# Regional Sea Level Rise Impacts Module

**Instructor Guide for Pause for Analysis and Discussion Questions**

This document provides suggested answers to the Pause for Analysis Questions included throughout the module in the PowerPoint slides and the Discussion Questions presented at the end of the PowerPoint slide after students have completed the module.

**Pause for Analysis Questions**

**1. What are the two main drivers of sea level rise discussed in the article?**

Thermo expansion and melting land ice (not sea ice) contribute to increased sea level rise.

**2. How does sea ice melt contribute to sea level rise?**

Sea ice is already in the water and thus melting sea ice will not impact sea level rise. However, sea ice acts as a barrier to prevent land ice from flowing into the water. As more sea ice melts, that will allow more ice that is currently on land to melt and/or flow into the sea, which will contribute to increased sea levels.

**3. Discuss with a partner or in a small group how you decided on what home price to use for this analysis.**

Ideally students selected the home price based on the areas of Tacoma (or whichever city you choose) where the most homes are projected to be lost from sea level rise, comparing the home price map from ArcGIS to the Riskfinder map. Some students also looked at other online websites, such as Zillow or Redfin, to find more current housing prices since the ArcGIS data comes from 2012.

**4. In a group or with a partner, discuss what assumptions you are making about how flood damages will impact houses based on the calculations for marginal damages you just made here, i.e. interpret the value in the cell E10. Do you think this is an over or under estimate of flood damages?**

If flood levels increased from a maximum of 5 feet to 6 feet, the damage from the additional foot of flooding would cause $X million dollars in property damages in Tacoma. This assumes that the entire value of the home is lost due to the additional foot of flooding.

This is likely an overestimate of flood damages, since the damages from one additional foot of flooding affecting new homes at the 6-foot flood level, is likely much less than the total value of those homes which is what the damage calculations are based on.

**5. Discuss with a partner or in a small group how you would interpret the value in cell F29 in Table 2 in your Excel spreadsheet. Be as specific as possible.**

Assuming the ‘slow’ sea level rise scenario, the expected marginal damage of one additional foot of flooding from 3 to 4ft is $X million, based on an 11 percent likelihood of a 4ft flood occurring.

**6. The multi-year likelihood is the probability of at least one flood occurring in the given period (e.g. 2016-2050), though there could be more. Consider the assumptions made in this analysis so far, would more than one flood occurring in the period affect the damage costs? Why or why not?**

No, a second flood would not affect the damage costs calculated here since the assumption here is that the entire value of the house is lost with the first flood, so a second (or third) flood would not cause any additional damages.

**7. What do you think are some of the underlying factors driving the shape of the marginal damage curves in the graphs? Hint: Think about the assumptions you have made when calculating the marginal damages. Discuss with a partner or in a small group.**

Answers will vary based on the different MD curves by region. Here are some possible points for discussion:

* Given how the damages are estimated, if most of the houses are located near the water (due to prime real estate) then the largest damages would take place with the first few feet of flooding given the assumption of the entire value of the house being lost with the first foot.
* A more realistic MD curve would be upward sloping, assuming that as the flood levels increase, the damages incurred by a single house would also be increasing, in addition to new houses affected at each level.
* The number of homes affected at each flood level does not increase at a constant rate – thus the MD curve is not monotonically increasing.
* Structures closest to the water may be more likely to be homes, which is the sole damage cost used in this analysis. Moving farther away from the water, there may be more commercial buildings, which would be damaged with higher floods, but are not included in the damage costs.
* In Tacoma, homes are close to the water, then the elevation rapidly rises so the first couple feet of flooding will affect more homes, but additional flooding will not if homes are not built on the steep slopes (based on regional topography).
* Note that the damage curve is not downward sloping due to more expensive houses being located at lower flood levels near the water (with the best views) since we use the median housing value for all houses regardless of their proximity to the water.

**8. Consider the best case and worst case scenarios described above. In a small group or with a partner discuss what factors (economic, social, political, technological, etc.) would increase the probability of the best case scenario playing out? What factors would increase the probability of the worst case scenario playing out?**

Best case scenario – improved technology and quick transition to renewable and green energy replacing fossil fuels. The adoption of national and international policies will also impact emissions trajectories, such as the implementation of a carbon tax or cap-and-trade system, or more progress toward an international treaty following the Paris Agreement.

Worst case scenario – continued dependence on fossil fuels, rapid economic and population growth, no climate change mitigation policies adopted, business as usual emissions continues. Technology for renewables is slower to develop that previously anticipated.

**9. What is a claim you can make about the marginal damages from sea level rise based on the probabilities you have entered and your analysis of the graph in Figure 3?**

Answers will vary by region, but there is typically a guaranteed amount of flooding under all sea level rise scenarios, then the MD curves diverge at some point, at higher flood levels. The curves will also vary based on the probabilities of the different scenarios, under a worst case scenario with high probabilities of extreme sea level rise the damages will be the greatest.

**10. How much would it cost to build a 1-foot tall sea wall along the length of the shoreline you just measured? After you’ve built the seawall 1 foot tall, how much would it cost to build it another foot taller?**

This question is meant to get the students prepared for graphing the marginal cost curve, which is based on a constant marginal cost per foot of wall, thus their MC curve should be a horizontal line at the cost of building a wall 1-foot tall calculated as $762 x length of wall in miles x 5280 feet.

**11. As a city planner, what recommendations would you make based on your analysis of the graph in Figure 3, i.e. how tall should the wall be? How do the total costs and benefits compare to the marginal costs and benefits of the seawall? Discuss with a partner or in a small group.**

The optimal amount of spending is where the MC of the sea wall equals the marginal avoided damages (or MB of the sea wall).

Since some of the damage curves are non-monotonic, you could base the recommendation on total costs and total benefits looking at the area under the respective curves. For example, if the MD curve intersects the MC at multiple points, you could compare the area under the curve at the second point of intersection and compare the total costs with the total benefits to decide if you should build the wall taller, past the first intersection point.

**Post-Module Discussion Questions**

**With a partner or in a small group, discuss the following questions:**

**1.Figure 3 highlights all the work you have done thus far in this analysis. With this in mind, what are some of the main assumptions you have made that are underlying the graph, specifically in the calculations for the marginal cost and expected marginal damage curves?**

Assumptions:

* The cost of building sea walls is constant per foot, when it is more likely increasing in height as the sea wall gets higher given that taller walls need a larger base. This would make MC curve increasing and likely lead to less flood protection
* The total value of the house is lost with flooding. A more realistic assumption could be that a percentage of the house is lost with each additional foot of flooding.
* The only damage costs come from housing values, which drastically underestimates the total costs of sea level rise. Commercial buildings, businesses, government buildings, parks, etc. are not included in the damages.
* The median housing price is used, which may not be reflective of the types of houses most likely to be damaged due to flooding.

**2. If you were to change these assumptions, how do you think the results would change? How might this change your recommendation on the seawall?**

Students should go through the previous assumptions they identified and explain how the assumption might be changed to be more realistic, and then how the damage estimated would be affected by the changes in these assumptions.

**3. Given the assumptions and limitations you have discussed, how would you go about improving this analysis to make it more realistic?**

* Include the damages from other buildings in addition to houses.
* Rather than assuming the entire value of the house is lost with the first foot of flooding, a percentage of the house could be lost, that increases with each additional foot. For example, the first foot of flooding could cause damages equal to 10% of the house value, then the second foot could cause an additional 10%, or a total of 20% of the house value would be lost under two feet of flooding.
* Include other considerations beyond just structural damages given sea level rise, or at least acknowledge potential disparities and inequities regarding which populations are most likely to be affected by climate change and sea level rise, and other considerations such as loss of ecosystems, beaches, natural habitats, etc. which are harder to value.

**4. The extreme sea level rise scenario has a very low probability of occurring. In fact, one model reports that even in the event of the worst case scenario (RCP8.5) the likelihood of 2.5+ meters of sea level rise by the end of the century is only 0.1% (Kopp et al. 2014; NOAA, 2017). Given this small probability, why do you think it is still important to take these extreme scenarios into consideration?**

Answers will vary. The goal of this question is to discuss the idea of how to deal with low probability but highly destructive events. 3+ meters of sea level rise would cause catastrophic damages, though it may be a low probability event. How does this compare to other situations and how do we deal with those? E.g. the risk of a house fire or earthquake may be low probability, but we still take out insurance to mitigate the risk. Or consider the application of the precautionary principle under circumstances of uncertainty but in the face of potentially catastrophic or irreversible events.