Land Subsidence in Hampton Roads

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HAMPTON ROADS PDC PLANNING DISTRICT COMMISSION

Why should we measure land subsidence?

- To develop better predictions of future rates of land subsidence.
- To understand where land subsidence is likely to occur.

Summary of Measured sea-level rise and subsidence from USGS report

[IPCC, Intergovernmental Panel on Climate Change; mm/yr , millimeters per year; NA, not available; NGS, National Geodetic Survey; NOAA, National Oceanic and Atmospheric Administration; SD, standard deviation; USCG, U.S. Coast Guard; USGS, U.S. Geological Survey]

What was measured	Monitoring technique	Agency	Number of stations	Period	Rate,[1] in mm/yr			
					Average	Low	High	SD
Global data								
Estimated average global sea-level rise	Various	IPCC[2]	NA	1961–2003	1.8	NA	NA	NA
Southern Chesapeake Bay region data								
Aquifer compaction	Extensometer	USGS[3]	2	1979–1995	–2.6	–1.5	–3.7	NA
Land subsidence	Geodetic survey	NGS[4]	17	1940–1971	–2.8	–1.1	–4.8	0.8
Land subsidence	Fixed GPS	NOAA/USCG[5]	3	2006–2011	–3.1	–2.7	–3.4	0.4
Relative sea-level rise	Tidal station	NOAA[6]	4	1927–2006	3.9	3.5	4.4	0.2

[1]Negative values indicate downward motion (land subsidence), positive values upward motion.
[2]Data are from Bindoff and others (2007).
[3]Data are from Pope and Burbey (2004).
[4]Data are from Holdahl and Morrison (1974).
[5]Data are from Snay and Soler (2008) and National Geodetic Survey (2013) from Continuously Operating Reference Station (CORS) network.
[6]Data are from Zervas (2009).

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Options

1. HRPDC could fund USGS to assess the methods of monitoring land subsidence and develop cost estimates. The resulting report could be used to support a state budget request or future grant opportunities. Estimated costs = $50,000.

2. HRPDC could issue a request for proposals for InSar analysis. The analysis would compare land elevations from the 1990s to 2000s to create a map of historic land subsidence across the region. Estimated costs = $250,000.

Option 1 selected by Commission in January 2015.

Draft Report

March 2016

Draft report is designed to provide direction for future monitoring efforts by describing:

- HRPDC's monitoring needs,
- listing current monitoring efforts,
- identifying promising technologies, and
- estimating costs.

Recommendations

Establishment and surveying of a benchmark network

- *$100K initial cost*
- *$20 to 40K annual surveying and data analysis cost*

Installation of extensometer stations

- *$700 to 2,500K one-time cost depends on number and depths of extensometers*
- *$20K annual O&M and data analysis and presentation cost*

How monitoring data are used

- **To avoid or mitigate problems caused by land subsidence** - Urban planners, resource managers, and politicians use monitoring data to guide their decisions.

- **To answer questions**, such as – Why is subsidence occurring?

- **To predict future land subsidence** - Predictive models that can test mitigation strategies require monitoring data for accuracy and reliability.

- **To make maps** - Maps showing critical areas for mitigating land subsidence are based on monitoring data.

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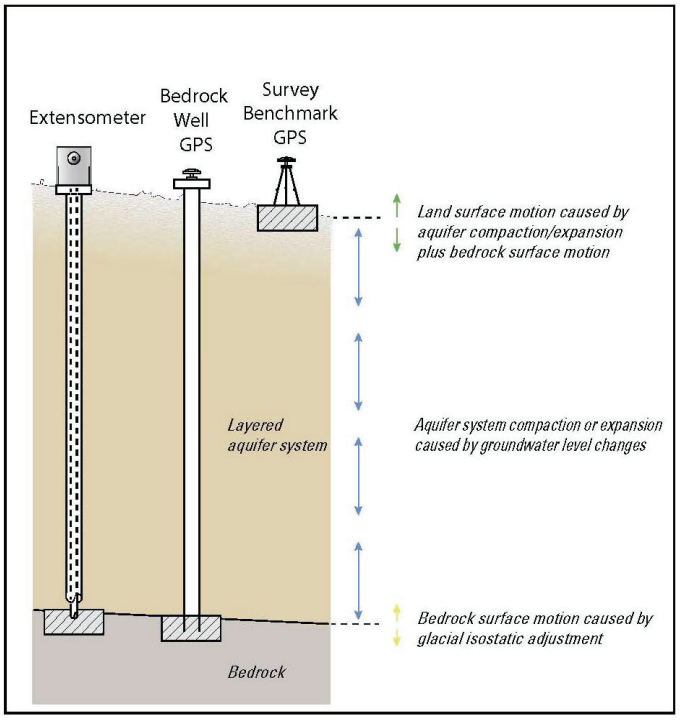
What land subsidence monitoring measures

1. Extensometer to measure aquifer system compaction or expansion
2. Bedrock well GPS to measure bedrock surface motion
3. Survey benchmark GPS to measure land surface motion



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Strengths and Weaknesses

Method	Type of data	Measures aquifer-system compaction independently	Spatial coverage	Temporal detail
Borehole Extensometer	Aquifer-system thickness at one location, continuous record	Yes	Low	High
Tidal Station	Sea elevation at one location, continuous record	No	Low	High
Geodetic Surveying	Land elevations at one or several locations, multiple times or continuous record	No	Low to moderate	Low to high
Remote Sensing (InSAR)	Land elevations over a wide area, at multiple times	No	High	Moderate

Subsidence in Hampton Roads approximately 1-5 mm/year

- **Extensometers provide sub-millimeter data (0.01 mm).**
- **Geodetic Survey achieve centimeter scale accuracy for absolute vertical position and millimeter scale accuracy for differential vertical position.**
- **Remote Sensing typical error is 5-10 mm. Maybe worse in Hampton Roads.**

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Funded Research

- USGS refurbished old extensometers in Franklin and Suffolk in 2015 and initial data indicates that they are now functioning. May add GPS antennas to measure bedrock motion (glacial isostatic rebound).
- NGS operates 5 CORS stations with continuous GPS measurement of land motions.
- NGS currently analyzing historic surveys on Atlantic Coast to determine rates of subsidence over past century.
- In 2017, new U.S. satellite will collect InSAR over Hampton Roads.
- In 2016, NOAA, USGS, NASA likely to analyze InSAR data over Hampton Roads collected from 2008-2011.

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Monitoring Recommendations

Install 1-3 new extensometers at existing tidal stations.

Cost: $1M/each to install and $20K/yr O&M each

Establish benchmark survey network using mobile GPS antennas from Piedmont to Coastal Plain. Conduct annual survey.

Cost: $120K for initial survey and $20-40K/year for annual survey and analysis

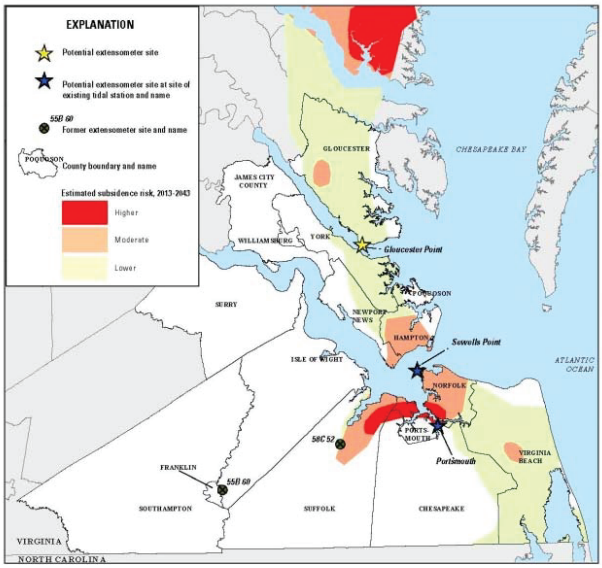

Figure 2. Map of estimated risk of land subsidence due to aquifer compaction 2013-2043 and locations of high potential sites for installation of extensometer stations to measure aquifer compaction and land subsidence. Risk of land subsidence at any location is determined by three factors: predicted groundwater level decline, thickness of silt and clay layers, and sediment compressibility. Groundwater level declines were predicted for 2013-2043 – future actual declines and risk may differ from predicted.

Next Steps

Discuss with HRPDC Coastal Resiliency committee to consider:

- Is this data a regional priority?
- Funding strategies: regional assessment, locality funded, apply for grants, pursue state or federal funding

Next meeting: March 25, 2016

Continue meeting with subsidence technical advisory group (NASA, NGA, USGS, ODU, etc) to track ongoing research and improve coordination and data sharing.