SNEP Symposium – Science Bringing Solutions Delivering Environmental Improvement to Southeastern Coastal New England

Room 3, Morning Session 1

May 18, 2022

Brenda: Hi everyone, for everyone that's coming in you are in room three for the first session which is wastewater technologies. My name is Brenda Escobar and I am going to be serving as your facilitator for this session. We are just giving folks a couple minutes, maybe a minute more and we can go ahead and get started.

Emily: Matt are you able to share your screen?

Brenda: Matt, are you on mute by any chance? I don't see a presentation being shared yet.

Matt: All right hold on a sec, I'm having to just set some permissions here.

Brenda: Okay

Emily: Let me know if you're having a hard time Matt because I do have a copy of it, but it would go smoother if it's on your own computer.

Matt: Absolutely. All right, is that working?

Emily: No, not yet.

Brenda: We don't see anything yet.

Emily: Try it now, I just changed your status.

Matt: All right. It says I'm sharing and the button is grayed out.

Emily: The sharing button is grayed out?

Matt: Yeah, it says only meeting organizers and presenters can share so maybe…

Emily: Okay. Oh, I'm gonna make you a presenter.

Matt: There we go.

Emily: You can also turn your camera on when it's time for you to present as well.

Matt: Any luck yet?

Emily: No, but I know it's coming.

Brenda: In the meantime, I just wanted to give a few reminders for when we get started. As I said my name is Brenda Escobar, I'll be serving as a facilitator for this session. I am with EPA Region One and I actually work in the civil rights office as an EEO specialist and do some facilitation on the side as well for the region, so I'm happy to be with all of you this morning and to have this discussion. Just as a reminder, I think you heard Adam say that all of our sessions will be recorded and posted to the EPA SNEP website, we will be taking questions so feel free to type them into the chat box and we can address them as we go along. There will be a dedicated Q&A session at the end of this session right before we break at 11:00 so feel free to input your questions and we can address them with each of the presenters. This morning we have three presenters. Matt I don't know if you're ready to go, if you wanted me to do the quick intro for you?

Matt: I'm ready to go, still it says I'm sharing but I don't…

Brenda: Yeah we can see it, I can see it, I don't know if everyone else can see it.

Matt: I'm ready to go.

Brenda: Perfect, okay so we have our first presenter who is Matthew Charette, I hope I said that correctly, he is from Woods Hole Oceanographic Institution and his presentation is "Validation of Permeable Reactive Barrier Technology for Non-Point Source Groundwater Nitrogen Remediation" so Matthew is a senior scientist at the Woods Hole Oceanographic Institution specializing in coastal groundwater geochemistry, so I will let you take over Matt for the presentation.

Matt: Great, good morning everybody and thank you for that introduction. I want to acknowledge our funding from the EPA SNEP program and my co-authors from the Town of Falmouth, Isotec, and Terra System.

So nitrogen pollution on Cape Cod is a multi-billion dollar and growing problem and this is owing to a housing boom that took place in our region that's led to severe ecological impacts to coastal water bodies. These are some aerial images from through today of Lower Great Pond, Falmouth. This is the pond in which our permeable reactive barrier pilot has been installed. Most of these houses are on quarter to eighth of an acre lots and each one has its own septic system that's discharging, you know, largely untreated wastewater into the aquifer and as you can see those houses are in very close proximity to the surface water to Great Pond in this case.

The problem with that is that on Cape Cod virtually all fresh water that enters the coastline comes from groundwater from submarine groundwater discharge even the rivers on Cape Cod are groundwater fed and the impacts of this nutrient-rich groundwater discharging into coastal water bodies has been a loss of eelgrass and associated bay scallop fishery, algae blooms, coastal acidification, and occasionally fish kills.

As I mentioned, this is going to be a very expensive problem to fix by traditional means, hooking all of the houses on Cape Cod up to a centralized wastewater treatment plant has been estimated at up to 7.6 billion dollars. This number is several years old now with inflation and construction costs rising, I wouldn't be surprised that this number has doubled since then and this is the capital costs only, you know, the operating expenses would be up to a hundred million dollars on an annual basis and so therefore many towns in the region have decided that we need to investigate alternative lower cost strategies, but many of these are new and unproven and they need to be validated before taxpayers are going to invest their money in these potential alternatives.

Aside from, you know, traditional centralized wastewater treatment towns are talking about using shellfish to take up at the algae that take up the nitrogen from these ponds as a relatively low-cost method for dealing with this problem. Denitrifying septic systems, widening inlets to increase the flushing of some of these coastal water bodies with you know the open ocean where dilution can handle these nutrient inputs.

But in this case we are testing promising relatively new technology at least for nitrogen, groundwater nitrogen treatment called the Permeable Reactive Barrier or PRB. The PRB technology, and then this cartoon I'm showing, you know, from the Cape Cod commission, we're showing just one septic system but the idea here is that you have nitrogen or nitrate plumes in the groundwater that are making their way to the coast. They're enriched from a large number of houses that are discharging their septic systems into the groundwater and in the PRB, the idea is to inject emulsified vegetable oil to stimulate this process of denitrification which is in groundwater here on Cape Cod a carbon limited process so we're adding the emulsified vegetable oil as a carbon source for the bacteria to naturally convert this nitrate into nitrogen gas which makes up you know almost 80 percent of our atmosphere and is harmless. So the EVO gets injected into the ground and ideally downstream of this PRB you have treated groundwater with very low to below detection levels of nitrate. It's potentially more cost effective than sewering for lower housing density areas and it's treating the nitrate at the point of discharge; we don't need to wait five or ten years like you would have to with the septic system with a centralized wastewater treatment system solution for all of this nitrogen to flush its way out of the aquifer. So in theory no waiting for improvements in water quality is a benefit of this PRB technology.

So we've installed with SNEP funding a pilot scale PRB in Falmouth Massachusetts at the head of Great Pond along Shorewood drive in east Falmouth Massachusetts. It's 120 feet long and the major design variable that we were, we are testing in our PRB is the lifetime of the EVO dosing, so we have effectively designed our PRB to fail within our three-year study period. So one half of the PRB or 60-foot length had what we believe to be on paper at least a one-year supply of EVO while the other foot section had twice the amount of EVO injected for in theory a two-year supply. There were 12 injection points along these 120-feet so we had 10-foot spacing between the injection points and the injection conditions were designed so that the EVO would spread in a radius of seven feet so that there would be sort of overlapping EVO along this entire 120-foot interval. The vertical injection depth was 24 feet and it was concentrated on the highest nitrate concentrations in groundwater that we determined from a preliminary site survey. And then lastly, in addition to the EVO calcium carbonate powder was added as a pH buffer the pH in groundwater on the Cape can be pretty low in the in the low, in the high 4’s to the low 5’s, denitrification ideally takes place the bacteria are happiest when the pH is well above five so we added the calcium carbonate to boost up the pH in the PRB.

So the injection event for our PRB took place in July of 2020. On the left here I’m showing the EVO storage and batching system so the concentrate, EVO concentrate, was mixed with water from a hot fire hydrant located across the street and then injected into the ground using pumps and a pressure gauge. I’ll talk about the pressures that were observed during the injection in a minute. This is a photo showing where the PRB was installed, the 10-foot spacing is shown by these wooden stakes here, and here is one of the injection points taking place using a direct push technology and slotted, vertically slotted, well screens in eight-foot intervals.

So this is just a very simple chart showing the EVO injection pressures and flow rates, so the injection back pressure is shown here on the top, the flow rates of the EVO solution are shown here on the bottom; I want you to focus on the injection pressures here for the one year dosage side and the two year dosage side. The blue colors are essentially good, the red colors are bad; blue meaning there was very low resistance of the aquifer to the EVO injection, the red colors indicate that the injection team had a very difficult time pumping the fluid into the ground. So you can see on the two year dosage side for the shallow and intermediate eight foot sections, the injection went very smoothly, but at the deep interval there were significant back pressures encountered. On the one-year dosage side you can see it was very heterogeneous, good conditions here at this one particular location, but even in the shallow part an intermediate part of the aquifer there was trouble encountered along the entire length of the one-year dosage and we'll come back to the significance of that in a moment.

The monitoring scheme for our permeable reactive barrier involved a series of up-gradient wells along both the one year and two-year dose side of the PRB and a series of down gradient wells. I think what was sort of unique about our PRB compared to previous PRBs that have been installed and are being studied is that we had high vertical resolution so we were collecting samples at 10 depths over the PRB injection interval on both the up-gradient and the down-gradient side and as you'll see we learned a lot by getting this very detailed information.

Okay, so I’m going to show you a series of plots that look just like this one where we see a concentration of some property versus depth in units of feet relative to mean sea level. These are the total organic carbon concentrations so this is a measure of what we're seeing in terms of the EVO that was injected into the ground and the different symbols are the different time points. This is from august right after the PRB was installed through to February of 2022. You can see and I should note that the background TOC values are less than one milligram per liter. You can see that the TOC levels on the one year dose side were very low, there was only a sample or two that was significantly above background whereas on the two-year dosage side we saw TOC concentrations between five and a hundred milligrams per liter decreasing with depth and these TOC concentrations appear to be correlated pretty well with what we saw in the injection logs. So on the one-year dosage side, we believe that they're effectively because of their resistance to the injection holes in the PRB that resulted in the one-year dosage never even getting started, but on the two-year dosage side the deeper part of the injection as indicated by this yellow box very low toc concentrations, higher concentrations near the surface so this is where we're seeing the PRB working mostly I think.

Okay so getting into some of the results in terms of the nitrate. The first thing I wanted to show you are the nitrate plumes that are entering the site. These are the two up gradient wells on the one-year side and the two-year side of the PRB and what you can see is that there's and these are over all of the quarterly injection intervals from pre-injection until our most recent sampling event in February of 2022. There we were incredibly surprised at the large variability in nitrate concentrations ranging from 0 to 25 milligrams per liter but looking at any particular depth here on the one-year side depending on when we sampled as low as let's take minus 30-feet as low as 9 and as high as 23. Here on the two-year side at the minus 5-foot interval as low as 4 and as high as 20. So quite a bit of variability these well keep in mind these wells are only separated by 60 feet; quite a variability both vertically and horizontally and in time as well.

So I'm just going to focus on the year two EVO dosage because as I mentioned before the year one dosage never kicked in due to issues with the injection. This is the up gradients, this is the control well, this is the nitrate that's coming into the site on the two-year dosage side and then this is the down gradient well so 15-feet downgrading of the PRB injection. Pre-injection for this well is shown here in the gray line with the triangles and the subsequent data are shown in the other symbols and you can see for the depths of minus 5 to minus 12 or so from a month after PRB injection we've managed to reduce the nitrate concentrations to near detection limit for all of these depth intervals so nitrate removal from as much as 20 milligrams per liter to 5 and 10 milligrams per liter down to background. So the two-year PRB is doing well and it's going strong nearly two years after the initial injection so it is meeting its design life to this point. The PRB nitrate removal is shown by the shaded region there.

For the pH and dissolved oxygen just to start to show you some of the ancillary data that we've been collecting, I mentioned that we added a calcium carbonate buffer to boost up the pH and get that pH into a range that's more suitable for bacterial denitrification compared to the up-gradient wells between 5.7 and less than 5 pH units. You can see that the pH has been boosted up by the calcium carbonate buffer by over 1 pH unit which is you know, exceeded our expectations. The dissolved oxygen concentrations have decreased from eight to four milligrams per liter down to near background levels which are the conditions that you need you need an oxide condition for the denitrification process to take place so we've checked both of the boxes for a healthy PRB for both pH and dissolved oxygen.

And then my last data slide here you know when you lower dissolved oxygen in groundwater environment you do sometimes have to be worried about, you know, what other sort of unintended consequences might be happening in terms of groundwater chemistry as a result of this EVO injection. One of the big things that, you know, people are concerned about is mobilization of dissolved iron. Mobilization of iron which becomes mobile under anoxic conditions and not that we're worried about iron necessarily per se from a human health perspective but arsenic has a very strong affinity for iron oxides and so when you mobilize iron oxides there's a possibility that you can mobilize arsenic as well. So I'm showing you here iron concentrations at up-gradient well within the PRB and a 15-foot down gradient and a 55-foot down gradient well and you can see that at about 240 days after the EVO injection the iron concentrations started to creep up and at the most recent sampling they increased to pretty, very high levels, nearly 80 milligrams per liter. However, you can see the arsenic concentrations start to creep up here as well peaking in at 375 days or so at this 15-foot down gradient at point .012 milligrams per liter which is slightly above the arson the EPA drinking water limit for arsenic. But those values have started to come down, we think as the system runs out of iron to mobilize and that iron gets re-oxidized and reabsorbs that arsenic downstream of the PRB injection, so it's something that we will continue to keep an eye on.

So just to summarize first with some sort of lessons learned to date and next step. You know we've learned as the EPA and their PRB manual has stressed as well that pre-injection hydrogeological survey work is critical and you know that absolutely needs to be done before a pilot or a full-scale PRB is installed to mitigate any issues with back pressure during EVO injection we think that this is, you know, we had this issue on the one-year side of our PRB but we think that this is easily overcome by increasing or decreasing the spacing between EVO injections or employ two row injection in a sawtooth pattern. We saw significant spatial and temporal variability in groundwater nitrate concentrations. This is something to keep in mind when in terms of trying to calculate, you know, what was the net removal of nitrate from this this PRB and then as far as it looks for the two-year dose the EVO dosing scheme that we determined is meeting sort of minimum expected longevity and we'll hopefully continue to keep an eye on it to see if the two-year dose lasts even longer than two years. In terms of next steps we're planning to actually quantify how much nitrate we've removed with this PRB and compare with USGS model inputs and then our main product will be to produce a design manual for larger scale PRB installation installations in this region so thank you, back to you Brenda.

Brenda: Thank you Matt so much for your presentation and for working with us on the technical difficulties a little bit earlier. I don't see any questions yet, but I think they might pop in towards the later end of the session so we'll keep an eye out for that. We will be moving just for the sake of time we'll be moving on to the second presentation which is with Bud Dunbar from Verified Water Incorporated, but are you on the line?

Bud: Yeah, can you hear me okay?

Brenda: I can hear you yes, I cannot see you, so I don't know if your camera's turned off?

Bud: Yeah, I think I may have turned it off, can you see my screen now?

Brenda: Yes, we can.

Bud: Okay, great.

Brenda: All right let me do a quick intro and then you can take it away.

Bud: Sure.

Brenda: Alright, so for our second presentation we have, the title is a “Low-Cost Nitrogen Sensor for Real-Time Monitoring of Nitrogen in Decentralized Treatment Effluent” and as I said our speaker is Bud Dunbar from the Verified Water Incorporated. Bud is a consultant for the New York State Center for Clean Water Technology focused on new treatment technologies for residential wastewater in Suffolk County New York. He's also a member of the water quality improvement plan advisory committee for the Town of Southampton community preservation fund providing funding for water quality improvement projects, technical sales of project process equipment in centralized wastewater treatment facilities, and bud has a bachelor of science in civil environmental engineering from Cornell University, so we're very excited to have bud with us. Bud if you can take it away.

Bud: Great, thank you very much. I’m gonna try to move through this pretty quickly it usually takes me about 45 minutes to do this. Verified water is commercializing technology out of the center for clean water technology and our first product is a sensor that measures nitrogen in septic systems.

Our team is, Dr. Qingzhi Zhu is the inventor of the technology. He's got over a hundred papers published and 20 years of experience developing instruments and just a very prolific and ingenious inventor. The vision for the project came from Dr. Chris Gobler who is the director of the Center for Clean Water Technology. He's got two labs reporting to him with over 20 scientists and engineers and just a fabulous advocate for this technology. Chris hired me to commercialize Qingzhi Zhu’s technology. I have a business background including early-stage venture capital.

So the problem that we're all talking about today is the stuff that's coming out of that pipe in the upper right corner, that's effluent from a standard conventional septic system and the problem is that there's a lot of these things in 26 million homes around the US and they don't work. The dissolved contaminants flow right through the septic system, some of them get treated, but most of them don't. The alternative is to run sewers to centralized wastewater treatment plants and we just can't afford that.

Some of the water that comes into these septic systems then flows through the leaching field, some of that water does get some amount of treatment in the filter, in the soil, and in the in the septic tank but the large majority of the nitrogen anyway flows down into the ground water and then from there into the surface water and back up into well water.

The US EPA surveyed a number of regulators and officials around the country and they identified septic systems as the number two polluter of groundwater contamination.

This is a just a set of data that I put together showing the 17 states that have the most households on septic systems. Florida is the center of this whole problem; they've got huge problems down there. But I just wanted to say that we here in southern New England are not alone in this process and in this problem and one of the themes of this presentation is that we need to reach out to other jurisdictions and tap into the knowledge and the experience that's happening all around the world. I’ve been in touch with people in Sweden where they've been doing on-site systems for 30 years.

This is a map of nitrate levels and, you know, there's strong data now out of Europe that correlates various forms of cancer to nitrate concentrations and drinking water down around two to 3 milligrams per liter. Most US limits are 10 milligrams per liter so if you live next to one of these dark dots, you should be concerned.

This map shows the percentage of new construction that are being built with septic systems and what this shows is that there isn't really any rhyme or reason to this, I think more a Matter of political will and here in New England we have greater densities than they have out in the mountain states but we have a much higher percentage of systems not being sewered and so it's an interesting distribution of where septic systems are heavily relied on and I don't think it really reflects the topography or the costs.

So the alternative to on-site systems is centralized treatment and sewer collection using the best available technology you know the cost of sewering a home in a suburb or a rural area is anywhere from on up to these new decentralized treatment systems on-site can cost 35,000 up to 150,000 thousand dollars so there's a significant cost advantage. This is just four projects here in Long Island, the average cost is sixty thousand dollars per household and this is a low-hanging fruit project in densely populated area so, you know, we've got a significant cost differential.

As a result, this on-site treatment technology is a what's called a disruptive technology. It's the value, the quality of the of the effluent coming out of these systems is improving much faster than that in incumbent centralized treatment systems and the cost is already about half so this this adoption of decentralized treatment is happening if we only address the 2.6 million houses that drain into impaired water bodies we're talking about a 65 billion dollar early stage market and as I said Suffolk counties alone is planning to put 200,000 of these units in and here in Suffolk county we have 40,000 dollars of subsidies available for these.

So where we come in is we measure the nitrogen and the effluent coming out of these tanks. These advanced systems can already produce effluent with total nitrogen less than 10 milligrams per liter, but you got to ask yourself how are you going to manage millions of mini waste water treatment plants? We think that you're going to start with getting some good data, so our product measures nitrogen it's in situ, we pump the water out of the effluent from the septic system and then measure it and pump it back in.

These are designed for long-term deployments; they would replace manual sampling and lab work and the data is online in real time and totally independent and completely verified.

We're measuring ammonium and nitrate plus nitrite separately and simultaneously. The unit gets buried at grade level inside a standard septic tank riser, the box is watertight. Sampling system runs down into the into the effluent and we'll pump the water from the source. This system ran for over 12 months without missing a measurement in six different kinds of wastewater. There's 450 samples, the data is essentially real time, it's transmitted over cellular system to a browser-based user interface.

We were fortunate enough to get sponsorship from the EPA, the Nature Conservancy, and many others. They ran a challenge to find a low-cost nitrogen sensor for this application and our system won that challenge, we got a fifty-thousand-dollar prize from the EPA but more importantly we were sponsored for a six-month ISO technology verification test and also we earned a 200-unit commercial order from Suffolk County which we haven't closed yet. In that test we took 135 samples to Barnstable County's commercial lab and the correlations between our data and the lab data were just extraordinary, 99.7 percent, 98.6 for nitrate. Our percent recoveries were way above expectations, we were looking to get at least 80 percent recovery and you can see we did a lot better than that.

This is the user interface for the unit and the data that we used to generate this graph wasn't real data so it looks a little choppy, but you can see that we'll be producing an average for ammonium and an average for nitrate and we could also plot DIN which is the combination of the two here

So this is the graph that I think most people are interested in. It shows that this sensor would be capable of producing very high recovery rates for total nitrogen using our DIN as a as a proxy for total nitrogen if we said that DIN, if we asked whether din was greater than 14 or not in 131 samples 91 of those samples DIN was less than 14. So of those samples, which of those was total nitrogen greater than 19? And that was only one out of 91 samples so we've got a false positive in point eight percent of the cases, we got a true negative in 90 out of those 91 samples where DIN was less than 14. When DIN is greater than 14, there were 40 samples, 36 of those in of those DIN was also greater than 14, sorry TN was greater than 19. so we had 14 false negatives, sorry 4 false negatives where DIN was over 14 but TN was so the system actually passed where we would have failed it which means that just in 4 out of 131 cases we would have sent a technician to the site to take lab samples to see what was really going on.

The cost of lab sampling is just, it's not feasible, we estimate that it costs about three hundred dollars a sample to send a technician out to the house, take the sample to the lab, have the sample analyzed at the lab, and, you know, you could be looking at for a typical pilot test 18 monthly samples and then 12 more monthly samples at each of 38 provisional sites, 18 monthly samples at 12 pilot sites, so you're looking at over $200,000 per vendor. And by the way, three years for one and that's just to get one data point per month

Our solution would provide real-time data, you know, assuming our system costs five thousand dollars a unit and you could redeploy it in five different houses before you had to refurbish it, you're still talking about a thousand dollars per site to get this validation data this pilot data and you know that comes out to be about two dollars and fifty cents a data point versus three hundred dollars a data point for conventional lab testing.

This is just a table comparing the cost of sampling with a real-time monitor versus manual sampling and I think the story is pretty compelling when you look at the graphics at the bottom of all my slides you see that real-time data tells a much different story than a single data point.

The ecosystem that we're selling this into is extremely complicated. There are many partners and players and there's a lot of stuff going on here, but right now we're just going to try to pilot 38 units, get them in the ground, and producing good data and demonstrating to everybody what this data can do for them.

This is a picture of the dock outside of my backyard and this guy came by every year every morning for years and years and he doesn't come around anymore because these bays are I live on the bay in southern Long Island and it's highly contaminated by nutrients and algae.

Finally, I just want to thank all of these people, can't name them all, but just a ton of help here and you know a lot of people have really put a lot of effort into this process and we're very fortunate. So I'll turn it over there.

Brenda: Bud, thank you so much for that presentation. I know you said that it normally takes 40 minutes to go through so I appreciate you keeping us on track here with the time. Again, if anybody has any questions for any of the speakers today please feel free to type them into the chat box and we can address them in the later portion of the session or whenever as we go through the different presentations. Again, thank you bud for your presentation.

Bud: Thank you.

Brenda: If we can get Jessica Thomas online, I believe she is our third and final presenter for today. I believe you are on?

Jessica: Yes, I'm here.

Brenda: Okay great, yes we can hear you.

Jessica: All right, let me see if I can share my slides. Can you see them?

Brenda: Yes, we can see. Give me just one second, I will just introduce your presentation and a quick bio and we'll get started.

Jessica: Sounds good.

Brenda: Great yeah.

Emily: Bud if you could turn off your camera and if Jessica you could turn yours on that'd be great, thanks.

Brenda: Perfect. So as I said we have Jessica Thomas speaking to us. She is from the University of Massachusetts Dartmouth School of Marine Science and Technology or SMAST and her presentation title is "Micro-siting and Nitrogen Removal Efficiency of a Liquid Injection Permeable Reactive Barrier in Residential Watersheds of Southeastern Massachusetts". Jessica Thomas is a PhD candidate as I mentioned at the University of Massachusetts Dartmouth School of Marine Science and Technology and she's currently working in collaboration with Dr. Brian House. She has received her BS and her MS in hydrogeology from Worcester Polytechnic Institute before beginning her career which has included work in both the private industry and academia so we're very happy to have you, Jessica. Take it away.

Jessica: Great, thank you so much, thank you for having me. So my project that I'll be talking about today is on micrositing PRBs and this project is in connection with a SNEP grant that Martha's Vineyard Commission received and worked on with our program, coastal systems program.

I'm gonna try to advance my slides, there we go, okay. We've been talking about through this entire presentation this morning the problems with nitrogen enrichment and we've been hearing about both the environmental impacts, the loss of habitat, the water quality issues associated with nitrogen enrichment, as well as financial impacts to tourism and fisheries, and then finally quality of life impacts we have issues with beach use, so this is a problem that coastal communities really need to be investigating

So they're working hard on that. The nitrogen that we're receiving in the coastal communities come from a variety of sources primarily we think of contamination as point sources like a wastewater treatment facility or stormwater discharge. However in these situations what we really are looking at are more non-point sources, we have some agricultural runoff or lawn fertilizer and specifically the one that we are focusing the most on because it's the most impactful in these systems are septic systems. So these communities are looking at a variety of different techniques in order to treat this nitrogen enrichment and the one I'm going to talk about is the permeable reactive barrier or PRB.

So, you've seen this this picture before that's been modified from the Cape Cod Commission. it's a great picture. It shows what a liquid injection PRB is and so you have some sort of injectate that you put in that's kind of this wall that your contaminated, your nitrogen contaminated groundwater will run through and in our case our wall was made out of an emulsified vegetable oil and that vegetable oil created a carbon source for the naturally occurring bacteria to perform denitrification and it also created the conditions necessary for that to happen the low oxygen conditions. So we have our impacted groundwater that hits our wall of PRB, it goes through denitrification and what we have on the other side is nitrogen gas which is not something that we're worried about and hopefully groundwater that has much less nitrate in it which is the issue that we have in our coastal water bodies.

In order to make sure that our PRBs work really well we have to make sure that we put them in the correct place. We want to make sure that the most amount of impacted groundwater flows through that wall so to do that we need to do a detailed micro-siting process. We're going to select our desired site, we're going to look at the depth to groundwater, we're going to look at how fast groundwater flows and in what direction. We want to look at our different nitrogen concentrations, how much nitrogen we have, what form of nitrogen we have because we want nitrate and where our nitrogen is, how deep it goes. We're going to look at the types of soils that we're working with, we want to look and see if we have any issue with tidal influence on our groundwater, and finally we're going to design our PRB and we're going to place it.

Our particular project was located on Martha's Vineyard. It is located next to Lagoon Pond which is a water body that has been impacted by nitrogen enrichment. There is a total maxim daily load target for this system and this red box right here is our PRB site so it's right on the western arm.

So if we zoom in on our site a little bit more we have lagoon pond up here in the top and our site is outlined in the red box and all the yellow sites are our initial groundwater wells that we put in mostly by hand, you'll see we had a lot of grad student power, so that we could get an idea of what those initial conditions were.

The first thing we did was we looked at groundwater levels and we predicted which way groundwater would flow based on those groundwater levels in the different wells and as you would expect groundwater flow tended to be towards Lagoon Pond. The next thing we did is we looked at the profiles on all of these wells for the nutrients and I'm just going to show you this one right here number three and the graph on your right has different concentrations and then this is a depth below the groundwater table and we looked at the different parameters for nitrogen to make sure that we had enough nitrate so that we could have denitrification happen and you'll notice this blue line is our nitrate. This site tended to have concentrations that are representative of residential levels anywhere between 2 and about 15 milligrams per liter and this particular site had the maximum nitrogen levels around two to three meters below the groundwater table so not super deep which was helpful.

After we went ahead and we did our initial assessment we wanted to get a better idea of how fast our groundwater was flowing and really make sure that we understood exactly the direction. Again, if you're going to get the best results out of your PRB you want to make sure that you get the most groundwater through it so we did a natural gradient tracer test. We injected a known amount of potassium bromide into these green wells right here and we just tested the red fence wells and waited for the potassium bromide to hit those red wells and what we found was the groundwater velocity was about what we had expected .6 feet per day, this area is about half a foot a day. But one of the things that we found that was a little interesting was that the groundwater flow direction wasn't exactly what we had predicted from our groundwater level measurements. This green arrow was what we had gotten by just taking groundwater measurements and the pink arrows are what we got from this natural gradient tracer test so we did modify our design a little bit to make sure that we accounted for that change in flow direction.

Finally we went and took a look at the soil borings and as we expected we had primarily a fine sand in the area there was a little bit of silty clay but luckily we had a pretty loose material so our injection went fairly smoothly.

Okay so before we went ahead and installed we found that we had very shallow groundwater in this system which was helpful for the cost for installation. Our soils were fine sands our nitrate was the dominant form of nitrogen which is what we wanted, our nitrate was in the range that we would expect for residential systems and areas, we had a fresh water system, our groundwater velocity was what we would expect at about a half a foot a day and we found that we had some elevated levels already of some metals which we looked at right near Lagoon Pond, they were in the root systems of some phragmites bordering Lagoon Pond. We had some elevated levels of manganese, iron and arsenic there but nowhere else on the site.

So we went ahead and we designed and installed our PRB and this happened in November of 2020 so we're getting to two years. The green dots that you see are our injection points and we were looking not only at how well our PRB was going to work, but we wanted to look a little bit about how our PRB moved, how it moved down gradient with groundwater and how it spread and so we've done some injections here at 10 feet apart and then some injections on the southern portion of the property at 15 feet apart. Oh, sorry. The yellow dots and the blue dots that you see are multi-level monitoring wells that we looked at throughout this application for a variety of different parameters. So our PRB was installed at about 80 feet from Lagoon Pond and it was 150 feet long.

Here are some pictures of the actual installation, we have the concentrated EVO and then our mixed injectate that was EVO and water. In the middle was our geoprobe where we would place the pipes in order to install with pressure and that machine was amazing. The homeowner was actually doing some construction, some landscaping, but this geoprobe went over the grass and you never knew it was there. And then finally on the right-hand side you have our injection happening under pressure and when they were done with the injection those pipes were removed you couldn't tell where we had injected.

So how are we doing? If you take a look at this graph right here, we have nitrate on the left-hand side and then down here on the bottom we have time. Our PRB installation happened right here in November of 2020. if you take a look at the yellow and orange lines that are kind of up at the top those are our up-gradient wells those are wells that had no treatment and we have a fairly wide variety of concentrations of nitrate but they do tend to range from about 2 to 12 milligrams per liter and those continue with time, we continue to receive nitrate up-gradient of our PRB. The next line I'd like you to look at is this green line, that line was about 22 feet from our injection site and pre-PRB we had a decent amount of nitrate in there and within a month or so two months we started to get levels that were down to the not detect. very low levels of nitrate. The purple line right here is about 34 feet from our PRB so it took a little longer for us to see these levels drop down to non-detect but they've been non-detect for quite a while as well or close to non-detect so our preliminary results show a significant reduction in nitrate in these down-gradient wells.

The next thing we did is we wanted to find out if this was really denitrification happening so what we did was we took a look at N2 n gas and what we would expect is that there would not be very much N2 gas up-gradient of our PRB but that we would be producing N2 gas down gradient of the PRB. So on the y-axis you have N2 gas and on the x-axis you move from up-gradient to down-gradient and this is the PRB location. There is some background N2 gas but we have a significant amount of N2 gas being produced down-gradient of our PRB, we're hoping to be able to use a mass balance approach to confirm the amount of denitrification that's going to be happening.

The next thing we wanted to do was to look at optimizing this design, we wanted to look at what the down-gradient movement of our EVO could potentially be. We wanted to make sure that our EVO wasn't going to end up in our surface water body. So the orange line is just nitrate, you've seen something like this before, we have our concentration right here so that's our nitrate on the y-axis and we move from up-gradient to down-gradient and this red line is where our PRB was injected so we start with a higher level of nitrate and by the time we get down to our down-gradient wells we have a very low level of nitrate. We measured dissolve organic carbon to kind of see where our PRB was, we have very low levels of DOC but some background in the up-gradient wells. And then within a couple of feet up-gradient and down-gradient of our injection we have a high level of DOC. This was taken at about nine months after injection so either this movement happened when it was being installed under pressure, these are only three or four feet from it, or they moved slightly. We did see down here at W11 a higher level of doc which may mean that there's a lighter fraction of the liquid injectate that had moved down gradient.

Finally, we took a look at secondary reactions, so in this reduced zone not only do we have denitrification that can occur but we can reduce metals so that they can become mobile in water. Generally, they are tied up with the soil but under these conditions they can move and we want to make sure that those don't get to our water body.

So the first thing we took a look at is iron. Our green line is our up-gradient well so we wouldn't expect that there would be any iron that's still bound up in our soil. So this is my iron and this is with time and this is when I installed my PRB. The red and the blue lines are down-gradient wells so we see a significant rise in iron, however we do start to see what we would expect as a tapering off of iron after the amount of iron that is in that treatment zone starts to be used up so we're going to continue to watch this and see if that pattern continues. But I think the most important line is the yellow line down here at the bottom, that line is right on the edge of Lagoon Pond, that is the 80 feet mark from our PRB and what we found was that while we did get some mobilization of iron none of it made it that far it didn't make it to our surface water body. Same thing with manganese, our green line is our up-gradient well we wouldn't expect to see much manganese there, we did see an increase in down-gradient. the red and the blue lines and we're going to need a little bit more data to see if we really are getting a tapering off of manganese as well. But again, the important line for me I think is the yellow line which is right next to our Lagoon Pond where we didn't see any manganese making it that far.

Finally, we took a look at arsenic, arsenic is right here on this y-axis and with time the green line is our up-gradient well and we don't see very much arsenic there. Our red and blue lines again are down-gradient where we are seeing some increases in arsenic. And finally, the yellow line is the one that is right next to Lagoon Pond where it doesn't appear as if at the high levels of arsenic are making it there. But I would like to point out that there is a freshwater ecological limit for arsenic which is .34 milligrams per liter and the maxim onsite level that we have does not come close to a level that we would be concerned about in these freshwater systems.

In conclusion, the installation of the PRB was fairly straightforward and it began removing nitrogen within days of its installation. We've reduced nitrate to very low levels throughout the site and the secondary products while they were produced were at fairly low levels and more importantly, they did not travel that far down-gradient.

I'd like to thank a few people, Martha's Vineyard Commission, specifically Adam Turner and Sheri Caseau for their hard work and leadership, the SNEP program for funding this, our site is actually someone's home so Amy and Dan are the homeowners and they have been phenomenally patient with us, ES&M who did the installation, Terra Systems who makes the EVO and finally all of these lovely people who are part of Coastal Systems Programs that made wells and take tons of samples.

Brenda: Thank you Jessica so much for that presentation.

SNEP Symposium – Science Bringing Solutions Delivering Environmental Improvement to Southeastern Coastal New England

Room 3, Morning Session 2

May 18, 2022

Sheryl: In the meantime while we're doing that, let me introduce myself. I am Sheryl Rosner. I work at EPA Region One and I'm in the regional administrator's office and it's my pleasure to facilitate this session today on habitat restoration and preservation. I am going to introduce our speakers, Rachel Jakuba is here from Buzzards Bay Coalition, Rachel is the vice president for Bay science at the Buzzards Bay Coalition where she oversees the Coalition's science and monitoring activities. These include water quality monitoring program that has collected data from over 200 locations for 30 years and a salt marsh monitoring program that includes monitoring of an innovative restoration technique. Rachel received her PhD in chemical oceanography from the Massachusetts Institute of Technology Woods Hole Oceanographic Institution joint program and her bachelors of science from the University of Georgia and our next speaker will be Casey Chatelain from the Barnstable Clean Water Coalition. Casey is the deputy director at Barnstable Clean Water Coalition. She has a BA in environmental studies and a master's of oceanography from URI and our final speaker is Kevin Dahms from Biohabitats Incorporated. Kevin is a water resources engineer whose interdisciplinary background in engineering and environmental science led to a passion for incorporating ecological design into stormwater management urban planning and coastal resilience initiatives throughout his career. He has applied this approach to a variety of green infrastructure low impact development watershed planning hydrologic monitoring habitat restoration and coastal protection projects. He has led and participated in various phases of project implementation including planning, site investigation, survey, conceptual through final design, construction documents, permitting construction, oversight operations, and maintenance and stakeholder engagement. In his free time Kevin enjoys hiking, running, and paddling along the water bodies in the watersheds and through the habitats that he and the Biohabitats work on preserving and restoring, that's awesome, so why don't we begin with Rachel who now I know you can share your slides and we're looking to do it right here in a second. We're looking forward to your presentation.

Rachel: Thank you. Okay, are those up okay?

Sheryl: Yes, I just want to mention that each speaker will be speaking for 20 minutes and my role is to make sure that we stay on time so I will probably give you a two-minute warning if you're looking like it's going over.

Rachel: That would be excellent, thanks Sheryl, thanks for the introduction. So again, I'm Rachel Jakuba with the Buzzards Bay Coalition and today I'm going to be speaking about a SNEP funded project that we did in partnership with the Woodwall Climate Research Center the Buzzards Bay National Estuary Program, Save the Bay, Narragansett Bay Bristol County mosquito control and USGS. Let's make sure the slide advances, there we go, is it advancing? Why isn't it advancing? Has it advanced over there?

Attendees: It has not, it's not, no it doesn't.

Rachel: Okay, let me try going out of slideshow mode, oh no. Of course. Emily are you on? So let me stop sharing actually because it's advancing on my, like I have it on two screens and it's advancing on one and not on the other so I'm gonna share it a different way and see if that works. Okay, so now do you see it not in presenter view?

Sheryl: Yes, it looks the same as it did before but you want to see if it advances?

Rachel: Is that going?

yeah I've never had to do this before where it's like the slideshow is stuck on one screen. Okay let's just try, all right so now do you see nothing?

Sheryl: No now we see it with the slides on the side.

Rachel: Okay so now let me try going into presentation view again. All right, now what do you see?

Sheryl: The first slide, now please advance PowerPoint.

Rachel: t's not advancing, okay.

Sheryl: What if you just go back to the slides on the side and it'll just be small for us.

Rachel: Yes, I think that's what we're gonna have to do so I apologize for that. We'll see if we can make it as big as possible but we can see that. Yeah but so let's just try and at least make it okay so you can see now my slides right

Shery: Yep.

Rachel: Okay can we make that even, all right so that's right, yep better than nothing. All right here we go, sorry for the delay there, okay so just to give a brief overview about salt marshes, they're you know, productive coastal wetlands that serve a number of important ecosystem services including storing carbon, acting like filters for nutrients, providing a physical barrier for storm impacts and flooding and they're really valuable habitat for a number of important organisms and this map on the right shows the Buzzards Bay Watershed and the red line and the green areas are highlighted are salt marsh areas are in around Buzzards Bay.

Salt marshes are naturally dynamic systems but across the northeast US and especially in southern New England, marshes have lost significant areas and the rate of loss is increasing in some areas and you can see that from this work that we did in one of our estuaries around Buzzards Bay the Westport River where we did a study of six salt marsh islands which are here on the map in red and we looked at those aerial images of those marsh islands starting in 1938 up to 2016 and we saw, you know, loss at all of the marshes and at a number of them this increasing rate over the last 15 years and these marsh islands a lot of the areas where we saw a loss were at the lowest elevation portions of the island. We know that sea level rise is a really significant stressor to salt marshes and that the marshes have to build up elevation in order to keep pace with sea level rise and not drown. Another pressure on these marshes is a high concentration of nitrogen.

When we look at marsh loss around Buzzards Bay it's happening all around Buzzard's Bay so not just in the Westport River estuary and we see different types of loss so these images are just showing different examples of salt marsh loss so this is the Westport River where we see in some places this sort of cabbing off of the marsh. We also see significant creek widening in some places and interior die back. And this rate of loss and the loss at all is really alarming and a number of communities, you know people are noticing it and communities really want to figure out how we can stop or slow this marsh loss.

And just as an example of the community concern for salt marshes, this is an excerpt from an email that we received about a year ago from an individual who says "the marsh grass is dying off in patches leaving just mud that the water now flows into and is creating new smaller canals and rivulets when the tides are high. The grass die off is a recent phenomenon within the last year from what I've seen the shoreline itself which my property of butts has not changed or been affected yet though once the marsh goes I would imagine that would soon follow. This area has brought us so much peace and joy we're doing willing to do quite a lot to save it."

And so for this is describing one of the types of marsh this interior diet dieback and that's the type of marsh loss that I'm going to focus on for the rest of this talk. So when we have water staying on the marsh for too long it drowns the plants and creates these areas of vegetation dieback and they have the potential to expand outward rapidly killing the vegetation and converting the interior marsh platform into open water or you know bare mud areas.

So in one technique that has been gaining speed in New England to try and combat this type of marsh loss is runnels and so runnels are these small channels to create a title connection between shallow water on the marsh surface and a creek or ditch and they follow typically topographic low areas or existing flow paths to drain just the root zone so these are generally about you know about a foot wide and a foot deep so they're not as deep as mosquito ditches and this was a technique that sort of was originally used for mosquito control and was pioneered as a technique for salt marsh restoration by Wenley Ferguson beginning around the year 2010. So when we started thinking about this as a potential technique and wrote the proposal for this project it was in 2019 and at that point there was very little published documentation on the effectiveness of runnels on you know how to implement them, but again there was a really big interest in in using these.

And so the goals of our project were to synthesize and communicate the existing knowledge on runnels to test pilot runnels in Buzzards Bay and to do it in a really to use really a very rigorous scientific design so that we had very clear and detailed information about the impact of the runnels and then to identify when and where runnels are most effective in the context of marsh loss patterns and environmental conditions in Buzzards Bay. So I'm going to talk a little bit about all three areas of our project today.

So right before the world shut down in early march last year we held a workshop in person with over 70 scientists, practitioners, research managers, and regulators and other stakeholders and this was an opportunity to develop a common understanding for the potential use of runnels in our region so we had speakers who have been implementing this talk about how they did it, where they did it, what were the, you know, how did they look at a site and what context did they use the runnels in? And then we had breakout sessions to examine and rank potential rental sites so this was to help us in terms of where we were going to put our actual runnels to get impact to get feedback from people on what made rental sites good sites and to the session to do that we brought aerial maps we brought photos of potential sites, information about wind wave exposure ownership, and a variety of characteristics for the each marsh.

Okay so we synthesized the information from the runnel into this journal article that came out in January and in addition we gathered information on from the literature on the history and use of runnels and then included a case study from the Winnipaug marsh in Rhode Island and we also in you know again this is an emerging technique and so there's still a number of research questions that need to be addressed and so we highlighted those.

And then finally with respect to sort of communicating and developing a common understanding for runnels so we held site visits with targeted audiences at our runnels experimental sites so we did one that's we have people here in the in the top right where we focused on people from the mosquito control agencies in our area so Bristol, Plymouth and cape cod to try and get people who have a lot of experience working on the marshes and also who have some you know permitting ability to do work on marshes more than other organizations so to make sure they understood you know how we had done this how we selected the sites how the runnels were dug and how we dealt with the permitting for the runnels and then in the lower panel here this is a picture from a site visit to Allen's Pond where we had non-profit staff actively engaged in restoration techniques around the watershed so people who are interested in potentially doing these types of projects at other sites and again going over how we did it, what we looked for in developing and selecting sites and how the process worked for us.

Okay so those were the key ways that we communicated and synthesized the information on the runnels.

And then I want to talk about the test runnels that we that we dug so again this is a map of Buzzards Bay and our two rental sites are highlighted in red so we had one at ocean view farm and Dartmouth and one at little Bay in Fairhaven and these two areas have somewhat different environmental conditions and marsh characteristics. In order to look at these the effective runnels we have a replicated before after control impact studies design so at each march we had five experimental runnels and sort of sites within the site and then five reference sites where we didn't dig a rental. So across these two marshes we have 20 sites in total and at all of these sites we're measuring vegetation metrics and we have photo stations so we can get a visual measure of change over time. And then with it within the 20 sites we have 12 sites where we're doing more intensive measurements so we're measuring elevation, soil characteristics, water level, shear strength, water quality, decomposition, and other environmental variables and this is just an image from us last year where we had some of our intensive monitoring going on where we had a lot of people measuring different things all the same time.

All right so here's two aerial images of the two sites so on these sites the runnel transects are these purple lines so these are where we're measuring things across the runnel transects and I have these are two are actually flipped and then the green is the control where no runnel was dug the stars indicate the more intensive sites and the blue is my this is hand done with excel or with PowerPoint so these are not perfect but the blue is the approximate roles where the locations of the runnels and so we began monitoring these sites in 2020 so before any runnels were dug the runnels were created between October 2020 and February 2021 and I will just point out that so they were dug in in October and November and then they were sort of adjusted up until the end of February 2021.

And here's some photos from our installation, so we used both digging this is the Bristol County mosquito control low ground pressure excavator that was on site and was used for some of our runnels and we also had volunteers and staff doing hand digging at some of the sites and it just depended on the firmness of the peat and the situation of whether we and also how long the runnels were so for short runnels it wasn't necessary to use the excavator some of the longer ones it made more sense and again in terms of this technique one of the things that Wenly Ferguson really stresses is important is it's been used as an adaptive management technique and so it's important that once the initial runnels were dug then you know we sort of went back sort two weeks later to see if the draining was happening as we expected it to or for instance in this rental you know after the excavator dug it after a couple weeks we went out and extended it into the diabetic area with shovels.

Okay and so now I want to show you some results so this figure is from ocean view farm and this is data from before the rental this is water level data so on the y-axis this is water level in meters and at the zero point so this is the marsh surface is this dotted line and this is data from sort of mid-July to mid-October and so again it's before the runnels were dug the blue line is the water level data every minutes so that's the trace of the logger and then what the green line is it's the daily minim so that is what we're using as a proxy for the water table height and what you can see is that before the runnels were dug we have these periods in time where there's standing water on top of the marsh surface for an extended period of time and after we dug the rental those that that disappears so we're still seeing the tidal flooding the you know the waters reaching the top of the marsh surface but it's not ponding or staying on the marsh the water table is below the marsh surface so the point of the runnels is in order you know it's to drain the standing water so that we can have the die back areas re-vegetate and fill in and so we were excited to see the water table results to see that dropping and this is again from ocean view farm which is a lower elevation marshes we saw a more dramatic change in water levels at this site than at the other site our little Bay site and we weren't sure if we would see any re-vegetation after just one year because again so the only growing season that we've measured so far is 2021. We have a single year of data post rental installation and what you can see here so on the left we have two images of the same die back area at ocean view farm before and after a rental was dug and then on the right from little Bay again before and after a rental was dug and even after one year at both sites we're seeing some re-vegetation which is really exciting to see there you know the rental sites these are two out of our ten runnels sites that were that were dug and they're they encompassed a variety of sort of sizes of dieback of conditions with respect to elevation and exposure and so there is a gradient in what we saw with respect to revegetation and one of the things that we're really excited about is that we've gotten additional funding to support another two years of monitoring so we'll be able to see you know how those different characteristics impact the revegetation at the sites and so the final piece of the project was to where we wanted to really try and take the information we gained and try and from this pilot test and sort of expand it outward to be able to look at other sites.

I’m going to use this sort of as my conclusion slide because basically what we what we saw was that you know the rental the rental runnels are very small scale features that really target specific area of die backs small areas of dieback and so trying to sort of look at a watershed scale and make generalizations just wasn't really appropriate these runnels there they are a valuable tool in an overall marsh management scheme but on any at any given site the project design and the runnels going in are still really highly context specific context specific they're very small scale features that need to be developed you know looking at a specific site on the ground in person and so we're recommending that it's important that projects include individuals either with training and experience using this technique or similar hydrologic management tools to really be able to understand the best way to implement them and continued monitoring again it's going to be really important for characterizing the potential sites and we'll be able to have more information about you know which areas of die back so for instance where we have higher levels of water that was standing on the marsh if we're not able to drain those as much you know how much revegetation do we see versus where you know we were we were able to lower the water table more and finally I just want to say that you know this was a really valuable partnership with a variety of people so we had you know these six organizations that came together all bringing different strengths and it was really key to have each of our key team members here we would not have been able to do this project without any one of them and it was really valuable to have that collaboration to support what we did and so I just want to close by thanking our funding sources so SNEP who funded the first two years and now our continuing funding through the Northeast Climate Adaptations Center Science Center and we have a number of landowners and collaborators and student interns who also who also supported the project so thank you very much.

Sheryl: Rachel that was a fantastic presentation so interesting and thank you so much and you made my job easy because you're one minute early so perfect, thank you for that. Now we are going to have Casey talk about Marston Mills River Headwaters cranberry bog restoration project, take it away. And I just want to say we will have time for our question and answer at the end so just hold your questions and we will get to them.

Casey: All right let's just before we get started make sure that this works. So are slides advancing?

Emily: Yes they're moving.

Casey: All right, glad that that is out of the way first. Yeah so thank you for the introduction my name is Casey Chatelain and I am deputy director for Barnesville clean water coalition today I am here to talk to you about our efforts surrounding the Marston’s Mills River headwater cranberry bog restoration but before I dive in I want to give a little bit of a background quickly on our organization we are private non-profit organization and our mission is to restore and preserve clean water throughout Barnstable this includes all water our Bays our ponds and our drinking water this effort in particular is located in the watershed feeding three Bays estuary which is here on the map with the red star unfortunately three Bays estuary is one of the estuaries in the region hardest hit from nitrogen pollution three bases has to remove a significant amount of nitrogen in order to reach what's called its total maxim daily load and achieve natural ecosystem function. While the Town of Barnesville does have a comprehensive wastewater management plan which is one of the maps behind me, much of this area won't see municipal sewer treatment for at least a decade and the upper reaches of the watershed won't see it for at least…

Sheryl: Casey you froze, can you hear us? Is Casey frozen on everybody's?

Emily: She is, if she can hear us it might be worth her just to stopping sharing for a minute and then try to do it again.

Sheryl: Casey can you hear us?

Casey: …Restore these…

Sheryl: Oh Casey you were you were frozen for a bit there and you're still frozen on our screen. Do you wanna? Can you hear us? Do you have a way to call her?

Emily: I might just try to send her a message.

Casey: …For free base estuary which is just over 46,000 kg of nitrogen.

Emily: Casey can you hear us? Sorry.

Casey: Yes.

Emily: You keep cutting out so I'm thinking could you just stop sharing for a second and then reshare, that might fix the problem.

Casey: Yeah, let me turn my camera off too and see if that helps.

Emily: Okay, thanks.

Casey: Where did people have trouble hearing me? Should I go back a few slides?

Emily: I think so, yeah.

Sheryl: We heard the first one, you froze on the on the red star slide.

Casey: Okay, there you go, red star. So for those of you that could hear me, are people hearing me better now?

Emily: Yes.

Casey: For those of you that could hear me, I'm sorry this is a repeat but want to make sure that everyone's up to speed on this the red star is where this project is located and Three Bays is one of the estuary's hardest hit from nitrogen pollution. The town does have a comprehensive wastewater management plan, but a lot of this area won't see that municipal treatment for over a decade with the upper reaches of the watershed not seeing it for over 20 years and that's simply just a matter of it's on the other side of town from the wastewater treatment plant so it's going to take a long time for municipal at here.

Now the Cranberry bogs are at the headwaters of the Marstons Mills River hence the name of the project and this is a unique opportunity to really turn off that tap of nutrients to Three Bays because once groundwater comes to the surface within these Cranberry bogs and it's laden with nutrients from upgrading development it flows down the river in just lower than eight hours. So this is an opportunity to use a nature-based solution to have a relatively quick impact on the estuary. But of course a. do we know that this will have a meaningful impact because there's a lot of nutrients flowing through? and b. can this bog actually be restored to a natural wetlands? The answer to the first question is yes we really do believe that these Cranberry bogs do have a meaningful impact. This is a little busy so I'm going to explain it on the left hand side the whole box red and white is the whole watershed load for Three Bays estuary and that's just over 46,000 kilograms of nitrogen every single year. In order to get to the total maxim daily load and achieve natural ecosystem function, inputs need to be lowered down to just over 25,000 kilograms of nitrogen per year, so this is a pretty significant that needs to happen in this estuary. On the right hand side we've broken out the top red section on the left which is the reduction that needs to happen and marked out what actually flows through these Cranberry bogs. Through work with the UMass Dartmouth School for Marine Science and Technology supplemented by data collection here at Barnstable Clean Water coalition we've determined that just over 7,500 kilograms of nitrogen flow through these bogs every year and so while we don't yet know how much a watershed, sorry, how much of wetlands restoration can improve water quality because the literature has yet to really come up to speed on that we hope to really make a crossroads and do a lot of research to fully understand this. This is an opportunity to treat a significant amount of that excess load, over a third of the excess load for Three Bays Estuary is coming through these bogs.

Of course being able to restore this is dependent on a couple things; first is this system suitable to be restored to a natural wetlands? Because in some cases Cranberry bogs are next to ponds or the river flows through it and they simply block the water up to back water up for flooding but it wasn't actually a historic wetlands if it wasn't a historic wetlands it's really hard to restore that. So this is an 1856 map of Marston’s mills the village within the Town of Barnstable where this project is located and our project is in this white box here and this predates Cranberry farming in the area and the whole area is drawn in as a wetlands indicating to us that yes before Cranberry farming a lot of groundwater was coming to the surface to form the headwaters of this river and we have more information that helps tell us that this is still the case and that water does want to come to the surface for this to be a restored wetland system.

An example of this is aerial thermal imagery. In July of 2019 EPA Region One contracted with a UAV company, commonly known as drones, to do a thermal study of the Cranberry bogs and see if we can detect where groundwater is coming to the surface within the bogs. Groundwater on Cape Cod is stays at a constant temperature whether it's winter or summer the blues on this map the lighter the blue the colder the temperature. With the lightest blues coming in at around 50 degrees and that's really cold for a very hot July morning. I was out there and sweating pretty early and so you can see that in these ditches there are pockets of extremely cold water trying to come to the surface even on the bog surface itself like right here breaking through despite over 150 years of compacted sand layers.

Lastly, as part of our feasibility study for this project we conducted what's known as a crown penetrating radar study. Now ground penetrating radar is similar to radar from an airport tower but instead of waves being bounced off of airplanes the waves are bounced off of the different layers of soil in the ground and this study showed us that there's over 14 feet of peat or partially decayed wetlands vegetative matter over a large portion of this site and this tells us that this was once a really productive wetland system and it could possibly be restored to that.

In order to fully understand the effectiveness of this strategy as a solution for nutrient pollution because while we do want this to be primarily a way to improve Three Bay's estuary we do want this to serve as a model for similar headwater bogs across the region we need to understand exactly how much nutrients how many nutrients are removed as a result from this work so this is a this is a crapped monitoring program that we have quality assurance project plan and so we sample at locations along the course of the Marston’s Mills River and at each of these stations along a transect we collect depth data and velocity data taken together we can calculate a discharge of the river at that station at that point in time. At that same exact time we collect a water sample to be sent off to the Barnstable County water quality lab so we can see the concentration of nitrogen in the water. Taken together we can then determine the load of nitrogen moving down river every single week. We have a long-term data set going with it actually starting in 2019 and since we haven't broken any ground yet we have a very thorough pre-restoration data set and this sampling will continue during and very long after this restoration so we can truly determine the impact that a Cranberry bog wetlands restoration project has on water quality.

Now what might this restoration look like? I emphasize might because this is a result of the conceptual design, a lot more very specific engineering and studying needs to go in to see just how feasible the different elements of this conceptual design are. At this moment we are just wrapping up firm selection for full engineering and permitting but even if this isn't the precise way this is going to look when all is said and done, a lot of these elements are going to be the same where we end up creating multiple flow paths and really backing the water up where we can to make sure that the water is really interacting with that peat that wetlands have and the bacteria that denitrify water that exist within that peat and using ponds as an effort to denitrify as well. And in all Cranberry bog restorations they end up scraping away the surface, and loosening up the sand, filling ditches that's all going to happen here and we're excited to see just how close to this conceptual design we can come.

Another element that may be incorporated into this restoration is bioreactors. You may have heard about this work previously from our partners at Mount Holyoke College, they received a SNEP watershed implementation grant for this work which is ongoing and right now when Cranberry bog restorations happen they filled the ditches with sand which doesn't really do anything for water quality and our hope is that we can fill specific ditches with wood chips, maybe wood chips and biochar which is what you can see here, in an effort to add an extra layer of denitrification to this wetland system. this particular bioreactor was installed in May of 2021 and we've been sampling it monthly and that sampling will continue through October. So after that mount Holyoke will study all of the lab results and hopefully have some more information for us so.

This is where we stand with our schedule right now. At the end of 2021 we had our feasibility study done and we had our QAPP approved and we just completed conceptual design about a month and a half ago as I mentioned we are just in the process of hiring a firm for design and permitting we had our final interviews and we're in the middle of pulling a contract together. That's going to be a longer-term effort and then in 2024 and 2025 we're going to actually complete construction and of course monitoring is key to this project so monitoring has been occurring will occur throughout the life scale of this project and hopefully long after this project.

Of course we couldn't do this work without our partners and they're here on the screen. I do need to say that we did get a pilot watershed initiative grant for this work which really allows us to keep this project moving along and it also helps us pay for the lab sampling of those Marstons Mills River water samples which is truly the key to determining how much this project helps Three Bay's Estuary and how this project can serve as a model for the rest of the region.

And so with that I want to thank you for your time, I know there's going to be questions at the end so I look forward to hearing any and if you have any questions or are intrigued about partnering on this work please feel free to reach out to the email address on the screen. Thank you.

Sheryl: Casey, that was an excellent presentation, thank you so much and we are even ahead of schedule which is great, we'll have lots of time for questions. We're now going to turn it over to Kevin who's going to talk about regenerative stormwater conveyance and sand seepage wetlands at Teaneck Creek Park New Jersey so take it away

Kevin: Great, thanks Sheryl. Let me, okay can you all see that? and let me see if it's coming up? Okay and is it advancing?

Sheryl: it is.

Kevin: All right, excellent. All right thanks everyone, so my name is Kevin Dahms I'm a water resources engineer at Biohabitats. We're an ecological consulting firm with offices throughout the united states I'm out of our Hudson River Bioregion in New York city and so I'll be discussing a project that we are just wrapping up construction on right now in Teaneck New Jersey, so I know a little bit outside the geographic range of SNEP, but the types of approaches and interventions that I'll be discussing, particularly regenerative stormwater conveyance and sand seepage wetlands that we used on this project, I think are very applicable. All Recently uploaded to sites up in in your region and definitely speak to a lot of the themes that we've been hearing throughout the day and earlier in this session.

So just real quick the presentation is going to be organized in sort of these four sections. I'll give a quick project background on the site and the project partners in the history of where this project started and then discuss the project drivers and some of the challenges that led us to pursue restoration at this site and then most of the focus will be on the project approach, so particularly focused on the regenerative stormwater conveyance and sand seepage wetland components of the project and then I have a brief slide on lessons learned and you know I think it'd be good to talk through some of those during the Q&A discussion at the end.

So first I do want to acknowledge all of the project partners on this we are working with the Bergen County parks department who is the project lead on this and the client. They're the owner of the site and they are a huge driver of initiating this project. The design team is Biohabitats and then we worked with a municipal engineer CME Associates, they led the landfill closure and remediation side of the project which I'm not going to go into detail today but I will mention it. Siteworks is providing construction management, the contractor is Sumco and then we had some really great partners through the Teaneck Creek Conservancy and Rutgers University who really initiated the concept design for this restoration and we received funding through Green Acres funding through New Jersey DEP.

So just to situate us on the project is located in Teaneck New Jersey which is in northern New Jersey just across the Hudson River from Manhattan so a really pretty dense suburban urban area these are the property boundaries for Teaneck Creek Park so as you can see this is pre-existing conditions, it's a really nice green natural space in a wide area of roads, houses and impervious surfaces.

So I think it's important to provide some context to this project so like I said we're just wrapping up construction and planting right now but this project kind of goes way back almost decades when the Teaneck Creek Conservancy was founded and really took over ownership of the park and wanted to restore it and make it a place for the community to use for recreation and so after their founding you know they started to set up trails and outdoor classrooms so there's some really nice amenities at the park and then like I said in 2008 the conservancy in Bergen county worked with Rutgers University to develop a restoration plan for the property. Out of that came a remediation plan which is associated with some of the debris piles and various dumping that had occurred in the site over the years and then leading up to that or on building on that Biohabitats was hired to develop a habitat restoration design that would be incorporated with the remediation p that design was finished up in 2018 and construction began in 2020 and like I said we're wrapping up right now so just it's got a long history I mean so it's really exciting to be able to present to you today sort of like the finished, nearly finished product and the process behind it.

So Teaneck Creek park is a very natural park it's got some pretty, it's got you know wood chip trails with some boardwalks throughout it does have some of these features of like outdoor classrooms, a butterfly garden and various designated spaces with programming and it does it's located right adjacent to Teaneck Creek so this is Teaneck Creek here and I'll talk a little bit about the history of the creek and its relationship with the park in a second.

So these were are the pre-existing conditions on the site. I think a couple of the ones that I wanted components I wanted to highlight was so there was a clay liner installed in this portion of the park and that was as a result of originally back in the mid 20th century it was planned to be used as a landfill and so they had put down this clay liner in anticipation of that and some dumping did occur there it ended up not becoming a landfill and then tina creek conservancy came in and so it's you know became a park so there was a clay liner throughout this area like I said the conservancy has set up an existing trail system throughout the park which is pretty well established and then there's these art and educational programming throughout the site so there's various natural art installations that we didn't want to disturb and obviously wanted to maintain throughout the project and so you can see Teaneck Creek runs right along here. I think important context so before you know back pre-existing conditions before any development or anything this was a historic aerial show this was a title wetland that was all cut off by a tight a couple tide gates that were installed lower down on Teaneck creek and so you know this project did not have, we did not address those tide gates and then there's various birming that's occurred so as we've heard throughout the day you know a lot of human disturbances have modified this site so as we're thinking about our restoration approach it is pretty heavily designed, however the intent is to restore a natural system and allow nature and a natural freshwater wetland system to naturally come back in the site so I'll go into that in a little bit of detail.

So the project drivers wanting to enhance the public experience that was the conservancy and the parks department's you know main goal making this a nicer place for the community to visit. There was impaired water quality in the water bodies on the site so there's a couple of areas of standing water on the site, ponds as well as in Teaneck Creek. And then there was erosion throughout the site so there's multiple storm water out large storm water outfalls that discharge to the park and so that was leading to massive erosion in gullies in certain areas of the park. This photo here in the top right is in an area of the park that was dubbed stormwater canyon it was just this severely eroding belly and then there was a few other locations too where these outfalls were discharging to the park and just creating direct channels either to the water bodies on the park within the park itself or directly to Teaneck Creek and so that was obviously causing a lot of water quality issues and then the site was covered with invasive species so we also had that as an element of our restoration.

Gonna just highlight where these various drivers or challenges were occurring on the site. So we have again the main driver from a stormwater management and hydrology perspective is these stormwater outfalls right here at the end of this is Puffin way or Oakden and then this is stormwater canyon here at the end of Hillside Avenue and so these eroding gullies that again we're just creating basically straight shots to Teaneck Creek into the various water bodies on the on the site. And then there was this heavily eroding brook up here that we also looked to address through a regenerative stream restoration regenerative stormwater conveyance approach. These are dragonfly pond is the one the major water body on the on the property and then obviously all of this ends up draining to Teaneck Creek where there's erosion and flooding issues as well as water quality. I think something we're all familiar with on these very urban sites is invasive species throughout mostly in this area was just filled with frags so this area is was just a huge frag field same thing down here a lot of knotweed on the site I’m not going to go into too much detail on that treatment but the as we've heard throughout the day restoring the hydrology to the site has a huge impact on you know addressing these invasive species in the long term. And then something I just wanted to mention as part of this project is these debris piles various like dumping debris that was put here covered with vegetation, removal of those debris piles was also part of this project as part of the remediation plan just I think important context to have because there was larger site disturbance associated with that. And then the county and the conservancy were really interested in trying to block the noise and disturbance from Degraw Avenue here to busy road and really impacting the site here so there's a component of developing a berm here to really block the park, again not going to be the focus of this presentation. So yeah, focusing on the eroding brook and the eroding stormwater gullies and how that impacts then water quality that's really where the regenerative stormwater conveyance and sand seepage wetlands components of the project came in.

Still the overall goals are enhancing the site natural resources so like I said it's a natural park and it already has some really valuable resources and we were just looking to enhance that and enhance the ecosystem services that they were providing in terms of water quality improvement and flood mitigation in Teaneck Creek. We wanted to increase the biodiversity like I said it's pretty heavily dominated by invasive species which doesn't provide the greatest habitat looking to mitigate the stormwater from those outfalls prevent those the sediment and nutrients from running downstream into Teaneck Creek and then overall just improving the visitor experience when you were out there before construction started you were really kind of walking through just trails of frag for large portions of the site and so we wanted to enhance that experience and allow the community to connect with the natural resources and the ecology of the park.

Here's just some quick metrics on the project so the overall restoration area was a bit over 20 acres the storm water regenerative stormwater conveyance or RSC and the upper northern trib there that restoration was about 430 linear feet we did have some trail realignment but it wasn't a priority in the project and then there were 16 debris piles removed.

So getting into the project approach and you know how we were going to implement restoration on this site. This graphic hopefully you can see it, you know, just generally provides an overview of the approaches that we took that I kind of just went through and I want to focus on the regenerative stormwater conveyance systems which are again at the end of puffin way here at this outfall and at the end of stormwater canyon or Hillside Avenue at the outfall here and then this grading and planting area is the sand seepage wetlands so those are going to be the focuses of this presentation and the idea is that we are mitigating the erosion in the stormwater gullies coming out of these outfalls here and redirecting the flow to this wetland system and so it's very similar to actually the previous two presentations where again, we're really trying to enhance the hydrology and improve the hydrology of the site so directing flow from these outfalls and through this wetland system which is a series of pools and riffles and berms and really holding that water on the site to provide infiltration and treatment before it reaches Teaneck Creek and then at the outfalls themselves providing stabilization and an approach to hold the water and infiltrate it in the immediate vicinity of that outfall as well. So just a little bit of a zoomed in on the graphic here of where these regenerative stormwater conveyance or RSCs were proposed.

And then talking about regenerative stormwater and veins. So RSCs are an approach that we have used Biohabitats and others have used quite a bit down in Maryland in the Chesapeake Bay and this was the first project where we've used it in New Jersey and so it is a pilot project for this approach in New Jersey and I think it is really applicable to other regions as well. So the idea is you have you have these outfalls discharging to an area of a park or an or you know really any sort of landscape and creating these eroding gullies that are washing nutrient-laden sediment and high flows into water bodies and so it's a very flashy system and all of that is causing pollution downstream obviously. And so the idea of an RSC is to try and stabilize that outfall so it's really it's an outfall restoration approach and what we do is this is a kind of typical graphic for an RSC you would have a pipe that's kind of that's coming in and you it might you'd fill that pipe with stone or you can cut it off and then backfill into the gully with a sand wood chip mix and then the idea is to bring the discharge of that pipe up to an elevation where you create a cascade or riffle and pool system that then is stabilized and holds the water in these pools and allows it to infiltrate and you get a kind of hyperate flow through the system rather than just surface flow scouring out a gully so this is a plan view of the you know cascade pool system and then what's going on below the surface where we're filling that with the sand wood chip mix to provide, again, some of that, a lot of the nutrient processing that we're looking for this is a photo of a completed project down in Maryland and I'll show some photos of Teaneck in just a minute.

I don't think we need to go into too much detail on like the actual designs I'm happy to discuss them in more detail during the Q&A but this is a profile and planned view of the hillside or the stormwater canyon RSC again a series of these pools and cascades and so this was a pretty steep system with really high flows and so it it's a pretty robust stabilization approach here where we're using large boulders to create these cascades and provide stabilization to the system but still holding the water in these pools and allowing it to infiltrate outwards and then generally our approach is to use like a pool riffle system to tie out to the flatter section at the end of the at the end of the RSC.

So just some before and after photos this is at stormwater canyon at the end of hillside avenue and you see the outfall here these are both actually abandoned pipes this is the only active pipe in the system flow coming down and really scouring out this area.

So we, the RSC approach is again these series of cascades and pools which are again heavy boulders on the cascades large boulders on the cascades and then this is all backfilled with sand wood chip and the water is infiltrating in there moving down through underground and during large storm events you get the overflow and so these are designed for the hundred year storm so it's all surface flow it's an open channel and since construction we had hurricane Ida come through a number of other large storms and they've held up really wonderfully and you know this is basically what you're seeing this sort of cascade system.

This is just a before and after at Oakdeen, slightly smaller pipe and smaller drainage area not as high velocity so a little bit of a smaller system but still the same approach using boulders mixed with cobbles and again filling that channel with the sand wood chip mix.

And then getting into the sand seepage wetlands, so after the waters convey down through that RSC we direct it to the sand seepage wetlands again trying to elongate those flow paths and restore some of the floodplain hydrology to the site. And so the sand seepage wetlands are a series of pools which is the lighter green here the pools are about one and to one and a half feet deep and then these berms that are holding the water and then the little gray rectangles here are riffles or flow control structures so those are grade controls throughout the system to hold the water higher on the landscape, allow it to infiltrate, allow treatment to occur and create more of this emergent marsh system throughout the site.

These photos are from a completed project down in Maryland and show I think like a good representation of how the system works and so again this is a an engineered wetland but the idea is to provide those ecosystem services in the same functions of a natural wetland and so you have a sand wood chip berm here that's holding the water back in those pools and then those flow control structures which are a cobble gravel mix are maintaining that water level in the pool and it's flowing downstream and you're getting this flow through the berm and through the sand wood chip mix soil that we're putting in.

This is what those upper and lower sand seepage areas looked like before construction you could see it's really out in the distance there that's the area where we're focused on same thing over here just filled with frag and really there's no not much flow getting to those areas it was just being cut through by those channels.

And so these are drone shots that were taken basically just after the grading work was done and so this is how those the sand seepage the wet sand seepage wetlands the pools and the berms look when they're constructed and so these are the flow path structures here and you can see they're holding that water surface elevation quite well and as it's moving downstream it's providing some flood mitigations providing treatment before the water reaches Teaneck Creek Park. I think something just to notice this is in the upper area so like the northwestern part of the site we are also directing storm flows off of that tributary that was that was kind of eroding, we're directing storm flows off of that into this system so it's moving down through the wetlands. This is before any planting so the contractor is planting right now but it's functioning just like we were hoping for. Here's just some photos of it after grading work again this is before planting we have some cattails coming up but this is all before planting happened so there's some invasive control and some prep work that was being done. prior to the contractor planting as well but again just to give you a representative photo from the ground

And this is what the projects down in Maryland look like over time you find finalize your grading you put in you know your restoration grade plant material and then 10 years later we're seeing a really healthy forested wetland system that comes back and so we're confident that that's going to be the case at Teaneck as well.

Lessons learned I think we can all probably relate quite a bit to this one is communication is stakeholders so the county and the conservancy did a great job of doing outreach to stakeholders but couldn't necessarily reach everyone and so when site clearing activities started to occur there were questions of like what are you doing to Teaneck Creek park? People thought we were putting in like apartment complexes or buildings like that and so really conveying the intent of the project is important. It's also important to consider the site conditions so for like RSCs one of the big drivers is the steepness of that gully and how deep is it and sort of what area do you have to work around and so thinking about those site conditions is important I mean here in Teaneck we had this you know kind of awkward or unique position of like this clay liner that was installed in this upper sand seepage area and so how do we deal with that excavating portions of that but leaving it because we're still getting that that flow through the sand seepage berms it was about four feet deep so it just wasn't economical to excavate all that out making sure that the timeline works thinking about invasive control and how that relates to grading and planting work collaboration between project partners . So this was a design bid build so we had a lot of different folks working on it which was helpful site works was providing construction management an alternative approach that we've used quite a bit down in Maryland is design build for restoration and we find that really valuable because it gets the contractor on board in the design process and you can identify potential issues or problems early on and get their input and incorporate that into the design so we've had a lot of success down in the Chesapeake Bay region doing design build for these restoration projects. Another lesson learned is the phasing of this, you know, I think there's different approaches it's a huge site it's an acre site and so I’m thinking about doing beginning and completing smaller sections and how that might help with public perception as well as just things like stabilization and control. And then speaking of site stabilization when you're disturbing this large of an area it's really important to get established vegetation and that requires irrigation, putting down wood chips and various alternative stabilization approaches. And then finally just talking about maintenance so this system is designed to essentially maintain itself once it's established but that's going to require some initial upfront work of keeping the invasive species at Bay and then also maintaining those RSC structures in the early stages. I will say after it's been graded for I guess almost a year now or so and in these sand seepage wetlands where we had these massive stands of frag we're seeing very little frag coming back which is really encouraging and yeah so with that I’m happy to talk in any more detail about it during the Q&A or answer any questions, thank you.

Sheryl: Well you guys made it so you didn't even need a facilitator, that was great.

SNEP Symposium – Science Bringing Solutions Delivering Environmental Improvement to Southeastern Coastal New England

Room 3, Afternoon Session

May 18, 2022

Ian: Hey all, I'm Ian Dombroski You may have heard of me this morning, so I'll be facilitating this session on understanding regional climate change impacts. We've got three great speakers and for, as the other sessions went, please type your questions into the chat during presentations and we'll address them at the end. So first up we, have James Heiss out of the University of Massachusetts Lowell. James is an assistant professor in the Department of Environmental, Earth and Atmospheric Sciences at UMass Lowell. His research focuses on using field measurements and numerical models to understand the influence of extreme events, waves, currents, tides and sea level rise on groundwater flow, salt water intrusion and the chemical transport processes in aquifers along the land sea transition zone. So James, with that, I will hand it over to you and thanks for being here.

James: Thank you, thanks for the introduction. As Ian said my name is James Heiss, assistant professor at UMass Lowell and so this background image that hopefully you can see is a nuisance flooding event in Seabrook New Hampshire and this particular event was in part caused by tides and in part caused by sea level rise. Here in New England and in New Hampshire, generally we can expect sea level rise to be about 1.2 meters by 2100, relative to 2000 levels and in turn that should translate to about a 15-fold increase in the frequency of these nuisance flooding events that I'm showing here. So in this presentation I'm really going to be talking about what nuisance flooding is, what causes it and then I'll talk about some work that my research group is doing, looking at the effects of tidal flooding, nuisance flooding on coastal groundwater systems.

So, what is nuisance flooding, it's also called tidal flooding, as you can see in these two images here, these events can occur during just clear weather or during sunny days, so it's also called sunny day flooding, the events themselves aren't really catastrophic, they don't cause a ton of damage, but they do have important impacts at the surface and because they're, you know, they're not catastrophic, they're also called nuisance flooding events, right, hence the name, but whichever name you'd like to use, together they're just the inundation of coastal areas during exceptionally high tides and what's key is that they occur without the aid of winds or precipitation, so these are events driven primarily by astronomical tides that are becoming worse due to sea level rise.

And as I mentioned there's a number of important surface water impacts that are relatively well known, so there are implications for coastal economies, because restaurant goers, tourists and shoppers can't get to where they want to go, affecting economies, there are other impacts as well, so there are frequent road closures that cause changes in traffic patterns and increased expenses for road maintenance and then there in the bottom left, let me get my pointer here, there are also implications for overwhelming storm drains, which means that even if there is a minor precipitation event, there can be significant flooding, because those storm drains are already overwhelmed, but there in that fourth quadrant there, there's some questions that still remain about the impacts of tidal flooding or nuisance flooding on groundwater systems and in turn how the impacts to groundwater systems might affect nutrient loads to surface water ecosystems, so I'm gonna be returning to that idea and that topic shortly.

But first, I just want to talk about what nuisance flooding is and kind of, what causes it. So this plot here, is a plot showing tide levels in Boston over a two-day time period, this horizontal blue line is the tidal flood threshold, that's a threshold that's defined by NOAA for Boston and it just means that whenever that threshold is exceeded, it will lead to tidal flooding in Boston and in an urban environment over here on the right side, this isn't Boston, but this is Indianapolis, Maryland, but I'm just showing it because it shows in an urban environment what a, in this case, a minor title flooding event can look like, right, so there's a clearly defined elevation threshold that must be exceeded for tidal flooding to occur, so back in this plot here on the left, this is again a four-day or rather a two-day time period, there are four high tides, but only two of them are large enough to result in tidal flooding, so there's a sub daily variability in high tide levels that affects whether or not a tidal flooding will occur. I think somebody might check their microphone to mute.

Over a 35-day time period, right, if we zoom out even more, we can see that there will be periods of the month, where there will be frequent tidal flooding events and periods of the month where there might be little, to no tidal flooding.

if we zoom out even more, then this plot is showing monthly mean high tide levels, again, in this case Boston, so each of these points is the average high tide level for that given month and I calculated these averages out to 80 years in the future, so this is about 2100 and what this is showing is, so zero is present day, what this is showing is that we're kind of in a descending portion of this really long period tide, it's about a 19-year cycle and what that means is that, in about a decade from now or a little bit longer, we can expect a rapid increase in the frequency of tidal flooding events in Boston relative to today, where we have little or a very small amount of tidal flooding. And this isn't new, there's a number of studies that are coming out that are highlighting the importance of these really long period tides on affecting the frequency of tidal flooding events in the future.

But those short period tides and those really long period tides that I just showed a moment ago, all of those, there's different title periods are accounted for in title predictions, right, when NOAA creates their title predictions, they incorporate those different title constituents and I think as everybody listening knows, right, those constituents or tides are really representing the motion of the earth, the earth, moon and the sun system, so right, one kind of quick example would be that the moon's orbit wobbles and actually it's that wobbling of the orbit that's responsible for that about 19-year cycle in in high tide levels.

So this is just showing how tidal flooding is expected to increase in frequency along the east coast of the of the United States, showing city by city, and so down here, this is events per year on the X and so if we just focus on the dark blues, this is kind of the present day number of flooding events, we can see that by 2045, the light blues, there's going to be a rapid increase in the number of these events, really across the board and this is primarily the result of this peak or this ascending portion of that really long period time and so what we are kind of anticipating from a groundwater perspective, is that groundwater is going to be affected, primarily groundwater salinities, will be affected as a result of more frequent inundation of the land surface farther inland of where the intertidal zone is located today.

Okay, so kind of getting at the some of the work that we're doing now. This is a cross section of a kind of a conceptual model of a coastal groundwater system, right, beneath land there is fresh groundwater, offshore beneath the ocean there is saline groundwater and within the intertidal zone and below it, in the beach aquifer, there is a saltwater freshwater mixing zone that forms and it forms because tides and waves move across the beach surface, some of that sea water will infiltrate into the sands and percolate down and it will then mix with that underlying fresh ground water forming, this this intertidal mixing zone. And this intertidal mixing zone is really important because, as again, I’m sure everyone knows, the fresh groundwater can be or can have high levels of nutrients in it and as those nutrients and that fresh groundwater flows through that intertidal mixing zone there are chemical reactions that take place within the mixing zone that can alter the fate and the fluxes of those chemicals before they're discharged into that surface water body and so in this way, you know, beach aquifers and coastal groundwater systems can kind of serve as a an ecological service by removing these nutrients before they enter the surface water and again as everyone is listening is well aware, there are important impacts when there are excess nutrients entering the surface water, so there can be algal blooms which lead to beach closures, to protect human health, there can be anoxic conditions that then lead to fish kills, so it's really important to really understand the different pathways whereby nutrients can enter the surface water, not just the surface water sources but also the groundwater discharge as well.

So what we're really trying to do here and understand, is to look at how coastal groundwater systems, shallow groundwater systems, might respond to increases in tidal flooding due to a rise in, a rise in sea level.

And so to do that, we're using numerical models and this is a cross section of our model domain here, so on the left side of our model, we have fresh groundwater that's inflowing into the model representing groundwater recharge farther up gradient, on the top of the model we are assigning a time varying pressure boundary to represent rising sea level and tides and so the code that we're using here, it's a USGS code, it's called sutra, it's a numerical model, it accounts for variably saturated conditions as well as variable density pore water flow. Okay, so we applied a slope to the top of the model, it was a pretty gentle slope.

We based that slope on Hampton Beach, which experiences a significant amount of tidal flooding, so this isn't in the SNEP region, but of course, tidal flooding can and does occur within the SNEP region itself, so this is just showing that the topographic profile that we extracted there. There's a tide gauge in Hampton, from that tide gauge, we use the 37 set of tidal constituents that NOAA uses in their title predictions.

To create a time series of water levels, tidal water levels, out 80 years into the future and so we took those water levels and then superimposed them onto three different sea level rise scenarios and ran a total of four model scenarios, the three sea level rise scenarios plus a scenario without sea level rise, right, and again the goal here is to see how groundwater salinity, groundwater flow patterns respond to increases in tidal flooding.

So this is just showing the application of those water levels to our numerical model.

So if we were to, kind of look at or rather count, the number of times that this point on the lane surface were to be inundated by tidal flooding events over that 80-year time period that spans our model simulation, we would see that the trend looks something like this, right, so we are expecting there to be a large increase in the frequency of these events and so we're representing them in this numerical model.

So here are some of these model results, so what this is showing, we have three columns, the left column is the low sea level rise scenario RCP 2.6, the middle is the intermediate sea level rise scenario and RCP 8.5 is the high sea level rise scenario, and this is showing groundwater conditions after 15 years and after 15 years, there's been very little tidal inundation and so groundwater salinities look much like we would expect based on our conceptual model, kind of what the groundwater conditions look like today. After 30 years, things start to look a bit different, for the intermediate sea level rise scenario, as those tidal flooding events occur more frequently, the high tide level moves farther inland we find that the width of that groundwater mixing zone has expanded, so it's about twice as wide as it was originally. At 45 years, we can see that there are these density fingers or density lobes that begin to form and we see them even more so after 60 years and these density lobes form because that sea water is infiltrating the land surface, the salt water is more dense than the fresh, so it wants to sink to the bottom of the aquifer, meanwhile that fresh groundwater is flowing to the sea or to the right in these panels and so it's forcing that seawater towards the sea. After 75 years, right, the model showing that there's a much, much larger groundwater mixing zone that forms compared to kind of the present day scenario and so right, we're anticipating that the expansion of this intertidal mixing zone is going to be important for groundwater chemistry and the discharge of nutrients into surface water because these mixing zones or really hot spots of biogeochemical reactions.

So we can kind of view those pore water salinity dynamics a different way. I’m going to be showing an animation in a moment, but before I click go, this panel up here is, again, showing groundwater salinities, this is for the intermediate sea level rise scenario, when I push go, we're starting at the year 2045 and the animation ends at 2070. The panel down here, each of these points is showing the maxim daily high tide level, alright, and this horizontal or rather this vertical line, is representing the time when salinities in the top panel are being shown. Alright, let me get my pointer back, alright and so this is really starting when tidal flooding really starts to kick off, you can see that those landward portions of the original intertidal zone become inundated, it results in infiltration of seawater, increases in groundwater salinity, if I move forward a bit, we can see the formation of those density lobes that try to sink to the bottom of the aquifer, meanwhile that fresh groundwater that's flowing to the right pushes those density lobes farther seaward, right, so we have a really dynamic groundwater system here compared to early on without sea level rise, right, so things are much more dynamic with sea level rise than without it.

Because that intertidal mixing zone is really important for groundwater chemistry or the reactions that take place in it, we quantified the size of that intertidal mixing zone. Let me get my laser pointer back, here over that 80 year simulation time, that's what we're looking up here in this panel, so these four lines are showing the size of that intertidal mixing zone, the colors in that top panel correspond to the tide levels in this bottom panel, you can actually ignore this gray line here. What this is showing, is that after 15 years, right, that's when we get the first tidal flooding events, as we can see here, for the high sea level rise scenario, when that occurs we have an increase in the size of that intertidal mixing zone. For the intermediate sea level rise case, we get the same thing, but it's delayed by about a decade in the after 25 years. Similarly, for the low sea level rise scenario, it's delayed by about five years relative to the intermediate scenario. If we then compare the size of that intertidal mixing zone for the intermediate case to the case without sea level rise, we find that it's about eight times larger than it was originally and so when we look at also the rate at which this mixing zone is growing over time, we find that the model tells us it might be between 58 meters squared per year to 87 meters squared per year and these are pretty large values, 63 meters squared per year is about the quarter of the size of a tennis court per year, so we have some pretty rapid growth rates here.

We also looked at vertical exchanges across the land surface, so right, we looked at infiltration rates across the land surface, as well as groundwater discharge rates across the seabed itself and that's what I'm showing over here, right, so without sea level rise, we have a pretty narrow zone of infiltration of seawater so everything below zero is infiltration, everything above zero is groundwater discharge, so the blue is without sea level rise, with sea level rise that intertidal zone and high tide levels intrude farther inland, so we get infiltration occurring in this case about 100 meters farther inland than the case without sea level rise and we do see as expected, there is groundwater discharge and so this region here of focused groundwater discharge is just corresponding to this portion of the aquifer here, where fresh groundwater is discharging into the surface water.

Ian: Two minutes left there, James.

James: Perfect, yep, so right, these are numerical models and really what they're showing is, that due to sea level rise, there's going to be an increase in the frequency of tidal flooding events which is, you know, generally understood already, but what we're showing here is that the groundwater impacts could be important, we see that there's a large increase in the size of that groundwater mixing zone, which again can be important for groundwater chemistry, so it might be important for, you know, future nutrient management strategies that might be located near the coast, like permeable reactive barriers, that might have the groundwater chemistry around them influenced by the presence of salt water and chemicals in that infiltrating seawater.

So again, these are these are models that are, you know, simplified, right, so what we'd like to do next is observe these groundwater responses to tidal flooding in the field, to kind of calibrate our models and to provide a more realistic kind of groundwater numerical simulation, so if anybody has access to or is aware of sites that experience tidal flooding within the SNEP region, please get in touch, we really like to calibrate our models when possible. Thanks very much.

Ian: Great, thank you James, that was very interesting and I'm sure a lot of people might take you up on that offer of areas with floods, so perhaps next, Elisabeth, maybe you could bring up your slides while I introduce you. So Elisabeth and I'm sorry I'm going to butcher this, Cianciola is the aquatic mitigation specialist for the Massachusetts Department of Fish and Game and their In-Lieu fee program and it is her third year in that role, she holds a BS in Environmental Science and an MS in Natural Resources and her prior work experience in, she also has prior work experience in the nonprofit sector as well as environmental consulting. So with that, I will give it over to Elisabeth. Thanks.

Elisabeth: Thanks Ian. Good afternoon everyone, today I'll be speaking about a watershed approach to environmental restoration and preservation on a changing coast, so definitely echoing some themes that you've probably heard in other sessions of today's symposium.

In my role, I support the Department of Fish and Games In-Lieu Fee program. Under section 404 of the Clean Water Act, the Army Corps of Engineers requires compensatory mitigation for unavoidable impacts to aquatic resources. An In-Lieu Fee program allows core permitees to make monetary payments rather than conducting mitigation for impacts on their project site, but there are a couple of conditions that govern the use of In-Lieu Fee payments. Payments are only allowed for impacts that remain after avoidance and minimization measures have been implemented. The Army Corps, it gets to decide whether on-site or In-Lieu Fee mitigation is most appropriate for each project and an In-Lieu Fee program sponsor is the entity that will then use the payments to fund mitigation projects and these projects can take the form of resource preservation, enhancement rehabilitation and restoration.

As shown in this table, multipliers are used to ensure that projects funded by In-Lieu Fee program provide greater ecological benefit than simply improving an area that's the same size as the area that was impacted, for example, the fee for impacting a tenth of an acre of wetland would be used to restore at least two tenths of an acre of wetland and as you'll see on the far right, preservation projects have the highest multipliers because they don't replace the functions that are lost when wetland or other aquatic resources are permanently impacted.

The Massachusetts In-Lieu Fee program was established in 2014 with the Department of Fish and Game as the sponsor. All In-Lieu Fee programs use geographic service areas, in Massachusetts we used a combination of watershed and ecoregion boundaries to define service areas, so on this map, from the far left in green you'll see the Berkshire Taconic service area and yellow is the Connecticut River service area, in beige is a Quabbin Reservoir, Worcester Plateau service area and on the right, you'll see our coastal service area divided into north, central and south sub areas and the service areas are used for the purposes of aggregating the payments to fund projects, so that even relatively small payments can contribute to larger projects.

Analysis done for the program's five-year report showed that the majority of ILF funds in Massachusetts come from projects in the transportation and utility sectors, this is fairly typical of an In-Lieu Fee program because linear rights of way don't offer very good opportunities for environmental mitigation, so an off-site alternative is usually more successful.

This is a map of the locations of impacts that have paid into the Massachusetts In-Lieu Fee program, as well as projects that have been approved to date and I show this to illustrate the density of activity on the coast of Massachusetts, so the majority of the program's work is happening in coastal watersheds.

The In-Lieu Fee program's goals are outlined in a document called the program instrument. A couple of those goals are listed here, to protect high quality aquatic resources under threat of loss or adverse change, to restore degraded wetlands that are connected to high quality wetlands, to restore riparian buffers on agricultural lands, to restore habitat continuity in coldwater streams and along the coast, and to facilitate coastal wetland migration to adapt to sea level rise.

And I wanted to take some time today to focus on a couple of projects that the program has going on in the SNEP region and I've grouped those into three different categories so we have some land conservation projects, some tidal restoration projects and then a couple of restoration projects that are still in the planning stages.

For the Yarmouth Reef project, the Department of Fish and Games division of marine fisheries or DMF, deployed about 2,000 cubic yards of repurposed construction material over a two acre area of subtitle habitat to introduce structure, some aspects of the project went a little bit differently than expected, for example, the transportation costs ended up being a little bit higher than they had estimated because some of the material was granite and it was transported to the site primarily by land, whereas DMF had initially planned to use primarily concrete that they would transport to the site by water, inclement weather also delayed the deployment of the material for a few weeks after the site was marked, which gave the markers some opportunity to move, but overall the broad dispersal of material off of the barge was effective in meeting the project design.

So the project was able to meet some construction specifications that indicated the majority of the space should be structured, but also have some openness to it and DMF is measuring both that compliance with the construction specifications and ecological changes on the site using the side scan sonar, both before the deployment, after the deployment and at a natural reef that they're using as a reference site and this monitoring will continue annually until 2025 and will include evaluating some metrics around ecological diversity and the productivity of the site.

The Nantucket Conservation Foundation also did a reef installation project with the In-Lieu Fee program, they installed a smaller reef, about 0.17 acres in November of 2021 on the meadowly creek salt marsh system, they used about 500 oyster castles as the structure for the reef and supplemented that with 30 shell bags seeded with over a million oysters spat, this project will also include purple crab trapping and some native cordgrass planting in a, about a one acre area behind the reef that has been experiencing some dieback

And this project found a couple of lessons learned that they'd like to share with the group and I will point out that this project is also being presented in greater detail in one of the other sessions today, if you'd like to check out the recording, so this project found that securing the permits prior to purchasing supplies or setting oyster spat was very important because the permitting process can be a bit lengthy, they found that practicing assembling the oyster castles on dry flat land would help the volunteers that were doing the assembly on site to be able to work effectively in water where the water may become turbid and they might not actually be able to see what they're doing with their hands, they might be working by feel and not surprisingly, of course, to plan the installation to happen during the lowest tide possible, again so that you can maximize how much you're able to access at the installation site.

So transitioning to the preservation projects that I mentioned, Mass Wildlife has used In-Lieu Fee funds to purchase land on the Nemasket River in Middleborough, this property includes about eight acres of marsh and six acres of forested wetland, the property includes the left bank of about five thousand feet of the Nemasket River and both banks of about another 1,000 feet of the river, but the majority of the property is forested upland habitat.

Although there are some challenges with utility easement and some ATV activity on the property, we found that it's providing some very valuable turtle habitat and the property is being effectively managed as part of the Taunton River Wildlife Management area.

Buzzards Bay Coalition also used In-Lieu Fee funds to grant a conservation restriction to the Westport Land Trust. The property includes, excuse me 3.6 acres of forested wetland and about 46 acres upland and 3,600 feet of a stream, the property encompasses the majority of the Lyons Brook Watershed, which drains into the east branch of the Westport River.

This property has some public walking trails and has been posted with signs about the project, so we encourage you to check it out if you're in the area.

The last projects that I’ll describe today, haven't been implemented yet as I mentioned before. The first one is an eelgrass restoration project that's planned by the Nantucket Land Council, they're hoping to restore about half an acre of eelgrass at two different locations, both of which have historically supported eelgrass and monitoring data collected recently suggests that the sites have suitable conditions for supporting eelgrass now. The planting would be spread out over a three-year period beginning this year and the site would use a reference site on Hussey Shoal to determine whether or not these restoration sites are on track to developing self-sustaining eelgrass meadows, that we'd like to see.

Lastly, the Chop Chaque Bogs project would restore about six acres of retired cranberry bogs by removing water control structures, moving sand off the surface of the former wetlands, pluggings and man-made drainage ditches that you can see in the aerial imagery here around the perimeter and through the center of the site and also to roughen the bog surface that's been compacted by the sand on top and the mat of cranberry vegetation. The site is owned by the Town of Mashpee and the plan is to have the Native Land Conservancy hold a conservation restriction on the site, to provide long-term protection of the restoration.

For additional information about the Massachusetts In-Lieu Fee Program, including annual program reports, project reports and fact sheets and announcements about available funding, we encourage you to visit the program website, thank you.

Ian: Thanks a bunch Elisabeth, that was great and I see that some questions are already flowing in. So, unfortunately our next speaker was to be Alicia Lehrer from the Woonasquatucket River Watershed Council, she unfortunately needed to not attend, but we do have a recording. So, I will give a brief bio and then I will pull up that recording. So Alicia Lehrer joined the Woonasquatucket River Watershed Council as the executive director in March 2008. She holds a BA in environmental science from Columbia University and an MS in natural resource science from the University of Rhode Island. Alicia's work at the WRWC, that's the Woonasquatucket River Watershed Council, has included spearheading migratory fish passage restoration at the first five dams on the river, working with partners to determine cleanup efforts of the center dale manor superfund site and leading the Woonasquatucket River greenway expansion and also the improvement and maintenance on that project. Alicia joined the clean water actions effort to establish the Rhode Island Green Infrastructure Coalition back in 2014 and has remained an active member to this day. This partnership has helped inspire her to create green infrastructure demonstration projects in Olneyville and Elmhurst, which are both right outside of Providence and begin to develop larger plans to help make the Woonasquatucket River corridor more resilient in the face of climate change. Alicia also serves as the Rhode Island Paths to Progress on the Rhode Island Path to Progress committee, working to establish a network of active transit, which is biking and walking trails, across paths in Rhode Island. So I will share my screen, one second here.

Alicia: Hi everyone my name is Alicia Lehrer and I'm the executive director at the Woonasquatucket River Watershed Council in Providence Rhode Island. I have been executive director there for 12 years and I love what we do. Today, I'm going to be sharing our work called Greening the Woonasquatucket River Greenway, purpose of that project is to clean water, create environmental justice, community engagement and resilience.

This is the Woonasquatucket River Watershed, it's about 52 square miles and although it is just a tiny little watershed, in a tiny little state of Rhode Island, we actually encompass more than a quarter of the state's population because our river runs right through downtown Providence, Rhode Island and it is the only urban wildlife corridor through the city of Providence.

Along that river, we have created the Woonasquatucket River Greenway starting from downtown, moving west through the city of Providence and then up in through Johnston, Rhode Island. That greenway is seven miles long and 75 acres of park land.

Like other rivers, the Woonasquatucket is prone to flooding, in the lower river, where its tidal up to the first dam along the river, we have the compounded problem of storm surge, sea level rise and regular flooding that comes from stormwater and then up a little bit further along the river we definitely also see the impacts of flooding just from the dense concentration of development in the upper watershed.

We've seen this firsthand, in March 2010, we saw some floods that occurred in Olneyville, it closed the only local supermarket for the neighborhood of Olneyville and here's one of the main streets, Valley Street on Olneyville,in Olneyville.

A little bit about Onlyville, because we're doing a lot of our greening the greenway in Olneyville, because it is an environmental justice neighborhood, so there's more than 7,000 folks that live there, it's a very high environmental justice index place, 92nd percentile for all environmental justice indexes in all of region one for EPA and in the state of Rhode Island, it's extremely high for a minority population, low income population, linguistically isolated populations and population that has less than high school education, it is also the highest density native Spanish-speaking population in Providence.

So we really chose to work there to improve quality of life and resilience for that community as an environmental justice community and to do so, we built a successful public-private partnership to green the greenway, I'm just going to take a second to explain how that works. Us, as the watershed council, we build partnerships in places where we can do projects, you'll hear more about that, we leverage funds, in this case, we've leveraged funds from the Southeast New England Program to do the greening the greenway project, matching a whole lot of other funds. We secure loans, so that we don't have to carry the load of the cash cost layout for construction on these projects and our own staff does the landscape construction and maintenance. Our big partner is the Rhode Island Department of Transportation, that's currently under consent decree for their stormwater management under their MS4 permit, as a partner, they provide funds for feasibility and design for our projects and they also provide some of the construction funds and they get some of the credits, for that consent decree, toward their consent decree. The property owners we work with, that can be public, private or even other non-profits, create an agreement to allow us to work on their property and continue to do maintenance there.

I'm going to explain the first pilot project that we did here. I spoke about Olneyville being our target area for greening the greenway and this project took place in a big parking lot right in the middle of Olneyville Square, which is the main shopping area for that neighborhood. Westminster Street is where all the shops are and San Souci Drive is a one-way street that flows, that goes right next to the Woonasquatucket River in Olneyville. That parking lot, directed stormwater straight from the buildings and the parking lot here into the Woonasquatucket river, no treatment, do not pass go, do not collect 200 dollars.

We asked the property owner at the time, that was Citizens Bank, whether they would mind if we took up some of their pavements, while maintaining most of their parking spaces, to do this stormwater improvement, they were amenable because it didn't cost them anything and we improved the look of their parking area, we improved the look of downtown Olneyville and they were happy to work with us on it, so they provided us that construction and maintenance agreement, we took up six thousand square feet of impervious surface, retained 38 parking spaces and the entrances and exits for them and created this bio-retention basin that captures most of the stormwater from the parking lot and their building, while also creating a beautiful walkway between the main drag and the river so that people can get from downtown Olneyville right along the river and enjoy it.

Concurrently, we were building a spur of the Woonasquatucket greenway along San Souci Drive and this is a rendering of what it looks like, this is built now, here's what the rendering of that green space and green infrastructure construction looks like at that parking lot.

Here it is under construction.

And this is what it looks like now, so an amazing improvement to an area that was just blacktop in Olneyville Square.

I also want to point out how important it is that we do all of the landscape installation and maintenance ourselves. This is our crew, the Woonasquatucket River Rangers, they are young people that we hire right from the neighborhood to train them in being the stewards of the river and the stewards of the

Woonasquatucket greenway and now they're learning skills on how green infrastructure works and how to maintain it, so they're the stewards of these spaces as well and they love that, because it's additional job training that they can use later in their lives. We also have signage that we attach to every project, in both English and Spanish, explaining to the public what's going on there, so that we're creating community buy-in and education.

After we started that pilot project, we looked at a lot of other sites in the greenway, especially in Olneyville, along the watershed, to determine where our next projects were going to be, so we created this matrix to help us determine what the highest priority projects were and some of the things that go into that matrix are whether the property that we're looking at drains directly into the river, whether it's well connected to the greenway and visible from the greenway, if there's matching funding opportunity, do we have existing partnerships, what's the educational opportunity we want people to see these things, are we get giving right out the stormwater credit that they want and then we add in some extra points if it could be like a new section of greenway or have some other great feature to it and then we take off points if there's some site restriction or something else, but that helps us direct what the projects are that we're going to do first and next.

And then we create maps that go along with all of the project sites to help us understand the ways that we're working. I want to show you this map, this is one of the maps, this one shows the Citizens Bank pilot project right here in Olneyville Square and you can see that we have a lot of projects in the surrounding area, we want people to see these projects as they're along the greenway so that they can understand that this is not just an isolated incident, but it's an initiative to improve the entire neighborhood. This yellow line here shows another project that we just completed and then the other highlighted areas are places that have been selected as possible project areas.

I'm going to show you another project we just completed called greening and cleaning Manton Avenue, that was the one that I showed that was under construction and it was using green infrastructure features, nature at work features, to capture and treat stormwater right along another main thoroughfare through Olneyville, Manton Avenue and before we began this project, all the stormwater went directly into pipes, right to the Woonasquatucket River, we installed four tree filters with attached catch basins to interrupt that flow and capture the stormwater and then added landscape elements to green up the street there and make it more inviting and a greater place to be.

Here's one example, right in front of a Dunkin Donuts, on Manton Avenue.

We added in the tree filter with the attached catch basin and these sidewalk planting areas and here we're capturing a great deal of the runoff both from the sidewalk and the street and treating it before it goes into the river, that happened all up and down Manton Avenue.

Our next project that we're very excited about, is working with Farm Fresh Rhode Island on their food hub, which is right next to a section of greenway near downtown Providence. We're going to be planting all the green infrastructure, our river rangers are going to be doing this, at the end of September and this food hub is going to be a place where people are gathering for farmers markets, for outdoor events and all the food that's grown in Rhode Island and distributed to folks that use it in Rhode Island, are going to meet at this spot, so this is a really exciting place to have visibility and improvements for stormwater along the Woonasquatucket River, here's the river over here and all the green infrastructure at this site captures 100% of the runoff from this site, so we're thrilled to partner with Farm Fresh.

We've got two more projects in design, one at the Puerta de Refugio, which is a church on Valley Street, remember one of those streets we saw that had intense flooding and Cathedral Art that makes art and gifts for cathedral gift shops, it's right across the river from that original pilot project here in Olneyville Square.

And then this project also spurred another SNEP project that our partners at the City of Providence Planning Department just received, to add a great deal of green infrastructure to a new section of greenway that we're creating from Eagle Square to downtown Providence, that's going to create a very strong connection between downtown Providence and the rest of the greenway and the rest of the river, and over in this area, all the water runs right off the streets into the river, here now we're going to be creating a new separated bikeway and green infrastructure that captures the stormwater before it goes into the river here.

That's pretty much my presentation on Greening the Woonasquatucket River Greenway. I appreciate you taking the time to visit with us today, please feel free to contact me with any questions, I love talking about this project and we will see you next time, thank you so much for joining us.