Tom Payne Intro

TOM PAYNE: All right, thank you. Thank you, Thom [Hardy]. And thank you, the other Tom [Annear] and to the Instream Flow Council, for inviting me to appear before this august assemblage. The title that you see up here was a result of several iterations of emails and comments, and it wound up being "Holistic Methods, the Integration of Multiple Components in Flow Modeling" [Slide 1]. But when I first started to actually prepare to talk on this topic a few days ago [joking], I realized that I might be stepping on some toes by using the Holistic Method name for a title. And especially with Angela being here -- where's Angela hiding? There you are. She's used that name as a formal instream flow approach, and I didn't really feel that I could appropriately use those words for my talk, especially with her in the audience. So I made a change from "Holistic Methods" to "Instream Flow Methods." [Slide2] I felt that was an improvement, maybe get me out of trouble with Angela, but the title still wasn't quite right because my talk is not just about instream flow modeling. I made another modification to where I'm using the term "hydraulic habitat modeling." [Slide 3]

For those of you who know a lot of acronyms, acronyms can often get misused, misrepresented, and misunderstood. Hydraulic habitat modeling is a pseudonym, actually, the generic acronym for PHABSIM, or Physical Habitat Simulation. It's kind of like the difference between Kleenex and facial tissue. Hydraulic habitat modeling is the generic term and less likely to be misunderstood. Now I'm a lot closer to what I wanted to present to you, which is SEFA, a new tool in the environmental flow tool box.

The next thing I tried to address was well, what does holistic really mean? So I did some really advanced academic research and looked it up in Wikipedia [joking] and I came up with the definition that holism is a theory or belief that the "whole is greater than the sum of the parts". [Slide 4] I'm not sure whether that actually meets the definitions that have been used for holistic environmental flow analysis, and I don't even know if relating to a "study of the whole instead of separation into parts" covers it either. I think it more means "looking more at everything". But now I'm still a bit confused about what "holistic" means in this context. So I started looking into the background, and it essentially derives from the natural flow concepts, to my understanding, and here we have several quotes attributed to various very knowledgeable people. [Slide 5] Holistic methods essentially derive from the hydrograph with many other elements brought in. There are several examples. [Slide 6] From the middle '90s, we have the South African building block methodology (BBM), with Jackie King instrumental in putting it together. The BBM evolved into DRIFT, which as I remember is Downstream Response to an Imposed Flow Transformation. Here's where Angela [Arthington] coined the term Holistic Approach and produced several publications describing the details. There were several other methods categorized by Rebecca Tharme at the time as holistic methods.

Well, holistic methods are not really what I wanted to talk about here today, so I started looking at other terms that might be more appropriate for my topic. I came up with "comprehensive". [Slide 7] Comprehensive means "complete, including all or nearly all elements or aspects of a topic". That definition seemed to be more of what holistic also implied, but it was much more like what I was trying to get at.

Yesterday, we heard some other terms: "integrative" and "analytic." I'm not sure if I'm getting more confused or getting more clarification from all of this discussion because now we have many terms. But I'm going to be using "holistic" and "integrative", and "comprehensive" and "analytic" as my surrogate names for two similar yet different types of approaches to environmental flows.

So which approach, the holistic-integrative, or the comprehensive-analytic, is better for addressing uncertainty?

I started looking back to find out a little more about how environmental flow approaches were derived, and I came up with good old George Baxter in Scotland in 1961. [Slide 8] How many people here have heard about George Baxter? [Few to no hands raised] It's really quite remarkable. He did some work for the city of Edinburgh, and it's unfortunate to say I think he did it before quite a few people in this room were born. [joking] But he got no credit for his innovation, and I think that is because his papers really weren't very widely distributed. His idea was to use percentages of mean annual flow for several very specific objectives: hydrologic variability, including salmon life history in several different aspects, such as attraction, spawning, and incubation flows, along with food supply, angling and freshet flows. So he was actually quite advanced in 1961 about addressing all of the elements of -- I can't decide whether it is a holistic or a comprehensive method. It was not simply a single minimum flow, it was a flow regime. But that concept didn't really get anywhere, unfortunately, until Don Tennant came along in 1975 [Slide 9] and did almost exactly the same thing in Montana, along the east slope of the Rockies. Tennant's idea was to recommend flows to protect aquatic resources in both warm water and cold water streams and protect the natural environment using a percentage of mean annual flow. He was considering hydrological variability, along with assessing specific channel widths and depths and velocities, and wetted side channels, getting into concerns for wildlife, including bird nesting. He was really getting pretty holistic/comprehensive even though in actual application by others it pretty much came down to a single flow, 30 percent of the mean annual flow, and then you're done. There were a lot of projects, a lot of environmental flow recommendations that derived from that sort of an approach. At least Don Tennant became very famous; he was even formally recognized by this group a few years ago for his contributions to environmental flow.

About that same time [1975], other folks who have also been suitably honored by the Instream Flow Council, were with the Instream Flow Service Group out of Fort Collins. We have several of those folks here today. This was the original flow diagram of the approach I am trying to present. [Slide 10] I am coming back to the analytic/comprehensive definition here because the Flow Group was starting to use some more mechanistic approaches. A lot of it was feasible, as Thom [Hardy] was saying, because of advances in computer technology, where the Flow Group did their original work on a CDC-Cyber mainframe using IBM punch cards. I've got a copy of their software package PHABSIM for hydraulic habitat modeling on one of these big magnetic discs, which I had to take up to Humboldt State University, have them load the disc on the CDC-Cyber, and then make requests to use the program over a modem.

But that was a great advance over using -- I don't know if I still have my slide rule. [joking] Computing technology has vastly increased our ability to work with more complicated programs and analysis. So this was the flow diagram in 1978. It was ultimately expanded into a much more complex diagram. [Slide 11] I don't really expect you to be able to read all the boxes, but even if you could, it takes a while to really absorb all of the concepts and flow paths that are in this analytic-comprehensive approach.

This is the complete IFIM. Unfortunately, it had this little aspect over here [points to left of slide 11] called "microhabitat per unit length" computed by the PHABSIM model, and that was pretty much all of the complete IFIM that most people did. In my early career as a consultant I was being told by regulatory agencies that I had to go out to a river, apply PHABSIM, and bring the PHABSIM habitat index results back to the agencies. They would then decide whether the proposed hydroelectric project was viable or not based on their interpretation of the index, which was typically peak-of-the-curve. To this day, the term IFIM is consistently and incorrectly used interchangeably with PHABSIM. Clair [Stalnaker], you still have your hair, and I'm very impressed that you haven't pulled it all out when people constantly use IFIM when they mean PHABSIM. I heard it misused here yesterday, so it still happens. The IFIM is actually a very analytic and comprehensive process, and it's supposed to address all of these other elements besides just microhabitat. [points to more boxes on slide]

So what happened in the early 1990s? [Slide 12] Instream flow management decisions were typically based on single or few fish species, and other aquatic species pretty much didn't come into the picture. Ecosystem processes and riparian management just kind of went away. Geomorphic processes and hydrologic viability were really pretty much neglected, too. Well, if you go back to the IFIM approach right here, [Slide 11] it has hydrology right there [points to box in center of slide]. You need that; you need all these other elements to fully implement the approach. So the IFIM got a bad rap, even though you shouldn't blame the cookbook when the chefs don't follow the recipe.

As a result, ecologists in general came unglued, and justifiably so. [Slide 13] There were some fairly harsh descriptions of what was going on in 1990's-era instream flow sciences, about approaches being overly simplistic and reductionist in terms of complex ecological systems, which was unfortunately often true. But as a result, there were a lot of alternatives generated that were more holistic and less analytic. Brian [Richter] has mentioned several of these, going back and starting with hydrology and incorporating hydrologic variability. This is where we came up with the Indicators of Hydrologic Alteration. You've heard his description of the motivations behind that approach. I don't think he said so exactly, but I think much of the motivation was driven by a lot of very poor instream flow recommendations and management decisions that were made about that time.

I mentioned Rebecca [Tharme] 1996 and her review of many different methodologies, which listed several similar approaches. The Range of Variability Approach came out at that time, as did the Natural Flow Regime concept, all starting back with the perspective of hydrology.

So, what's happening now with environmental flow approaches? [Slide 14] As I mentioned, I think are two major categories, both going in the forward direction and getting more alike. [Slide 15] The holistic/integrative category that pretty much started with hydrology is now starting to incorporate ecological flow mechanisms to try and justify the rationale for why you would recommend hydrologic variability. In cases where you might have to justify arguing for a certain portion of the hydrograph and assess it more precisely, you would look for support from comprehensive/analytic ecology-flow relationships. And the comprehensive/analytic approach, which starts with biological and physical mechanisms and brings in the hydrology, is getting more holistic/integrative.

So, I don't know. Do either or both approaches help us deal with uncertainty? I'm not going to answer that right now – and I may not even answer it later – but I'm posing the question and describing pathways and mechanisms.

We have already seen this [Slide 16] and I think everybody gets the idea, where it [ELOHA] starts with hydrology [points to top of slide] and then pulls in flow-ecology relationships [points to bottom of slide].

This is a newer one. [Slide 17] HEFLOW came out from Oakridge in 2013 with another flow diagram, which I can't claim to fully understand yet – it takes a while to absorb all these pathways. The authors believe there are some special considerations where you deal with environmental flows and hydropower projects in particular. They define HEFLOW as a holistic approach, although I think it's a good thing they didn't call it the Holistic Hydropower Environmental Flow, because then it would be called HO-HEFLOW, and nobody would take them seriously! [joking]

It remains to be seen how that particular approach will pan out over time, but that brings me to what I actually wanted to talk about today. [Slide 18] Do I have any time left, Thom [Hardy]? Eleven minutes?? Okay. Well, then I'll go very fast!

We've talked about some legacies at this workshop, and I think it's been pointed out more than once that some of us are getting pretty old [joking]. There are a lot of environmental flow tools that remain very useful in the context of site-specific recommendations where you're required to assess the impact of changing flow that in this particular spot. A lot of the older tools are still around, and there's still a need for them, but they haven't kept up with newer technologies and computer operating systems. So Bob Milhous, Ian Jowett, and I have created this new program, SEFA, or System for Environmental Flow Analysis, which essentially replicates the structure and processes of the complete IFIM. However, because the term IFIM has been misused and could be a bad word to certain people, then we're using SEFA instead of IFIM. I would like to note that what Dudley described doing at every single step of his comprehensive Susitna project assessment was describing the elements of IFIM, from study scoping and issues identification to study design and agency consultation. I was checking off the IFIM boxes while he was describing the process he went through. But he wisely didn't use the term because then people might think he was just doing PHABSIM hydraulic habitat modeling.

At any rate, the structure of the SEFA software amounts to a very large toolbox. It does a whole lot of things in addition to just the same-old, same-old software packages out there. It includes the step of legal-institutional analysis and scoping of project objectives [pointing to boxes on slide]. You get down to here where you have a pathway break where you can put in a river model, which means a whole description of a river channel geometry with the gradient, cross-sections, the velocities and those characteristics. You can do a lot more analytic studies once you have a river model. But you don't have to go that pathway. Depending on your requirements, you can jump out to standard setting methods, such as Tennant and the 7Q10. There are still instances and still jurisdictions where they use the 7Q10, such as in Alabama. Fortunately, they never get down that low because Alabama for the most part has a lot of water. Did you notice on some of the graphs and pictures we saw this morning that Alabama was still showing pretty green? The green means the state still has under-"utilized" water resources, so they do use the 7Q10 but don't really have the current capacity to reach it.

In Florida they have a legal statute that sets "minimum flows and levels", so they have to deal with the fact that they have a statute that uses that definition. The different management districts have different approaches to it, but that's what the statute says. And you can use this software to derive these types of recommendations.

Since I don't have that much time left, I will just start winging through the rest of my slides and give you some idea of what the software can do. [Slide 19] SEFA essentially merges several existing software packages—PHABSIM that Bob [Milhous] did, RHABSIM that I wrote by stealing all of his code and making it useful [joking], and then RHYHABSIM by Ian Jowett out of New Zealand, who developed exactly the same modeling process (as PHABSIM) independently. So, SEFA is based on the IFIM, the same general schematic, with many different analytic elements. We tried to make it user-friendly and menu-driven and have cool graphics and all that good stuff, but it actually contains many different environmental flow methods. And with all these different methods available, [Slide 20] you can actually apply all of them or as many as you choose as appropriate, and then you can see whether you're getting some consistent replication of your results. This replication in turn reduces uncertainty and gives you more confidence in your recommendations.

So this is just a quick list of all the capabilities that are in SEFA. Rather than just reading down that list, I will give you a very quick tour of the things that it can do. [Slide 21] It is open to user choice, so you can pick out modules and do certain types of approaches, or do them all, depending on your needs. SEFA is intended to be more of a guideline that says that if you're going to be addressing environmental flow from the analytic point of view, that you should be addressing all of these different aspects that are in this pathway, or at least have a good reason as to why you might not be addressing a certain aspect. But the software is very flexible. You can link your habitat analyses with water temperature, essentially temperature-conditioned habitat suitability over distance, and you can combine the results from 1D models and 2D models into the same analysis where you don't have to be separately evaluating the results.

Except for the nerds that are out there, I don't want to get too deeply into this. [Slide 22] For stage-discharge rating curves, you can use either log-log floating or point-bound regression analysis. In other words, SEFA allows a three-point regression that either splits the error among three points or else it binds to one, and then splits the error among the remaining points. Because of that choice, SEFA has the ability to precisely reproduce your observed depth and velocity conditions at your calibration flow. That's been one of the knocks on PHABSIM, that you will always have this regression error issue. All choices in SEFA are configurable, and you can decide to take the old PHABSIM type pathways or you can take the new SEFA pathways.

There are several different algorithms for simulating velocity, including a new from Ian that is computed point by point using hydraulic conveyance, that is, the conveyance of water around each sample point rather than using a Manning's n roughness equation like PHABSIM. They're really not that different and each has strengths and weaknesses. Then there's also a logarithm of the depth method for simulating velocity. Both the water surface elevation rating curve calibrations and velocity calibrations can use interactive graphics. So visually, you can go through the calibrations and see directly what kind of simulation results you get, as in: are they stupid, are they reasonable, do they make sense? For international use or for scientific reporting, SEFA is completely switchable between metric and US units.

Here's a typical plot of a cross-section profile with velocity, a standard 1D graphic [Slide 23]. You can right-click on any one of these types of images and create a full copy that you can cut and paste through Notepad and anyway, lots of power there. And, sorry, but I did run out of time. I have a lot of really cool features left that I'm just going to have to go through very quickly. You've got a roll, pitch, and yaw program to visualize your cross-section. [Slide 24] You can do a simulated 2D graphic, which is switchable among the variables and you can see the patterns that you get between adjacent cross sections. [Slide 25] This is calibration of log-log rating curves. [Slide 26] It's has drag-and-drop features to work with the data for error correction and quality control.

You can do adjustment and calibration of the velocities by working with the bottom half of the image and pulling the conveyance factors up and down and seeing what it does to the simulated velocity. [Slide 27] Your ultimate objective using these graphics is to get a good calibration out of the hydraulic habitat model. [Slide 28]

SEFA has an entirely separate habitat suitability criteria [HSC] module, where it maintains libraries or you can create HSC from sampling data by several different methods. [Slide 29] There's generalized additive models [GAMS] available in addition to standard approaches, or you can test for interactivity in your depth and velocity variables to see whether you should go to multi-variate analysis or not, scatter plots of depth against velocity [Slide 30], HSC curve development with use–to-availability [U/A] ratios. [Slide 31] This feature can show you very quickly if you have gotten in trouble by having U/A ratios showing that your species “prefers” habitat they don’t commonly use. This is a very common problem with U/A ratios. SEFA also has some terminology changes from older programs. [Slide 32] Weighted usable area, for example, is a very misleading name, implying an inaccurate concept. There is no actual area in the habitat simulation, since it’s all based on point sample data. So a more accurate terminology is Area Weighted Suitability If anybody wants to argue about this—I mean, have a discussion [joking]—I would be happy to engage.

Okay, the program also allows you to split out your different transects, your habitat relationships in several different ways to see what’s driving your analysis. [Slide 33] You can perform sensitivity analyses by making different choices of different methods, which is a way of addressing uncertainty. [Slide 34] Here you get the same results if you use a geometric mean of your habitat variables versus standard multiplication. You can use the standard setting approach using the habitat retention method. [Slide 35] You can use the Tennant standard setting method, but with the modification of actually testing the depth and velocity hydraulic criteria that Tennant specified in his papers rather than just automatically using his fixed percentages of mean annual flow. [Slide 36] There’s the capability of doing fish passage analysis [Slide 37], and computing sediment flushing flows. [Slide 38] SEFA has the ability to specify substrate size categories by percentage, point by point throughout your data set, so you can do a deep flushing flow analysis, or you can do a suspended sediment concentration analysis [Slide 39], or see how fast sediment drops out over distance. [Slide 40]

You can calibrate [Slide 41] and simulate [Slide 42] water temperature. You can then look – high flow down here, low flow up there [pointing to slide] – to see how far down the river it is before you reach equilibrium. DO modeling can be done, with daily calibrations [Slide 43], and then simulations over time [Slide 44].

Getting back to the subject of time series analysis, SEFA will import any type of data over time. [Slide 45] The import data is typically daily flow, but it can also be all of these others listed here, especially lake elevations. If you have a whole time series of lake levels, you can look at frequency of occurrence and duration and relate these factors to habitat metrics. The program is also capable of modeling primary productivity.

For illustrating time series data graphically, [Slide 46] you can show the input data, produce box and whisker plots, and create duration graphs with a time filter if you want to use only a portion of your complete data set. SEFA also has the capability of producing the Indicators of Hydrologic Alteration statistics, and allows the import of a habitat index from any other method, such as MesoHABSIM or the Demonstration Flow Approach, and perform time series analysis, or implement the Uniform Continuous Under Threshold (UCUT) method. [Slide 47] Here are graphs of a typical flow time series, [Slide 48] flow duration analysis with several options, [Slide 49] Area Weighted Suitability over time, [Slide 50] and event analysis, or how often do you reach certain event thresholds, along with confidence intervals. [Slide 51] Here's an image of the UCUT, [Slide 52] and what else is currently under construction, including a hydro operations model [Slide 53] and area-under-the-curve habitat duration comparisons. [Slides 54 and 55]

SEFA maintains a website at www.sefa.co.nz for more information. [Slide 56] The program is quite cheap, because we are only attempting to cover our expenses and make this tool readily available. Upon request, you can even get a 30-day free trial. Ian and Bob and I are going to be doing an advanced habitat modeling course in Fort Collins this October 13 to 15, and there will be an announcement on the web site soon. SEFA is living software, with continuous improvements and the addition of new modules and methods as they develop.

In conclusion, [Slide 57] I think both of these main approaches to environmental flow analysis, the holistic/integrative and the comprehensive/analytic like SEFA, are still developing, and I think they are even starting to converge. Even though the first is basically a basin-wide tool and the second is more site-specific, I think they are coming together. As has already been mentioned, both approaches could without a doubt use better ecological flow models, but only increased knowledge brought about by monitoring, which is often sadly lacking in the United States, will further decrease uncertainty. Thank you.