

Ecological Flows Science Advisory Board (EFSAB)

Meeting Summary

April 16, 2013

Stan Adams Training Facility, Jordan Lake, Chapel Hill, NC

X Approved for Distribution May 14, 2013

Attendance

Members

Hugh Barwick, Duke Energy
Tom Cuffney, US Geological Survey
Linda Diebolt, NC League of Municipalities
Chris Goudreau, NC Wildlife Resources Commission
Jeff Hinshaw, North Carolina State University
Sam Pearsall, Environmental Defense Fund
Judy Ratcliffe, NC Natural Heritage Program
Jaime Robinson, NCAWWA-WEA
Bill Swartley, NC Division of Forest Resources
Fred Tarver, NC Division of Water Resources

Division of Water Resources

Harold Brady

Alternates

Rebecca Benner, The Natural Conservancy
Kevin Hart, Division of Marine Fisheries
Ian McMillan, NC Division of Water Resources

Sarah McRae, US Fish & Wildlife
Vann Stancil, NC Wildlife Resources Commission
Tom Thompson, Duke Energy
David Williams, NC Division of SWC

Guests:

Mary Davis, SARP
Phillip Jones, RTI
Jim Mead, Environmental Defense Fund
Kimberly Meitzen, The Nature Conservancy
Jennifer Phelan, RTI
Haywood Phistic, LNBA(online)
Marion Hopkins (online), EPA Region 4
Kyle Hall (online)

NCSU Facilitation Team

Mary Lou Addor, Natural Resource Leadership
Institute (NRLI)
Nancy Sharpless (NRLI)

The purpose of the Ecological Flows Science Advisory Board: The Ecological Flows Science Advisory Board (EFSAB) will advise NC Department Environment and Natural Resources (NCDENR) on an approach to characterize the aquatic ecology of different river basins and methods to determine the flows needed to maintain ecological integrity.

Presentations, reports, and background information of the EFSAB are available at: www.nc-water.org/sab

Webinar: If you cannot attend the meeting in person but would like to join us via the webinar, you can watch the presentations and listen to the live streaming audio of the meeting by going to <https://denr.ncgovconnect.com/sab/> and typing your name in the space labeled "guest."

NOTE: The EFSAB will meet **May 14, 2013, 9:00am until 4:15pm** at the Stan Adams Training Facility, Jordan Lake Educational State Forest Center Chapel Hill, NC
(see page ? for meeting agenda topics and directions to location).

April 16, 2013: Summary of Decisions/Recommendations and Proposed Actions

Decisions and Recommendations

1. A subcommittee is set up to organize and rewrite the recommendations generated from the March 2013 meeting. The group will meet May 1, 2013. An invitation will be sent to those EFSAB members who were not in attendance to learn about the subcommittee established. A draft of the revisions will be circulated before the May 14 EFSAB meeting.

Proposed Actions

1. Review and sort the recommendations generated March 2013, from opinions, process for recommendations, and reword partial recommendations into recommendation language.
2. A range of acceptable deviations from unaltered flow would be used if the sustainable boundaries approach were used.
3. Seeing results of this approach on some smaller streams, perhaps ones that also have PHABSIM sites.
4. Run PHABSIM in-stream flow studies on mountain sites.

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I. Executive Summary

TITLE: Preliminary Results of the Biological - Environmental Classification (BEC) system—Fish Classification and Methods fo Optimizing Fish and Macro-intvertebrate Classes

Presenters: Jennifer Phelan, Phillip Jones, RTI; Tom Cuffney, USGS

Jennifer introduced the presentations with an overview of events leading to the BEC project, and what the BEC project would be including. She then introduced Tom Cuffney to present preliminary results on developing a stream classification system based on geographical assemblages of benthos and associated environmental (physiographic and hydrologic) attributes.

Tom explained the statistical methods that he tried. He used 6 environmental variables in his analyses: Cumulative drainage area, Sinuosity, Precipitation, % Sand in soil, Elevation, and NHD slope. He did a cluster analysis of environmental variables. Results showed weak structure in the data (edges of cluster are fuzzy, not breaking distinctly). Using existing classifications (he called a priori) and environmental variables he found that the best classifications were Ecoregion 3 and Fenneman's. Then he described the classification effort using invertebrates, which he found that the clusters developed with environmental data were not good at explaining patterns in the biological data (using partitioning around medoids-clusters PAM)). Using the invertebrate clusters to identify clusters in environmental data did no better.

Next steps for invertebrate analyses

- Derive invertebrate metrics (aggregations of species attributes) with emphasis on those sensitive to flow (e.g., filter-feeders, collector-gatherers).
- Directly related invertebrate metrics to environmental variables (classification and regression tree (CART)) to develop integrated classifications
- Relate invertebrate metrics to flow variables
- Repeat analyses using metrics derived from species level as opposed to genus

Phillip Jones then presented the preliminary results for fish data. He used similar methods to Tom. He first looked at species data in terms of environmental classification. Ecological drainage unit, was the best one, and was comparable to Omernick level IV. The results for PAM analysis clustering were not good. Hierarchical clustering provided better results.

Their recommendations

- Correspondence between independently derived environmental and biological classification is weak
- Most promising approach is a classification system based on integrated biological and environmental attributes (e.g., CART univariate analysis)
- Need to adjust/optimize taxonomic resolution and environmental spatial scale
- Consider the purpose of a classification system...are the number of classes workable?
- Use an existing classification scheme? (one of these existing ecoregions, etc)

Major Discussion items/concerns/questions:

Some comments included:

- Instead of doing clustering and moving on to flows, now we're doing back and forth between the two to get the clusters related to flow variables, so it gets a little more complicated
- In the end it will be a fairly simple set of classes, like 2-3
- Its important to capture in the report that the results show a lack of ability to have very defined categories, so other people don't have to go back and do this
- There is some chance we'll decide we can't classify rivers and streams in NC in a way that provides clear direction on how to set ecological baseline (which is an accomplishment)
- How to set an ecological baseline without classification?

Decisions Made: None

Proposed Actions or Identified Decisions to be made: None:

TITLE: SARP: River Classification Framework

Presenter: Mary Davis

Mary Davis provided a presentation on the classification framework developed for the Southern Atlantic Conservation Cooperative (SALCC). We are not proposing a classification, but providing a classification framework. We're giving attributes that can be used in any number of ways. They looked at a number of variables to use for classification. They decided on size class and flow variability. Size class is based on basin area and flow variability (based on median daily variability). They found using these that it follows eco region. She provided examples of how classifications are used, with Michigan and the Potomac watershed as examples.

Major Discussion items/concerns/questions:

Some comments included:

- Using physiographic region, size and variability gets down to as few variables as possible, which may help us move forward.
- I think this work is pointing us in a similar direction- we're not that different from where other folks have trod, it is all coming back to basics.

Decisions Made: None

Proposed Actions or Identified Decisions to be made: None:

TITLE: Review of March 19, 2013 Recommendations List Developed by the EFSAB

The EFSAB reviewed the recommendations brainstormed at the March 19 meeting. As a result of this review, a subcommittee was established to organize and rewrite the recommendations list. The list as brainstormed was a composite of opinions, processes for getting at recommendations as well as partial recommendations. The subcommittee is scheduled to meet May 1 and will circulate their discussions to the larger EFSAB before the May 14, 2013 meeting.

Decisions Made:

A subcommittee is set up to organize and rewrite the recommendations generated from the March 2013 meeting. The group will meet May 1, 2013. An invitation will be sent to those EFSAB members who were not in attendance.

Proposed Actions or Identified Decisions to be made:

Review and sort the recommendations generated from opinions, process for recommendations, and reword partial recommendations into recommendation language.

TITLE: Combining the Concepts of Eco-deficit and Sustainability Boundaries: A Trial Balloon

Presenter: Chris Goudreau

Chris Goudreau presented a trial balloon which proposes combining concepts from the papers of Richter et al. (2011) and Vogel et al. (2007) to determine ecological flows. This approach could be used with or without classification. Chris suggests applying sustainability boundaries to eco-difference curves. The EFSAB would need to decide what the acceptable deviation from unaltered flow would be, but when the eco-difference from a proposed withdrawal exceeds that deviation, that withdrawal might compromise the ecological flow. Another way to do it, which would be more stringent, is to say that if a certain part of the curve is outside of that x% band, then that would indicate that the proposed withdrawal might compromise the ecological flow.

Major Discussion items/concerns/questions:

- Can you talk a little bit more about the importance of not looking at seasonality versus looking at seasonality? Because one of the concerns I would add is that that critical period maybe in September. R: Yes, the example I have up here is January, so I would think you would want to do it, say, like on a monthly or at least on a seasonal basis, not on an annual basis.
- This is a very sophisticated strategy for combining a presumptive standard with the eco-difference concept, and I really like it. The problem is that we'll have the same problem with this as we would with any presumptive standard, and that is making the case that a presumptive standard answers the legal question of how the eco-system will react, respond.
- As part of the BEC, is this one of the metrics that RTI is looking at in terms of trying to correlate biological condition to degree of hydrologic alteration information. I don't know if eco-change is one that you (RTI) had looked at yet. R: We've calculated it but, yes we're using it. We have eco-surplus, eco-deficit, eco-change, and the eco-deficits and the eco-surpluses are expressed on an annual basis and on a seasonal basis for the four seasons that you used for PHABSIM.
- What if you relate biology and you find out that the biology itself is plus or minus 30%?
- Can you show us some of the smaller stream systems or wonder what those implications might be? How do we get to that point?
- Could RTI generate these graphs for a number of sites? R: They already have them.
- There are different sustainable boundaries for the different drainage basin sizes. So depending on how much water is actually available, you'll have different percentages around that sustainable boundary that you could withdraw in order to stay within a range that would still in theory protect your ecological integrity.
- The eco-deficit analysis is part of the BEC analysis for ecological flows.

Decisions Made: None

Proposed Actions or Identified Decisions to be made:

- The range of acceptable deviation from unaltered flow to use if the sustainable boundaries approach were used.
- Seeing results of this approach on some smaller streams, perhaps ones that also have PHABSIM sites.

TITLE: A Proposed Process and Report Format

Presenter: Sam Pearsall

Sam proposed a trial balloon for process and a report format:

1. Classify the rivers and streams of NC. This classification should include, at the absolute minimum, classes distinguishing hydrologically distinct physiographic regions.
2. For each class, determine which variables are the most important (characterize the class). Base these on biological responses to variations in flow. Include all available IFIM / PHABSIM data.
3. For each class, determine what the ecological baseline is. This should be based on the most sensitive biota for which we have adequate data. The ecological baseline should consist of:
 - a. A subdivision of the year into relevant "seasons." These will vary from class to class
 - b. A target flow for each season. This should be expressed as a % of inflow defined at the catchment level; the most powerful family of strategies demonstrated by IFIM work.
 - c. A band of allowable variation, or alternatively, specification about frequency, magnitude, and duration of excursions from this base flow that will not cumulatively violate the definition of ecological integrity.

Major Discussion items/concerns/questions:

- You've got the question mark beside "Classify" but you don't have one beside the flow and biological relationships, and that seems to be as much in question as the first one does to me.
R: I think we're definitely seeing biological responses to flows. Whether we're able to sort those into classes or whether we have to treat them individually, remains to be seen. But we know and the data support the notion that organisms respond to flows.
- So, when are those results coming? R: As the result of an additional investment from state agencies, RTI should be able to produce results by August.

Decisions made: None

Proposed Actions or Identified Decisions to be made: None

TITLE: DWR's Trial Balloons

Presenter: Fred Tarver

DWR proposed 3 trial balloons:

1. Use 80% of inflow as the flow by requirement, statewide for now.
2. Use 40% of annual average flow, statewide for now.
3. Use monthly median, statewide for now.

Fred noted that these are all based on PHABSIM in-stream flow studies, which is a widely accepted approach, but it is based on habitat. You have to assume that if you create the habitat, the biota will be there. He also noted that the charts he looked at are in the Piedmont, so he is proposing to run PHABSIM sites in the mountains as well.

Using 80% of in-flow a certain number of guilds are below the 20% loss of habitat. Using 40% of annual

average and monthly median produce similar losses of habitat. Monthly median and 80% of in-flow maintain variability in flows mimicking a natural hydrograph, although 40% of annual average is more of a flat line.

Major Discussion items/concerns/questions:

- If we're going to use a flat 80% of flow by on the basis of some geographic unit whether it's a basin of some order, it makes sense to me that that percent of flow-by perhaps should vary according to season. There may be times when 80% may be inadequate.
- But isn't that percentage, when you run it through the model, that's a daily time step. Say it's 20% of inflow, so if it's 20% of inflow, it doesn't matter if it's—it's not a seasonal or monthly thing, right? The percentage of flow-by is done on a daily time step.
- It seems to me that the department has suggested the best member or a member of each of the three large families of implementation strategies and in each case they've recommended an annual approach. I'm thinking that a seasonal approach has merit.
- If you get more data and it says you need to do the Piedmont differently from Mountains, you can potentially have different numbers for those two.
- If you can't show that similar habitats respond to flow in the same way, you can't talk about statewide application using this method, in my mind.
- In either the Piedmont or the Mountains, what we've tried to do is run enough different habitat suitability curves through the program so that we've covered anything that would be there. Then going further, you use the most limiting species or guild and if we've got habitat for it, everything else is okay.
- So a suggestion might be taking a flow by approach, but then having some sort of threshold number.
- We need to have what constitutes an allowable excursion and how often can you have one?
- I feel like a monthly median is kind of a nice number. If you model, it looks like you're cutting it off at some kind of flat line, but the reality is it would be highly variable, and the amount of water that you are shooting for in September is going to be higher than the 80% flow by would be.

Decisions made: None

Proposed Actions or Identified Decisions to be made:

- Run PHABSIM in-stream flow studies on mountain sites.

II. April 16, 2013 - Meeting Orientation and March 19, 2013 - Meeting Summary Approval

Members and alternates of the Ecological Board Science Advisory Board introduced themselves and their affiliations. Guests in attendance and the facilitation team also introduced themselves. Everyone was reminded to sign-in who attended the meeting.

A brief orientation was conducted of the meeting facilities (restrooms, concession) and available technology (webinar). Members and alternates are encouraged to sit at the main meeting table and guests at tables away from the main meeting spaces. During discussions of the members and alternates, guests may comment once members and alternates have completed their comments and questions. During small group work, guests can also participate in small group discussions but may not dominate the time. Everyone is asked to ensure that space is created for others to engage. From time to time, the facilitators will conduct a straw poll to determine the current level of support for an idea or what additional information is needed, not necessarily for a final decision.

The EFSAB approved the March 19, 2013 meeting summary with the change requested to the following section to read as:

In Lieu of Classification Approaches -edits were made to the following comment to ensure it accurately conveyed the author's intent. Item #20 (April 16, 2013)

If we get to a specific point on a graph as a recommendation, we need to provide justification for reaching that conclusion. For example, if the approach uses PHabsim, I would need to see validation that the habitat modeling approach actually reflects what is going on [with the biota]. That's what I need to get some comfort with recommending a discrete flow boundary.

The agenda for the meeting was introduced. The meeting objectives as presented included:

- Introduction of the Draft Framework for Recommendations—Results of the March Brainstorm
- Presentation: Preliminary Results of the BEC—Fish Classification and Methods for Optimizing Fish & Macro-invertebrate Classes
- Presentation: Preliminary Results of the BEC—Macro-invertebrate Classification
- Presentation: SARP: River Classification Framework
- Debriefs of the Presentations
- Results of the Recommendations Brainstorm at the March 19, 2013 Meeting
- Introduction of Trial Balloons
- Next Steps and Agenda for May 14, 2013 Meeting

The process for discussing and seeking consensus on a proposal was presented in February as the following:

1. Record each proposal separately for consideration and discussion
2. Check for understanding-*what questions do we have? do we all understand the proposal in the same way?*
3. Revise proposal as needed
4. List levels of support from charter
 - a. Level 1: Endorsement (I like it)
 - b. Level 2: Endorsement with a minor point of contention (basically I like it)

- c. Level 3: Agreement with reservations (I can live with it)
 - d. Level 4: Stand Aside (I don't like it but I don't want to hold up the group)
 - e. Level 5: Block (I cannot/will not support the recommendation, decision, or proposal)
5. Poll for level of support of each proposal – *what is your level of support?*
 6. Record level of support

III. Preliminary Results of the BEC—Fish Classification, Methods of Optimizing Fish and Macro-invertebrate Classes

Presenters: Jennifer Phelan and Phillip Jones, RTI; Tom Cuffney, USGS

(Note: this presentation contained 44 slides, which are posted on the ncwater.org website. This summary does not contain all of the slides, but a select few to help facilitate major points).

Jennifer Phelan

We're providing an update of where we are on the BEC project. This is a project collaborative with USGS and RTI. Phillip Jones and Lauren Patterson, myself and Tom Cuffney. Its producing interesting though maybe not very clear results. We'll present some preliminary findings. Also funded by DWR and WRC.

So want to refresh memories about project and why we're doing it. The biofidelity analysis- purpose was to link biology to stream classes. We found stream classifications systems based on flow metrics (EFS and McManamay) could not be extrapolated beyond catchments with USGS gages

- 49% to 64% match between classifications based on USGS gage versus WaterFALL modeled hydrologic data
- ~ 270 USGS gages in NC
- ~70,000 NHD+ catchments (that's a challenge obviously)
- Streams class can change depending on period of record used to determine classes

Even if you used same data source, and changed period of record, you can change stream classes. That is another problem of using flow based classification.

So we concluded we need a classification system that

- Is not based on sensitive threshold values
- Is consistent and reproducible using USGS stream gage and modeled data
- Is easy to understand and implement
- Can be applied throughout state
- Captures the distribution of aquatic biota in North Carolina

Based on these needs we developed the Biological- Environmental Classification project with 3 objectives (which correspond to 3 steps of the project):

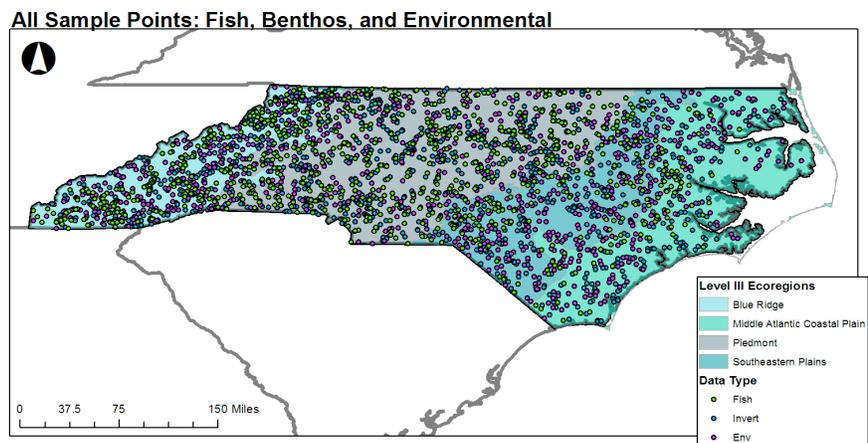
1. Develop a stream classification system based on geographical assemblages of aquatic biota (fish and benthos) and associated environmental (physiographic and hydrologic) attributes – Biological-Environmental Classification (BEC) system

2. Determine flow–biology response relationships for each BEC class
3. Determine and link significant flow metrics (and associated flow–biology relationships) to each BEC class to support determinations of ecological flow

Step 1: Determine BEC classes based on aquatic biota assemblages and environmental characteristics Tom and Phillip have been working on Step 1, they will present preliminary results of where we are today. I'll hand it over to Tom to talk about where we are from the environmental and benthic perspectives, then will hand off to Phillip about fish and recommendations about where we go from here.

First thing is we looked at classification of environmental attributes and how those divide among the states. We had about 3500 sites across the country, 1700 are invertebrate sites, 860 are fish sites, RTI put in another 900 random points to ensure there would be good coverage across the state. As you see from this map we do have good representation of environmental attributes across the state. In terms of environmental factors that could be extracted by GIS there were 17 that we had to work with.

1. NHD drainage area- it divides basins into small sections and they accumulate together
2. Cumulative drainage area
3. NHD slope
4. Slope
5. Elevation
6. Minimum elevation
7. Relief (max-min elev)
8. % flat land (<1% slope)
9. % flat low land
10. % flat uplands
11. Precipitation
12. Evapotranspiration
13. Precip-Evapotranspiration
14. Temperature
15. Sinuosity
16. Aquifer permeability
17. % sand in soils



First thing we did was look at it in terms of correlation matrix. These are just the correlation variables, the highlighted ones are strongly correlated with each other. One of the dominant features of course is elevation which dictates a lot of the values for other parameters. In terms of doing the clustering we wanted to pull out a subset of variables that are not correlated with each other. What we used was absolute value of $\geq .7$ and came up with 6 environmental variables that summarize this environmental matrix.

- Cumulative drainage area

- Sinuosity
- Precipitation
- % Sand in soil
- Elevation
- NHD slope

What we also did was go back and relate the full environmental matrix to reduced matrix. This is what is known as a RELATE Analysis. These are distributions of the permutations test, this is a permutations test. This is the correlation to the actual data. Two things that came out of this is that there is no overlap so these are significantly different as you would expect and also you have a pretty high correlation. Bottom line is that the reduced matrix is pretty well representing the full matrix even though we're dealing with less than half the variables.

Cluster analysis: Environmental Variables involved:

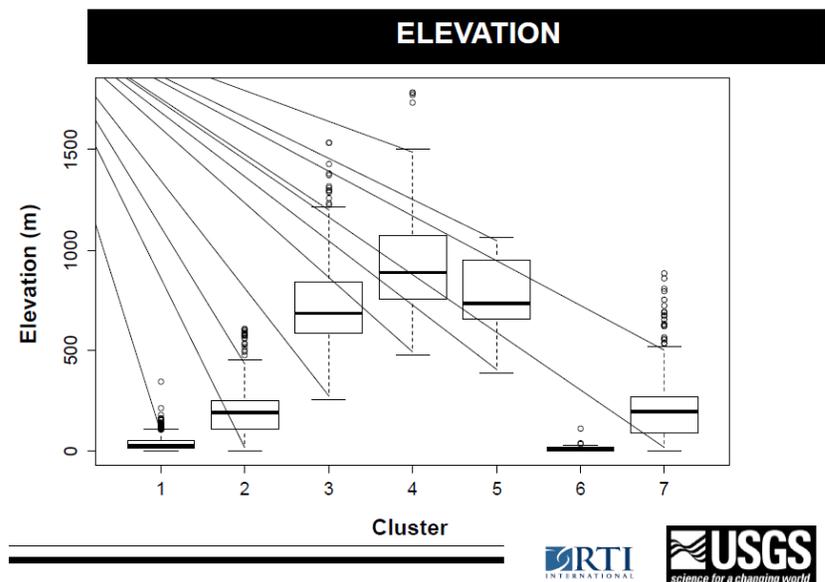
- Partitioning around medoids (PAM) which is a form of K means clustering
- Standardized data (mean = 0, sd = 1)
- Euclidean distance
- Examined 2-60 clusters- want to use environmental clusters and relate them to biology
- Average silhouette width used to determine "best" clustering for environmental
- Box plots of variables in "best" clustering to get an idea of what is really different among these clusters

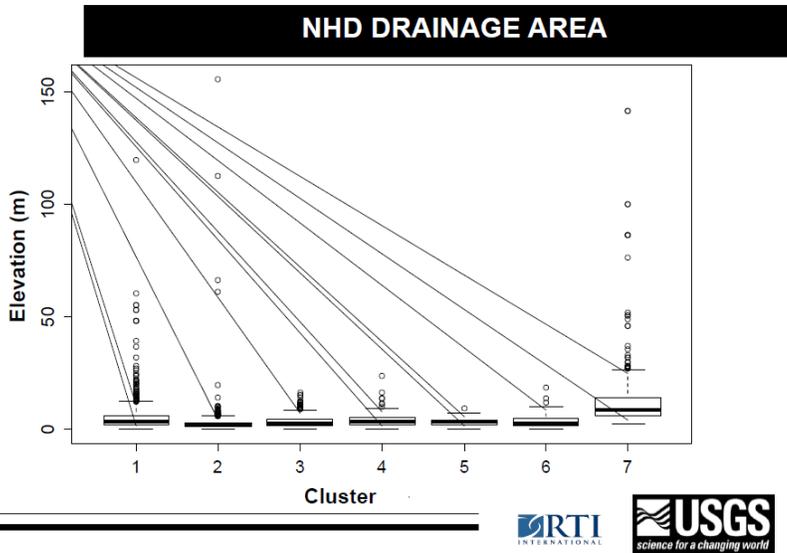
This is output from PAM analysis- average silhouette width, it tells us how distinct the clusters are from another (slide 12). In this case I truncated it to 30. You can see the cluster values peaked here at .34 That comes out to being our best number of clusters for these env variables.

- 0.71-1.00: Strong structure
- 0.51-0.70: Reasonable structure
- 0.26-0.50: Weak structure
- <0.25: No structure

So that means this is weak structure in these data. This isn't unusual it means the edges of cluster are fuzzy. These data are not breaking distinctly, they grade one into another. Not unexpected. A couple examples of the box plots. One of

the things, elevation which is driving everything in here one of the most important variables. Three of the clusters (3,4,5) have high average or median elevation, and 2 that are intermediate and 2 that are low. This is about the best differentiation that we had.





Then here is the NHD Drainage Area which was one of the worst we had. Similar across the board, what is distinctive among these are these outliers.

You can go back to the data and look at Characterization of Clusters, look at low, medium high (slide 15). We can break these things out, put them on a map.

These are the 7 groupings here, truly there is kind of a mountain (which divides into 2 groups), piedmont, coastal plain. What is strange is that this class 1, which kind of occurs everywhere. That doesn't seem reasonable. I don't have a whole lot of confidence that this best clustering is very representative.

Q: what is 1?

R: See Characterization of clusters, Cluster 1

What you are seeing is a catch all that doesn't fit into anything else falls into that category. So the other thing to point out are the number of a priori classifications that already exist out there:

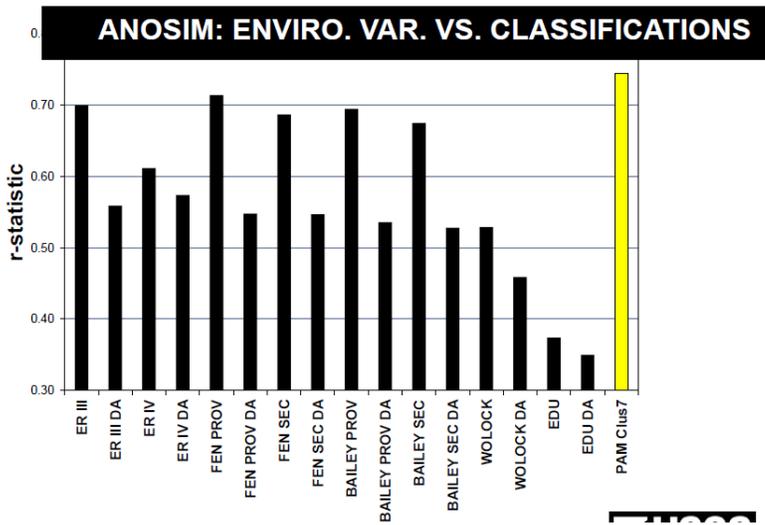
- U.S. EPA Omernik Ecoregions III and IV
- USFS Bailey Ecoregions: Provinces and Sections
- Fenneman's physiographic Provinces and Sections
- USGS Wolock's hydrologic landscape regions
- Ecological Drainage Units
- We also broke into stream size drainage area in km²:
- $X \leq 10$
- $10 < X \leq 100$
- $100 < X \leq 500$
- $500 < X \leq 1000$
- $X > 1000$

CHARACTERISTICS OF CLUSTERS

Cluster	Elevation	Drainage area variability	Precip.	Sinuosity	NHD slope	% Sand in soil
1	Low	High	Low	Low	Low	High
2	Med	High	Low	Low	Low	Low
3	High	Low	Med	Low	Low	Med
4	High	Low	High	Low	Low	Med
5	High	Low	Med High	Low	High	Med
6	Low	Low	Low	Low	Low	High
7	Med	High	Low	Med	Low	Low

We have 16 a priori classifications we can look at as well as the classification that we derived. The stream size is arbitrary- was my break down by drainage area. Its' something we'd like to play with. If

anyone has feedback on better breakdowns I'd like to hear it. I looked at an Analysis of Similarity, which is a multivariate ANOVA, working with ranked classes instead of quantitative. What you are looking at is R statistics- the higher the R the higher the difference, or the greater the correspondence of the classes (slide 18). **This is our best classification for the environmental variables (PAM Cluster 7?).** The ones that are pretty high are Ecoregion III, Fenneman's, Ecological drainage units did not work very well. We have choices of a priori classifications, PAM classifications. Moving on to classification of invertebrates.



Classification based on invertebrate biota, presented by Tom Cuffney

We had 1700 sites to begin with, had to toss some out got about 1044 that we used in the analysis. Looking at correspondence of invertebrates with a priori and the environmental clusters we derived. Characteristics of invertebrate data used:

- Sites rated by DWQ as
 - Excellent, Good, or Good-Fair
 - Standard qualitative or their swamp methods (these provide best representation of entire community)
- Most recent data for each site
- Ordinal scale data (unlike the fish data. This puts some limitations on the analysis, and is why we're using ANOSIM)
 - Absent < rare < common < abundant
 - Coded as: 0, 1, 3, and 10
 - ANOSIM (MANOVA for ranked data)
- Eliminated rare taxa: occur < 5 sites won't influence data
- Lowest taxa level: Genus (this data is also used for a study on DE River, allowed us to reduce down to 490 taxa)
- Ambiguous taxa resolved, taxa harmonized

These are the environmental variables, PAM clusters from 2- 60. Those PAM clusters applied to the invertebrate data and seeing how well it differentiates. What we find here is that it doesn't differentiate very well at all (slide 22). **So there is not a very good correspondence, in other words the cluster we were developing with environmental data, are not good at explaining patterns in the biological data.** I highlighted the 7th one here, this was our best environmental differentiation and its not very good for invertebrates. If you look at the a priori classifications in reference to the

invertebrates rather than environmental, this is our PAM clustering did not work very well. There was a small tendency to pick up with drainage area was added, which is different from the environmental. All in all the environmental clustering is not as good as what we are getting with the a priori classifications.

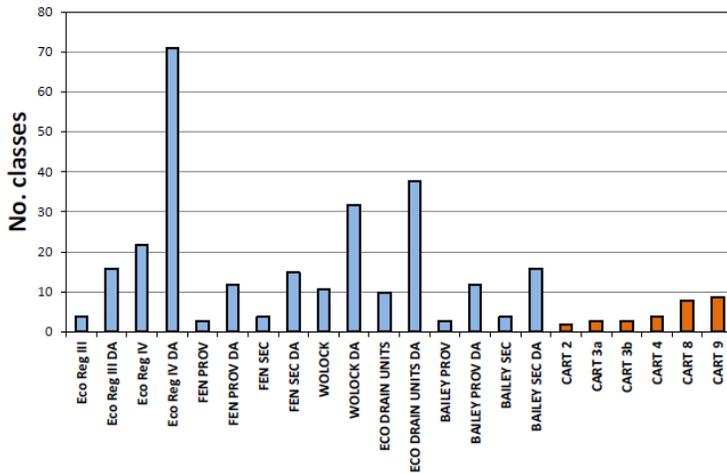
So then we looked at invertebrate clustering itself with multiple possible clustering methods

- K-means: uses Euclidean distance and was not appropriate due to nature of the biological data
- PAM: Bray-Curtis, very low silhouette values (low structure in the data)
- Hierarchical clustering (Bray-Curtis):
 - Agglomerative: you start with sites separate and then put them together, it had many small clusters (problematic)
 - Divisive hierarchical clustering: what are “best” clustering?
- Examined 2-60 clusters
- ANOSIM to assess correspondence between clusters and invert data (similarity matrix)

Here is an example of the PAM clustering and why we dropped that (slide 25). These are supposed to peak at some point but instead drops down. There is something going on here with the PAM clustering analysis and the introduction of Bray –Curtis similarity matrix. Something is not right, this says there is no structure in the data but if you do a multidimensional scale you’ll see there is structure in the data. We did take the divisive clustering, this is the invertebrate clustering now applied to the environmental data, what we had hoped to see is that this peaked somewhere you and would get a peak that would identify what number of clusters you should use to match. What we get instead is an asymptotic relationship. It peaks at 18 being the best one. *So using the invertebrate clusters to id clusters within the environmental data is not better than the use of environmental clusters to identify clusters within the invertebrate data. So what next?*

Next thing is to move on and talk with Phillip about this approach and this is where we’re headed, to more directly link biology with environmental data by going to CART (classification and regression tree) analysis and regression trees so you can develop models to try to define clusters. So these sites here (slide 27) have <242.9 meters, these are greater than, they continue to divide so you are directly linking biology to the environmental. This has pluses and minuses, you may ask why we didn’t start with this. This is a univariate method, which means you have to take the community data and reduce it to a univariate value, there are hundreds of ways to do that. So now instead of looking at a couple models we’re looking at many models in order to understand the data structure. It becomes more complicated, though it is now directly relating biology to environmental data. If we look at this again, the a priori clusters and then the ones we get from CART analysis, we’re getting things on a level of what we got before, which you’d expect since these are derived form the data. In other words these sites are based on the biology. You want to see these up in this range here (slide 28). What’s interesting is that a lot of the other a priori classes are at least as good as what we are getting out of the CART analysis. If we look now at the number of classes, *this is an important thing because the whole effort is to come up with a number of classes*, then use to categorize the state going into the other things. So if you have 200 classes that is not a useful number. You see (Number classes slide) that if you add in drainage area you get over 70, a much better job here of controlling the number of classes that will be statistically meaningful, with the CART analysis. The other thing to look at, when you do these clustering and come up with overall metric to tell globally if you have statistical

NUMBER CLASSES



significance, then you can look at pairwise comparisons. You find you have a lot of insignificant pairwise comparison. When you do CART analysis it means you don't have that. There are advantages with going with CART analysis.

Next steps for invertebrate analyses

- Derive invertebrate metrics (aggregations of species attributes) with emphasis on those sensitive to flow (e.g., filter-feeders, collector-

gatherers). Be smart since there are many to choose from.

- Directly related invertebrate metrics to environmental variables (CART) to develop integrated classifications
- Relate invertebrate metrics to flow variables:
 - Flow surplus/deficit and IHA metrics (to communicate with other people doing this)
 - CART analysis (does good job identify important flow variables)
 - Analyses (e.g., quartile regression) to look at flow relationships
 - Within classes
 - State-wide
- Repeat analyses using metrics derived from species level as opposed to genus

Classification based on Fish, presented by Phillip Jones, RTI

I'll step through analysis for fish data, very similar methods to what Tom presented, some differences because data was different. Here is a map of the sample sites for fish. Main thing to point out that it is a little lighter in the coastal plain.

Data Description and Formatting

- Took most recent sample at 858 unique XY coordinate locations
- Count data at species level
- Data was log transformed, because a number of species that have hundreds to thousands of collections.
- Species observed at <5 sites were removed
- Sample locations with no fish were removed
- Bray-Curtis method used to calculate dissimilarity matrix

Analytical Approach

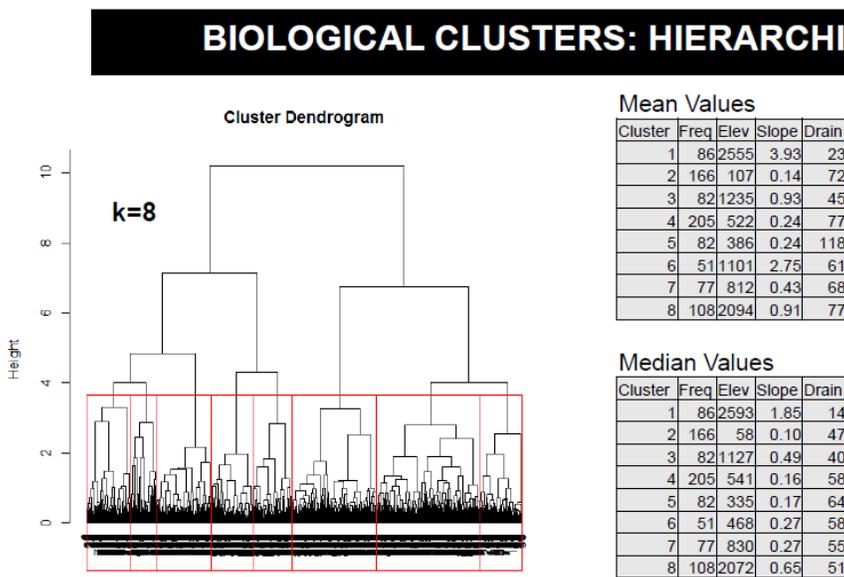
- Environmental Classifications
 - Associate sample locations and community data with (what Tom called a priori) eco-region level, drainage class, and USGS-derived environmental clusters
 - Test explanatory power of each classification (PERMANOVA)- similar to ANOVA but doesn't make same assumptions
- Biological Classification
 - Use community data to create biology-based groups with PAM and hierarchical agglomerative techniques
 - Test significance and explanatory power using a number of metrics (Silhouette width, multi-scale bootstrap re-sampling, PERMANOVA)

First, this looks at species data in terms of environmental classification (slide 36). This is assigning class based on x-axis, then looking at explanatory value. You can see they are low, best ones are close to .4. *The best one, ecological drainage unit, was based on fish evolutionary lineage, so its not too surprising that's the best for fish data. You can see its comparable to Omernick Level IV. USGS is on the right about level with second tier (~.2 value).* Looked at some drainage schemes, they were consistently very low, did not have much power.

Next step looked at just using biological data where there were groups that shook out, looking at species information. Here are results for the PAM analysis, the results were not good (slide 37). I used it for raw data and transformed to matrix. In both cases, these values tell you is there is not a lot of structure in the data that is identified by this approach. Similar to what Tom found with same methodology.

Then did another approach called Hierarchical clustering, a nice feature is you can do a multi-scale bootstrapping that gives you a p value for the clusters. Otherwise this is subjective, its up to you to define how many groups you want to see, you can put any number you want. So when doing resampling, I found 62 clusters out of 858 possibilities that met standard significance test of alpha-0.5.

You can see they are clustered pretty far down on the bottom, so pretty high resolution in terms of data, I mean if you had 2 groups...this is saying there are some significant groups, but they tend to be small, with high numbers. This is an example of 8 (slide 39- shown), the rectangles on each of the cluster groups. This is an example of what you find to be statistically significant, to give a sense of scale. One thing to get across, even though there is a difference between statistical significance and ecological significance, so even just using



coarse resolution number of 8, I broke out mean and median environmental values for the 8 groups, there is nothing there that seems unusual. You can see how elevation and slope would influence the biology you'd find at these sites. There are ways you'd use this type of analysis to talk about fish biology and get results that are reasonable. Just to show you geographic distribution of the groups, this is a density plot of the 8 clusters, you can see it falls out how you'd expect, see Sandhills and Coastal Plain, Piedmont, then type clusters in higher resolution. Even though resolution was quite above statistically significant threshold, the results are pretty reasonable.

So I added the 8 group cluster analysis to the graph I showed earlier showing explanatory power. This time the clusters showed better than a priori methods, also added the red bar- how much explanatory power the number of clusters give you.

That's it for fish. There are a couple other things you can do with cluster analysis.

- Incorporate select environmental variables into biological clustering process (instead of using just species data into matrix for clustering- get better results and more explanatory power)
- Assess cluster p-values in terms of centers and multivariate spread (its not hard to get significant groups, but when you look at what groups are characterizing, you see centers of groups are very close together. That's typically a function of how sampling works and number of samples per site. Good way to tease out if clusters are legitimate or contain the same info.)
- Classify 'best' cluster results in terms of environmental variables; assess predictive power using 80/20 training/test regime (take 80% of data and test how well it does using the 20% of data you didn't use. You can send it in loops and do it many times, figure out why they aren't characterizing very well)

Recommendations

- **Correspondence between independently derived environmental and biological classification is weak**
- **Most promising approach is a classification system based on integrated biological and environmental attributes (e.g., CART univariate analysis)**
- **Need to adjust/optimize taxonomic resolution and environmental spatial scale** (for instance with fish, in general the more clusters you put in the better it is resolved as you are dealing with a high resolution level. Just 3-4 regions may not capture that)
- **Consider the purpose of a classification system...are the number of classes workable?**
- **Use an existing classification scheme?** (one of these existing ecoregions, etc)

Questions (Q), Comments (C), Response (R):

Q: Why wouldn't drainage, like Neuse vs Cape Fear vs Broad, be a fundamental characteristic that would define clusters?

R: I was surprised as well that stream class was not useful in characterizing variability. Tom- you found something similar that stream size wasn't useful?

R: If you add stream size for the invertebrates it improved (combined with a-priori). Added another column to ecoregion that included stream class or stream size.

C: Not interested in size- basin.

R: was interested in looking at developing in the region. The problem is if there is not a consistent relationship between drainage size across all the sites, you won't see a relationship. So you can see a small drainage that has been developed, a small drainage that hasn't been, and you wouldn't expect a drainage covered by a Wal-Mart parking lot to have same species assemblage as a small mountain drainage. They will have very different biological assemblage, so there won't be a relationship between drainage size and species. One of hypotheses I had was looking at land use- small drainage developed against small drainage not developed.

C: number of those species would be pretty low,

C: A lot of species found in this analysis are in multiple basins, not like you'd have site fidelity with a lot of species. Most occur all over mid-Atlantic or Tennessee side, they won't fall out.

C: There will be certain species that have different characteristics- run of river fish vs those that spawn in Neuse.

C: This is all wadeable streams, that's a major component that may be an R factor.

R: One thing that surprised me is that you have fairly small drainage classes in coastal plain units that were sampled. Whereas rivers like Roanoke and Neuse are not going to be sampled with this data set.

Q: You took most recent dates of sampling, did you go back and look at what years those were, and if there were variability for years?

R: I have that information, I hoped to have enough sites to have repeated sampling, but we would have lost a large number of sampling sites. I had most recent year but didn't graphs that.

C: In study I did, I noticed there were years where abundance and frequency were higher, so that could be a factor. It might be useful to look at spread.

R: It's pretty wide. Some have been sampled 3-4 times.

Q: Are you planning on doing anything with the non-wadeable streams?

R: I'd love to but we don't have a lot of data.

C: There's data with Marine Fisheries, years of data.

R: It would be great to have that, have looked at that as part of relicensing, but if you have a source you can provide let me know and we can look at it. The only issue that may come up is if there are vastly different methodologies.

Q: Could you pull results from different sampling methods to come up with an index?

R: Depends, if you had consistent methods for large streams, you could have a large stream group based on that data, and a wadeable stream group.

Q: Did you make adjustments for different sample methods for fish?

R: Wadeable streams are fairly consistent, so we didn't do that. It would be an issue if you looked at other collection methods of data.

Facilitator: we invite you to think about how this informs the work of the EFSAB. Thought to break it down regarding your thoughts of what Tom presented, what excites you, what is missing for you, and how it informs your work. We'll do that for each presentation. What excites you?

C: It doesn't seem to provide any real discriminatory power as analyzed. Take home message, we may be plugging in the biological data, but we may not be using an appropriate metric, using genus for invertebrates for example, as opposed to another characterization of benthos. Is that accurate?

Assumption is if you plug in taxonomic characteristics it would provide that discriminatory power, that doesn't seem to be the case.

R: Based on limited environmental data we have (pretty limited, 16 variables, down to 6), the clusters based on that really gives you now more ability to explain the structure of the invertebrate data than the existing a priori classifications. If we want more ability to differentiate we need to go to different

methods like CART analysis.

Q: Can you explain the CART stuff more? You would collapse the biological data for each site into some number, then use that, there are 100 different ways to do that? Can you expand on that?

R: All the analyses have handled the community as an entity. Now we will break it down and look at aspects of the community. You emphasize different aspects of the data set. So you can emphasize riffle guilds, or filter feeders, there are hundreds of those you could put together. From literature, we know there are other sets more sensitive to flow. That's where we'd focus initially. There is also give and take- look at data, analysis...could bring in IHA metrics, to see how they relate to some of these flow metrics as well, actual flows we're talking about are eco-deficits. If we start screening the large number of metrics representing communities, we may wind up with different aspects of communities responding to flow changes differently. That's what you want. So I think that approach has a lot of positive aspects, so instead of doing clustering and moving on to flows, now we're doing back and forth between the two to get the clusters related to the flow variables so it gets a little more complicated.

Q: Regarding scheduling next steps, where do you envision this thing in the next month or two?

R: It's all ongoing. Though I'll be out of town for a month in May and things will slow for me (Tom). Earliest I could present additional work to the group will be in June (same for RTI?).

Facilitator: Thoughts on Phillips presentation? Anything that is encouraging?

Q: Re. slide X, I was thinking drainage basins or ecoregions, makes sense to me biologically with my experience of where fish are. Was this any more explanatory? It gives me confidence that it may not be better at explaining it, it is something about the biology that we know

C: One take home is that, in the end it will be fairly simple set of classes. It may be real simple, like 2 or 3. Maybe we're at that point where we need to reset our expectations that we may have a finely tuned system. This stuff and what Mary will present lead me to think that.

C: That seems reasonable to me. Also the folks that would use this tool are going to appreciate that.

C: One thing that is important to capture in summarizing for report, point out results for lack of ability to have very defined categories so other people don't have to go back and do it.

C: Something else about having simple classifications, BEC project next steps are to develop biology-flow relationships. If you have too many stream classes, it defeats your purpose- if you have many classes and not enough data it is difficult.

C: There is at least some chance we're going to arrive at the conclusion that we cannot classify rivers and streams of NC in a way that provides clear direction on how to set ecological baseline. If so, we'll be the first in the country to have tested the assumption that you must classify first, as rigorously as we have, and arrived at that conclusion. It may be characterized by some as failure, but it is quite an achievement. So the thing we must cope with, is how to set ecological baseline without classification, which as far as I know has not been attempted. I think we're approaching a good place- either we'll have a class system we believe in, or we would have altered national paradigm, and will need a conclusion about how to move forward without classification. One or the other will happen in the next 60 days.

IV. Presentation: SARP: River Classification Framework

Presenter: Mary Davis, SARP

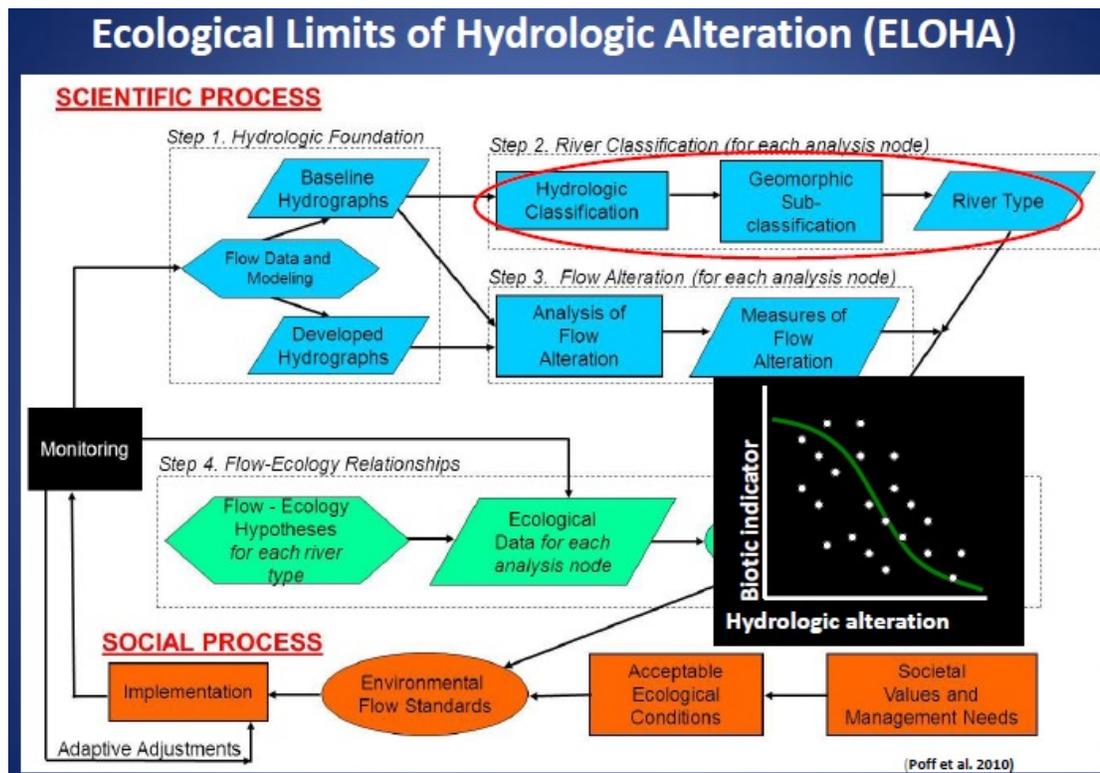
We've been working in OK, LA, doing much the same thing. Today I'm reporting on a product we've been developing for SALCC. It fits in nicely and it's not a bad time following the work just reported on

to step back and look at classifications again. I've been coordinating the Southern Instream Flow Network since 2007. We've come together as part of the Southern Atlantic Regional Partnership (Fish and wildlife organizations in 14 states, leveraging resources). Purpose of the network is to facilitate protective instream flow policies and practices in 15 southern states by providing science-based resources and opening lines of communication. Today I'll talk about the SARP River Classification Framework and then spend a few minutes about how classification is used.

We are not proposing a classification - we're providing a classification framework. There are lots of attributes that we can use to characterize a particular point in a stream. We're giving you attributes that can be used in any number of ways.

SARP River Classification Framework Objectives:

- Characterize streams by ecologically relevant characteristics
- Provide common terms for describing rivers across the region (trying to get beyond drawing lines around a river, but saying data for fish, macro-invertebrates can be used from other states.)
- Support development of flow-ecology relationships



My work is guided by the ELOHA (Ecological Limits of Hydrologic Alteration) framework (see slide 9)- you've been introduced to this so will not go into a lot of detail. We're talking about characterization. Experts that developed ELOHA felt that

characterization would be a necessary step before describing eco-responses to alteration. We're finding that may or may not be the case.

The question is – what does this characterization look like? For SARP we've done the hydrologic classification and the geomorphic sub-classification.

I want to point out our classification system is standardized with NHD plus dataset, which RTI is doing hydrologic modeling based on. It was a community based process- we called together experts from around and outside the region to discuss what were the ecologically significant components that we

wanted to classify, and what were the reasonable breaks for those classes using a quantitative metric. The Nature Conservancy out of Boston did our modeling, so Kim and Becca are familiar with the work.

Geomorphic subclassification

Stream gradient: each one NHD plus river segment is given an attribute of stream gradient, we had five levels of classes. Very flat up to high gradient in the mountains- we had quite a bit of variability throughout the SARP region.

Ecoregions: Each segment is attributed to different ecoregions, EPA III and IV, freshwater and ecological drainage unit.

Stream temperature: We tried doing a stream temperature classification, but we could not find breaks for what was largely a warm class in the southeast. TNC were able to put breaks for their stream classes based on biological associations, we applied that stream temp model to SE, that's what assigned most of SE to a warm class. We thought that's not right, there are more divisions than that- we know that south Florida should have a hot class. We weren't able to distinguish temp to break out anything other than warm class for the SE. For the fish assemblages we were able to pull together from similar data that you've been working with. Elevation, eco-region, slope were better predictors of assemblage than temperature. Though NC does get into the cool classification.

Stream size: based on basin area and mean annual flow.

Baseflow index

- characterization of the dominance of groundwater versus surface water flow in the river.

Soils- much new data from NRCS

- Available water capacity
- Soil organic carbon
- % Sand, Silt, and Clay

Bedrock Geology: broken largely by influence on stream pH. We didn't get far on PH because we didn't have good validation samples

Land forms: TNC has done cool modeling- hills, valley, aspect. Now we have an interesting component called land forms

Land use: urban, agriculture

We have a tremendous amount of information. The way I visualize it we have each one of these NHD+ segments in a matrix, we've got columns for each of the attributes. We use that to get towards our hydrologic classification. Before I get to that let me talk about the classification that we chose to use in our framework. Again, this is meant to provide info it is not meant to override or exclude other classifications that are in place, this is meant to add information.

We ran into same problems NC did by trying to use cluster analysis of hydro metrics to describe hydro classes of rivers. You get good correspondence with some of the metrics like drainage area or base flow index driving the formation of different clusters, but then you start looking at how the members of each cluster are classified. You may call some of those members perennial, but then there are members of that cluster that have many days of low flow and are really intermittent. So you can't go out to a river and say "that's an x" because the clusters are multi-dimensional and the membership is

not distinct. So we gave up on the multi-variant cluster approach to develop hydrologic classifications. That's the original EFS, McManamay, we had someone named Conrad working on this- we gave up on it.

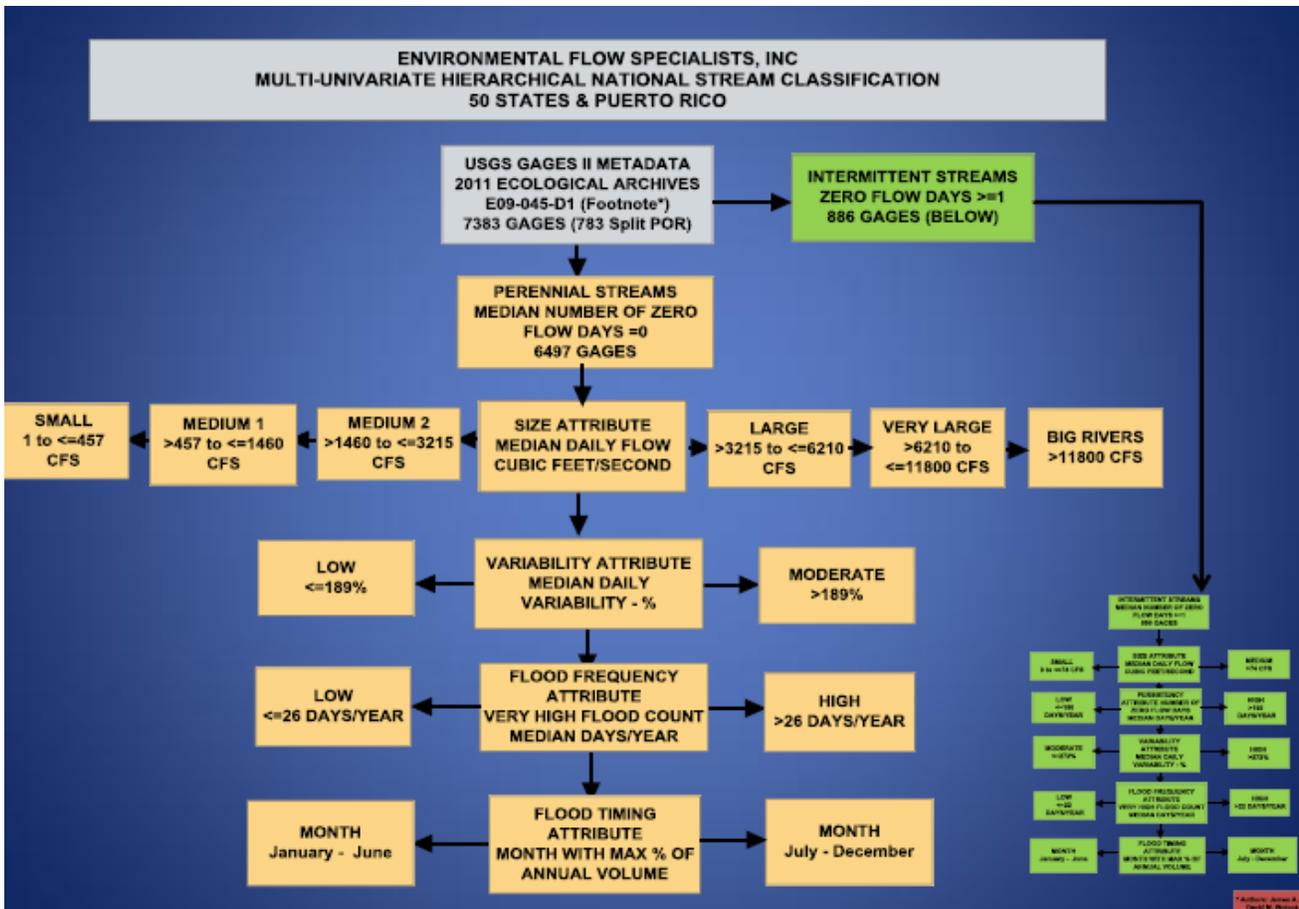
Since then, Henrickson was doing a national hydrologic classification. He also saw that the cluster analysis wasn't working- he did it in many places (PA, TX) but nobody was using it. He came up with a more ecologically relevant logical approach to classifying rivers. This is his approach.

It's a hierarchy of classification based on what experts think are the most important factors describing a river. You can walk out and say- that is a perennially baseflow fed river and people know what you are talking about.

Perennial vs intermittent

Size (median daily flows)

Variability of flows (groundwater vs surface water)



Flood frequency- median number of days water out of the channel
 Flood timing(Across nation there is a seasonality shift for high flows)

This committee went through the variables. We had to use available information- gage data at reference gages or minimally disturbed gages. We had to make some adjustments. The classification I'll show you follows this the best we could. The beauty of this system is it forms a national classification, but you can subclass within these classes that he assigned, so you can stay consistent

with the national but we found we really needed a regional.

First thing we found, we could not distinguish perennial vs intermittent streams. Its defined by whether there are any zero flow days. There are problems with defining zero flow days, such as gage variability. We found a lot of low flow rivers that get down to 1-2 cfs, but within error of gage that could be zero. Trying to model zero flow days was a non-starter.

C: At a national level it makes sense talking about desert streams vs perennial streams, but in the southeast it makes much less sense.

In SE, we can define intermittent based on a stream going dry, or it's just so flat and slow you can't detect flow. Not to say intermittency is not important, but in our classification we weren't able to offer that distinction.

Size attribute- they did it by median daily flow. We didn't have that information, plus we had already finished a size classification for the South Atlantic region. We have size attributes and most of it fits into their small size (which is a sizable river)

- Headwater,
- Creek,
- Small R.,
- Medium R.,
- Large R.,
- Great R.

Variability attribute (median annual std deviation/mean flow)

- Very low,
- Low,
- Medium-High

Flood frequency attribute- we didn't have the data to analyze it. Somebody could do that in the future.

Flood timing- we don't have any differentiation in the east. As you move west you pick up high flows later in the year.

What we wind up with: the hydrologic classification came up to be very simple.

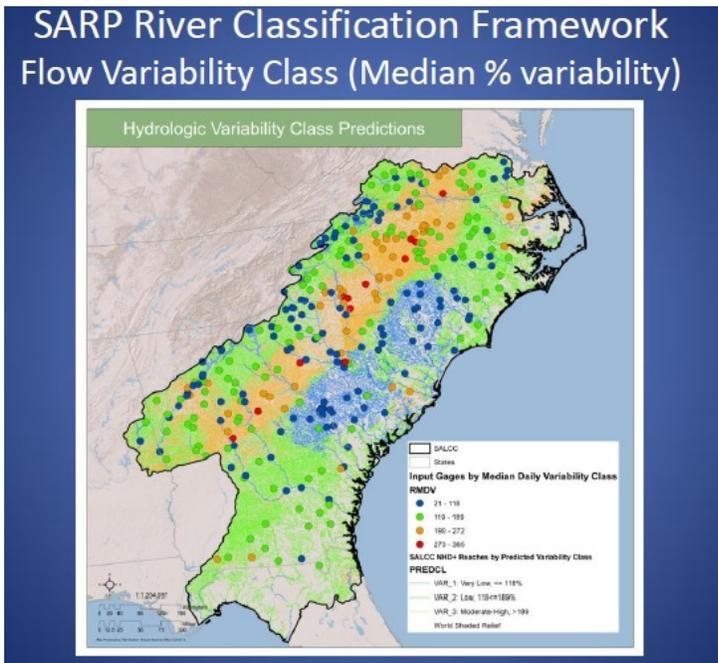
We can offer **size class and variability**. We have stream size class, using basin area – can use flow or basin area. We found people more comfortable with basin area than flow. That comes with NHD+ database. It was no problem to assign size for all NHD+ reaches.

For Flow variability class we only had that at gage stations.

Predict Flow Variability Class for Ungaged Locations (The modeling work consisted of four major steps)

- Compile set of USGS gages, assign hydrologic class, and link them to the appropriate NHD+ reach
- Attribute each stream reach and gage with GIS predictor variables
- Build random forest (RF) classification models using the random forest package in R (statistical package)

- Apply the best RF model to each stream reach and map each stream reach according to the “highest probability” class



Of 75 predictor variables we used, consistently the most important variables were:

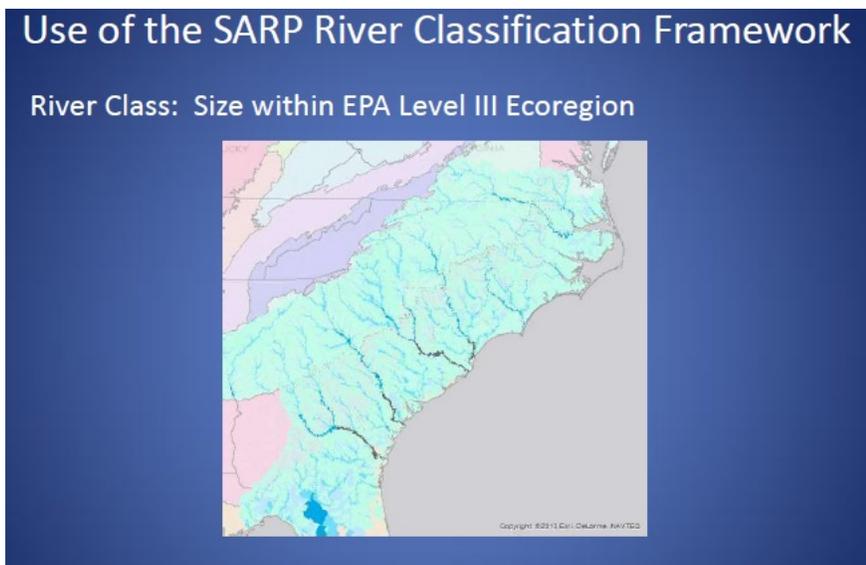
- mean baseflow index – relative importance of ground and surface water
- stream size
- cumulative drainage area and
- run-off coefficient.

This is what we came up with - Flow Variability. The dots are USGS gages, blue are very low variability, tend to be in SC and southern NC and large rivers. Green-low variability (mostly coastal plain and up

to base of mountains. This is the SLCC boundary. Medium variability, red is high variability. There weren't many high variability sites so we combined with medium variability. Orange is medium-high variability. If you zoom in you can see there is some distinction at the reach level that doesn't show up on a map like this. As you'd expect, larger rivers are low variability.

Blue is coastal plain.

I've got 3 slides coming up showing this classification framework is meant to mix and match what attributes might be useful.

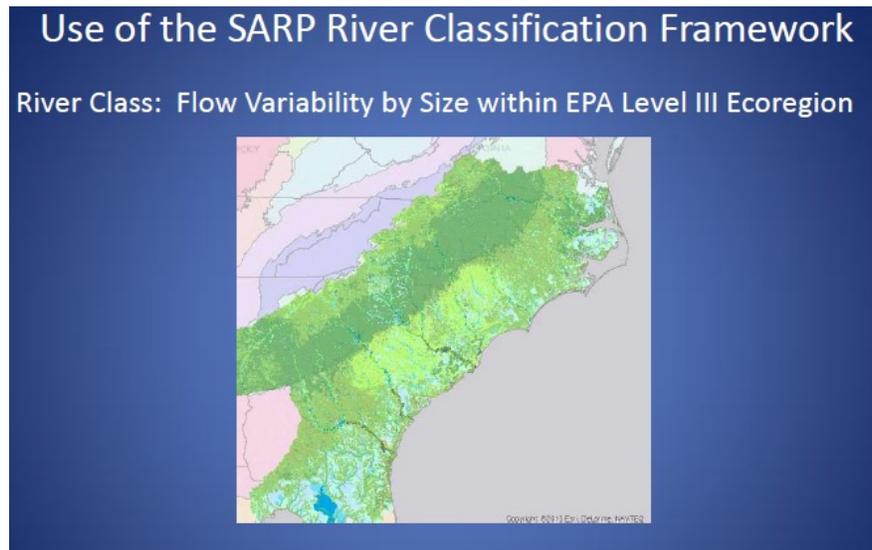


This slide shows Ecoregion III but Ecoregion IV was more important for fish and macro-invertebrates. Then you can put size on top of that, and flow variability on top of that. So then you can talk about size of river, how much groundwater it is, and what ecoregion. That tends to be what ecologist do when they describe rivers, and we've found that fish assemblages in groundwater dominated systems tend to be more sensitive to water withdrawals than those in highly variable systems. They've already

adapted to highly variable systems. Whereas groundwater driven rivers assemblages aren't as well adapted.

I also want to show when I listed variables important for describing variability classes-

- mean baseflow index – relative importance of ground and surface water
- stream size
- cumulative drainage area and
- run-off coefficient.



Ecoregion is not in there. What I love about this is it follows the ecoregion. It just fell out.

You have a lot of attributes, what do you do with them? Having followed your process, I wanted to review how these classifications are used. Basic question is when do you classify? I'll use Michigan and the Potomac watershed as examples.

Authors of ELOHA conceived of the classification before analysis which is what you have been working through for a while.

The concept is the flow-ecology relationships are determined a priori. The assumption is the classification is going to some way be sensitive to flow alteration. So far you've got things grouped but haven't answered if they are predictive of flow responses.

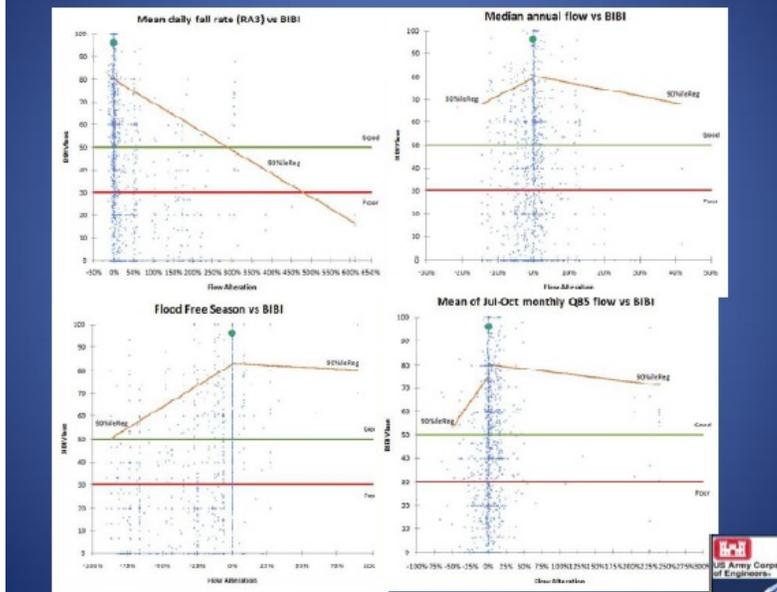
So, the question is, classify before the analysis or to inform the analysis?

Michigan- their experience for setting instream flow has been brought as a good example of ELOHA. MI had a lot of data, they used a lot of expert knowledge about fish and their reason. They came to an a priori approach to classification using stream temp and stream size. Two parameters that fish are sensitive to and were sensitive to water withdrawals. If you withdraw water you slow a stream down and warm it up, change classes. And the fishes respond to this. They used their fish data from 17,000 fish sample locations. Those locations dominated by cold fishes were classified as cold water, etc. Its very simple, logical. They used a modeling approach- IFIM type habitat suitability of fish tolerance to stream temp and assemblages in different sizes to develop a complex and interesting approach to say how fish in different streams responded when you withdrew flows...

The point is their classification was done beforehand, logical, but has never been tested. They didn't go through the rigor you did to see if classification had any relation to flow sensitivity- they are using models.

That is an example of successful classification early on.

Flow-Ecology Relationships



Potomac watershed used a different method- they used hydrologic modeling like you, pulled in macro-invertebrate data from states that intersect with that watershed. Rather than classify first, they threw the data into a regression analyses. X axis- measure of flow alteration Y axis- measure of macro-invertebrate condition

They had a wide range of variability of the condition of macro-invertebrates. So at this point the question is will classification help improve the strength of these relationships? What they found, was some biological metrics do not need to be classified.

With Family level taxa- these did not need to be classified (they didn't make any difference):

- watershed size
- season
- bioregion

On the other hand, there were other variables that did need to be classified.

- % shredders- related to watershed size
- %net caddisfly- related to season
- % Chironomidae- related to bioregion

So what these other experiences tell you about when to classify- it's not clear. TNC released a report of 9 case studies of ELOHA. Sometimes classification worked and sometimes it didn't. Regarding who has ever gone without classification, it would be in the report.

Questions (Q), Comments (C), Response (R):

C: I think the link to that report went to EFSAB

I was glad to see Tom and Philip working on letting response to flow alteration begin to inform the appropriate class. It may be as simple as ecoregion, or size of river. The analyses seem to be moving in that direction.

Q: I started thinking about how we might use this report--the 3 slides of using physiographic region, size, variability. It gets down to as few variables as possible, may help inform us moving forward. Rather than gradient, temperature-physiographic province will essentially do the same thing. Why use 2-3 variables when you can use one.

R: If you include biologic classification before you set standards, going back to the slide Phillip had (8 centroids in NC) I wasn't sure how you'd assign biological class to unsampled locations?

C: When you were showing various parameters that didn't show correlation, I thought seasonality was

interesting given all the seasonal cues for spawning, etc.

C: On national level, snow runoff is important.

R: Not to say that in a river with a pattern, that you don't want to try to maintain it.

Q: This is just for the Potomac, it may be scale related.

R: This is season of sample, you'd expect taxa to shift.

Q: Regarding intermittent vs perennial, my gut tells me it's not zero flow days, you have 7Q10 of a certain level. You can classify streams by what their 7Q10 is, and it explains some vulnerability to the biota. If you have rivers with really low 7Q10s, they are probably not great candidates for water withdrawal, if you're talking about a screening tool for water withdrawals.

R: That logic is what led us to realize that in the east we see zero flow days differently than in the western U.S. In west, they are drying the river out. Here you can dry the river out or have negligible flow. So we needed to get a different parameter than zero flow days. Size is directly correlated with mean annual flow. Instead of 7Q10 you can use size class as a proxy for very low flow.

C: That's what Susquehanna approach, where they had more stringent requirements for smaller watersheds. Same idea.

C: if we go that direction, it seems like we'd want to draw the connection. We're using stream size which is highly correlated with x, y, z. It would explain these concerns.

R: John Kauffman was working on a report in VA looking at effect of withdrawals on small streams vs large streams. Size is important.

Facilitator: Questions of clarification? Or thoughts on how this informs your work?

C: I think its pointing us in a similar direction- we're not that different from where other folks have trod. Folks have tried different things but it is all coming back to some basics.

R: Talking about taking fish and macroinverts forward, what the Potomac found was that it was flow alteration that sometimes classification helped, sometimes it didn't. It's a little different trajectory than what you are on.

Q: Where are we with flow alterations? We have streams that are in a current state, and we need to have measures of ecological integrity related to current state. How are we going to capture what the current state is? For unsampled reaches?

C: If you successfully model biological with your flow or your physical, if you have information from ungaged sites, that's your prediction.

Q: Wouldn't it be a reference though, we have to throw in land use somewhere.

C: RTI is developing that, right?

C: Yes, and we'll be presenting that. We have the IHA metrics, and correlation between some of the metrics, have since increased and revised metrics to those we're currently using. I'll present those at future meeting. Characterizing current condition – there is a possibility to use modeling to characterize that regardless of biology data...you could almost classify rivers based on current conditions now. How altered are they? (this was difficult to hear in the recording, but this information will be presented by RTI in future)

Q: This project has essentially been completed? The SALCC effort?

R: Yes, we're done. It will be distributed to SALCC.

Q: Is it a state where you could take a GIS system and do an analysis on NC?

R: Most of state has been done, just need to get flow variability for the mountains.

Q: Regarding the work on the ungaged streams? What was error?

R: 20% error.

C: What they did in the NE classification that could be done with ours, even stream size can be

collapsed down to small/medium/large.

R: One advantage of hierarchal classification approach, you don't need to be worried about sensitivity of class breaks. We have the number and we have the category. I would imagine Tom would use basin area rather than class of stream size for example, then you don't have to worry about class breaks- the data will tell you the important break.

V. Presentation: Results of Recommendations Brainstorm in March

Presenter: Mary Lou Addor, Facilitator

Given the recommendation framework developed at the March 19, 2013 meeting, what do you believe are the next steps to move you and the rest of the EFSAB closer toward recommendations for a planning tool and writing a recommended report? The EFSAB was asked to respond to 4 questions about the brainstormed list of recommendations:

1. General reactions including how it is organized? Categorized?
2. What changes/additions could be added to the recommendation list based on what you heard today about:
 - a. BEC
 - b. SALCC
 - c. Anything else missing? If so, which category?

General Reactions:

1. Organize parts- condense
2. Page 3: charge/parameters – place in a preamble/preface to the report (examples: flow requirements and other aspects of the law that must be made explicit)
3. Refined charge – a report will read by a larger audience other than DWR. Convey context about the report so that it is not misinterpretative or raised unnecessary flags for constituents, planners, etc.
4. Include the EFSAB's reactions and concerns regarding the original charge (ex: defining/characterizing the ecology)
5. Philosophical points of view many need to be edited. Example page 6, necessity of model. Separate out statements of concepts, opinion from recommendations
6. Page 10: pre/post monitoring – outside of EFSAB charge.
7. Pre/post monitoring withdrawals discussion: caution, if the recommendation report includes future considerations, remember that the work of the EFSAB is a planning tool and is not being applied to policy/permitting decisions. Make sure this section is expressed as future learning and understanding.
8. Page 9: Triggers for future site (DWR already has established triggers) – how that might relate to adaptive management.
9. Allow the EFSAB to include value added recommendations, insights, concerns as a result of 3 years of work to share with the broader audience.
10. Include definition of consensus principals, recommendations, trial balloons.

11. Page 4: In lieu of classification approaches, # 17, 18, 20 – fall under determining ecological flows. Page 5: other aspects – points 1-9, except 3 – determining ecological flows.
12. Acknowledge the EFSAB used models to respond to charge – but is not advising DWR on models to use nor that DWR has to use models.
13. Use actual gage data where it is available/OASIS calibrated for gage data.
14. Treatment of Coastal areas (question: why is it separated in the recommendations framework) when what happens in Piedmont affects the Coast.
 - a. Limited coastal data
 - b. None of the models accessible to EFSAB could analyze coastal variables (flows difficult to predict)
 - c. Withdrawal pressures slight in coastal area; EFSAB more focused on Piedmont followed with Mountains given more data, models to analyze variables and withdrawal pressures are greater.
16. Approaches to flows
 - a. In the recommendations framework – it includes how to estimate flows but it is missing how to link ecological flows. Pages (2, 3, 6, 7) – Tom Cuffney recommendation
17. Page 5: In lieu of PHABSIM – habitat to biota (there is a data gap).
18. Develop a Work Team to sort through the brainstormed list of recommendations

What changes/additions could be added to the recommendation list based on what you heard today about BEC and SALCC:

BEC

19. With BEC – there is high uncertainty. We need to be afraid to classify “happily” and sufficiently. Be prepared to move forward in the absence of a suitable system. There is the possibility of identifying ecological integrity without good classes. Be mindful, some are unable to conceive how to move forward without some sort of classification system.
20. BEC has 2 parts – Classification and Biological Response Curve. Just because classification doesn’t work doesn’t mean Biological Response Curve will not.
21. Have a number of good classifications we can try to use that could be useful.

SALCC – Mary Davis

22. IHA – other aspects to define ecological integrity using CART analysis (wide use of this method).
23. How do we feel about the national approach? Mary was not recommending the national approach since southeast systems differ from western systems but did suggest use of the Northeast approach given drainage, etc for the SE region
24. Confusion around if she was using a prior vs. alternative prior classification; she said some things will drop out naturally as a result of their system.
25. What systems have been tested with biological composition? Fall back classification may be topoedaphic (though it remains untested; other states have used classifications that remain untested such as Michigan’s).
26. Doubts on getting to biology (to determine flow alteration to biology). Perhaps look to role of habitat...In order, consider:
 1. Is unaltered flow the best metric?

2. Next Surrogate level is habitat
3. Biology/be great to find linkages
4. Literature

In Lieu of Classification Approaches -edits were made to the following comment to ensure it accurately conveyed the author's intent. Item #20 (April 16, 2013)

If we get to a specific point on a graph as a recommendation, we need to provide justification for reaching that conclusion. For example, if the approach uses PHabsim, I would need to see validation that the habitat modeling approach actually reflects what is going on [with the biota]. That's what I need to get some comfort with recommending a discrete flow boundary.

Develop Work Team: Fred Tarver, Sam Pearsall, Chris Goudreau, Amy Pickle, facilitation team where possible

2. Organize
3. Rewrite
4. Circulate before the May 14 EFSAB meeting

VI. Introduction of Trial Balloons

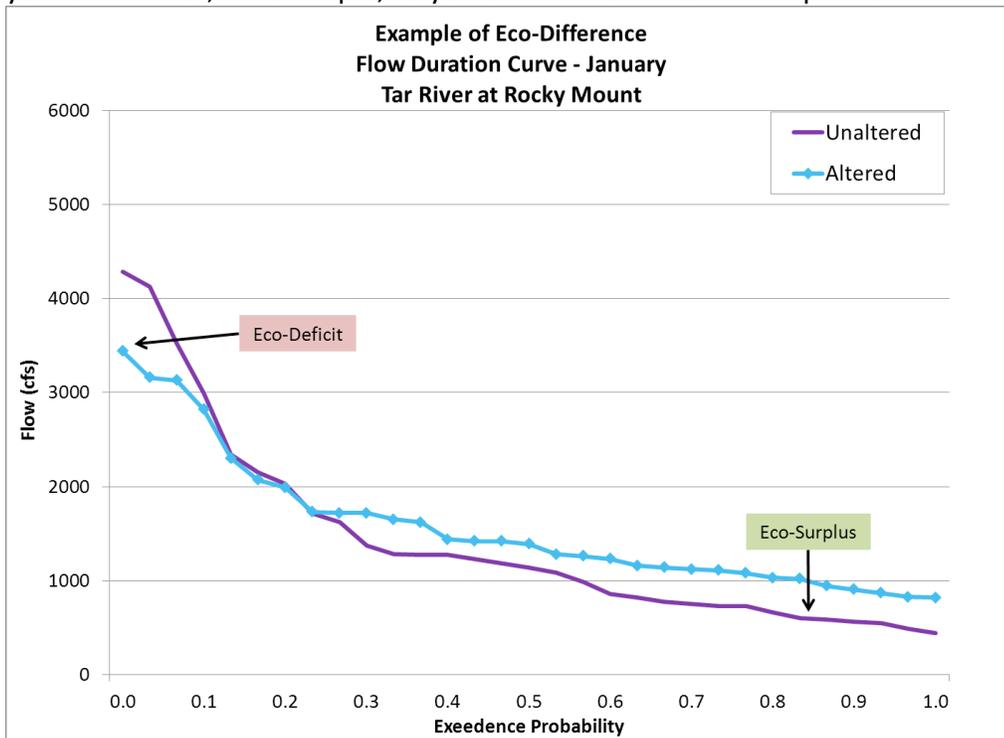
The facilitator next invited the presentation of several trial balloons that some EFSAB members have proposed:

Eco-difference Trial Balloon, presented by Chris Goudreau

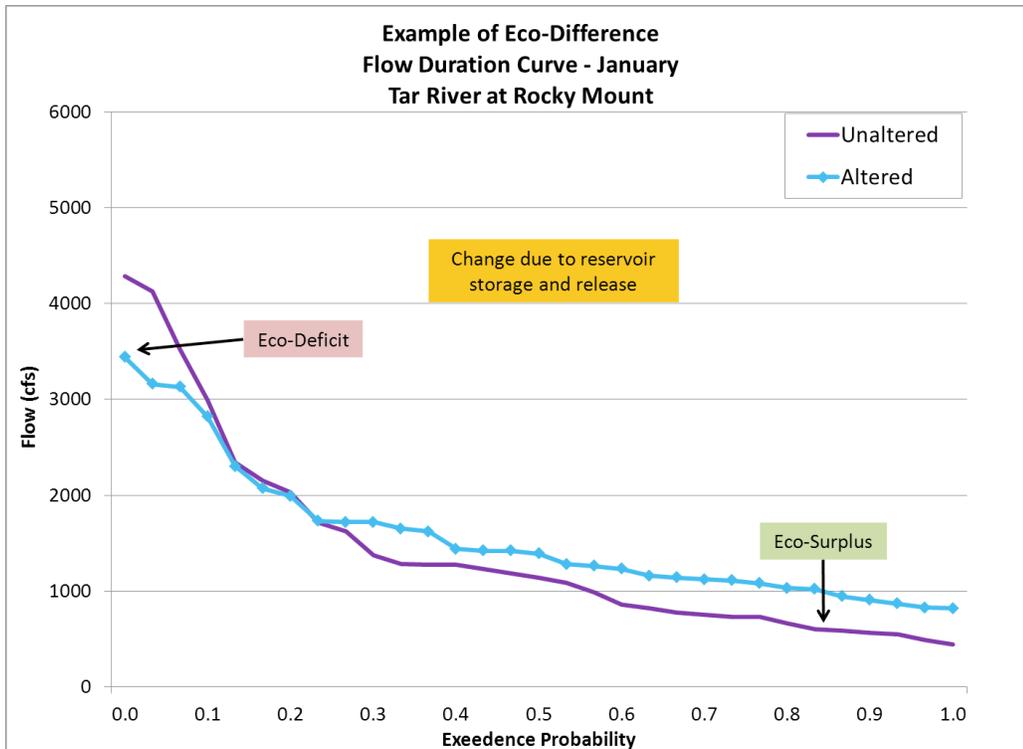
This is a concept that I think can be applied whether we have classes or not. You might tweak it, if we do have classes. For certain classes, you could make some adjustments to some numbers in it and different for other classes, so it's not prescriptive. It's really for the basic planning tool. So, what I did was look at the Vogel paper again, which describes this concept of eco-deficit, eco-surplus. RTI had also been using this in their internal research. Essentially what you do is for a point on a river, you create flow duration curves for multiple years and then take the median of those curves. You do that for an unaltered condition and for an altered condition and then the difference between those curves is what is either called eco-surplus or eco-deficit. If you have less flow in this river, in an altered condition, then that would be an eco-deficit. So it's really this median of a flow deficit or surplus. This really is just dealing with this relatively simple concept focusing on flow magnitude. So, the reason why this came up, Vogel looked at this, was when they looked at all the IHA statistics and all this stuff was correlated, they asked which one is more important? This was kind of a simplified metric to do away with all that correlation. It focuses on magnitude and if you shorten the time period, you can do this on an annual basis or on a monthly basis. You do get some seasonality or timing in it if you do it on a shorter time frame, but it doesn't really get at things like duration or frequency aspects of all your flow statistics, so just keep that in mind.

So here's an example of an altered flow curve and an unaltered curve and the difference between them. On the top part of that flow duration curve would be eco-deficit and the bottom part is eco-

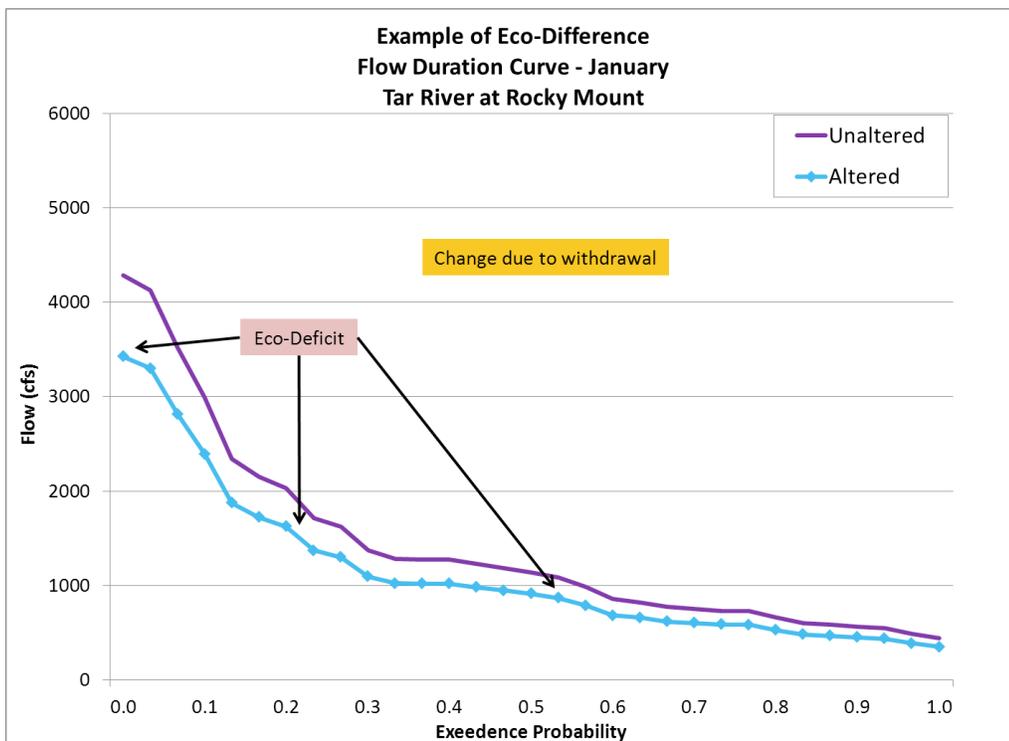
surplus. You can have an overall no net change in volume, but you've shifted it from one part of the year to another, for example, so you still have deficits and surpluses.



This next slide is an example of a reservoir where you would have lower high flows but higher low flows and so you shifted total volume around. I took some data from Tar River at Rocky Mount; there's real data there, but some of the altered flows I just kind of made up or took a certain month out of the flow record to give you an example.

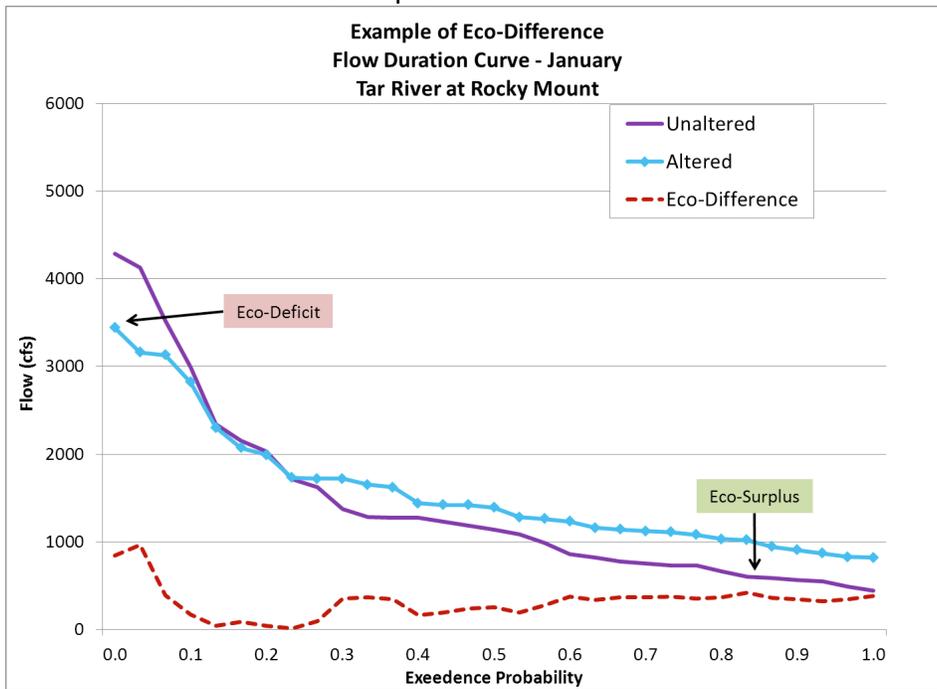


The next slide is another example where you have a flow deficit all year long, for example, from water withdrawal.

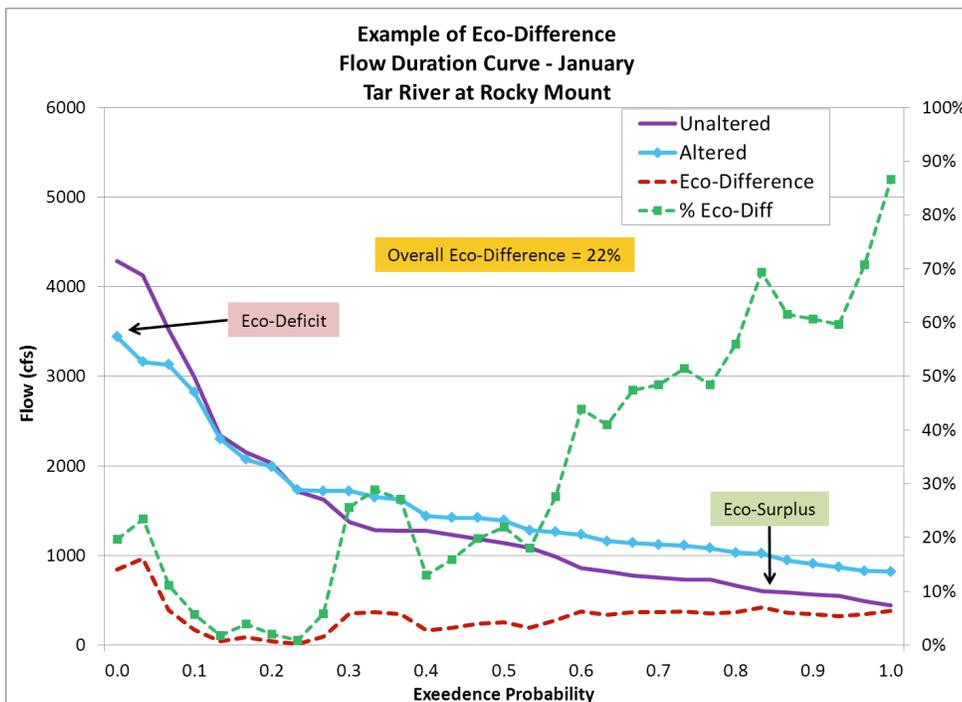


So what I'd call eco difference is really the absolute value of a deficit or surplus. When calculated on

an overall percentage basis, eco-difference gives measure of relative change from the unaltered condition. Let's use an example.



So the bottom curve there would be the eco-difference of those two curves, just subtracting one from the other, the absolute value of it. So when they're right on top of each other, it's zero and when they're far apart, you get some higher value. When you do that on a percentage basis,



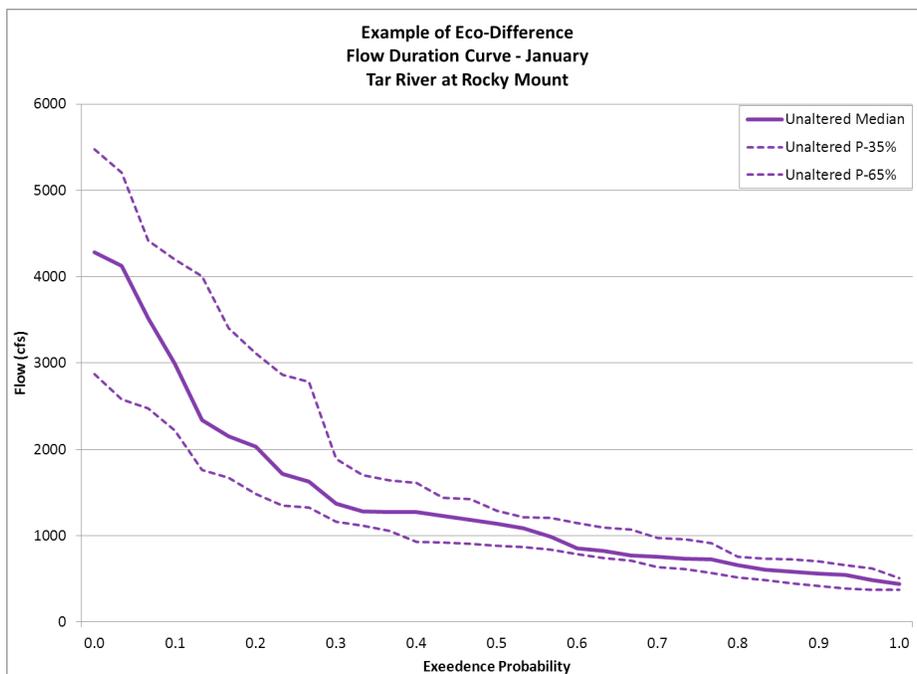
(that's what that orange box is in the middle), you see, overall, 22% difference between those two

curves, in an absolute sense. And you can also look at it as which parts of the curve are the most divergent, which is the green line.

The other thing I was thinking about is Richter's paper about sustainability boundaries—which includes the presumptive standard discussion as well. Richter's paper discusses deviation from inflow on a daily basis, suggesting that $\pm 11-20\%$ provides moderate protection, while $\pm 0-10\%$ provides high protection. The paper talks about how, as long as you're not too far away from that central value, you're okay. They talked about it on a daily flow basis, so you withdraw 10%, that's okay. We talked about it here, concluding that 10 or 20 percent withdrawal on a daily basis would be an acceptable approach. And then, if you wanted to be more conservative, you could have less than 10% or 10-20%. This approach maintains the flow hydrology curve.

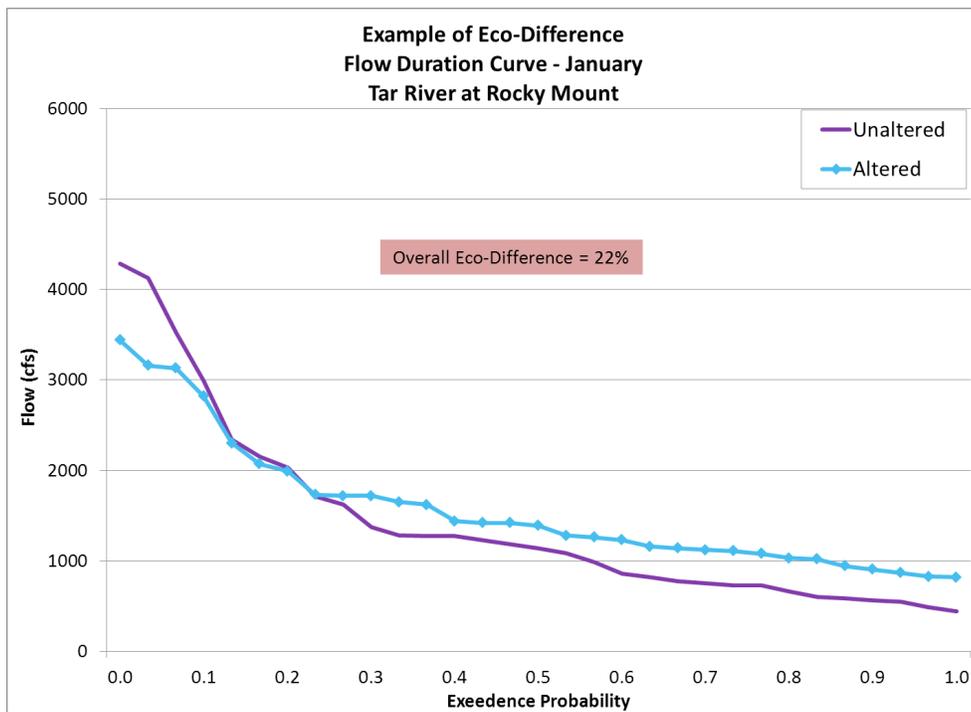
So I was thinking about how to combine these two things. I'm not breaking new ground here. For the Susquehanna study part of their recommendations recommend the same kind of deal. I am suggesting applying those sustainability boundaries to the eco difference curves. So I have some examples. First I just chose 15% just to show you how it looks, but that would be one of those decisions we would need to make: what should that number be?

So here is a flow duration curve that has a 15% plus and 15% minus boundary around it.



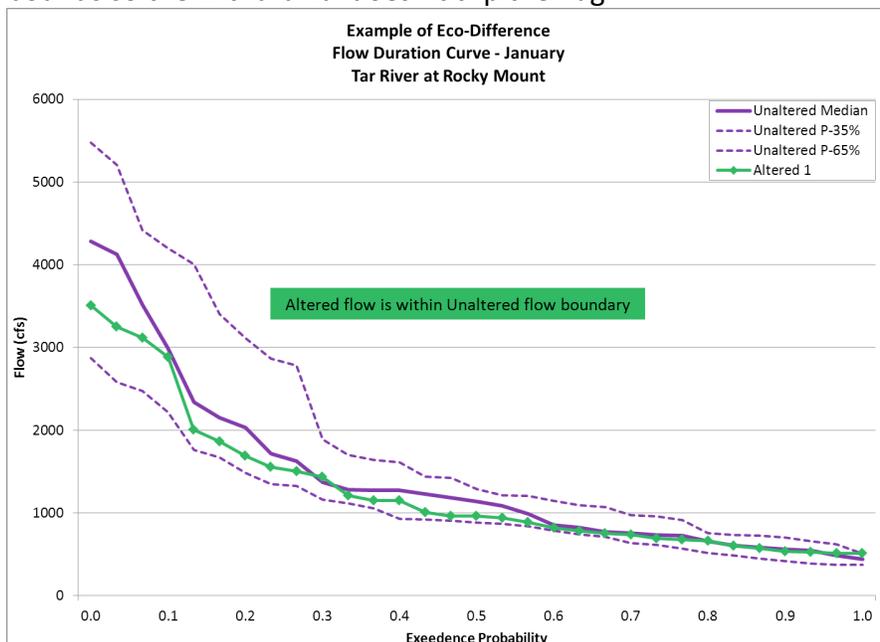
For each point on here, since this big curve is made up of—I forget how many years I did, say 60 years of data—this width here is derived from the variation in the data itself. It's not just plus or minus 15% of the flow value, it's based on whatever the cumulative flow duration curves you have in your data set. So when I was thinking about how it would be applied, say by DWR, is if you compare a new flow regime proposal to the existing condition, one way would be if the eco-difference is 15% then it would indicate that the proposed withdrawal might compromise the ecological flow. And so here's an

example where the overall flow difference is 22%. That would be one way you could apply

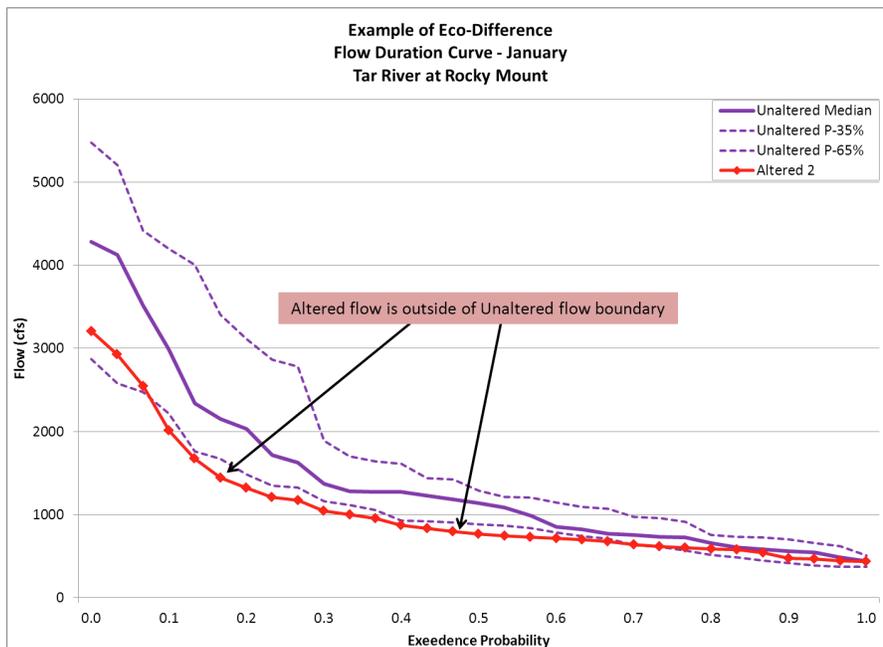


this. The computer model says we've got a problem at this point in the model.

Another way to do it is to say that if a certain part of the curve is outside of that 15% band, then that would indicate that the proposed withdrawal might compromise the ecological flow. This approach is actually more stringent because only one part of it has to be more than 15% out, not the overall total being more than 15%. So in this case here, the altered flow is the green curve and it lies within the bounds so the withdrawal doesn't trip the flag.



In this next example, it would. Part of it is in, but part of it is out. And then part of it is back in. So this would be a more stringent application of it, that would trip the flag.



Questions (Q), Comments (C), Response (R):

Q: One observation and one question. The observation is that it's important to remember that you're not weighing surplus and deficit differently. So surplus and deficit count the same, even though one of them may be much more troublesome than the other for any given stream. The question is when you measure a current flow regime against the 70-year average, one of the things you're always going to find is that there's some eco-difference that is entirely attributable to climate change or some other natural evolution of the system. For example, the Conservancy for many, many years liked to show pre-dam and post-dam flow regimes on the Roanoke, and as it happened when the dams were built, the climate changed.

R: Yes, but the way I would think this would work, though, is when they run it through the model, those conditions would be the same. The only thing that would be different in the model would be the change due to withdrawals, not changes due to climate. It's modeled. You could account for that. In other words, those curves would be derived—if you were going 60 years of unaltered, then you would run 60 years of altered with everything else being the same.

R: Got it. Okay. That's how to solve that problem.

Q: So you're using this to guide a use decision on an impoundment or something like that, not necessarily long-term changes, but maybe incremental or slightly incremental changes that over time add up to a substantial eco-deficit?

R: Well, it would all go down to how DWR uses the models. The way I would understand it, for example like using OASIS, you would run a period of record under unaltered and then a period of record under altered, with whatever those total alterations are, 30 and 50 years out, whatever the time step—whatever the projected future conditions are. So they would incorporate cumulative

impacts to that point in the model.

C: You can model any future conditions over the full period of record and come up with a difference.

R: And you're looking at what's the central difference.

Q: Can you talk a little bit more about the importance of not looking at seasonality versus looking at seasonality? Because one of the concerns I would add is that that critical period maybe in September.

R: Yes, the example I have up here is January, so I would think you would want to do it, say, like on a monthly or at least on a seasonal basis, not on an annual basis. Because then you would pick up—okay, well it looks good in January through May but oh, we've got this problem in October or something. And it would tell you what kind of a problem you've got. Is it a surplus, is it a deficit, is it a certain part of the flow duration curve? If the problem is in the high flows, that might lead you to one kind of recommendation and if the problem is down here, in the low flows, it might need another kind of recommendation.

C: This is a very sophisticated strategy for combining a presumptive standard with the eco-difference concept, and I really like it. The problem is that we'll have the same problem with this as we would with any presumptive standard, and that is making the case that a presumptive standard answers the legal question of how the ecosystem will react, respond.

R: And I think it goes back to some of what Tom's question was, when we were going through the exercises, what is that link? And it might be that the answer is there are linkages in the literature, but we don't have anything specific to this particular case and that's where we have to hang our hat.

Q: But as part of the BEC, is this one of the metrics that RTI is looking at in terms of trying to correlate biological condition to degree of hydrologic alteration information. I don't know if eco-change is one that you guys had looked at yet.

R: We've calculated it but, yes we're using it. We have eco-surplus, eco-deficit, eco-change, and the eco-deficits and the eco-surpluses are expressed on an annual basis and on a seasonal basis for the four seasons that you used for PHABSim.

R: So I think that we'll hopefully know.

C: So one recommendation with this—going with this method—is as well as having the sustainable boundary, you might also want to have a lower threshold. Say for example you have a particularly low flow year, and that's something that could take you down close to and below your 10th percentile flow. So it's often important to put some sort of low flow threshold when using this approach that, you know, you want to be careful not to fall below. And then, often times, what you can do as well as looking at the percent eco-deficit, you can translate that back out to the number of days that during a low flow year or low flow month, that water wouldn't be available to be withdrawn to get an idea of what kind of limits might be applied to different permits. So, if you have a hydrograph that is of a higher flow year than that year, those months, you might not have any days where you have a restriction, but if we happen to go into a drought year, then you might be able to predict if we're in a drought year, then yeah, there might be 10 days in August where withdrawals would be problematic. So I think it's important to try to look at the boundaries of high flow years and drought years with the median approach.

R: And so again, as a planning tool, this would just say there's a problem and then what do you do about it?

C: I was saying everything Fred was going to say—we need to not drift into permitting language. But

as a tool for identifying when ecological integrity is at risk, this looks like a useful tool.

Q: The flow for the Tar River at Rocky Mount is pretty substantial; you are above 1,000 CFS a considerable part of the year. But if you were working on a much smaller system, would you use the same boundary? I'm just wondering if that 15% at a stream that never exceeds 1,000 CFS might be more ecologically significant.

R: And I think that's really where the discussion would have to happen here--is that percentage. If we don't have empirical data to help us set that, then it's going to be literature and professional opinion and do you make adjustments for the things like Kimberly's talking about or you're talking about. This isn't a silver bullet, it's just an approach that still requires some thoughtful input on what those numbers are.

Q: What if you relate biology and you find out that the biology itself is plus or minus 30%, which would be pretty low, actually. How do you handle the risk, then? Because you're going to have to have it much higher than your lower level there and a less than 50% chance that you're actually going to crash the system. So how do we, I mean, how do you use this without being able to incorporate into it some estimate of the variability in the biological response?

R: I think it's the same question that could be asked about everything that we're talking about. We're struggling with what that is.

R: I think we're fortunate here in that we have a number of biological sites where we can address that.

R: I think for certain situations and systems, we can probably have a better guess at that.

R: You know that variability's going to be enormous.

R: Yes, and it goes back to what I was saying earlier is how much do we trust in kind of the underlying paradigm that flow is the master variable, that we just trust it as long as we're keeping—and that's kind of what Richter's papers are all about, that sustainability boundaries thing. Not trying to dig too far down into what really happens with the biology—it's just under the assumption that if you maintain the flows, you maintain the biology.

R: So I see it kind of like as a recipe. You have this recipe for ecological integrity, right? And you need to know how much water goes into that recipe. There are a lot of other ingredients to ecological integrity, but if you get the water right, you may or may not get ecological integrity because you might use salt instead of sugar. We are not measuring that, nobody is measuring whether we're—you know, determining whether we're using salt or sugar in the recipe. But we do want to try to make sure we get that quantity of water right. And so, if we are constantly assuming—if we're saying we're not getting it right if the recipe—if the integrity doesn't come out right, that's not the way to measure it. You can't measure whether you're getting the water right by whether you're getting ecological integrity right because there are too many other ingredients in the recipe. But how do we come back to—do we have enough water going in. And I think that's where Richter's saying that if you're getting as close as you can to this historic, natural, unaltered flow then the odds are better that you're getting enough in. That's really all they're ever going to be able to achieve. So, I mean I just feel like if we hang it on whether we can catch that biological or ecological integrity piece, we'll undercut our ability to actually use flow.

C: Well, the law says that we're supposed to advise DENR on how to determine how much water is required to maintain ecological integrity. I understand that there are lots of other things required to maintain ecological integrity, but it seems to me that we have to address the question in the law. If we're unable to connect how much water there is to ecological integrity because the variables are too complex, then we just are going to have to report that out and we will have failed with our mission. I

hope that we can, in fact, come up with some answer, however rough, for how much water is required to maintain ecological integrity. Am I misunderstanding your concern?

R: My concern is when we come back to whether or not we have a reference situation at Tar River in Rocky Mount or that with the adaptive management that we go out and measure and validate whether we got our guess or our well-reasoned flow correct, we don't have any control over how many NPDES permits are going in at that point, that will also influence ecological integrity. So, I feel like that the most straight forward approach is to say, how close are we to the unaltered flow? And the closer we can achieve that, that's the whole contribution that DWR can make toward ecological integrity.

R: I think what we're talking about is something that's been going through my mind for a while. You look at the charge in the statute; it is what it is, but my response to that would be, in whatever we're writing up, say yes, but we really can't answer that head-on for the reasons you're pointing out and the best we can do—we tried to find these links, we went way beyond any other state that's ever done this to try to find those links, and here are the few links that we found and the other ones we don't and so, we have to just step back and use the assumption, the ecological theory that this is what is driving the system and so on and so forth and make the justification that way. It doesn't say that—I don't say we would fail, it's just that's where we're at now.

R: If we go back to the department and say our best shot at the answer for your question is stick to natural flows, we've probably failed. If we go back to the department and say our best shot is stick within this range around the natural flows for the following reasons, that's not failure. If we can go back to the department and say stick within this range around the natural flow because here's how the ecological integrity of the system will respond if you don't, then we have succeeded in a very big way. While I think that we're going to come in somewhere between B and C, I sincerely hope we come in somewhere B and C, I hope we don't go back with A.

R: I would expect that we would be able to show that there are relationships. They are not going to be tight, but I don't think you need them to be tight if you can show that. The first thing to show is that this ecological difference is related to biological responses and what components of biological responses are they related to and if they're ecologically significant, then that's building the justification for that. It's not going to be perfect relationships. You're not going to have real tight bands around it, but you will be able to say the probability of getting a good community is decreasing as this eco-deficit is increasing.

R: Of the work that I've seen so far from RTI there are some relationships there, they're going to be for certain streams, certainly related to or are constrained by the data sets that we have--wadeable streams that have either bug or fish data. So, outside of that, we still have a black box and so we might see what Sam's talking about for certain streams, and the other ones it's going to be more generic. But I think this kind of approach, and other approaches, would be useful in either case.

C: I like it.

After the facilitator prompted for further questions and there were none, the facilitator asked if the Board wanted to add any recommendations to the list as a result of this presentation.

C: When I listened to Chris talk and look at his presentation, I see no conflict at all between what he has proposed and what I'm about to propose. As a matter of fact, I see them as potentially merging into some common system. I think we keep it on the table.

Q: Just a point of clarification for me then is are the things we're keeping on the table going to be part of that one recommendations document that Sam et al are sort of shrinking down? If so, then yes, I agree that this should be a part of that. Or are we having other mechanisms for keeping things on the table and that whole generation of recommendations lists is one thing, and there's this trial balloon, and there's another trial balloon, and then we consider those, or what?

Facilitator: That's sort of what I'm asking you all, as a group, how you want to approach this. I think one way to go is to add proposals to this list that essentially are staying in front of the group. And then the Board can hone down from that list; that's what I understood the group wanted to do. So, that's essentially what I'm asking is what you want to do, how do you want to work this into where we are?

R: I think at some point this is going to devolve to a writing committee. When I do my presentation on my trial balloon, I'm going to show how Chris' trial balloon fits right in. I'm going to show how Fred's happy face number one fits right in and it seems to me that what we're actually doing with these trial balloons is framing the solution in different ways but I think we're all—I think we're actually working toward what is appearing to be more and more like a single solution.

Facilitator: That is the value of the trial balloons...

C: I mean, I think what these trial balloons are going to represent is a suite of recommendations that are presented in this format but maybe we could have you present them in the type of format that we're going to go after with that work group. And I guess it would be—and that way it could be included in that. But these are clearly like, not only having them individually laid out, like sort of separated—this is actually in a total package direction. So I mean I just think—I see that they need to be integrated somehow.

R: What I see is that that other big long list of stuff is the framework within which a specific trial balloon needs to fit within. If it meets all those other things on our list, then, it can move forward.

Q: So would you have to break this apart into those component pieces?

R: Oh God.

R: I know; it's sort of fully developed, or at least, you know, pretty far developed into that.

R: I think as long as we can show that it meets the framework, I don't know that we need to tear it apart.

Q: Presenting the flow data, you give it in a flow duration curve. Richter presented his in an annual hydrograph, I don't know if—

R: Well the Vogel paper talks about eco-deficits; Richter's uses the flow duration curves.

C: So I guess one uses flow duration and one uses annual hydrographs, I don't know which would be—

R: Well because Richter's approach is on a daily time step, you can take, as long as you're within plus or minus 10 or 20 percent each day. So it really goes back to some of the stuff that you were proposing, the percentage withdrawal or flow by. That's really what his thing is, is just putting a percentage on a daily time step; that's why he can use annual hydrographs.

C: I was saying that it could be presented either way.

R: I've heard Sam talk previously about flow duration curves and how you kind of lose some of the resolution and...

R: The reason why you do it this way is so you can do the calculation.

C: An annual flow duration curve would hide important data, but you're proposing monthly flow duration curves.

R: Or seasonal.

Facilitator: So back to the question of how we work this into moving forward—I'm wondering if maybe what might be useful, Chris, would be to put together the questions that you feel this raises and need to be addressed to be, like you were saying, determining what would the value be or what would the range be, that sort of thing perhaps, that could go on our list for further discussion.

R: Can we also—I don't know who does this stuff but I mean, can you look at—can you show us some of the smaller stream systems or wonder what those implications might be? How do we get to that point?

R: I just did this--pulled gage data and generated spreadsheets. I mean really, this could be done and I assume automated, and maybe someone's already done it, with model data and spit this stuff out. I mean, that's certainly what RTI's doing so, to get that—it took me awhile to do this. I mean if they could spit it out and you know, a bunch of them...

C: They've already got it.

R: But do we want to see that for then—streams that we have PHABSIM data for? I mean, just some way to tie in all these different sets of data so that we're looking at apples and apples. I just have a hard time with a lot of different...

C: So one of the things, Judy, with the analysis that I'm doing at the 44 gages is really similar to this instead of looking at the entire curve, though, I just pulled out the 5 percentiles so that it would capture like, changes in high—the 75th and 50th, the 25th, and the 10th --and one of the things I'm looking at right now, is how those change across basins and with different drainage basin areas. So looking at what, for example, the discharge is at the 10th percentile flow across the different drainage basin areas, and then what that—and if you look at a sustainable boundary around that, how many million gallons per day would be available to withdraw and stay within a sustainable boundary. And I'm doing it by variation by drainage basin and on the monthly time steps. But instead of looking at the entire curve, I'm just pulling out 5 of the percentiles from the curve. So that might be useful and I mean that stuff will be available in June. But it looks at the monthly variation and variation by drainage basin area. But it's really similar, it's really similar to that. And one of the things is there's different sustainable boundaries for the different drainage basin sizes. So depending on how much water is actually available, you'll have different percentages around that sustainable boundary that you could withdraw in order to stay within a range that would still in theory protect your ecological integrity. But I'm also translating back out the million gallons per day so you've got to see what how much water would be available as opposed to just a CFS reading.

C: Good points.

Q: It's also correct—right, Jennifer?—that the eco-deficit stuff is part of the BEC analysis for ecological flows?

R: Yes.

C: We're not testing different scenarios, but we are comparing or looking at ecological responses to these deficits.

R: And I was saying before, it was like on the annual basis and then by seasonal eco-deficits in addition to try to also [inaudible] percentiles, as well.

Facilitator: So we've come up with a couple of things to discuss further: 1) the range to use; 2) perhaps seeing it on some smaller streams, perhaps ones that also have PHABSIM. And then what I would suggest in the interest of time today, is if you have additional thoughts that come from this that you would like to have added to the list for consensus principles or identified areas for discussion that you e-mail Sam, or us, and we can add that into the list to be included in the work that the subcommittee

does. Does that make sense? Does that work? [group members nodded, and there were no objections]. The facilitator then invited Sam Pearsall to present his proposal.

Sam Pearsall's Trial Balloon

Was it Herman Cain, the presidential candidate who had the 9-9-9 plan? I have the 3-3-3 plan:

1. Classify the rivers and streams of NC. This classification should include, at the absolute minimum, classes distinguishing hydrologically distinct physiographic regions.
2. For each class, determine which variables are the most important (characterize the class). Base these on biological responses to variations in flow. Include all available IFIM / PHabSim data.
3. For each class, determine what the ecological baseline is. This should be based on the most sensitive biota for which we have adequate data. The ecological baseline should consist of:
 - a. A subdivision of the year into relevant "seasons." These will vary from class to class
 - b. A target flow for each season: this should be expressed as a % of inflow defined at the catchment level; the most powerful family of strategies demonstrated by IFIM work.
 - c. A band of allowable variation, or alternatively, specification about frequency, magnitude, and duration of excursions from this base flow that will not cumulatively violate the definition of ecological integrity.

I'm keeping in mind as well as I can our mandate and suggesting that our recommendation to the Department should consist of three parts. One is our actual recommendation to the Department on how it should go about deciding how much water is required to maintain ecological integrity as defined in the Act. Number one would be our recommendation. Number two would be our experience, reporting on how we came up with that recommendation: What research we did, what strategies we tried, we can talk about how we looked at a couple of purely flow based strategies, we had a hard time doing biological integrity with those, there are other issues with those. Finally Part 3 would pretty much be attachments; Number 3 would basically be a bibliography including all the presentations and all of the papers that were incorporated into our deliberations and a URL so that a reader of this document can get to each of them if they chose to do it. This would be a page or two of references, not the references themselves. So that's the first three. Within that, we've got three more under number one and these are the same three things that were on Jennifer's what, third or fourth slides this morning? One is classify. Two is develop flow biology relationships. And three is determine ecological baselines. I had originally called this classification, characterization, and prescription but prescription sounds a little bit like permitting so I thought we shouldn't use that. And then three more, and these are one, come up with seasons, assuming that they won't be the same for every class. Number two, target flows. And number three is allowable variance, and by allowable I don't mean legally allowable, I mean some other kind of allowable. And that's it. That's my whole trial balloon. The thing that Chris was proposing is a strategy for solving those two problems, and it's entirely possible that this one isn't going to work out. I still have high hopes that it will. And Fred's strategy is also there. So, I mean that's it. There's nothing particularly unusual or innovative or remarkable about that—we've been talking along these lines for a couple of years and all I hope to do today is just remind you that that is sort of along the lines of what we've been talking for awhile and keep it alive as a potential outline for how we frame our report. End of presentation.

Q: You've got the question mark beside "Classify" but you don't have one beside the flow and

biological relationships, and that seems to be as much in question as the first one does to me.

R: I think we're definitely seeing biological responses to flows. Whether we're able to sort those into classes or whether we have to treat them individually, remains to be seen. But we know and the data support the notion that organisms respond to flows.

Q: So, when are those results coming?

Q: May/June?

R: Well, as the result of an additional investment from state agencies, RTI should be able to produce results by August. Now if we can get some preliminary results or partial results before then, we will. And Tom I think you're chugging right along and probably will have some updates right along, except in May when you'll be out of town.

R: There will be somebody else here representing the USGS and will bring whatever I have done by that time.

Q: Okay, this is another clarification question on my part. So this recommendations document is being shriveled? And now for me to understand is going to be a set of—these are our recommendations of how to proceed and then the trial balloons are examples of how you could proceed? Is that basically right?

Facilitator: Yes.

R: I didn't really understand what a trial balloon was so I made something up and answered it.

R: But to me this is similar to the set of recommendations that we have this long list that you'll help simplify, but Chris' is something very different, it's actually quantitative, it fills in the framework. And to me a lot of these recommendations were just that, a framework, not really a recommendation. I would just say this is a methodology, or a process, or things you must consider to be able to do anything and then that's an example of how you could actually do it. Is that right in my thinking?

C: I see a trial balloon, personally, as a recommendation in process. I see the trial balloon as something that we have as a placeholder right now until we can develop them into recommendations, at which time the trial balloons will cease to be trial balloons—they'll become recommendations.

R: Right, but there's still a recommendation for how to fill in some component of this broader framework that's a little bit more quality and a little less quantity.

Facilitator: you could have five of them in that one place. Or six, or whatever.

R: Okay. I was trying to sort out the difference between this big list of recommendations and something that's much more specific and focused in quantity that Chris presented. Sam's framework helps me understand how it all comes together. It's just the terms that we're using, calling these recommendations and those trial balloons, means very little to me. But I'm understanding now what we actually mean.

R: I had that same semantic difficulty. I didn't know what a trial balloon is.

R: But I'm understanding what they are now.

C: They're floating proposals.

C: Straw men.

R: Straw men, yes.

Sam also offered a report format outline:

1. Preface

2. Recommendations

- Classifications
- Flow/Biology Relationships
- Determine Eco-system baseline

3. Experience

- What the EFSAB did to arrive at these recommendations
- What was tested? What was the level of rigor?
- What was reviewed? How did the review contribute to overall understanding?

4. Attachments

- References of Articles
- Publications

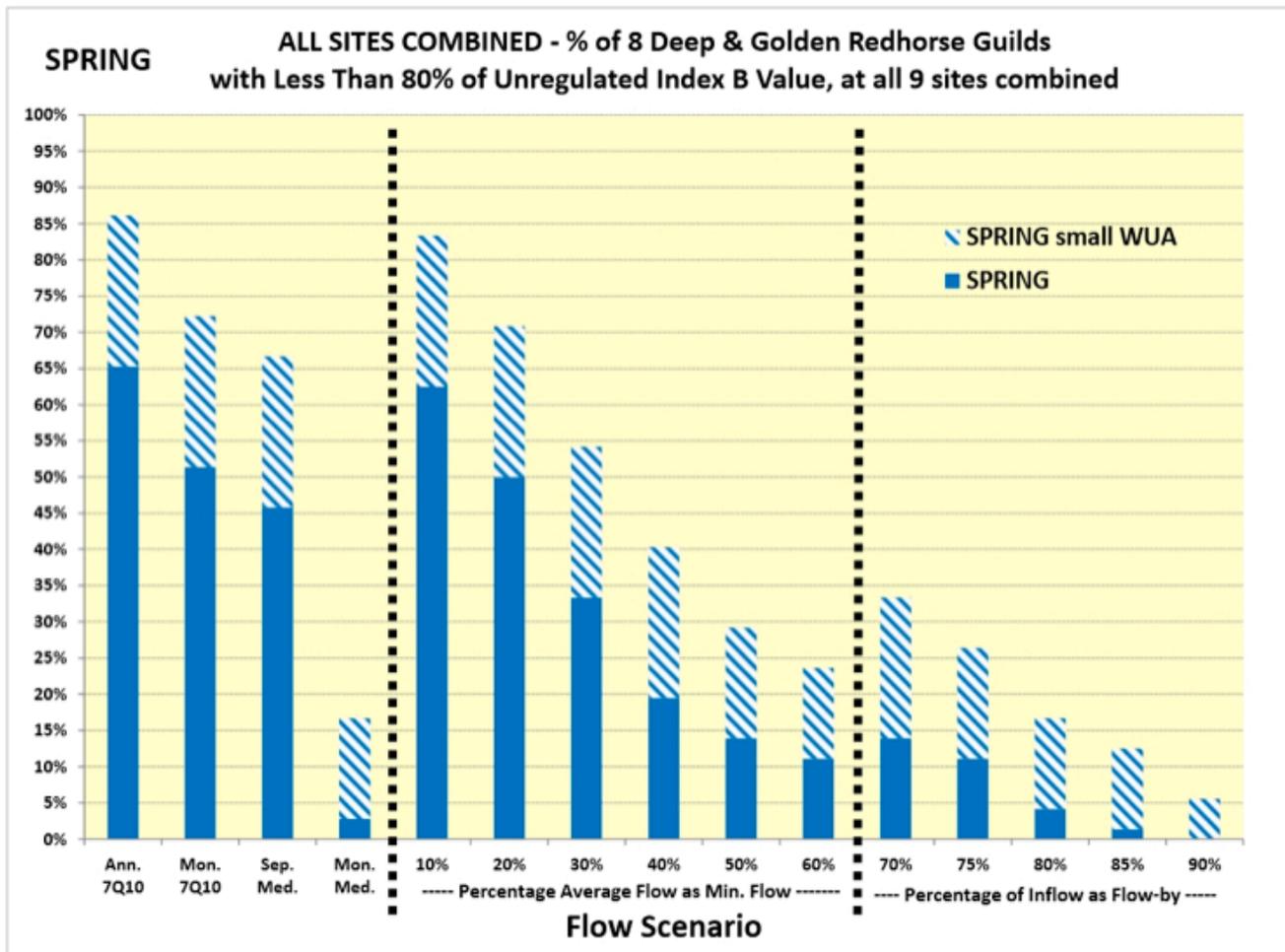
Fred Tarver's Trial Balloon

The facilitator then invited Fred Tarver to present his trial balloons. Fred presented his dual matrix, which he sent out before the March meeting. On the top header the right side shows the potential ecological flow methodologies we've been looking at. And then on the left side are the characterizations/classifications that we've been attempting. Down the center are some of the flow strategies that we've been looking at when Jim was producing the charts from PHabSim. When you try to construct a flow strategy, you can say well, based on the ecological flow strategy, which ever way

2013 EFSAB DUAL TRACK MATRIX ☺ = initial trial balloons													
←←←	CHARACTERIZATION	METHOD	Q (Flow)	ECOLOGICAL FLOW	METHOD	→→→							
			↓										
PHYSIOGRAPHIC	ECOREGIONS	GIS Overlay	↓	SEASONAL/MONTHLY	→				YEAR	→			
REGIONS	(Physio-Topo-Geographic)	(Bio-Env. Class.)	↓		% INFLOW	% Q Statistic	Q Statistic	STATE-WIDE		% INFLOW	% Q Statistic	Q Statistic	STATE-WIDE
	[SALCC]	[RTI]	↓										
			% of Inflow										
			90%										
			85%										
			80%										☺
			75%										
			70%										
			% of Q Statistic										
			(Annual Avg.)										
			60%										
			50%										
			40%										☺
			30%										
			20%										
			10%										
			Q Statistic										
			MEDIAN: Monthly										☺
			MEDIAN: SEPTEMBER										
			7Q10: Monthly										
			7Q10: Annual										

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you choose to pick, whether it's a yearly flow strategy, a seasonal, or a monthly flow strategy, you can come up with—is it a percent inflow, a percent of yearly average flow or one of the more traditional flow-by requirements. These are all based on PHABSIM in-stream flow studies and there's a plethora of papers evaluating the IFIM process, so we're actually looking at responses to flows but this is habitat. So you have to make that leap of faith between habitat and the biota; when you buy into this process, you kind of buy into the fact that if you create the habitat, the biota will be there. If you look at these habitat responses, obviously as you move to the left side of these three suites of flow requirements, you have less loss of habitat with monthly median as opposed to the traditional



7Q10, for example. You have fewer guilds having a loss of habitat exceeding 20% at the left side of these flow regimes, so monthly median, 60% of annual average, and then 90% of inflow as your flow by requirement. As a trial balloon, DWR proposes using 80% of inflow as the flow by requirement. And since we haven't come up with a classification/characterization process yet, we figured well, we'll just go with a statewide requirement for right now because it kind of gets back to what Chris was talking about with the sustainability boundary, or the presumptive standard. If you maintain the natural hydrograph, minus a certain percent, then in theory across the state it should protect the biota there. The happy face represents 80% of inflow as your flow-by statewide application. You could argue, if you

look at these charts, these are all based on in-stream flow study sites that are in the Piedmont, so technically, an astute observer of these bar charts might say well, actually your smiley face should be over here under physiographic regions for Piedmont because these are all based on Piedmont studies so the proposal is to look at Mountain PHABSIM sites so hopefully the responses might compare to these similarly. We're scheduled to do those in the next month or so. We picked this 80% inflow as your flow by. At 80% a certain number of guilds that are below the 20% loss of habitat so, when we're putting forth trial balloons we said well, rather than just putting forth one, give people something else to consider so we picked 40% of annual average and also the monthly median. And as you look at these various bar charts, you'll notice that they have different habitat responses so, some will be greater than others but for the most part it seemed like they're pretty much on the same line of the number of guilds that were below the 20% loss of habitat. So that's kind of our philosophy for why we picked these three. Also, maintaining some of the natural variability--if you have the monthly median, that does maintain a certain amount of variability in your flows, as does the 80% of inflow as your flow by requirement. That still maintains some kin to natural variability. The 40% of annual average is sort of a flat line since it is, you're taking a percent of a single value.

Q: Why no monthly or seasonal happy faces?

[00:45:15]

R: Well, that's a good question. Jim did look at some seasonality in terms of some of these studies, but as some of it shows up there, I guess we could have gone deeper into the weeds and pulled up some seasonal ones, but I guess at the time we didn't, so...

R: Well, I understand why you didn't but as a strategy for consideration if we're going to use a flat 80% of flow by on the basis of some geographic unit whether it's a basin of some order, it makes sense to me that that percent of flow-by perhaps should vary according to season.

R: I mean I thought that the point was that the 80% seemed to be protective, even at the low flow seasons and that's if you match that even at low flow seasons, we wouldn't hesitate to allow.

R: There may be times when 80% of flow-by is inadequate.

C: You would have to go back and look through each of those curves again to find out whether that was the case or not.

R: As a straw man, it seems to me that the department has suggested the best member or a member of each of the three large families of implementation strategies and in each case they've recommended an annual approach and I'm thinking that a seasonal approach has merit.

R: Monthly median would be.

C: Monthly median would capture some of the seasonalities.

R: A monthly median is even harder than seasonal median, but I'm just not positive that this will solve the problem as implemented on an annual basis. I'm reasonably comfortable that it will do a better job of solving a problem if it's implemented on a shorter time step.

Q: But isn't that percentage, when you run it through the model, that's a daily time step. Say it's 20% of inflow, so if it's 20% of inflow, it doesn't matter if it's—it's not a seasonal or monthly thing, right? The percentage of flow-by is done on a daily time step.

R: For very low flow streams, 100% of in-flow may be required at certain seasons.

R: Well, so you'd have to go back through all of those curves and unless one of them just stands out as crashing it. That's really, I guess, the assignment was to—is there a difference.

R: My recommendation is that if it's possible and practical, we should--whether we have classes or not--we should think about seasonal flows and targets for those seasons and allow the variations from

those targets and if it turns out that the target is 80% of instantaneous flow, or 80% of daily mean, or whatever flow that geographic unit, whether it's a ridge or a basin of some order, it should to the extent possible, reflect reality. It should reflect something we know about that kind of stream.

Q: And are you saying, in terms of seasonality, go from 80 to 90 some other variable at certain times of the season?

R: If you're defining that your strategy is percent of inflow, for some order of basin, you have the option of saying it should be 80% all the time. But you may have the option of saying it should be 80% above a certain low flow threshold, below which it should be 90%, and below that it should be 100%. We talked about that earlier today. You may not have the information that you need to make that—to write that kind of prescription, or it may be that it's too complex and cumbersome to implement. But ideally, whether we have classes or not, I think we should do our best with seasonality and we should do our best with making our target flows fit reality.

R: That's tricky.

C: The node in OASIS is going to have to be classified, potentially, or the node is going to have a goal or an objective-- 80% flow-by or something like that? So if the node is placed on a stream that's class X, it will end up with this classification and it would get a prescription. So when we're thinking about how finely we have to understand it, we just have to understand where the nodes are probably going to go-- what types of streams are going to get requests for withdrawal and if those are streams that have so little total discharge at low flow season that they meet 100%, that would be a prescription. But I would think that a lot of the withdrawals aren't probably going to be targeted to those streams, that they're going to be targeted as streams that with this 80% would be potentially a reasonable daily target. I mean is that fair? Is that what we're supposed to be thinking about, is when you're actually classifying the node, once you place it into OASIS, that is going to have a class and it will either be sufficient to have this statewide 80% or as Sam's pointed out, there may be streams of a particular size or their ability to have base flow, for example, that may be more vulnerable and they need to go in a different class.

R: Yes, when you set those flowbys for the particular node, if they are going to differ statewide, to some extent you have to know how to set up those various nodes in terms of when are those flowbys when do you have the red flags come up. So when you place those nodes, if we're going to have something other than statewide, you have to know what that flow scenario is in order to have those red flags pop up, if they do.

Q: The framework though that you have in your matrix can handle those more specific approaches, right? You move the smiley face a couple columns to the left or whatever, and you're still within your conceptual framework.

R: Yes.

C: If you get more data and it says you need to do the Piedmont differently from Mountains, you can potentially have different numbers for those two.

R: This matrix is just my concept; the trial balloon is where the smiley faces are. The matrix can be modified. Like I did say, since these are based on Piedmont, then perhaps, it may not be a statewide concept, it might be Piedmont and when we look at the PHABSIMS for the Mountains, it might vary for the Mountain sites.

C: What I want to point out about the way you guys are going to run the Mountains is it seems like when we were in the Piedmont, we decided to have at least a suite of guilds that were shared amongst those and it seems like we would want to have, to the best of our ability even though I understand that some of the Mountain streams will have unique guilds, that there would be comparable guilds, so that we can compare the results from the Mountains to the Piedmont to understand if that same guild responds the same in the Mountains versus the Piedmont. Is that reasonable? Is that part of the objective?

R: I sent an e-mail about this.

R: Recently, you mean?

R: A week or so ago.

Q: That spreadsheet about the various sites, or whatever?

R: Yes, and then before that, the guilds. There will be some differences. But there will be some similarities. But they're not going to be a one-to-one match.

R: I don't think it would be a one and one match, but at the same, I feel like there's—that the advantage of including the responses to the same guilds is that the guild is that biology link to the habitat; you're really describing habitat. It's really, purely, a description of habitat so if you took the guild conversation out of it for the moment and you just said, how well are we maintaining fast, shallow habitat? Do we maintain that in the Mountains? Do we maintain it in the Piedmont, and in the Coastal Plain at 80% flow by and strictly pull ourselves back to a habitat conversation. Flow versus habitat. I think that is the simplest way to assess it and then the next step would be lining the guilds back up and then have that conversation about how the biology responds. What I really want to know is, does the French Broad act exactly the same way as the Tar River at Tarboro under certain flow conditions? And it's very likely they could—the shallow increases and the deep decreases at 80% in a predictable way. Is it equally predictable for the French Broad as it is for the Tar River? And then afterward, you come back to how the guilds match up and whether in the mountains, you really are trying to tell with the chubs if the Mountain suite of chubs act the same way as the Piedmont suite of chubs. You see what I'm saying? If we don't have any one to one matches, this conversation is just purely hypothetical. If you can't show that similar habitats respond to flow in the same way, you can't talk about statewide application using this method, in my mind. We really are talking about habitat, right?

R: Yes, I think saying it that way, my response would be, even if the guilds are different, the question is are we protecting the habitat.

R: That's the question, but if we use the terms of the guild, just like when we called our old classification when we say the Coastal Plain streams, it kind of messes you up—it messes up your ability to speak about how well we are maintaining habitat availability.

R: Yes, because in either the Piedmont or the Mountains, what we've tried to do is run enough different habitat suitability curves through the program so that we've covered anything that would be there. Then going further, you use the most limiting species or guild and if we've got habitat for it, everything else is okay.

R: Right. The only thing that worries me about that is when there are those ecological communities that don't have that component. If it was zero in the natural hydrograph and it goes to 200%, are we capturing that change and is it meaningful to the ecological integrity. I think that is where there's a shift we might not be capturing. So, anyway, I think that this Mountain work is critical in trying to make this work, unless you just really want to have a Piedmont prescription.

Q: When you have the flowbys, is there a threshold other than just like a 7Q10 for WaterFALL that you

try to present in that region?

R: The way that was analyzed is there is no threshold period. Just flow equals 0.8 times flow.

R: So it could, in theory, then produce some really low flows during drought times?

R: The way this was modeled-- now in reality, we can implement it in a different way. I mean this also assumed that flow would be modified every day. And again, in reality, that would be twice a week

C: I guess the only baseline would be whatever the lowest value in the flow record would be? Don't you default to whatever the model flows in the deck?

R: Yes.

C: So a suggestion might be taking a flow-by approach, but then having some sort of threshold number.

R: That's kind of like what Sam was talking about--what triggers a flag? Is it frequency or duration or some sort of threshold that you'd have to--

R: We need to have what constitutes an allowable excursion and how often can you have one?

R: To meet the definition in the statute. Still be able to recover.

R: But it's still--I guess that still wouldn't necessarily protect much natural variability because you could always take it right down to that threshold continuously.

C: I have a feeling that nature will keep variation in there in spite of our best efforts. But I agree that targeting a percentage of a period of record flow is going to be very challenging and it's going to be based on the use of models. There's just nowhere where, or at least there are not very many places, where someone who wants to take water out of the stream has a convenient gage right upstream and a convenient gage right downstream and can report on what they have actually done to instantaneous flow.

R: But again it's a planning thing.

R: Right. Those are site-specific kind of questions, like whether--

R: It just raises the flag.

R: Yes, it's basically a model activity anyway.

C: A couple observations, as well as just reminders, is that this was set up with no floor, no safety net beyond which you would not go. It's always some percentage skimmed off, whether it's 10, 20, or 30 percent of ambient flow removed. One threshold that gets thrown around sometimes would be okay, well yes, but you can't go below the 7Q10. Well, there's nothing magic about 7Q10, in fact, flow often will go below the 7Q10 for a couple of scattered days, ever year. The 7Q10 is a flow that occurs for seven consecutive days, once every ten years. But say 7Q10 is 10, you may get a flow of 8 here and there during a dry time depending on the kind of year it is. So, if you let ambient flows go to 8 occasionally, well, so does Mother Nature. That's one thought we had in mind. Another is, remember this is a percentage reduction, so at low flows the magnitude of that reduction is small. The 7Q10 at Rocky River at Highway 64 near Siler City, which is apparently--it's a small-ish stream, but it's still got a drainage area of over 50 square miles. The 7Q10 there is a very flashy, slate belt stream--7Q10 is 0.5. Eighty percent would give a flow of 0.4 and I defy you to measure 0.1 CFS in a stream.

R: That's where I feel like a monthly median is kind of a nice number.

R: But that is much less variable, that is--

R: That's when you model it. The natural variation is significant around that median and you don't have instantaneous withdrawal, common sense, instantaneous withdrawal. You have intermittent withdrawal up to a certain amount per day and it can be on average, right? So it could be more on one day and less on the next day. If you model, it looks like you're cutting it off at some kind of flat line, but the reality is it would be highly variable, and the amount of water that you are shooting for in

September is going to be higher than the 80% flow by would be.

R: At times, yes. You should still have to have a discussion, like Sam talked about, in terms of what's an acceptable excursion beyond your threshold because if you set your target as a median flow, well, again half the time under natural circumstances the flow is less than that threshold.

C: And the other half the time, it's more than.

R: Right.

C: The eco-difference is going to be substantial most of the time. Another trial balloon goes unpopped.

R: Despite everyone's best efforts.

VIII. May 14 Meeting Agenda and the Timeline

The EFSAB proposed the following items for the May 14 agenda:

- BEC update on flow/biological response relationships
- Board's Input on concerns about endangered species
- Complete Report Outline and section-writing assignment

The EFSAB also updated the timeline as follows:

June 18:

- PHABSIMS using Mountain sites – how it correlates with class
- Update on BEC?
- What's missing
- Determine numbers

July 16:

- Coastal Discussion
 - Contributions from Coastal Coordination Group
- Endangered Species
- Draft report strategy agreed-upon

August 20: To be determined

September 24: To be determined

October 22: To be determined

December 3: Final Meeting

IX. Information on Next Meeting

The draft agenda for the May 14, 2013 meeting includes:

- Biological-Environmental Classification (BEC) preliminary results for classification
- Flow / biological response relationships proof of concept
- Endangered Species
- Discussion of Framework for Recommendations

The next meeting of the EFSAB is scheduled for **May 14, 2013** at the Stan Adams Educational Center from 9:00am until 4:15pm. Please remember to bring lunch and refreshments with you. Coffee will be available on site and soft drinks are (\$1). **Webinar:** If you cannot attend the meeting in person but would like to join us via the webinar, you can watch the presentations and listen to the live streaming audio of the meeting by accessing the link and typing your name in the space labeled "guest": <https://denr.ncgovconnect.com/sab/>

Meeting Location & Directions: The meeting location is the Stanford M. Adams Training Facility at Jordan Lake Educational State Forest. Directions are: 2832 Big Woods Road, Chapel Hill, NC 27517. From Rt 64 and Big Woods Road, it will be the first Forest Service sign on the right. Pass the office building and continue on through the gate to the education center. For Map link: <http://go.ncsu.edu/stanadams>

