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Moderator: Courtney Chambers
June 26, 2012
12:26 pm CT

Courtney Chambers: Good afternoon everyone. My name's Courtney Chambers and I work at the ERDC Environmental Lab and Technology Transfer for Ecosystem Restoration. I'd like to welcome you to today's web meeting on CASM the Comprehensive Aquatic Systems Model and then also a bit about the adaptive hydraulics tool as well.

I'll give you today's speakers on CASM and ADH. Dr. Tony Clyde is a limnologist in the Tulsa District's Planning and Environmental Division. He's responsible for water quality investigations, environmental compliance, ecosystem restoration studies, and national environmental policy act compliance and documentation, and currently represents the Southwestern Tulsa District and the Southwestern Division on the USA Headquarters Water Quality Committee. Dr. Clyde currently serves on the Adjunct Graduate Faculty of the Environmental Science Program at Oklahoma State University and the Adjunct Graduate Faculty of the University of Oklahoma Health Science Center College of Public Health Department of Occupational Environmental Health.

Our other speaker today is Dr. Candice Piercy. Candice is a Research Environmental Engineer at the Engineer Research and Development Center in the Environmental Laboratory Wetland and Coastal Ecology Branch located in Vicksburg, Mississippi. Dr. Piercy is a member of the integrated ecological modeling team and conducts research on the role of hydrology and hydraulics in aquatic and wetland ecosystems. She's currently developing coupled ecological-hydrodynamic modeling capabilities within EL which is the environmental laboratory. Additional responsibilities include the development of hydraulic, hydrologic, and small water shed models to describe the hydrologic condition of wetland or aquatic ecosystems.

More information about Tony and Candice can be found in their bios which are posted on the Learning Exchange with the rest of today's meeting documents.

We're very thankful for their willingness to share with us today. Okay, Tony at this time I'm going to give you the presenter rights and we can begin.

Dr. Tony Clyde: Okay, and I'd just like to thank the environmental lab for the opportunity to share some of this work that we've done in our work associated with the Red River Chloride Control Project for the (unintelligible) River Basins is of Oklahoma and Texas.

This application is specific to Lake Texoma to address potential impact from that project at Lake Texoma. So the objectives of this CASM application order is I evaluate those various chloride management alternatives that we've been assessing over the years and its various considerations since about 1993 or 4. We designed it to look at future with and without project applications. And primarily based on input from past meetings - again dating back to the mid-nineties with the natural resource agencies - we were directly assessing the relationship between total dissolved solid, light extinction, and primary productivity in the reservoir with concerns related to reduction in total dissolved solids or chloride control would impact primary productivity and that would be realized through the food web in the lake.

Additionally in 2006 we had peak problem of golden algae bloom that lead to substantial fish kill not a significant fish kill but a substantial fish kill in

January of 2006. And so we included some key problem relationships between total dissolved solids and the other nutrient dynamics in the lake as well.

Because of long-term storage losses that have been documented by the Corp and other state agencies in Texas we've also incorporated sedimentation relationships into the model to look at sediment issues as related to chloride management alternatives. And then ultimately to evaluate what are quality in the model populations within the lake looking at the responses to the various chloride scenarios.

So the CASM itself - the Comprehensive Aquatic Systems Model - it's a basic ecosystem model with water chemistry and food web components. Depending on how you set it up and parameterize it you can have it function on both stational and temporal scales. And it basically simulates daily water quality parameters based on a math balance approach looking at the external inputs from the water shed - if those are available. If not they could be literature derived or best professional judgment provided. Internal dynamics within the lake and then the nutrient recycling components within the lake are based on a producer/consumer relationship in assessing those biomass states on the model community that you based on community structure that you put into the model.

Each application in the CASM has the flexibility to create a specific food web for that application. So for every application, you can have a different food web with different key compartments depending on the investigation objectives.

And here its production output is grams of carbon, Dr. Steve Bartell the coordinator of this model, he had put out things in total biomass, or I guess it was in a total standing crop in the past. And he's gone to a more common or a more standard approach of just looking at grams of carbon and output of all of the compartments including fish that you can back track that out looking at dry ways and wet ways environment going back to total standing crop in terms of fish and phytoplankton and zooplankton types of community.

Most of the information that goes into the CASM is either literature derived or site specific data. And the constants are derived from those data utilized in the model's calibration.

In terms of Lake Texoma, we have quite a bit of historic data going back to the mid-1970s. So we were able to incorporate quite a bit of on-site specific constants; light saturation and sinking rates, respiration, those kinds of parameters in the model.

So the basic producer of bioenergetics then are based on just that change in bioenergetics that inflow and outflow, photosynthesis within the lake, sinking rates, mortality, grazing, respiration, all go into that producer bioenergetics.

And so for the difference equation, it's basically you look here at the photosynthetic rate, temperature, light limitation, nutrient limitation, this habitat modifier is similar to suitability index that you would see in a habitat suitability type of application where it's a trapezoidal function. Its unit list runs from one to zero. And so it's just basically what is the quality of the habitat on a scale from one to zero similar to HEP analysis.

Respiration and then sinking mortality, again, loss to grazing and then (physical scour) as well. So consumer bioenergetics are very similar in looking at consumption or ingestion and egestion, respiration, just activity - general activity - energy utilized just in moving around, gonad promotion or production, excretion, and immortality and predation.

And, again, here's the difference equation looking at that. And it still has that habitat modifier in there. With the producer of populations that habitat modifier is based on salinity, current velocity, and water depth. And in the photosynthetic reaction or the primary producer reaction or equation for that is the geometric mean of those three components of the habitat quality modifier.

In the consumer because it's water depth, current velocity, salinity, at least in Lake Texoma it averages about one part per trillion but it's significantly more saline than other lakes in the area. It also includes dissolved oxygen in that habitat modifier particularly when you're looking at the consumer populations of fish.

So in Lake Texoma historically we've been able to identify based on water quality parameters primarily the total dissolved solids, chloride, sulfates, magnesium, potassium, sodium, some real distinct zonal patterns in the reservoir.

And so in Lake Texoma and the Red River arm here we have this Red River zone, a Red River transition zone, a main lake zone or body, and the dam is here. Then a Washita river transition zone and Washita River zone and that's just based on the zonal patterns that were identified by (Kimmel Thorton and Payne) historically in some of their work.

And the food web structure for Lake Texoma is fairly complex but pretty straightforward. It includes major compartments of cyanobacteria, green algae, micro flagellates, and diatoms, and then a separate key carbon compartment here in this iteration of the model.

Zooplankton, rotifers, (talenoids), (podosteras), and cyclopoids, those were all based on data collected in the lake from previous chloride studies. And then (dressed in) shad, gizzard shad is the primary prey fish or striped bass. The resource agencies in Texas and Oklahoma that we've coordinated with as well as the Fish and Wildlife Service have concerns that the striped bass population in Lake Texoma will be impacted through chloride management alternatives and implementation of the project in the basin.

And so all of this work has been leading to trying to assess what those impacts truly are to the striped bass population specifically because it's quite an important economic component of the lake. It's a naturally producing population of striped bass one of the few lakes in the United States that have a naturally reproducing striped bass population. So there's very little stocking that goes into that now. And it brings in people from all fifty states when you look at the data provided by the Texas Parks and Wildlife Department and Oklahoma Department of Wildlife Conservation.

We also included some other (unintelligible) fish, some other sport fish in here as well as some basic information on aquatic insects, anthropods, and mollusks. Lake Texoma is the plant - the primary production in the lake is primarily through phytoplankton. There's very little parasite and very little emergent vegetation and very little submerged vegetation in the reservoir.

So once - once we got this all parameterized and got everything in and started looking at the model just during the calibration phases we started looking at some of the historical data that was out there. And, again, we're primarily interested in impacts on primary productivity and how those impacts are moved through the food web.

So we looked at extinction coefficient, (unintelligible) depth, and some of the annual productivity data that was produced in past studies. And I'm going to go back to this map real quick. These stations here are fixed stations. They're long term monitoring stations the Corps has established for water quality purposes in general and this study specifically.

The data at all these stations go back to again the mid-70s. And each one of these reservoir zones we modeled a basically a compartment, a column of water that was representative of the volume of the lake in that zone. And so in some of the studies were compared to, Station 3 and Station 24 in the upper river zones where a great deal of work was done and some of the primary producer and production studies.

But we moved this up to Station 1 so Station 1 and 3, Station 25 and 24 in the historical data equally describe that particular zone of the reservoir.

So that when we start looking here, Station 9 and that transition zone of the red river arm, Station 24 in the real green zone is a Washita river arm and then Station 17 in the main lake body we were able to look at actual data from the University of North Texas.

And the CASM output and we can see here that you know the mean - we're basically on the same graph paper, which is not always a bad thing when you're modeling.

But we get pretty good agreement between - at least on the means, minimum, maximum, we overshoot a little bit on the CASM but in terms of secchi depth that means secchi depth is pretty consistent with what we've measured during past study periods.

Secchi depth we see a lot of the same things as if the mean secchi depth of these various transitions or these various zones of the reservoirs, these stations, be fairly consistent.

Although we have some issues with Station 17 where we missed that a little bit and we think that's due to the volume of the (ethalimni) versus the volume of the hypolimnion in that particular part of the lake.

That is there's some mathematical equation or some of the equations look at average temperature over the entire water column, we think we've got some temperature issues with the model.

But that's the only station where that shows up, it's also of course the deepest station in the reservoir and this was pretty important when we started looking at this, just look at the percent of total annual productivity.

The - past studies we were able to look at percent annual productivity and broke it out by bacteria, green algae, diatoms and micro flagellates and were able to look at these intensive stations in previous studies.

Station 3, 9, 17 and 22 in the Red River zone, Red River transition main lake body and the Washita River transition zone. We were able to look at grams to (unintelligible) to meters square per year and then with the CASM output with the model columns at one, Station 9, Station 17 and Station 24 look at what our estimates of total annual productivity would be.

Breaking it out by the various compartments as the primary producers and we're able to find quite a bit of agreement between the various groups of algae contributing to that primary productivity.

Historically Lake Texoma it's shifted since at least the mid-90s and maybe a little bit prior to the 90s, but we've had this shift to a final bacterial dominated alga assemblage. And that's throughout the year although seasonally diatoms become a little bit more abundant and outnumber (sinofites) in the winter months.

But the differences between the model output and the actual measurements were pretty consistent across the board that we were within the ballpark with the model as we initially began to calibrate it and with the parameters that we had with the initial parameterization.

So after a little bit of minor tweaking to look at some of the light extinction and look for additional light data, surface light intensity data for the area, we were able to start looking at some of the future without project development.

And in the future without project conditions that we wanted to assess when we initially set up the model, we wanted the ability to look at what the impact of sediment rates in the reservoir were having on reservoir productivity over the longer term. Outside of just this project from an operational standpoint, you know what management alternatives may we have to look at operationally as well as just related to this project.

So we looked at the degree of annual environmental variability and the water quality parameters over 30 years with data that we had, and then also turns included the ability to turn on or off that environmental variability with or without sedimentation.

And the sedimentation rate at Lake Texoma is about 10,000 - a little over 10,000 acre feet per year with about 7000 acre feet of that sediment being deposited in the conservation pool and the remainder being deposited in the flex and soul pool. And then looked at this over a 50 year planning horizon, some of the basic results were that just looking at the annual environmental variability, we saw about 12% variability on an annual scale in (phytopoints) and biomass and then striped bass biomass we saw about 17.5% variability just inter-annual variability.

No chloride control at all, so when we grab this out over that 50 year planning horizon we've got biomass and metric tons of carbon per year, we need to see this interannual variability year 8, 16, 24, 32, 40, 48 is what's presented here. But this is no chloride control project, it's interannual variability differences in temperature, light intensity, primary productivity, secondary productivity and consumption rates.

When you look at the effects of sediment impact on the reservoir and that loss of reservoir storage and just looking at the primary producers then you can see over the longer term there is a loss in primary production over that 50 year planning horizon.

We still have quite a bit of interannual variability but we definitely get a decreasing trend of biomass over the planning horizon.

And we see a similar thing for striped bass again about 17.5, 18% variability on an interannual rate but when you look at sediment, without sedimentation you would just think everything is ticking along fine and we're just going to have striped bass production remain steady throughout the future 50 years of the lake.

But when you look at sedimentation impacts on the reservoir you see that a great deal of interannual variability still but again a negative slope indicating a trend of decreasing primary productivity and some of that -or decreasing striped bass productivity.

And some of that is based on - at least some of the hypotheses that we have in what we're seeing here is that as the conservation pool is continuing to be filled with sediment and that storage capacity and the loss, what we think we're seeing here is a couple of things.

Decreased primary productivity also paired with what fisheries, biologists term the thermal squeeze or the ever shrinking volume of the (epilemnia) during periods of stratification and so over time we lose thermal refugia and this decrease in population in overall biomass is likely due to mortality from thermal stress and the lack of thermal refugia along with increasing volumes of (inopsic) water that's not available to them during a critical time of the year in July through September.

So then future without project conditions that we assessed was to look at decreased light penetration in the water due to increased turbidity resulting from decreased total dissolved solids compensation.

That decreased light penetration is hypothesized to lead to decreased primary productivity rate and then ultimately be transferred up the food web to decrease support fisheries, biomass and also a decrease in catch rate and recreational opportunities in the reservoir.

Previously in a different iteration of the chloride control project ERDC came out and took water from Lake Texoma and took it back to the environmental lab and conducted a series of sedimentation rate studies and analyses in large scale microcosms at the Vicksburg facility.

And what (Schervin and Toro) were able to see is that about 85% of the variants in the sedimentation rate at Lake Texoma was due to varying total dissolved solids concentration and that 13% of the variance is due to differences in initial turbidity.

So the hypothesis this time was then that there is a potential impact due to the varying total dissolved solids concentration in Lake Texoma and as we decrease those there would be an increase in sedimentation rates.

However when we looked at the initial turbidity of 8 and 16 NTUs in that Trevor and Furrow study we found that there was no significant difference in the sediment rates between the two initial turbidity values.

And that has from a planning perspective for the (Fulta) district in terms of communicating results with the resource agencies, that's been somewhat contentious and which is what leads us to this round of CASM applications to Lake Texoma.

Because 85% of the variants and sedimentation rate was due to varying TDS concentrations yet there was no significant difference in the settling rates between the two initial turbidity values.

So in this application we looked at alternatives of zero, you know no project, zero percent TDS reduction, 4%, 8%, 12% and 16%. Once fully implemented the chloride control project would have a target reduction of about 8% of total dissolved solids.

And again that's what the spatial gradient in Lake Texoma are set up on as reservoir zones are strongly denoted by the CDS gradients in Lake Texoma.

So Lake Texoma is really a great place to look at just dilution and at section components of TDS as it's transported through the lake and settling rates in various portions of the lake.

So when we started looking at just the effects of environmental variability without project in terms of this zero reduction in CDS and at the various target levels again 8% is our target reduction once the project is fully implemented in the upper basin. But even doubling that to 16% you can see that we have a great deal of interannual variability, that's the same variability that we saw without project but that in the peaks and troughs is about where we see any distinctions between some of these and even with TDS reductions we see modeled outputs that show greater production in some years at the peaks or leading up to these peaks of biomass concentrations relative to the trough's low points in biomass production.

When we look at that same output with the sedimentation component activated and accounting for loss of storage due to sedimentation, under these various chloride management alternatives we can see that that same decreasing trend of (phytopoints) and biomass outputs in the lake over the 50 year planning horizon is significantly observed, definitely observed. And again we don't see hardly any difference between the target reduction rates that we assess here, again 4, 8, 12, 16% reduction that was modeled versus the without project conditions.

And we see similar outputs for Texoma striped bass population, this is striped bass as a whole, we have the ability to look at young a year, juvenile and adult striped bass individually in the department.

You see here again still that great degree of interannual variability, the various scenarios that were modeled here range from about 17 to 20% interannual variability but without sedimentation really no significant impact on the striped bass production.

When you look at sedimentation rates as well as the chloride alternatives, you still see that interannual variability but that declining trend in biomass output of the reservoir particularly tapering off at year 40 through 48 and a lot less variability. Again it's hypothesized at this point that what we're seeing here is that as we continue to lose about 6000 acre feet per year in the conservation pool that what we're seeing here is there's less interannual variability for multiple reasons.

One is that we're also pushing the upper limits of the model, looking out 50 years and the other thing is that we're also reaching the impact where we're starting to see significant influences from the thermal squeeze and the loss of thermal refugia and increasing Gnostic volumes that the hypolimnion during stratification.

So as we were pulling this together for inclusion in our planning study some of the discussions that we had in house were you know looking at statistical versus ecological significance and is the CASM model appropriate and is it an appropriate tool to give us that ecological significance is ultimately what we're trying to look at are the ecological outputs and the ecological impacts to Lake Texoma from chloride management alternatives implemented in the upper basin.

Statistically you may have a statistical difference but it may not mean much on an ecological spatial and temporal scale.

We have continued to develop (peep) parvum that golden algae model compartment of the lake, we completed some additional work in 2011 with the collaboration between the University of Oklahoma biological station at Lake Texoma.

We've been studying (peep) parvum for the last five years in Lake Texoma and so they had some interesting data and some new toxicity data that was incorporated into the cell point and end (phytopoints) and departments of the model.

And we also were able to obtain a little bit of zebra mussel data specific to Lake Texoma. We have confirmed populations in - of zebra mussels in Lake Texoma in 2009. And in 2010 we were able to collect some (belliger) density data and some settling rate data for the lake that's been incorporated into the model as well.

Although a lot of the zebra mussel dynamics that were put into other versions of chasm for I believe Rock Island district in the upper Mississippi basin. We incorporated some of those dynamics for lack of other dynamics available in the literature. But we do realize that that's limited, that there are some different dynamics in Lake Texoma in terms of temperature tolerances, salinity tolerances that aren't experienced in the Mississippi river.

Let's see, some of that - filtering efficiencies related to zebra mussels could present a more serious impact than the chloride management activities, primary productivity. That's still something that's ongoing, while the population of zebra mussels is well established in Lake Texoma it hasn't totally taken over every solid substrate in the lake.

So the degree to which the filtering efficiencies is going to impact primary productivity is still ongoing in studies with the University of Oklahoma and Texas parks and wildlife department, looking at that.

And then some of the things that we've continued to look at is that other issues at Lake Texoma like zebra mussels, like (peep) parvum, additionally with (harmp) larval blooms becoming more of an issue within the Tulsa district and in the state of Oklahoma and Texas.

The historical data that we have is showing Lake Texoma is single bacterial dominated, there's some anecdotal evidence that harmful algal blooms have impacted some aspects of recreation in 2006, there was a report of a dog death that was attributed to cyantoxin exposure. And then last year a blue-green algae outbreak across the state that lead us to posting some advisories and warnings at Lake Texoma and other lakes in our district that you know there's always this constant desire for more data.

You know and you need more data, or do you just want more data, and you know, what does it cost to get that data. But the hydrology that was used in this application of CASM was modeled using dyn-high 5, attached to WASP which is an EPA model that was put together for ecological impact assessment during a previous iteration of chloride control studies.

And so we're still trying to figure out whether moving to ADH to put that direct link to the physical model to better understand where sediment is being deposited and how is it effectively being moved through the lake and some of the other nutrient dynamics in the reservoir. So we may be able to better assess and move out just from a planning approach to being able to use this more as an operational model as well that we can use to look at operational management alternatives longer term.

With that I'll turn it over to Courtney again.

Courtney Chambers: All right, and Candice I'm going to give you the presenter rights now and you can share your desktop. Candice we can't hear you, are you on mute still?

Dr. Candice Piercy: All right, yes I was.

Courtney Chambers: Okay.

Dr. Candice Piercy: So Tony has set me up perfectly to lead in to what I'm going to be talking about which is this dynamically linking ADH and CASM. So I'm going to back up a little bit and talk more generally about some - broadly about what is the benefit of this dynamically coupled modeling approach.

So just generally some environmental issues in the 21st century, they're quite complex. We're dealing with changing climatic conditions, we've got to include sea level rise. There's also changes to land use including increasing urbanization and we're dealing with a dynamic system so we really need models to tell us what we can expect, project - I'm not going to say predict because I'm not sure that we really can truly predict but we can project what we think is going to happen in the future.

And under all of these complex issues it really needs to use holistic approaches to understand the system. The reductionist approaches of the past where you isolate one variable and analyze it in the laboratory aren't truly capturing the dynamics.

So that brings us to this sort of idea of coupled hydrodynamic ecological models. So when we have ecological systems that rely on a hydrologic component it can be flood plains, (scenic) environments, lakes, estuaries, whatever. The ecological system really depends on what's happening in the physical system and it needs to be coupled to truly capture those dynamics. And there's several ways to account for behaviors and cause for assistance.

CASM is a suite of models, there's also fish behavior models, there are population dynamic models. So this coupled hydrodynamic ecological approach can apply to any of the ways you want to capture these ecological behaviors.

So benefits of this coupled ecological hydrodynamic approach is that we can capture this dynamic impact. So ADH CASM in particular can capture that dynamic feedback between constituent transport and biota. So you can actually capture the uptake of nutrients, you can capture the release of nutrients say in a fish kill or something like that.

There's a couple different ways you can couple models, one of them is a one way approach which is what we were doing with Lake Texoma where you actually apply - you have the physical condition provided by a hydrodynamic model where you have say salinity or total dissolved solids and you feed it into the ecological model. There's also a two way couple which is what this ADH CASM couple is, where you actually feed the physical environmental parameters into the ecological model. And then you run that and you actually can simulate the nutrient uptake or reduction of total suspended solids say from filtering. You can feed it back in to this hydrological model so you actually can capture that behavior.

It's also intrinsically spatially explicit so to capture the hydrodynamic within an ADH match which I'll show you what we're using out in the Chesapeake Bay, you actually have to have spatially explicit results and you will capture that hydrodynamic behavior.

You also embrace temporal variability of flow and water quality and the ecosystem dynamics, for instance where we're working in Chesapeake Bay there are these low dissolved oxygen events that happen during the summers when you have these - it gets really hot like in some of the basins, the highly urbanized basins in Maryland and the Potomac River and you actually get this plume of high temperature low DO water that comes into the bay.

You can actually capture that dynamic. Just a caution though, frequently the scales that are important to hydrodynamic models are not necessarily important for ecological purposes.

For instance say the physics of ADH require you to resolve at a very small concept, 15 minutes, 20 minutes. That's kind of insignificant for an oyster that would - that's going to live several years. So you end up having this conflict of temporal scales, you may also have a conflict of spatial scales whereas some of the hydrodynamic models again in Chesapeake Bay may have very large grid size that are hundreds of meters by hundreds of meters.

Whereas you haven't - I'm using my example of oyster reefs, that are only a few meters wide in some spots. So you actually have a conflict so you really need to make sure that your temporal and spatial variability is resolved between the two models.

So just briefly talk about ADH I'm sure many of you have heard this spiel before, ADH is a suite of hydrodynamic pools, there's a computational engine and it can link to unsaturated ground water flow, models, complete (unintelligible) equations for modeling hydrodynamics in and around structures.

And then the shallow water equations and this is the part of ADH that we're actually using for our application. And this is actually how the ADH CASM linkage works.

You have ADH, I hope everyone can see my pointer.

Courtney Chambers: Yes we can.

Dr. Candice Piercy: Thank you Courtney, have your hydro input that go into ADH and then ADH will crank for - CASM runs on daily time stamp, ADH will crank for a day then it will stop. It will kick its environmental parameters, the water quality information, the current, all of that over to CASM.

Where it actually will run one time stamp of chasm and then you'll actually simulate growth and uptake for that one day and then it will feed it back to ADH and modify that water quality feature so you actually have the dynamic feedback.

And they run simultaneously. And you can get any number of outputs from this so what's been used in the past you can use this directly for environmental benefits, for actually measuring - let me go back - probable effects, population biomass, community structure actually sees how things are changing dynamically.

So these are just some of the ADH CASM outputs that have been developed - actually derived before you can get them to transport deposition if you turn on the sediment transport portion of ADH and see how that affects your bio - you can see what effect if you were to mediate those low DO events, what effect would that have on your (unintelligible) and ultimately on your keystone predators within the Chesapeake Bay.

So our focus has been on oysters. Oysters are pretty important to the bay, mostly because they are so threatened. The oyster population is at 1% historic levels and it's an important fishery, both culturally and economically.

Oyster fishery, it's worth more than $100 million annually, it's hard to get you fingers on exact numbers since you calculate them. But oysters also provide tremendous environmental benefits from water quality, biodiversity, storm protection.

Oysters are also quite complicated because they are an ecosystem engineer, they actually modify the flow around them, they filter the water quality so this dynamic feedback is very important to capture.

So that's why we really needed to use a tool like coupled ADH CASM. There are other organisms that also do this such as SAV and even - you can even look at flood plain forests for this dynamic feedback where you actually see a direct influence of leaf out in bottom land hardwoods on the water table.

So capturing that feedback is really important in certain systems. There's also a variety of different viewpoints on how to restore oysters and maintain the fishery and that's where the Norfolk district actually came to us with their question.

Working in a tributary of Chesapeake Bay called the Great Wicomico River in 2004, nine reefs were restored with additions of shell and spat on shell and how they go about this is they basically take this shell and spat on shell, put it on a barge and blow it off with the water cannon.

And they were actually - the build up the reef symmetry that way. There was - this study was published in science, they restored the recent both lower and high relief reefs, are historically how oyster reefs have been restored in the past.

They go and blow as much shell off as they can and they build it up to about 10 to 20 centimeters above the existing bed height. High relief reefs, they build it between 30 and 40 centimeters so just a little bit higher and it gets away from that sort of high - that area of high sediment concentration right near the bed.

Consequently even though they almost doubled the reef site, you can barely tell the difference in the symmetry when you actually plot it out on the symmetry map. This is directly from ADH right here, you can barely tell the difference. So we really needed to use this ecological tool and CASM to capture what the difference was between the two - the low relief and high relief reef.

Because as they found Dave Schulte who is this guy here, he’s an oyster biologist in the Norfolk district found oyster density of five times greater in high relief reefs and the hydro alone isn’t going to capture that.

So we had - we decided to come up with three different modeling scenarios to find out what effect oysters have on water quality in the vicinity of the reef.

We had pre-construction which showed no structure, no oyster structure and no function. Just the reefs alone where we just looked at the effect of changing the symmetry we didn’t turn on CASM.

And then we applied CASM to capture the effect of the oyster reef structure and the function. And the structure is important because you actually do see the effects of bi valve on our flow, this video is from Dr. Jessica Kozarek who works at the St. Anthony Falls lab at the University of Minnesota.

I believe this is a Ward E back freshwater mussel but their feeding habits are similar to oysters and you can actually see how the shell itself in the flow can affect the boundary, the flow in the boundary and you can actually see that this mixing behind the shell itself.

So you actually do - there is a physical change as well as an ecological function. So this is our ADH mesh, this is the Great Wicomico river it's situated directly south of the Potomac River so those low dissolved oxygen, that's what I mentioned before just flow right up into those little tributaries every summer.

They're - here are the nine reefs, you can see highlighted in white there and this mesh is - we had to create increased node density in and around the reefs to be able to capture the hydrodynamic variability in and around the reefs.

This is the CASM food web for the Chesapeake Bay. This is a reduced complexity web, you can get very complex with these, this is directly from work by Dr. Steve Bartell from 2003, this is from the Pawtuxet river but it applies to the entire bay.

We're interested primarily in oysters but we also need to include striped bass in this just because these do have that sort of predatory relationship.

And this is basically up here is our reduced complexity function of grant parvum for meter squared and the environmental parameters directly affect the growth rate of each of these groups.

Sorry if I'm stumbling over the terminology, I'm an engineer, not an ecologist. But here's briefly we're just getting into our results now, this is basically our hydrodynamic results of the flow in and out of the river and you can see how the reefs are kind of situated in the shallower areas up here. And have lower velocity which is good for not shooting your oyster larva out into the deep parts of the bay where they have no hope of surviving.

And we're just getting into our results right now and we are seeing on average about a 5.6 reduction in percent in total percent of solids at reef one which is right near the mouth of the Great Wicomico River and we're analyzing more and more results each day to figure out what the direct impacts of those reefs on water quality.

So the coupling of these models we actually can get those direct benefits out, the total percent of solid reduction nutrient uptake, all of that. It also captures the critical system processes and then captures these feedback loops in the interspecies dynamic so you can actually see what effects management may have on your food web structure.

So coupled modeling in general, not just CASM as the ecological model if you wanted to incorporate it to some population dynamics model or this sort of agent based fish behavior model you can actually see the - actually directly measure ecosystem model services. And how management affects different multiple levels of the structure so you can look at these (unintelligible) plankton all the way up to (unintelligible) in the lower Columbia.

We also can use our modeling capabilities to examine those future conditions that are really tricky to kind of project out such as sea level rise and ocean acidification and we can look at issues across scales, we can - this approach allows us to get as detailed as we need to be or as coarse as we need to be.

It also has this holistic approach so we can capture those system dynamics and we can also use the food web in itself can be developed for any system. It's data intensive like Texoma and the Chesapeake Bay are very fortunate areas because they are quite data rich. If you have a skilled ecological model you can figure out ways to use surrogate data as needed but you also can target what areas you may need for future research needs.

So management implications for this, we can do this sort of scenario analysis, we can look at different harvesting strategies for oysters. We can look at different hydrologic management scenarios or climatic regimes and we can develop this sort of system level risk assessment which is important as we move forward into sort of this era of unknown climate conditions.

And the modeling tools also provide a mechanism for actually visualizing those dynamic feedback loops which may be hard to intuitively gather just from your general knowledge.

So that concludes my part of this talk, here's some contact information from - for each of us. I've done this work in conjunction with Dr. (Todd Swannack) who is my ecologist and any ecological questions you may direct towards him.

I am the engineer who primary does the hydrodynamic modeling but that's an important thing to note about this ADH CASM, it does require a multidisciplinary team because no one person can do both things.

But I'll turn it back to Courtney for any questions now.

Courtney Chambers: Okay great, thank you Tony and Candice. I'm going to go back to our other screen so that we can see our chat screen. One second.

Dr. Tony Clyde: Courtney this is Tony, I just wanted to add that all of the output that Candice showed being produced by the CASM ADH application for Chesapeake Bay also are available in all the versions of CASM and the various applications if we can generate those specifically for Lake Texoma for any of the compartments or for the lake as a whole.

Courtney Chambers: Okay great, thank you Tony. We did have a question, it got sent to me on accident, how does CASM compare to RMA 11?

Dr. Candice Piercy: I'm going to have to let Tony answer that one, I'm not...

Dr. Tony Clyde: And I'm not familiar with RMA 11.

Courtney Chambers: Okay, well this...

Dr. Tony Clyde: But I can - if you forward that to me I can do some homework and answer that.

Courtney Chambers: Okay, I'll forward that to you, that was from (Rob Whitler), I'll forward that information. He said he had to get off the meeting early.

But perhaps you could...

Dr. Candice Piercy: I can forward that on to Todd as well he probably would have a better knowledge of that than I would.

Courtney Chambers: Okay thanks. And then we had one from (Ellen Cummings), she said these sound like programs with large data requirements, how much time or money does it take to run?

Dr. Tony Clyde: I'll - Courtney do you - or Candice do you want to?

Dr. Candice Piercy: I can take some of that, I guess it's...

Dr. Tony Clyde: Well yours is a different - yours will be a different answer than mine.

Dr. Candice Piercy: It will be and my answer is going to be the classic engineering answer of it depends. So if you have an area where you already have ADH developed then the time and money does get reduced substantially because a big chunk of the time is actually developing hydrodynamic models.

If it's already developed then all you're really developing is the CASM model. If you're in an area such as Chesapeake Bay where a lot of your work is already done for you as far as developing that CASM, Dr. Bartell has already developed that food web. Your data needs are reduced and you can probably get it done and fixed. I'm going to put a six month ballpark out there just for our - that's how long our particular part of the study is going to take.

But you have to add on six months for the hydro development on there too. So it really is going to depend on how large of an area and how easily accessible those data are.

Dr. Tony Clyde: And for the Texoma application in CASM we had a separate hydrodynamic model outside of ADH, there's some computational time issues with running current with ADH that we didn't have.

And so actually to run a 50 year simulation in terms of just running the model it takes me about five minutes. And once it's up and running the time and money that it takes to get it to that state of readiness is dependent upon the type of study and what questions you're trying to ask obviously.

So classic ecological answer as well, it depends on what you're looking for, but you know for our application I can tell you it was about $180,000 to have Dr. Bartell do the work.

And that data was already available, he didn't have to do a whole lot of data collection. And we over the last 30 years out of all of this data is related to chloride control activities is probably $3.5, $4 million overall.

(Ellen Cummings): So they are - this is (Ellen), thank you both. So they are pretty data intensive and therefore possibly costly to do. So you're not going to do them for small projects.

Dr. Candice Piercy: No, they would be for more complex projects. At least within our team down here we try to get you - we try not to use the Cadillac if you know we - if you can do the same job with like a riding lawnmower.

Dr. Tony Clyde: And not that W2 is a riding lawnmower by any means but we can get a lot of similar outputs from W2 in terms of water quality and primary productivity impact.

What we don't get is some of the food web dynamics and our food web it's for the Texoma application was agreed - we sat down with the resource agencies at a meeting, brought Steve Bartell here. And we created this food web based on input from all of the stakeholders. And so that can increase your complexity as well and so while we had a lot of data that cost a lot of money over 30 years, it was all geared towards Lake Texoma and chloride control.

But if you - the more simple your food web design is, the less costly data collection parameterization, calibration will be for that application of CASM.

Dr. Candice Piercy: That is a very good point too and there's also several different versions of CASM and it will also depend on how complex the version you're using.

(David Lagarl): I have a question, this is (David Lagarl) from the Chicago district, thank you Tony and Candice for a great presentation. We're doing a similar ecosystem restoration project in northwest Indiana called Cedar Lake, much smaller than Lake Texoma.

And we used EFDC to run the hydrodynamics in that system and then we developed our own HSI which is based on the trophic state index. We did not do a food web modeling. My question for Tony is I kind of came in late, I apologize for that but when I did walk in your slide was talking about secchi depth. Does your model look at atrophic state index at all?

Dr. Tony Clyde: Our model did not directly look at atrophic state index but we can definitely calculate predicted TSI for phosphorous secchi depth or chlorophyll based on the outputs.

What I was showing there in that slide was that once we parameterized the model and that was one of our early runs before we did a whole lot of calibration activity and we were already starting to get really good comparisons between measured and predictive values for the lake.

(David Lagarl): Great. My follow up question to that is I'm not sure where you are in the feasibility study, and where model certification is, can you touch upon that Tony?

Dr. Tony Clyde: I can and we are at the FSM point for this particular study and the - we have not gone through the approval process for CASM applications like Texoma yet. The chloride control project if some of you are not very aware of it, is an ongoing project in the upper Red River Basin of Oklahoma and Texas that is funded by congressional ads, it's never in the president's budget.

And it doesn't meet current OMB or HQ policy so it's just a congressional ad study and we don't have those any more. And so we are out of money, so we don't know when we're going to be able to get it approved or certified for the single use but we anticipate that would be an additional $120,000 cost to go through that process.

(David Lagarl): and I assume the eco PCX, you've already coordinated with them on this model?

Dr. Tony Clyde: We have been coordinating with ERDC and the eco PCX for the last 18 months, two years or so.

(David Lagarl): Well I sure hope you get your funding restored, it sounds like it's a great project. Thanks a lot.

Dr. Tony Clyde: You're welcome.

Courtney Chambers: All right, if there aren't any other questions if you do have a question just go ahead and speak up, I'm sorry, I'll give you one last opportunity before we close today's meeting.

(Ellen Cummings): Okay, I have - this is (Ellen) again, I have a curiosity question, are striped bass a native species to the Lake Texoma area?

Dr. Tony Clyde: And that's the $4 million question. No they are not, they were stocked in Lake Texoma I believe in 1972 or '73, may have been later than that.

But they were stocked, it was a successful stocking, they were stocked for a series of about 8 or 10 years and once the population densities and size classes developed they were able to - there's enough open river upstream in both the Washita and the Red Rivers that they have that 40 miles or so of flowing river that keeps the eggs buoyant and oxygenated. And so that they actively spawn in both of the main stems of the lake.

Courtney Chambers: All right, thanks Tony and thank you Candice.

Dr. Tony Clyde: And I guess (Ellen) I have a follow up then, is that related to - well I'll add it's a significant economic sport fish in the region, it's estimated to be about a $40 to $60 million fishery, just the striped bass alone.

So there's been a lot of emphasis by the resources agencies for us to focus on impact to striped bass even though they are not native to Oklahoma.

(Ellen Cummings): I'd say it's a recreational resources, not necessarily an environmental one then.

Dr. Tony Clyde: Exactly, yes. We agree.

Courtney Chambers: Okay, well based on our time we're going to go ahead and begin wrapping up at this point but thank you again Tony and Candice for sharing this capability of joining the CASM and ADH models.

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