Thank you for joining our sixth Crisfield/EPA ORD Technical Working Group (TWG) providing technical feedback on proposed nature-based solutions (NBS) and co-benefits for Crisfield’s coastal resilience!

 AGENDA for June 12:

1. Updates (5 min)
* New Crisfield Proposed Projects map by ESRGC
* Next TWG meeting July 8 – 3-4pm to discuss proposed NBS project locations
1. Additional Batch 1 Modeling results (45 min)
* Discussion: In what ways are these results meaningful for Crisfield?
* Proposed Batch 2 modeling
1. Draft co-benefits and decision analysis (45 min)
* Discussion: What approaches can we use to identify project scale locations for further analysis?
1. Resilience and Climate Smart Design (15 min)
* Discussion: Connecting NBS and resilience planning
* Discussion: Implementation and monitoring

Attendees:

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| **Organization** | **Expertise** |
| City of Crisfield, climate resilience projects | Local knowledge, funding |
| National Oceanic and Air Administration (NOAA) Fisheries, Restoration Center | Local fisheries habitat and restoration  |
| US Army Corps of Engineers, Engineering with Nature program | Coastal hydraulics, modeling of nature-based solutions |
| Virginia Institute of Marine Science, Center for Coastal Resources Management | Urban and environmental coastal planning, sustainability |
| Center for Watershed Protection | Watershed planning, providing engineering support for Crisfield |
| Eastern Shore Regional GIS Cooperative | Local mapping, spatial data |
| Tetra Tech | Coastal engineering |
| Tetra Tech | Storm modeling |
| EPA Office of Research and Development | Project Navigator |
| EPA Office of Research and Development | Ecosystem co-benefits |
| EPA Office of Research and Development | Community engagement |

The additional Batch 1 storm modeling results show wave heights over time at 10 locations throughout the coastal Crisfield area from hours 0 to hour 54 of the simulated 50-year storm (Hurricane Dorian from September 2019), as well as across 6 transects from offshore in the Bay through different NBS at different locations approaching Crisfield for a 30-hour average between hours 24 and 54 of the storm (after which the wind field dissipates, and significant wave height drops to zero).

NBS cannot decrease storm surge levels in the kind of coastal layout Crisfield has (where marsh is not flush to land, and Bay water reach directly up to Crisfield’s shore) because of the “bathtub effect” (as surge water rises, if it is blocked in one area, like the marshes, it can flow around, e.g., through the lower Annemessex, and the entire water heights in the Crisfield area rise like in a bathtub). So increasing surge levels are not necessarily an aspect of the storm that these strategies can deal with. Therefore, EPA ORD is focusing on wave energy that these NBS in this area are capable of reducing through friction.

The modeled hurricane has a circular wind field, and because the wind is moving, the waves are changing direction. To understand the effectiveness of different NBS in different locations, you have to interpret wave height reductions relative to wind direction at that time, i.e., if the wind is blowing perpendicular to an NBS (e.g., from the west across the artificial oyster reefs off Janes Island), that NBS is likely to be more effective than when wind is blowing parallel to it.

Different proposed NBS have different heights, which can be communicated relative to sea level, as well different water levels, approximate average ballpark magnitudes:

* Sand dune restoration (+7 ft)
* Living breakwaters (+4 ft)
* Artificial oyster reefs (-5 ft)
* Marsh restoration (+2.2 ft)
* Low marsh in 2020 (+0.6 ft)
* High marsh in 2020 (+1.4 ft)
* 1-in-50-year storm in 2020 (+4.8 ft)
* Extreme nuisance flood every other month (+2.5 ft)
* Common nuisance flood once a week (+1.5 ft)
* Common high tide twice a day (+1 ft)
* Common low tide twice a day (-1 ft)

Water level communication challenges include explaining and differentiating sea level, engineering datums like NAVD88, underwater bathymetry, flooding levels relative to what vertical reference point, flooding heights in the Bay versus flooding depth on land, and how to standardize.

Batch 1 includes results (10 location time series, 6 spatial transect 30-hour averages, and wave attenuation maps) for storm simulations of the following separate NBS scenarios:

* Existing NBS (2020) – Existing marshes provide a lot of protection
* All new proposed NBS implemented (2020)
* Reefs only (2020)
* Dunes only (2020)
* Marsh restoration only (2020)
* Living breakwaters only (2020)
* Janes Island NBS only (2020)
* Cedar Island NBS only (2020)
* Dunes + Reefs (2020)
* Dunes + Marsh restoration (2020)
* Dunes + Reefs +Marsh restoration (2020)
* No new NBS interventions from existing natural infrastructure (2050)
* All new proposed NBS implemented (2050)

2020 existing NBS map of significant wave heights during the storm show wave heights of about 1 foot (on top of the surge) in the Bay reduced to 0 feet in the marshes, and down to about 0.25 in Daugherty Creek, Jenkins Creek, and near the shoreline of Crisfield. If there were no marshes, there would be a lot higher waves at the edges of Crisfield, as a storm approaches the City.

Takeaways from storm wave height time series and transects (challenging to interpret given changing wind field which changes direction waves are coming from throughout the storm):

* No observed effect of reefs offshore of Janes Island (P1) likely because waves were coming predominantly from SW and, therefore, parallel to reefs (and dunes) – need to model wind coming from W to assess artificial reef and dune effectiveness
* Noisy signal and likely model error after 54 hours because wind died down, but can potentially look at the full hydrodynamic flow part of the model output to see if there are any differences in how quickly inundation of land decreases post storm without and without proposed NBS
* Point in middle of Janes Island (P2) shows existing marshes clearly reduce wave heights (marsh obviously works), and marsh restoration would reduce them even more
* Transect crossing Janes Island from the Bay (CS1) also clearly shows even existing marsh reduces wave heights to essentially zero, with NBS reducing them to zero sooner, with wave heights increasing again in Daugherty Creek, but not to as high as they were in the Bay
* Calculating wave height reduction as a percent of pre-NBS wave height would standardize for different capabilities of existing NBS and estimate how well NBS work compared to what’s possible (but the same percentage would translate to different absolute wave height reductions)
* Protections observed in Daugherty Creek depend on direction wind is coming from, because that would mean waves passing over different NBS features or not (marsh to W and NW, some open water with marsh beyond to N, breakwaters to SW)
* Difficult to interpret patterns from single point estimates since there is a lot of variability among locations and complex water channelization and hydrodynamic energy patterns
* Will evaluate sheer stress, erosion, and current velocities to make sure NBS do not introduce any unintended consequences based on how they are redirecting water flow and height
* Can apply artificial wind field that does not change direction to evaluate NBS effectiveness, would be different than this batch of modeling simulating complex true storm conditions

Takeaways from 30-hour average significant wave height maps for 2020 and 2050, no NBS and all NBS:

* If no new NBS are implemented, and assuming an average 8 inches of sea level rise by 2050 (which is the same assumption FEMA made for the on-land hard infrastructure design), marshes are going to be inundated more, and if they are going to be underwater more, they are less able to attenuate waves, so where in 2020 wave heights were close to zero, in 2050 wave heights in inundated marshes are going to closer to 0.3 – 0.6 feet
* If all proposed NBS are implemented, wave attenuation will be improved likely several inches in the marshes, behind breakwaters and in Daugherty Creek, but will not be able to return to attenuation levels observed in 2020, because water in the entire Bay will be about 8 inches higher and that will induce the bathtub effect where higher water can just flow around obstructions – this is part of the resilience discussion and the hybrid infrastructure discussion
* In terms of presenting maps of relative attenuation (% of original wave height that NBS is able to attenuate), some of the 100% attenuation patches in the marshes (where open water has been converted to high marsh) only show 10 – 50% attenuation by 2050

TWG asks (and any other feedback):

* What additional analyses should be conducted? (e.g., keep wind direction constant)
* What additional outputs should be assessed? (e.g., current velocity, erosion, inundation timing)
* What are priorities for Batch 2 modeling? (e.g., different storms, triage smaller projects)

Questions and feedback from TWG about storm modeling:

* Why was January 2022 used as a calibration dataset? Tetra Tech explained these were typical non-storm conditions used to calibrate background, usual water patterns including tides.
* Communicating water heights and what they mean is challenging, and variable. The fall storm season (including September, during which the hurricane storm is modeled) is different from the winter typical conditions. Virginia is currently undergoing a vertical datum updating project, which should be released sometime after 2027 (but will be 7 years out of date since the current epoch ends in 2019, so important to keep that in mind for design purposes going forward). VIMS shared National Tidal Datum Epoch update fact sheet: <https://tidesandcurrents.noaa.gov/datum-updates/ntde/>
* Crisfield is currently looking for funding to put up a billboard or some kind of art to show what different datums represent (e.g., sea level versus NAVD88, mean high high water, etc.) and what different water levels look like for landmark places in Crisfield. The goal is to create some type of physical representation of water height markers out where people can see it.
* Transects showing which NBS occur where along the transect are a good visual
* Question if current NBS modeling takes into account current open water areas in the marshes – yes, it does, as well as current marsh vegetation density. Marsh restoration assumptions are to fill in open areas that are not navigationally used (like kayak trails) and raise height of marsh to levels of high marsh in the year 2050 (i.e., to keep pace with sea level rise)—this is done to understand what the maximum possible benefit of marsh restoration (and creation, in areas where open water converted to marsh) could be—map of specific areas converted is available
* Don’t understand why in Daugherty Creek (P6), sometimes shows NBS effect (decreased wave height) when wind and waves come from the N (across Janes Island) but other times no effect when wind from same direction—Tetra Tech suggests this might be due to different water levels
* Modeling constant wind direction can help represent flooding conditions from wind-driven tides; we know NBS will not protect from the rising tide levels but it might help decrease wind-driven waves on top of the tides; wind-driven tides usually come from the S/SW, as water gets piled into the Chesapeake Bay at high tide, because at low tide it’s leaving the Bay, heading south – there are not typically cyclonic wind fields associated with tidal movement. Water levels have also been observed to be low on the mainland/Western part of Chesapeake Bay and high on the Eastern Shore, so it’s also possible that water is pushed and/or wind blows east to west
* Crisfield is very vulnerable because it has water on all three sides, so all those sides and incoming angles are relevant for wind direction
* USArmyCorps suggested looking at time series at additional, intermediate points following a path of sailing into Crisfield from the Bay, into the Lower Annemessex inlet, including points outside the inlet and inside the inlet to better figure out the trends as you approach Crisfield.
* TWG invited to share any other feedback from reviewing detailed slides in shared presentation.

Takeaways from co-benefits analyses, changes to identified metrics resulting from changes to land cover by implemented NBS:

* Started with bathymetry changes caused by implementing NBS from storm modeling land cover maps, and added in additional land cover categories affecting co-benefits link rip rap shoreline, soil type, vertical shoreline, shallow shoreline, submerged aquatic vegetation (SAV), etc.
* Then used models to assign a co-benefit value (for each co-benefit) by landcover category.
* Marsh restoration represented in storm modeling as filling in open water patches and assuming high marsh elevation in 2050 for all marshland in NBS area – this could impact co-benefits in artificial way (because marsh restoration can be designed in more complex and spatially heterogenous way—the way it’s modeled is simplistic, “max restoration” scenario)
* Vegetation cover assumptions for marshes were that high marsh is 100% vegetated, low marsh is 60% vegetated, and tidal flats are 0% vegetated—these assumptions correlate well with the unvegetated-to-vegetated ratio calculated for different types of marsh cover, and used as an estimate of marsh quality and longevity
* Compared and averaged multiple literature-based spatial estimation methods for blue crab, striped bass, and waterfowl metrics (based on habitat suitability for different life stages, including food availability and capacity of habitats to provide food)
* Estimated changes in co-benefit metrics between 2020 and 2050 if no new NBS intervention:
	+ Quality and longevity of marsh: **down 9%** (in fraction of vegetated marsh – total marsh area actually increased from 2020 to 2050 as the marsh shifts with sea level rise but the quality of that marsh decreases)
	+ Blue crab habitat quality: **down 1%** (in catch per unit effort of blue crab for different types of habitats present in 2020 versus in 2050)
	+ Striped bass foraging areas: **down 2%** (in catch per unit effort of striped bass)
	+ Waterfowl overwintering habitat quality: **up 4%** (in kilocalories per square meter – ducks prefer a medium water to vegetation ratio in marshes, so sea level rise increases water areas, which the ducks prefer for feeding on aquatic species)
* Estimated changes in co-benefit metrics in 2020 if all NBS implemented, and if benefits will last until 2050:
	+ Quality and longevity of marsh: **up 12%** with NBS in 2020, still **up 11%** by 2050 (marsh restoration improves quality of marsh, and if you are designing it to last until 2050 (by adding elevation to keep pace with sea level rise by 2050), then it will last until 2050 (because you designed it to))
	+ Blue crab habitat quality: **up 9%** with NBS in 2020, still **up 9%** by 2050
	+ Striped bass foraging areas: **down 1%** with NBS in 2020, still **down <1%** by 2050 (marsh restoration fills in open water where fish would have lived and foraged so less fish predicted with NBS – could design marsh restoration to retain water/vegetation balance)
	+ Waterfowl overwintering habitat quality: **up 3%** with NBS in 2020, still **up 3%** by 2050 (less than if no NBS because NBS fills in open water areas in marsh that ducks like)
* Ranking of best to worst NBS in terms of improving each co-benefit relative to 2020 status quo:
	+ Quality and longevity of marsh: Best: 2020 All NBS; Worst: 2050 No NBS (in general, NBS including marsh restoration rise to the top and ones with just oyster reefs, breakwaters, or dunes are the lowest; Janes Island has more potential area of poor marsh to improve with marsh restoration than Cedar Island so Janes ranks higher)
	+ Blue crab habitat quality: Best: 2020 Full marsh restoration only; Worst: 2050 No NBS (marsh is blue crab habitat so options with marsh restoration do better than those without; Cedar Island has more total area of marsh so ranks higher if you are calculating just number of crabs in marsh not necessarily how much marsh quality improved)
	+ Striped bass foraging areas: Best: 2020 Oyster reefs only; Worst: 2020 Marsh and Dunes (fish negatively affected if open water is filled in with marsh restoration)
	+ Waterfowl overwintering habitat quality: Best: 2020 Full suite of NBS at Cedar Island only; Worst: 2020 Full suite of NBS at Janes Island only (Cedar Island has greater water-to-vegetation ratio, and more large creeks not filled in with marsh restoration, while Janes Island minor creeks were converted to marsh so less open water for ducks)
* Consequence table showing different co-benefits across different NBS options help compare short term (2020) and long-term (2050) benefits (can see initial marsh restoration can immediately improve marsh quality and blue crab habitat, but benefits shift to striped bass and waterfowl with sea level rise as more open water areas develop in marsh, especially if no restoration). Include wave attenuation by NBS at points closest to Crisfield shore (P3: NW of Crisfield and P6: SW of Crisfield). Include estimated ballpark costs for each set of NBS based on NOAA coastal NBS guidance. Can also look into incorporating erosion from shear stress.
* Can ask community members at next public meeting to rank different benefits and co-benefits
* Costs are very high – may want to scope projects into $10 million grant size chunks. Tetra Tech will explore how best to do that.

Questions and feedback from TWG about co-benefits calculations:

* Are the percent changes in co-benefits for every year over year? EPA ORD said No, they are the percent change over the entire 30-year period between 2020 and 2050
* Spatial resolution challenge – currently small, tidal creeks are assumed to be filled in as part of marsh restoration (while larger creeks were not), but restoration could be designed to not fill in the smaller creeks, either. It is just too small to be spatially modeled at the current scale of the storm modeling. Marsh restoration design also includes runneling (including small channels in marsh to drain marsh in a healthier way during low tides to prevent standing water that rots the vegetation), but those are also too small in spatial resolution to be included in this round of storm modeling. Both small tidal creeks and runnels would maintain habitat for striped bass, which would result in higher striped bass catch numbers than the current calculations show
* Idea of polling community to rank co-benefits appreciated. Would be powerful to include in grant to show community involvement in project scoping.
* Project cost may influence polling, if they think it’s going to come out of taxes and their pockets. Different than asking if they want to see grant fund go toward this. Need to ask Mayor Taylor to weigh in on whether we should have the cost discussion. Don’t want to scare people with the thought that taxes are going to be raised so important to state source of funding.
* Every time a grant window comes up, the more information the City has, the better, especially from the community, to be able to apply for different projects as opportunities open

The 2050 results show that NBS help protect the natural infrastructure (marshes) around Crisfield into the future as sea level rises, but will not alone protect Crisfield from flooding. Need to connect with other resilience planning efforts (hard infrastructure, storm water updates, ditch maintenance, public education on environmental changes and resilience options) for Crisfield to apply holistic approach. May help to address comprehensive planning in next community meeting, tentatively planned for July 2025.

Questions?

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**[END MEETING]**