Contribution of Citizen Science Towards Assessing Impacts of Sea-level Rise on the Extent of Groundwater and Marine Inundation on a Barrier Island Setting

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What is Citizen Science?

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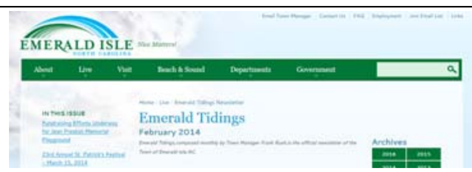
Citizen science is a tool that connects the public to the scientific community with the goal of expanding scientific knowledge and literacy (Bonney et al. 2009).

Project Development

Community Engagement	Scientific Research	Citizen Science
NC Coastal Federation NC Aquarium @PKS Towns on Bogue Banks Trinity Center PKS	Impacts of sea-level rise and climate change on groundwater	Groundwater level and and stormwater monitoring

Motivations for citizen scientists

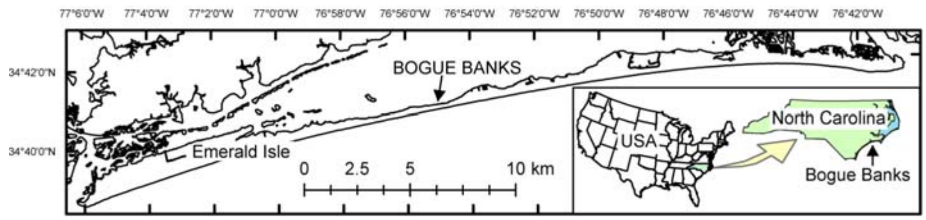


Storm Water Pipe Installation To Begin Along Coast Guard Road, in Lands End

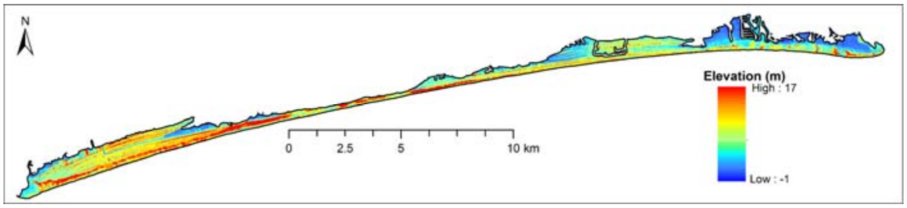
Work will begin in February on the installation of new storm water pipe along Coast Guard Road and in the Lands End community.

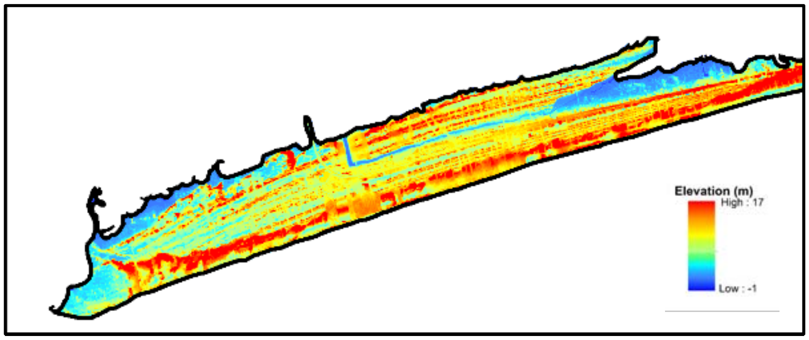
The new pipe will connect the Town's new storm water pump station located at Island Circle (at The Point) to the Town's overall storm water system that discharges at Emerald Isle Woods Park. The new pipe will also connect existing pumps in the Lands End pond system to the Town's overall system. These new storm water pipe connections will provide a reliable receiving site for storm

Study Area

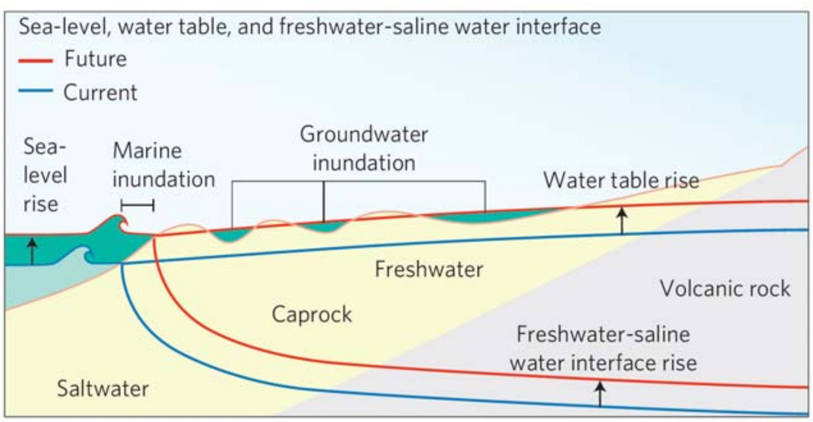


Topography





Groundwater flooding



Rotzoll K, Fletcher CH. 2012. Assessment of groundwater inundation as a consequence of sea-level rise. Nature Climate Change DOI: 10.1038/NCLIMATE1725.

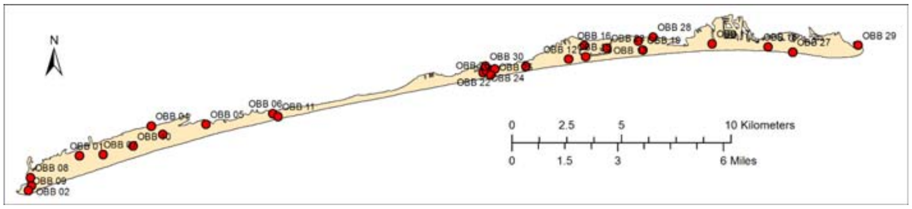
Process

- Groundwater well installation
- Stakeholder engagement and recruitment
- Water level monitoring
- Data analysis

Methodology

- Natural Environment
  - Installation of 29 monitoring wells in Surficial aquifer
  - Groundwater monitoring
  - Groundwater modeling
- Stakeholders
  - Pre and Post content tests
  - Pre and Post participation surveys
  - Focus Groups
  - Other activities?

Water level monitoring



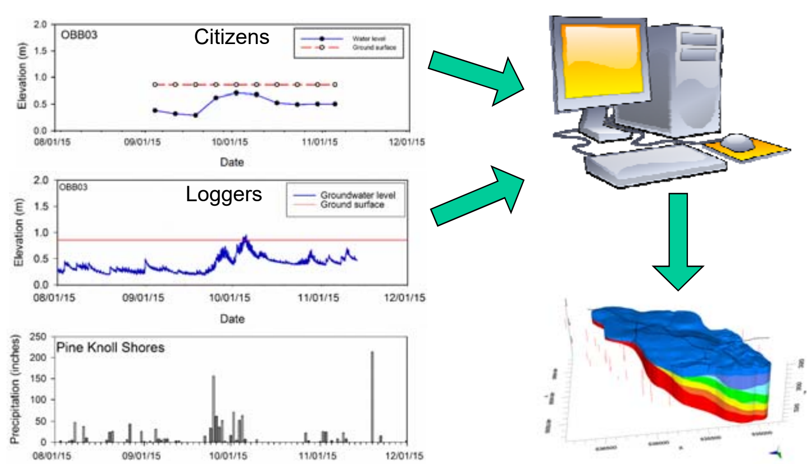
Recruitment

- Primary Partners
  - North Carolina Coastal Federation
  - Town of Pine Knoll Shores
  - Town of Emerald Isle
  - Town of Atlantic Beach
  - The Trinity Center and other property owners
  - NC Aquarium at Pine Knoll Shores
- Secondary Partners
  - Citizen Scientists
  - Target: 10 volunteers for 20 wells
  - Recruited: 8 volunteers for 15 wells
  - Participated: 7 volunteers for 12 wells

Groundwater level Monitoring

- Manual water level measurements
- Synchronous water level measurements (e.g., once a week on Friday @10AM)
- 10-week period

Did groundwater levels go above the land surface?



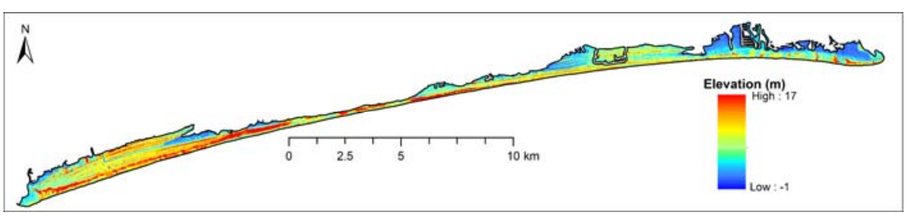
Source: http://www.swstechnology.com/

Sea-level Rise Scenarios Over 100 years

- 0.2 m
- 0.4 m
- 0.6 m
- 0.8 m
- 1.0 m
- 1.2 m
- 1.4 m

(Jevrejeva *et al*., 2012; NRC, 2012; Rahmstorf *et al*., 2012; Horton *et al*., 2014).

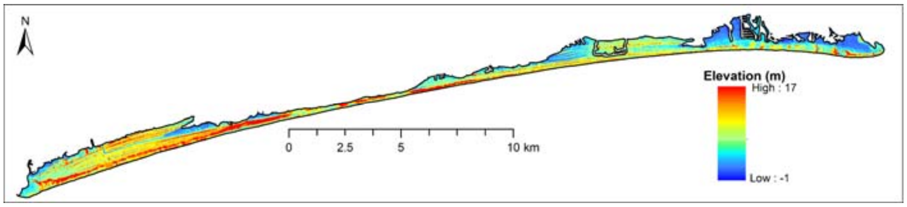
Geospatial Modeling



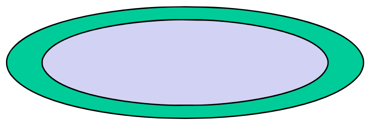
Bath tub model

- Baseline
- 0.2 m
- 0.4 m
- 0.6 m

Geospatial Modeling



Bath tub model



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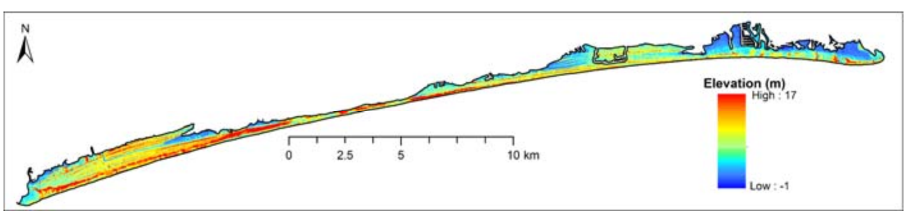

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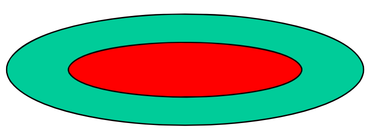

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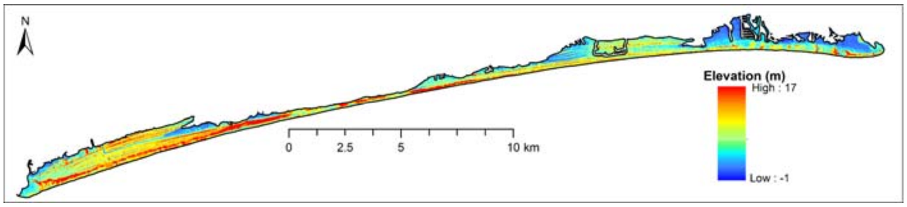
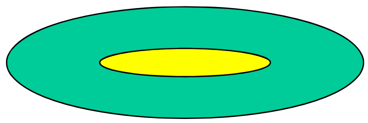
Marine Inundation

Geospatial Modeling



Bath tub model



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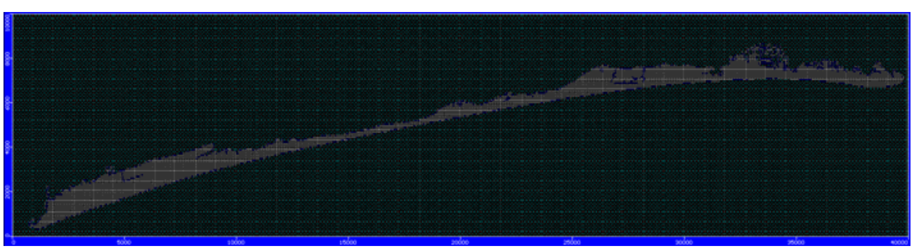
Groundwater Inundation

Groundwater Modeling

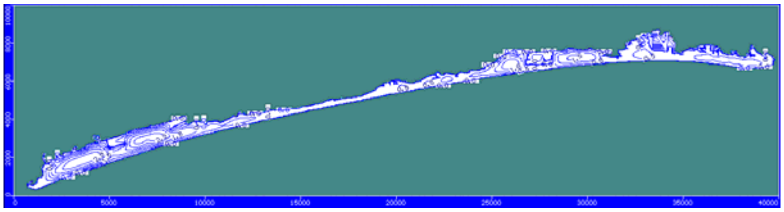


Steady state model
Constant head boundary conditions
Variable recharge rates
Homogeneous aquifer
40,000 m by 10,000 m

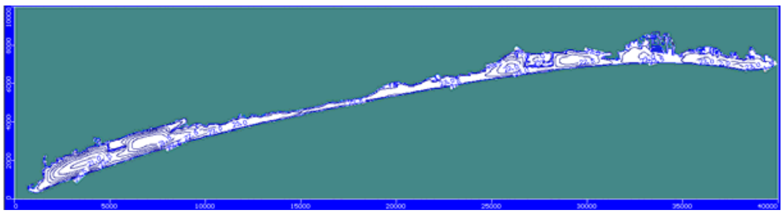
NRMSE = 14.6%
Hydraulic conductivity of 0.3 m/day

Water table contour maps

Baseline Conditions

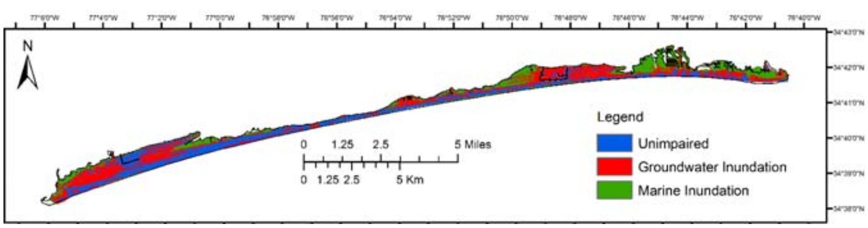


Sea-level rise = 1.4 m



Groundwater and marine Inundation Maps

Sea-level rise = 1.4 m



Marine and Groundwater Inundation

Seal level-rise scenario	Impaired Area (km^2)	Unimpaired Area (km^2)	Proportion of impaired area (%)	Proportion of unimpaired area (%)
0.2 m	4.8	23.4	16.9	83.1
0.4 m	5.9	22.3	20.9	79.1
0.6 m	6.8	21.4	24.1	75.9
0.8 m	7.7	20.5	27.4	72.6
1.0 m	9.1	19.2	32.1	67.9
1.2 m	10.1	18.1	35.8	64.2
1.4 m	19.2	9.1	67.9	32.1

Marine vs Groundwater Inundation

Marine

Seal level-rise scenario	Impaired Area (km^2)	Proportion of impaired area (%)
0.2 m	2.2	7.8
0.4 m	3.6	12.7
0.6 m	3.6	12.7
0.8 m	4.8	16.9
1.0 m	6.1	21.7
1.2 m	6.1	21.7
1.4 m	7.9	27.8

Groundwater

Seal level-rise scenario	Impaired Area (km^2)	Proportion of impaired area (%)
0.2 m	2.6	9.1
0.4 m	2.3	8.3
0.6 m	3.2	11.4
0.8 m	3	10.6
1.0 m	2.9	10.4
1.2 m	4	14.1
1.4 m	11.3	40.1

Marine vs Groundwater Inundation

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Marine

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Groundwater

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1.0 m	2.9	10.4
1.2 m	4	14.1
1.4 m	11.3	40.1

Conclusions

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- Results from groundwater and geospatial modeling indicate that the land that could be lost to groundwater inundation may be as large as, if not larger, than the land that could be lost to marine inundation under projected sea-level rise scenarios of 0.2 – 1.4 m over the next 100 years.
- The effects of groundwater inundation may therefore be far much greater than those of marine inundation (with losses of 28% for marine inundation and 40% for groundwater inundation).
- Groundwater inundation should therefore play an important role in future discussions about how climate change and sea-level rise may impact groundwater resources in coastal communities.
- Citizen Science an effective way of engaging people to take part in science.

Acknowledgments

- North Carolina Sea Grant
- North Carolina Water Resources Research Institute
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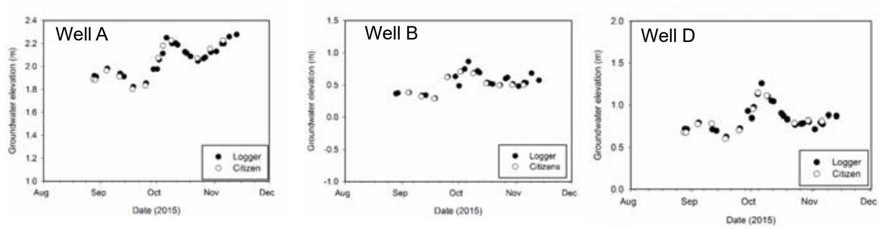
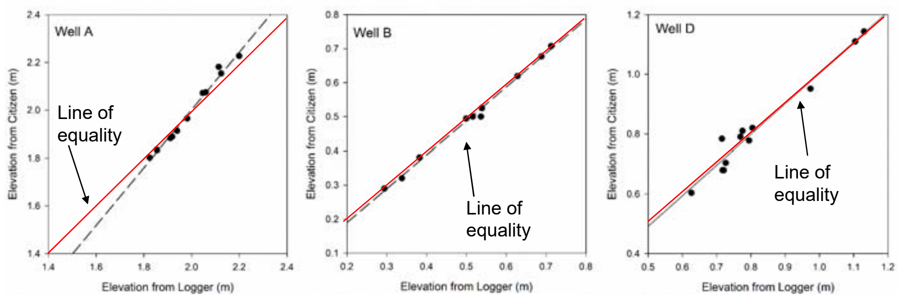
- North Carolina Coastal Federation
- North Carolina Aquarium at Pine Knoll Shores
- Atlantic Beach
- Emerald Isle
- Pine Knoll Shores
- The Trinity Center
- Citizen Scientists
- John Woods, James Owers, Jim Watson, and GEOL graduate and undergraduate students
- Tom Allen, Dept. of Geography and Environmental Planning
- Engagement and Outreach Scholar Academy, East Carolina University

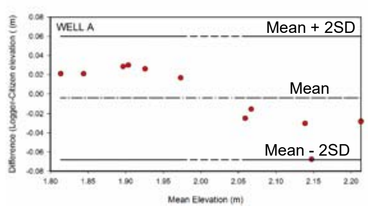
Pilot Study: Citizen Scientists vs Loggers

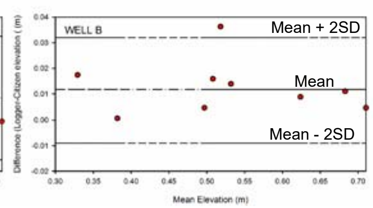


Citizen Scientists vs Loggers



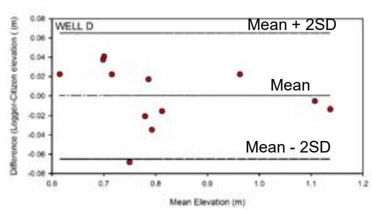
Bland-Altman Method





Mean diff: -0.0042 m
Limits of agreement (2SD): -0.068 to 0.06 m

Mean diff: 0.0012 m
Limits of agreement (2SD): -0.009 to 0.032 m



Mean diff: 0.0004 m
Limits of agreement (2SD): -0.065 to 0.065 m

Water level measurements