US ARMY CORPS OF ENGINEERS
Moderator: Courtney Chambers
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Courtney Chambers: All right, at this time I'm going to give you today's speaker on environmental flows. Mr. Kyle McKay is a research civil engineer with the U.S. Army Research and Development Center in the Environmental Laboratory. Prior to joining ERDC Mr. McKay received a Bachelor of Science in Environmental Engineering from Colorado State University where he constructed and tested physical models of hydraulic and static processes at the Engineer Research Center. He also received a master's from University of Illinois Urbana-Champaign in Civil Engineering where his research focused on improving discharge predictions in flooded rivers. Since joining ERDC in 2007 Kyle's research has focused broadly on examining ecological effects of infrastructure projects. Some of his research projects have addressed quantifying environmental benefits of ecosystem restorations, fish passage improvements, environmental flows and management, vegetation flow interaction and the effects of woody vegetation on levee integrity. Mr. McKay serves as the USACE representative to the International Navigation Association working group - on alternative bank protection methods for inland waterways. Then from August, 2011 to 2012 Kyle participated in the Army Corps of Engineers long-term training program at the University of Georgia where his doctoral research focuses on managing freshwater for ecological objectives. He is stationed in Athens, Georgia to facilitate cooperative research between ERDC, the University of Georgia and EPA Ecosystem Research Division. This information about Kyle can be found in his bio posted on the Learning Exchange with the rest of today's meeting documents for your future reference.

Kyle, we're really happy to have you with us today. And at this time I'm going to give you the presenter rights and we can begin.

Kyle McKay: Okay, thank you, Courtney.

Courtney Chambers: Yes.

Kyle McKay: I'd like to thank you all for joining us today. Today I'm going to talk to you about different ways of managing water for environmental objectives. So before I get too far into it I want to acknowledge everyone that contributed both directly and indirectly to this presentation. These kind souls have started my thinking on the topic more than once and I really appreciate all of their help. I've sort of written up for today's presentation - what you see on the left are a few key topics that we're going to cover today. So the first is a brief review of the larger research topics on environmental flows and how this presentation fits into that. The second is a quick review of what are environmental flows and how am I going to use that term. Sometimes I may say e-flows - just in case, I'll go ahead and point that out - and then what are different types of environmental flows and what are fish passages and then applying environmental flows.

So we all know that there's a high demand for freshwater ecosystem services and that water managers inside and outside the Corps must make tough tradeoffs across conflicting objectives. And this isn't unfamiliar to the engineering world. So here, in yellow, I've shown some typical related objectives for water management - things like provision of municipal water supplies, flood risk management, navigation interests.

But quantifying ecological response and managing water for environmental objectives is a little more tricky. So here at the bottom I've shown some common environmental objectives - things like habitat provision and ecosystem processes like facilitating nutrient dynamics or nutrient retention.

So it gets tricky when we're trying to conceptualize these larger topics that aren't quiet as, well, at the time.

I also want to point out that when I use the word "tradeoffs" I don't necessarily mean that the opportunity - we're sacrificing one objective for another. In many cases win/win scenarios can be identified between both environmental and economic objectives.

So how do we manage water for these environmental processes? Well the traditional viewpoint is - or the easiest to conceptualize, maybe is infrastructure management shown in the upper right - things like managing a reservoir or managing navigation pools and looking at the effects of different ecological end points.

But we can manage these environmental flows in other ways as well whether it be channel operations or something like reshaping stream banks to change hydraulic patterns on floodplains or it could be through purchasing water rights in the West or managing withdrawals or something like levee setbacks. These are just a few of the ways that we can manage how water interacts with local ecosystems. But the question remains what flow levels are needed to sustain these healthy ecosystems. So our research project has three primary questions that we're tackling.

The first is what alternative techniques exist for modifying hydrographs in ecologically meaningful ways? And this is what I'm going to talk about today, this task one.

Secondly, how do we quantify ecological response to changes in hydrologic variables? And this is the issue of slow ecological relationships? How do we couple hydrology with an ecological response variable?

And then third, how do we roll that up into a decision and what techniques are appropriate for assessing tradeoffs between environmental and economic objectives?

Today I'm going to focus primarily on task one but I did want to briefly mention tasks two and three just to give you an idea of what else we're working on.

So for engineering objectives the relationship between different river levels and response variables is often much more clear. For instance, when working with municipal water supplies we want to keep the intake submerged or when working with flood risk management, we want to keep peoples' feet dry, or when working with navigation we want to maintain draft depth. But for ecological processes the relationship between discharge and the ecosystem integrity is much less clear and part of that is that ecosystem integrity or some sort of ecological incline can be measured through a variety of different ways. For instance, I mentioned habitat provision for an endangered species or managing population demographics for that same animal. So things just aren't quite as clear in ecological grounds so people often work towards the slow ecology relationships and there are many techniques for developing these relationships.

There's a variety of statistical models that have been developed of every variety one can imagine. But for this project we're focusing on two particular topics.

The first is a more incremental improvement to the state of the practice of habitat modeling. And what we're doing is we're working to incorporate stochasticity to hydrographic stochasticity into applications using habitat models such as HEC's ecological functions model.

The second test we're working on is a more long-term view which seeks to provide a more objective means for identifying ecological thresholds in the flow target. And in this task we're adapting existing techniques from geomorphology in river engineering and applying them to ecological processes. And in particular the technique we're using is effective discharge analysis which provides a means of combining discharge magnitude and frequency into a suite of different metrics.

Martin Doyle and some other folks, in 2005, kind of kicked the tires on this concept but now we want to delve in a little deeper. And we're doing this first by examining the sensitivity of effectiveness analysis to the uncertain models that we use in ecological modeling. And secondly we're working on adding new dimensions of the flow regime, things such as duration, timing and rate of change to this framework.

Additionally, environmental flow problems often require some combination or trading off of multiple objectives. And we're addressing multiple criteria techniques for application to environmental flow problems. In particular, we're interested in ones that combine different lines of investment such as habitat, population survival or recruitment rates - these ecosystem processes like carbon transport and things like behavioral (unintelligible).

Many environmental flow problems are real-time or management oriented issues. So we're also working to develop techniques for incorporating ambient water availability so when there's drought we operate or maintain water in a different way than when it's a very wet year. We probably do.

Again, this is not - these topics aren't the primary focus of this presentation today. But I am happy to follow up with anyone interested in more details about these two ongoing efforts. But we should probably get back to the primary focus of the day.

So what are environmental flows? Some folks refer to these as in-stream flows by the way. This is a seeminly simple question but this has been tackled by a lot of folks and from a lot of different angles. And if you start looking to the literature on the topic it can be very, very overwhelming.

There is a ton of work both in the peer review - journal-centric view of environmental flows, as well as applied boots on the ground realm of water management. And the people participating in these discussions have ranged from groups like NGOs, such as the Nature Conservancy, to agencies like the Corps' The Sustainable Rivers Project. But even larger groups like the World Bank and the United Nations have weighed in on this topic.

So it's kind of all over the place. But what it comes down to, for me, the easiest definition was the one that everyone got together and agreed on in 2007. So at a conference in Australia in 2007 over 750 scientists from over 50 countries including Corps personnel got together and defined environmental flows as follows.

Environmental flows describe the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.

I've added some emphasis here just to drive home the point that it's both quantity, timing and quality. And I'll focus mostly on quantity and timing today but the role of quality shouldn't be overlooked.

I'll also point out that this definition emphasizes sort of the classic Eugene Odum way of thinking which is that humans are a part of, not apart from, their ecosystems so you'll notice here both human livelihoods as well the health of an ecosystem are included in this definition.

So how do we conceptualize hydrographs? Well this gets challenging and there are two primary approaches that have been applied to address this topic. The first is the natural flow regime paradigm and the second emphasizes different environmental flow components.

I'm going to start with the natural flow regime and in this - in a similar article by Leroy Poff and others they highlighted five different elements of the flow regime. But it's magnitude, frequency, duration, timing and rate of change and how these variables are combined change where the river hydrographs typically work (unintelligible), as well as how an ecosystem responds to it.

And each of these different elements can influence different aspects of the environment whether it be water quality, physical habitat or biotic interactions as complex as something like competition. And then those all in turn feed into the forager concept of ecological integrity.

And one of the biggest take home messages for me in their discussion is that hydrologic processes greatly influence ecosystems' health and they do it through a variety of different avenues. So making sure that we first understand hydrology and second, understand how that influences different environmental endpoints is critical to river management.

(Stewart Bond) and (Angela Arkington) followed this article with another in 2002 where they said well, specifically, how does the natural flow regime influence ecological processes and they identified four key principles.

The first, in the upper right, says that hydrology sets the physical template which then influences biotic diversity in a particular area.

The second emphasizes that hydrology influences different life history patterns for aquatic and riparian animals. So whether you're looking at cottonwood germination or sturgeon spawning these both fall under the category of life history patterns governed by hydrology.

Third, they've highlighted how hydrology influences connectivity between ecosystems, whether it's lateral connectivity between a river and its flood plain or longitudinal connectivity between head waters, a main stem river and the estuary. Hydrology certainly influences those.

And, fourth, they suggested that invasive species are less adapted to these disturbance regimes characterized by the natural flow regime and that maintaining the natural flow regime suppresses invasives to some degree.

So this is the second primary way that people have used for conceptualizing a hydrograph which relies on environmental flow components. And here, working from low to high flows, they highlight everything from extreme low flows during droughts. You can think of these as what we've traditionally coined, minimum flows, to things like base flows as well as high flow pulses in small floods which may influence flushing of algal growth or floodplain access to large floods which could impact channel movement or long-term sediment (unintelligible).

Now, how can we go about using these different conceptualizations of a hydrograph to modifying them for environmental flow purposes? Well, there have been more than a few methods suggested for doing this. In a fantastic review in 2003 Rebecca Barnes identified over 200 methods that have been applied.

But here what I'm going to use is the definition of environmental flow alternatives as - as - I'm going to use it in a very general sense of any scheme or rubric for managing water for environmental objectives. And what I mean by this is, what is the logic for flow management and, in particular, environmental flow management.

You'll notice that here I'm talking about how we manipulate hydrographs, not how we measure ecological response - that I'm saving for that other task. I mentioned Task 2 where we're looking at flow ecological relationships.

So today I'm going to go through each of six different categories of environmental flow methods and I'll discuss a few key features of each of them. In the literature you see four broadly acknowledged categories - things like hydrologic methods relying on indices such as minimum flow indices or sustainability boundary. But you also see hydraulic methods relying on parameters such as weather parameter or cross-sectional area.

And then you'll see added complexity with things like habitat analysis for specific (taxa). And then holistic methods started to emerge where people started working with environmental flow management from a multi-objective viewpoint, not just for threatened endangered species but also for maintenance and sediment and nutrient processes in the river.

And then recently, since that fantastic review in 2003, two other techniques have kind of emerged from the literature and that is application about optimization technique and application of techniques at a regional level. So we'll go through each of these one at a time.

So hydrologic methods, generally, are simple rules that can be applied from a desktop computer. Usually these are based on long-term data and can be applied very rapidly. However, they sometimes can have relatively low ecological relevance in terms of they may be relevant to one specific (taxa) for which they were defined, but they may not capture things like high flows as well.

So, for instance, minimum flows would be slotted a specific amount so here I've shown a hydrograph in black that's been modified by a minimum flow in the red line there and it goes down to a basement threshold where no more withdrawals can happen.

Another alternative would be something like a sustainability boundary which was proposed by Brian Richter and others where they specified a percentage of water can be removed all the time from the river, even during low flow.

And here you see both of those compared and importantly here are three that does the withdrawal and these have equivalent withdrawal volumes but they look very different in terms of their effects on the hydrograph. But in terms of the amount of water provided to a local municipal area, they're identical.

So a second technique that people use is hydraulic rating. And here those hydrologic metrics are translated into hydraulic parameters such as weather parameter or sheer stress variables. And typically these are used to look for thresholds or break points in curves relating discharge in a hydraulic parameter.

Historically these have been applied largely with habitat methods. And there hasn't been a ton of activity using these specific methods and very long so there haven't been a lot of recent developments. And part of that is because of how closely tied they are to habitat analysis which have developed significantly over the years.

So in habitat analysis typically a group is looking at requirements of an individual (taxa) or a build to (taxa). So you may be interested in a specific authentic garter like the Halloween garter in the Southeast or you may designing around a generic concept of a small (unintelligible) fish that doesn't move very much.

There's a very long history of habitat analysis including things like the in-stream flow incremental method or IFIM and there are many, many tools available to do these types of analyses.

The Hydrologic Engineering Center's ecological functions model is a really fantastic tool and I encourage people to talk to John Hickey about two new developments ongoing with that model. And in that case, that model can be used not only to do habitat analysis but to look at some other ecological functions in a geospatially explicit way.

So as these models have developed there's been increasing computational precision because we can do things like develop two-dimensional hydraulic models now. But there still remain some weaknesses such as the habitat is not necessarily what we're interested in. So, for instance, habitat - we're not interested in building habitat for endangered species we're interested in maintaining an endangered species. So populations are what we actually value, not the habitat for that population.

So some base level assumptions could be criticized but these have been demonstrated to hold up in court and they have a long legal precedent as well as based on some repeatability and predictive capacity as well, so these are very strong tools for doing environmental flow analysis.

Following from those, people began to suggest these more holistic methods which rely on multiple objectives and in particular these types of recommendations come in two flavors. The first is a top down approach where typically a river is looked at deviation from a reference or an unimpaired state.

And then conversely, you have bottom up approaches that effectively assume there is no water in the river and then add components back to a hydrograph until they reach a hydrograph that they think mimics the natural flow regime. These typically have a broad ecological basis and focus on the whole ecosystem but they can sometimes be resource or time intensive to develop but not always - not always. These can be developed rapidly.

So in terms of optimization, most of the literature on this topic comes not from the ecological world view but instead the economic and engineering applications in those four operations. And typically these are formulated around three different types of functions, objective functions, constraint and penalty functions. And these models are really powerful at optimizing what flow regimes best meet those functions but again it requires pairing with a holistic method to identify what those key objectives are and what the structure of them would look like.

Recently there's been a large push for these regionalized methods, in particular the ecological limits of hydrologic alteration, or ELOHA, is a method that's being applied a lot of different places where flow recommendations are made from many strains on a particular basin. And for a variety of ecological processes and then they can be applied rapidly throughout a region.

Some of the advantages are that once developed, these can be applied to broad spatial scale. But again, they can take some time and resource requirement, depending on the level of detail of interest. Importantly, there have been a lot of recent developments and this seems to have quite a bit of traction in the literature and in application. And there's already been evidence of more than 11 states and five countries applying this method since the paper came out in 2010. So people seem excited about this and it seems like a strong way to move ahead.

So now, given those six options, how do we decide which method is appropriate for our given application? And so, here I'll review a few key guiding questions and topics that come to mind and might help sort through which method is appropriate. So here I'm going to use kind of a crude example of choosing the right tool for the job and using multiple tools on a single job.

So say you're hanging a picture in your house. Here's a photo of me hanging some of my art. I need a particular tool, I need a hammer to hang that. But in many cases, these methods are applied together.

So, for instance, if I were building a retaining wall, like this fine structure in my backyard, I would need both a hammer and a post hole digger. So again, just reminding folks that it's all about choosing the right tool for a particular application, there is no silver bullet that works for every single environmental flow decision.

One of the key things that comes to mind initially are what are the project's objectives and how do we get a clear roadmap for where we want to go with this particular project and what are we trying to accomplish? And this not only streamlines planning of environmental flows but also helps with monitoring environmental flows because clearly you're monitoring to protect your objectives.

Again I'll point out that habitat is not the only end point, not the only project objective that could be set it could be related to population demographics. For instance, maintaining a specific survival rate for a threatened endangered species, or maintaining ecosystem and energetics in terms of carbon dynamics or carbon flows through a flood plain. So there are lots of different project objectives that can be measured many different ways but it helps people get on one page moving ahead together.

Next what comes to mind is what is the project scope, what is the spatial extent of our analysis? If we're working in a reach that's two miles long, we probably want to develop a very high fidelity approach, maybe using localized habitat modeling. However, if we're developing a regional approach and there are thousands of miles of river, we may not be able to develop habitat models for that particular problem.

So again, the tool has to fit the job. Some key constraints that come to mind are of course time and resources. But there's also some others, like the level of controversy and the need for a tool that stands up in court or the availability of expertise for a particular application.

And then finally at the bottom, I've mentioned operational limitations. Sometimes these are critical to bring up at the very beginning of the project scope and process. For instance, clearly explaining flood levels to the team before you get started to make it clear what the limits of high flows may be in a particular system.

Another key element of working with environmental flows is that these problems are typically best tackled by multiple disciplines and potentially multiple end-users of the water. So identifying a process for how the team should function and what the team dynamics are is critical. Whether it's who should be on the team or how are the experts going to be used in the process, whether it's identification of flow threshold, establishment of habitat suitability models, or maybe they're identifying flow targets in another way.

It's nice to have that listed out from the beginning, what you intend the team members to bring to the table. Some good practices for working with the panel approach have been listed here and I'll go through these. But I also want to make the note that it's - some of these are very useful beyond the context of environmental flows.

I think these are overarching good practices that extend to a lot of different environmental problems. Again, the first is what is - how is the team going to function? The second is what are the project objectives and, third, how are we collecting and managing data?

Are there data holding requirements that we want to establish? Maybe there are and maybe there aren't. How are we acknowledging both our knowledge uncertainty as well as uncertainty about future conditions?

Next, how are we considering both social and environmental implications of these recommendations? There are implications for both when you're changing hydrographs in any way. Next, how do we develop our standard for documenting our process as well as our findings? And then finally, how do we identify our knowledge gaps and include decision making in the future?

Next, there are a few kind of in-the-weeds sciencey topics that probably need to be addressed in this process. The first is sources of variability, whether that be year-to-year variability in terms of wet years and drought contingencies for water management. Or within year variability in terms of high flows in a particular season and low flows in another.

Often these problems are approached with the assumption that discharge is the master variable. This appears a number of different places in the literature. However, for some problems discharge may not be as critical as something like velocity or temperature threshold - so making sure that we’re not overemphasizing the importance of discharge at the expense of losing understanding and system function.

Next, what time scales are appropriate for each ecological process - often daily and monthly discharge data are used in environmental flow recommendations but this is largely a matter of how we conceptualize things. And I don’t think a particular fish (taxa) cares whether it’s June, they care what the temperature and flow levels are.

For instance, a single fish species could show movement response on the scale of minutes. They could utilize habitat and a given reach on the scale of hours and their survival could be dictated on the scale of weeks or months. And hourly changes and a hydrograph associated with hydropower or withdrawal peaking, could easily affect all three of these time scales. So minimally the time scale of recommendation should be considered and documented for each process of interest or project objective.

Next, what is the condition that we're using as our "natural flow routine" - what is our reference condition? Bruce Pruitt and Sarah Miller recently wrote a great paper on identifying - or two great papers on identifying reference conditions for restoration project planning. And I encourage people to go look at those and think about how references are identified in your particular system.

And then finally, where is the process positioned in the water shed? Are we talking about headwater strains, low-water strains or are we talking about high order main stem levels? Are we talking about coastal waters - what's both up and downstream of a particular study reach and how did that influence our findings.

And then the final issue that should be considered is what is the institutional, legal, and cultural framework under which we're working? Making sure that everyone understands from the beginning what the setting and constraints are really helps avoid conflict among the team members and conflicts with perhaps existing regulations. Also this institutional framework may dictate how quickly we can move out in terms of decision-making.

And some of us have definitely proposed incremental decision-making where a more course resolution hydrologic technique may be applied prior to more detailed analyses from something like a habitat or holistic method. In particular, people have identified these sustainability boundaries or these percentage-based boundaries provide a strong starting point to these discussions.

And then finally, how are we incorporating the notion of environmental "hypotheses" into our framework here. And environmental flow recommendations always contain some uncertainty and they should always be considered hypotheses about the response of a strained ecosystem to a given driver - for instance, discharge.

And environmental flows and their ecological outcomes should be monitored to validate these hypotheses and hopefully adaptively manage accordingly. So with that I'll be happy to take any questions. But before I do I wanted to highlight a couple of key take-home points.

The first is that there are so many techniques out there - over 200 - for manipulating environmental flows. And minimum flows are not the only way of conceptualizing environmental flows. Minimally, environmental flows should address different elements of a flow regime, tradeoffs between social and ecological objectives and key assumptions and uncertainties in how we're going to reduce those over time.

So thank you for your time and I would be happy to answer any questions you have.

Courtney Chamber: Great. Thank you very much, Kyle. I'm going to take us back to our interface, yes, if you don't mind, thank you.

And at this time if you have any questions please speak up and remember to take your phone off of Mute or you're welcome to utilize the Chat features in a question to everyone, if you don't mind. Thanks.

Kyle McKay: Well, if you do have any questions you're welcome to contact me later and there's also a technical note which reviews this same content. It should be coming out relatively soon. It's in the final stages of preparation with editing. So...

Courtney Chambers: All right, Kyle. Well, let's give a few more minutes. Any other questions?

All right, well thank you all very much for joining us today. And, Kyle, thanks for sharing your research about this topic with us. I hope you all have a very good afternoon.

If you have any suggestions for future topics for our webinar series we welcome those. You can contact myself, Courtney Chambers, or Julie Marcy as webinar coordinators.

I'm sorry - did I miss someone? Okay, all right. Well thank you very much and I hope you all have a wonderful afternoon.

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