td>
<td>1,946,142</td>
<td>660,781</td>
<td>$ 5,180,006</td>
<td>$ 7.84</td>
<td>3.3</td>
</tr>
<tr>
<td>TOTAL</td>
<td>N/A</td>
<td>1,629,863</td>
<td>$ 7,726,942</td>
<td>$ 4.74</td>
<td>8.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Survey Date</th>
<th>Material Harvested (CY)</th>
<th>Material Stockpiled (CY)</th>
<th>Material Recovery (%)</th>
<th>$/CY of Material Harvested</th>
<th>$/CY of Material Generated</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 2011</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>April 2013</td>
<td>405,399</td>
<td>NM(2)</td>
<td>NM(2)</td>
<td>$ 6.28</td>
<td>NM(2)</td>
</tr>
<tr>
<td>May 2015</td>
<td>459,862</td>
<td>253,930</td>
<td>55%</td>
<td>$ 11.26</td>
<td>$ 20.40</td>
</tr>
<tr>
<td>TOTAL</td>
<td>865,262</td>
<td>NM(2)</td>
<td>NM(2)</td>
<td>$ 8.93</td>
<td>NM(2)</td>
</tr>
</tbody>
</table>
Conclusions

- Increase in available disposal capacity
- Potential increase in anticipated life of DMCA 2
- Generation of fill material for dike raising
  - Beneficial reuse of dredged sediments

Recommendations

- Duplicate effort in DMCA 1
- Subdivide DMCA 2 to facilitate ditching within the interior portion of the DMCA
  - Provides additional opportunity to achieve system steady state where volume capacity of DMCA is perpetually restored between dredging
Subdivide DMCA 2