Monitoring flood severity within a coastal community: Developing a waterproof housing for a thermistor and pressure sensor

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Introduction

As climate change, specifically sea level rise, continues to worsen, the ability for coastal communities to adapt and survive flood waters becomes paramount. Residents of Hampton, New Hampshire have faced growing concerns from flooding, especially those near estuaries and marshes. King tides are where the sun, moon, and earth align, which results in the highest high tide elevation of the month. These, as well as storms, make water levels a safety concern and a responsibility of the town leaders to communicate this issue for the well-being of the residents.

We teamed up with another Innovation Scholars' group to create an instrument that measures the pressure and temperature of the floods all while being able to withstand the intensity of the water. Our overall goal of creating this instrument is to give the residents of Hampton updated data on the trends and patterns of flooding to help them make more informed decisions regarding the safety of themselves and their property.

Methodology

Generating Concepts:

When brainstorming concepts for the housing of our device, two options were viable: a housing made of PVC and a pre-made box.

Housing Options	PVC	Pre-Made box
General Pros	Durable, Waterproof	Simple, Waterproof, already 100% sealed
General Cons	Limited to cylindrical shape; have to find end caps	Expensive, not as unique
End Caps	Snap in plugs or wingnut expansion plugs	Not required

The interior of the device also needed to be considered as the batteries, the circuitry, and the wires, needed to be secured. To ensure they stayed undamaged during deployment, the inner workings of the device could not be free floating. The two ideas that were generated for the interior were dividing the device lengthwise (horizontally) or widthwise (vertically). The batteries needed to power the circuitry during deployment would be on one side of the dividing shelf and the circuitry on the other. Three options were considered for the device's deployment strategy: attached to government owned light posts or electrical poles or placed on public property with brake discs or screw in ground anchors. On both the electrical poles and ground anchors, the devices would be vertical. With brake discs, the devices would be attached horizontally. Attaching the devices to government owned property like poles and posts would leave them relatively high off the ground. Therefore, ground anchors and brake discs were more reliable for better data. Placing the devices on public property required permission from the Board of Selectman in Hampton.
Regarding the sensors, their placement was the main concern since the sensors were already decided to be the blue robotics pressure and temperature sensors

Sensor Placement	Through End Cap	Through PVC
Pros	Takes advantage of seal already created by cap; cap flat so sensors easily fit	Endcap independent of any wiring; endcap stays undamaged
Cons	May damage cap; wires to sensors could get crushed by seal	PVC is rounded, so sensors will not sit perfectly on it

Developing Solutions:
The housing was chosen to be PVC with an outer diameter of four inches. PVC would allow the housing to be more waterproof and able to be attached to a larger variety of objects for deployment An outer diameter of four inches was chosen for the size of the PVC to provide adequate storage space of the inner circuitry and batteries. Both options of endcaps were ordered so tests could be performed regarding waterproofing. The wingnut expansion plug was chosen for the endcap as it was more waterproof than the snap-in plugs. This decision led to the sensors needing to be placed in the housing instead of an endcap since the wingnut expansion plug does not have a flat surface to provide an adequate seal between the cap and the sensors. This required an epoxy to seal the sensors to the PVC to ensure a waterproof seal. It was decided that the shelving would be placed horizontally in the device and the circuitry and batteries would be on opposing sides of the board. It was also decided that the shelf would be attached to one endcap. This would allow the circuitry and batteries to be removed from the device by only removing one endcap. Furthermore, the batteries and circuitry could be accessed equally if there were technical issues. Lastly, a hole would be put in the middle of the shelf to allow the wires to connect the batteries and the circuitry. The final decision for the entire device was regarding its deployment. It was decided that attaching the sensor to a brake disk with hose clamps would be the best option. This allowed for the deployment to be independent of fixed structures and allowed the sensors to be closest to the ground. Furthermore, the break discs did not require any digging into public property.

Construction

- The first step in constructing our instrument was to cut four pieces of the PVC pipe, since the piece of PVC was 60 inches long. Four identical housings were made to be 15 inches long. This was completed with a handsaw. Due to the thickness of the PVC and the manual hand saw, some small flaws were present on the PVC where it was cut. These were remedied with a belt sander, as it smoothed the edges and made sure the cut was perfectly level. Making sure the ends of the PVC were level was crucial to ensure that the endcaps would seal tightly and prevent leaks.
- Next, the sensor holes had to be created. These holes would allow for the sensors to attach to the device with their sensors facing the outside and their wires facing the circuitry. These holes were created with the drill press. Once the PVC pipe was secured to the drill press and the holes were clearly labeled, the correct size drill bit was used to create the exact size holes needed for the sensors. The sensors were then screwed into place securely. To ensure that they would be completely waterproof, an epoxy was placed around the seals that the sensors created with the PVC pipe.
- The final part of constructing the housing was creating the interior shelving to hold the circuitry and batteries. The first step to this process was to cut the shelving out of wood to fit in the pipes. This was accomplished with a bandsaw. A hole was needed in the center of the board so that the batteries could connect to and provide power to the circuit. To create the hole in the center of the board, the drill pressed was used once again. Furthermore, the end of the board that was attached to the endcap needed to have a cutout that allowed space for the screw on the endcap to occupy. This was made with a bandsaw and a chisel.
- Lastly, the shelving and the inside of the endcaps needed to be prepped to be attached with angled brackets. The attachment between the angled brackets and the wood and endcaps were made with small screws. To prepare to attach these with screws, we had to drill and tap holes in the shelving and in the inside of the endcaps. Once this was completed, the angled brackets were attached to the boards and the endcaps to attach them both together. Finally, the housing was assembled and could be attached to the brake disk with hose clamps

Image 1: Anne and Catey (respectively) measuring the end caps and shelving to ensure they fit together for drilling and installment

Images


Image 2: October 2021 king tide in Hampton, N.H.

Image 3: The end of Auburn Ave right next to the marsh where we plan to deploy our instruments. Orange stars represent where we will deploy each of the instruments.

Design

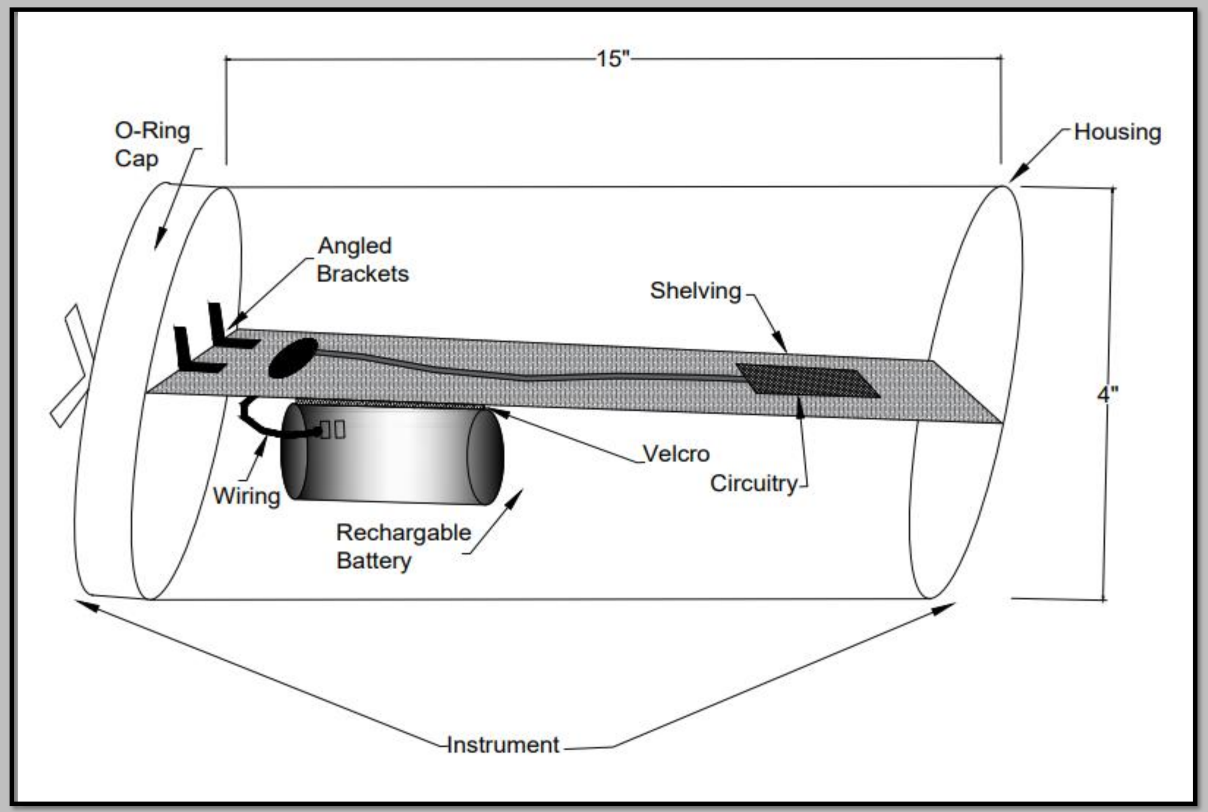

Figure 1: Schematic of Instrument


Image 4 Final Product of Instrument

Experiments

Assessing Permeability of Instrument through Pressure of Water (Experiment I)

Procedure:
1. Fill device on both sides of shelf with clean, dry paper towels.
2. Seal the endcaps tightly by turning wingnuts as tight as possible.
3. Using a rope, attach a 15 LB weight Make note not to interfere with the endcaps or sensors when tying the rope.
4. Attach another rope to be the line that drops the instrument into the water.
5. Mark the rope at 3 m and 6 m from the top of the instrument.
6. Attach the other end of the rope to a secure surface near the engineering tank.
7. Drop the instrument carefully into the water until the top of the water is equal to the 3m mark. Leave for 30 minutes. (Note that many bubbles will come to the surface at this time, these are likely from the dry rope and not the instrument.)

8.Unseal one of the end caps carefully.
9. With dry hands, carefully remove the paper towels and check for any signs of leakage.
1. Pay extra attention to areas that are more likely to have leakage such as the sensors.
10. If there are no signs of leakage, repeat steps 6 through 9 for 6m of water.

Calculated Pressure Experienced:
Where "Pabs" is absolute pressure, "patm" is atmospheric pressure, "ro" is density of water, "g" is gravity, and "h" is water depth from the surface.

<u>Pabs at 3m</u>
=patm+ro*g*h
=101,300 Pa+(1000 kg/m^3 * 9.8 m/s^2 * 3m)
= 130,700 Pa

<u>Pabs at 6m</u>
=patm+ro*g*h
=101,300 P a+(1000 kg/m^3 * 9.8 m/s^2 * 6m)
= 160,100 Pa


Image 5: Anne securing the instrument with weights and ropes to drop the instrument into the pool

Assessing Permeability of Instrument through Force of Waves (Experiment II)

Procedure:
1. Fill device on both sides of shelf with clean, dry paper towels.
2. Seal the endcaps tightly by turning wingnuts as tight as possible.
3. Using hose clamps, attach the housing, along with a pressure and temperature recorder, to a metal pole roughly 6 meters long.
4. Attach the pole to the horizontal platform on the Chase Wave Tank.
5. Using the program on the wave tank computer, create the following waves:
   - Height of .1 m, period of 1 second
   - Height of .15 m, period of 2 seconds
   - Height of .3m, period of 1.5 seconds
   - Let each run for 5 minutes, then take a break for 5 minutes, giving the water time to settle
6. Detach the metal pole from the horizontal platform in the wave tank.
7. Remove the hose clamps from both the housing and the sensor.
8. With dry hands, carefully remove the paper towels and check for any signs of leakage.

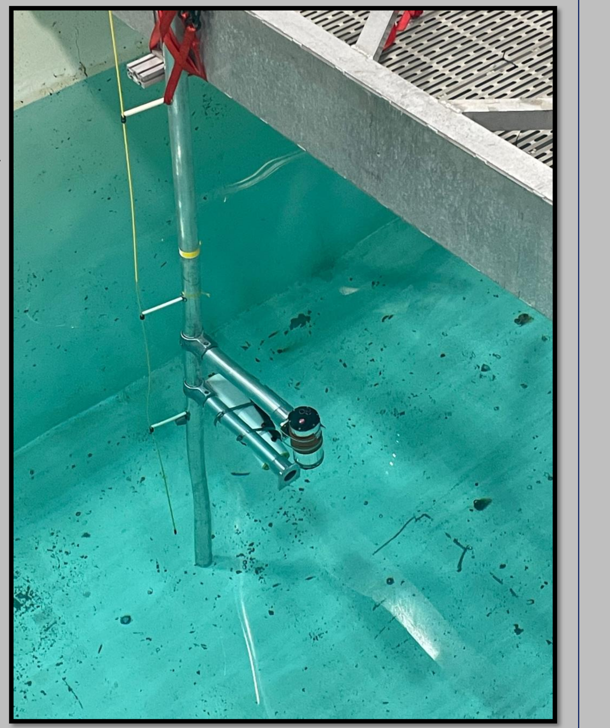
Image 6: Instrument attached to pole in the wave tank

Results

- After completing both experiments 1 and 2, we found that the housing kept the inside of the instrument completely waterproof.
- The paper towels placed in the instrument turned out to be completely dry, which was the goal. As Figure 2 shows, the housing experienced an estimated 160.1 kPa of pressure, but still did not have leakage. If the sensor can endure this much pressure, we anticipate it will remain waterproof as it is submerged by the tide.
- Experiment 2 tested whether the force of the waves would damage the sensor or lead to leakage. Image 7 shows the dry paper towels from this experiment, proving that the housing can endure both the pressure and force of the ocean.

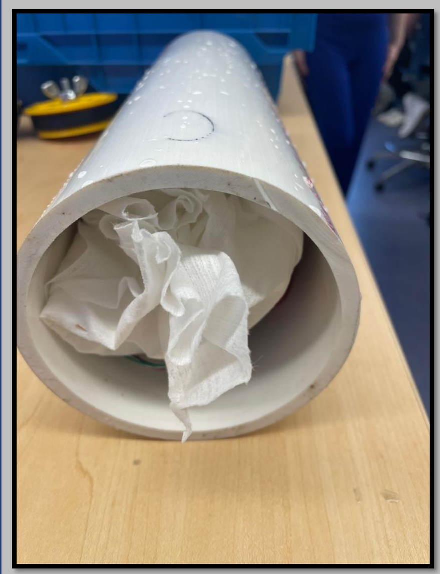
Image 7: Positive results from Experiment 2 resulting in dry paper towels

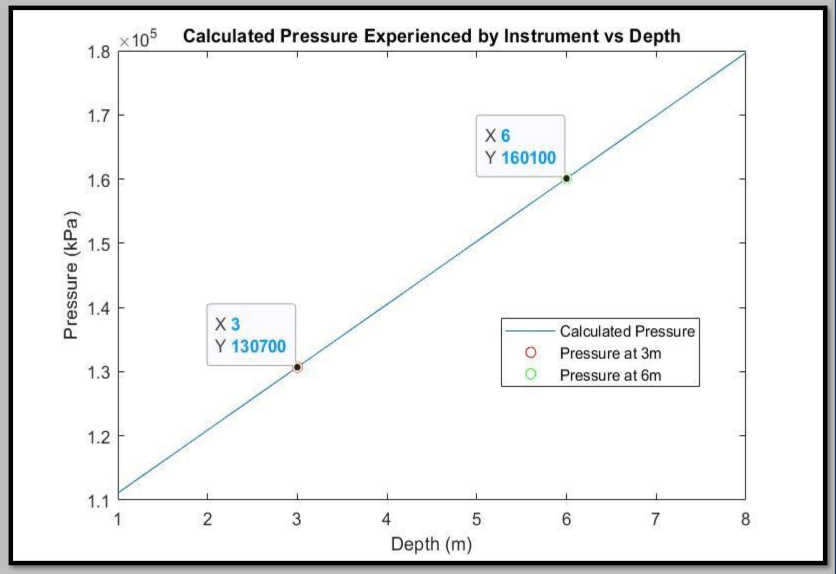

Figure 2: Graph of calculated pressure experienced by the instrument in increasingly higher depth levels

Conclusions

Since our experiments were successful, we plan to follow through with the deployment process in Hampton. We received approval from the board of selectmen in Hampton to deploy our 4 instruments at the end of Auburn Ave, which is located right next to a marsh (See Image 2). By doing this, we hope to collect data from the tide patterns of the marsh. Once this data is analyzed, we hope to have data available to the residents of Hampton so they can make informed decisions regarding their safety. Another goal is to eventually have our instruments available in the lending library at UNH. This would allow the UNH community to have access to the instruments we created.

Acknowledgements

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