Rising oceans threaten military bases: report

By: Meghann Myers. July 29, 2016 (Photo Credit: U.S. Coast Guard)
Minor (Nuisance) Flooding

Hours per year nuisance flooding on Hampton Blvd.

Dr. Larry Atkinson
Old Dominion University/CCPO
2018
Moderate Flooding

Years with most flood hours:
1-2009 Veterans Day NorEaster
2-1998 Twin NorEaster
3-2015 Joaquin/NorEaster
4-2006 Thanksgiving NorEaster
5-1999 Hurricane Floyd
6-2012 Hurricane Sandy
7-1962 Ash Wednesday Storm
8-1933 Ches-Potomak Hurricane

Ezer, 2016
Measuring Sea Level Rise

Sewell’s Point Tide Gauge
# Measuring Sea Level Rise

<table>
<thead>
<tr>
<th>Water Level Recording Station</th>
<th>Record length (years)</th>
<th>Sea Level Rise (feet/century)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eugene Island, LA</td>
<td>35</td>
<td>3.2</td>
<td>1</td>
</tr>
<tr>
<td>Grand Isle, LA</td>
<td>69</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>Galveston Pleasure Pier, TX</td>
<td>54</td>
<td>2.2</td>
<td>3</td>
</tr>
<tr>
<td>Galveston Pier 21, TX</td>
<td>112</td>
<td>2.1</td>
<td>4</td>
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<tr>
<td>Chesapeake Bay Bridge Tunnel, VA</td>
<td>41</td>
<td>2.0</td>
<td>5</td>
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<tr>
<td>Sabine Pass, TX</td>
<td>58</td>
<td>1.9</td>
<td>6</td>
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<tr>
<td>Ocean City Inlet, MD</td>
<td>41</td>
<td>1.8</td>
<td>7</td>
</tr>
<tr>
<td>Rockport, TX</td>
<td>79</td>
<td>1.8</td>
<td>8</td>
</tr>
<tr>
<td>Wachapreague, VA</td>
<td>38</td>
<td>1.8</td>
<td>9</td>
</tr>
<tr>
<td>Lewisetta, VA</td>
<td>46</td>
<td>1.7</td>
<td>10</td>
</tr>
<tr>
<td>New Canal, LA</td>
<td>34</td>
<td>1.7</td>
<td>11</td>
</tr>
<tr>
<td>Colonial Beach, VA</td>
<td>38</td>
<td>1.6</td>
<td>12</td>
</tr>
<tr>
<td>North Spit, CA</td>
<td>39</td>
<td>1.5</td>
<td>13</td>
</tr>
<tr>
<td>Sewells Point, VA</td>
<td>89</td>
<td>1.5</td>
<td>14</td>
</tr>
<tr>
<td>Cape May, NJ</td>
<td>51</td>
<td>1.5</td>
<td>15</td>
</tr>
<tr>
<td>Duck, NC</td>
<td>38</td>
<td>1.5</td>
<td>16</td>
</tr>
<tr>
<td>Apra Harbor, Guam</td>
<td>23</td>
<td>1.5</td>
<td>17</td>
</tr>
<tr>
<td>Freeport, TX</td>
<td>36</td>
<td>1.5</td>
<td>18</td>
</tr>
<tr>
<td>Bay Waveland, MS</td>
<td>38</td>
<td>1.4</td>
<td>19</td>
</tr>
<tr>
<td>Corpus Christi, TX</td>
<td>33</td>
<td>1.4</td>
<td>20</td>
</tr>
</tbody>
</table>
Measuring Sea Level Rise

Rate = 3.3 ± 0.4 mm/yr
Seasonal signals removed

NOAA/Laboratory for Satellite Altimetry

Sea level change (cm)
What causes the sea level to change?

Terrestrial water storage, extraction of groundwater, building of reservoirs, changes in runoff, and seepage into aquifers

Surface and deep ocean circulation changes, storm surges

Subsidence in river delta region, land movements, and tectonic displacements

As the ocean warms, the water expands

Exchange of the water stored on land by glaciers and ice sheets with ocean water
Melting Land Ice

If all ice melted

- Antarctic – 200 foot rise
- Greenland – 20 foot rise

This is not likely to happen for centuries, but ice is melting faster than expected and the dynamics of the ice sheets is changing.
Ocean warming and expanding

0-2000 m Global Ocean Heat Content

- 3-Month average through Oct-Dec 2014
- Yearly average through 2014
- Pentadal average through 2010-2014

NOAA/NESDIS/NODC Ocean Climate Laboratory
Updated from Levitus et al. 2012
Land subsidence
about 1 ft. per century in Virginia

Groundwater pumping
TRENDS:
- Global Tide Gauge Data (1880-2009): 1.54 mm/y
- Norfolk Tide Gauge (1927-2011): 4.54 mm/y

Storm surge →

~6 mm/y

Last 20 yrs

Impact from changes in ocean currents

Satellite data

Ezer, 2016
Small changes in ocean currents cause **big changes in coastal sea level**

The Virginian Pilot 2018

Sea Level in Virginia
Historic data and projections

Virginia Institute of Marine Science 2017
2050: ~60 full days of flooding per year

(SLR=4.5 mm/y)

Today: ~10 full days of flooding per year

Until the 1970s: ~20 hours of flooding per year

(source: T. Ezer, ODU, 2015)
Rainfall Trend

Annual Maximum Series at Norfolk Airport

Slope = 1.98 inches / century
Confidence = 95%
Rainfall Trend

- Upward trend of Annual Maximum Precipitation Series between 3-7% per decade.
What is at risk?

- Land inundation and shoreline erosion
- Destruction of wetlands
- Saltwater intrusion
- Increased threat from severe storms
- Difficulty living in the coastal zone
  - Property Insurance
  - Transportation
  - Economic stability
Hampton Roads infrastructure

Potential impact of sea level rise on military sites

Reference Sea Level rise may approach 1 meter by 2100.
A 10-foot storm surge today would exceed the 3-meter rise shown in the map.
Loss of Wetlands

Arkema, et al., 2013
Storm Flooding

Virginia Department of Emergency Management,
Virginia Hurricane Evacuation Guide
Water Infrastructure

Bringing Together

• Coastal Flooding
• Stormwater Conveyance
• Combined Flooding
Flood Impacts

Cost of damage to a 2,000-sq.-ft. home by 6 inches of floodwater:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finished floor, wood, carpeting</td>
<td>$15,870</td>
</tr>
<tr>
<td>Doors, base trim, windows</td>
<td>$2,150</td>
</tr>
<tr>
<td>Electrical, plumbing</td>
<td>$320</td>
</tr>
<tr>
<td>Cleaning</td>
<td>$2,000</td>
</tr>
<tr>
<td>Kitchen and bath cabinets</td>
<td>$4,500</td>
</tr>
<tr>
<td>Appliances</td>
<td>$180</td>
</tr>
<tr>
<td>Washer, dryer</td>
<td>$150</td>
</tr>
<tr>
<td>Repairs to furnace/AC</td>
<td>$270</td>
</tr>
<tr>
<td>Bedroom furniture</td>
<td>$1,800</td>
</tr>
<tr>
<td>Kitchenware and food</td>
<td>$330</td>
</tr>
<tr>
<td>Living room furniture</td>
<td>$2,700</td>
</tr>
<tr>
<td>Computer accessories</td>
<td>$1,100</td>
</tr>
<tr>
<td>Media equipment</td>
<td>$150</td>
</tr>
<tr>
<td>Accent furniture and accesories</td>
<td>$450</td>
</tr>
<tr>
<td>Personal items</td>
<td>$650</td>
</tr>
<tr>
<td>Total</td>
<td>$39,150</td>
</tr>
</tbody>
</table>

www.houselogic.com
Response Options

**Adaptation**
- Changes in Land Use & Relocation
- Weatherproofing
- Buildings & Infrastructure Retrofits
- Natural Resource Protection

**Mitigation**
- Smart Growth
- Water & Energy Conservation
- Green Infrastructure
- Sustainable Transportation
- Renewable Energy & Conservation
- Carbon Sequestration (Sinks)
- Anaerobic Digestion