King County Normative Flow Studies Project
Science Review Team Work Session #5
Thursday, April 28, and Friday, April 29, 2005
Center for Urban Horticulture, University of Washington, Seattle

Meeting Report
June 7, 2005
SRT # 5 REPORT ON DRAFT PUGET SOUND LOWLAND STREAMS

MEETING BACKGROUND

Flow regime is one of the primary factors determining river health or condition. Recognition of this long-neglected fact stimulated King County to initiate a comprehensive study, staffed by an interdisciplinary team of King County personnel and consultants, of the interactions between streamflow and river health with a view toward protecting and restoring anadromous salmonid populations specifically, and river health more generally. The expectation of this project has been that by identifying those interactions, the project can provide information to guide management actions that mitigate the effects of flow alteration on King County's streams and rivers.

Periodically, the Normative Flow Studies Project team has met with a panel of experts convened by King County, the Science Review Team (SRT). This consensus report from the fifth meeting of the SRT represents our collective judgment on progress to date, especially as reflected in the King County and Parametrix report (April 2005) titled "Development of Hydrological and Biological Indicators of Flow Alteration in Puget Sound Lowland Streams."

PUGET SOUND LOWLAND STREAMS REPORT OVERVIEW

This King County project began with an important objective, to connect flow alteration to specific consequences for biological condition in King County streams and rivers. That is a tall order but one that has long been neglected. We commend King County for its vision in initiating this effort. The most important limiting constraint to the success of this project is the lack of a comprehensive data set collected specifically to explore this complex interaction, a limitation that is beyond the scope of this project to correct.

Given the limits of this path (no new data collection), the project does provide useful information. For example, the analysis points to important flow variables that County managers should be aware of. Those insights are, not surprisingly, limited, and causal relations between flow and biota cannot be precisely defined with the data at hand. Using those results to produce a detailed management tool to guide county regulatory and incentive programs with precision, as initially envisioned by the early project scoping documents, is beyond what should be expected from this level of study. The reality is that a more deliberately designed and executed study would be needed to accomplish that goal.

Given that the county has already mined existing data for what can be learned, the next step in this process should be for the county to determine how to use the results in hand to develop management guidelines. We suggest that the county consider carefully how to use those results and how to define the next steps in this process.

Even though this effort did not comprehensively document the effects of flow on salmon populations and river health, we do not believe the county should abandon this important effort. Rather, the relationships demonstrated should emphasize that more deliberate research and documentation is crucial to the future of water and river management in the county if the goal is to significantly and cost effectively improve river health.

That said, we also believe that a short-term effort to clarify and strengthen some components of the present draft report are in order. Most importantly, the report needs to do a better job of stating its discoveries in clear and definitive ways.

We turn now to a series of such activities that should be completed in a short period (a few months at most). This list has two major contexts. First, additional **data mining and evaluations** may either strengthen the inferences deriving from this report or put to rest some areas of analysis that persist in the current document, despite an apparent lack of adequate foundation for their continuation or use. Second, some energy should be directed in the next few weeks to **clarify ambiguities** in the current report. Without these clarifications, no "next-generation" effort, whether management-oriented or as a future study, will adequately capitalize on what was learned in this important, even pioneering, effort.

IMPROVING THE REPORT

Major Needs for Additional Data Mining and Evaluation

1. Strengthen the discussion if/when/how modeled or simulated results can be used more effectively. The use of HSPF simulation results continues to vex the analyses. On the one hand, simulated results expand the range of available information many-fold. On the other hand, the presented comparisons with gage data are not terribly promising and the "assessments" provided throughout this document do not inspire confidence. In particular, the discussions on page 16, ¶2-4, and page 43, ¶2, present the reason models are being used; nothing in the report clearly shows how well the models simulate the hydrologic parameters being used in the analysis. They provide no basis to consider whether the biology-hydrology relationships are overstated or understated when predicted using the simulation results. In short, some explicit consideration of model accuracy and precision is needed for the simulated flow variables.

One might also ask when and why model results are or are not appropriate for certain flow measures. This is especially important given our recommendations in SRT#4. We noted then substantial "queasiness" and suggested that hydrologic model (synthesized flow) data "should be eliminated from future analyses." We also asked if there had been

any “systematic evaluation of whether the chosen hydrologic metrics for this study show significant differences between simulated and gaged flows.” (These quotes from page 2, SRT#4 report.) Comparisons of gage data and simulation results have been made for selected parameters. In some cases, those evaluations did not involve the specific measures shown to be important to biology; in others, the lessons of those analyses (i.e. the fits are not great) were ignored.

To strengthen (or finally bury) the use of simulated flows, the report must provide some measure of how well the model data matches observed data. It is crucial that this be done explicitly with respect to the specific hydrologic parameters thought to be biologically important based on project evaluations, not just for a subset of flow metrics that may be routinely used as calibration variables.

It is not sufficient to determine that the simulated general streamflow patterns match those of the observed streamflow. That is, we must understand the ability of the simulated parameter to match the measured parameters for each of the key flow factors that this investigation has shown are associated with biology.

As the above activities are accomplished, one can explicitly explore and document the sensitivity of hydrologic variables when derived from model estimates. This might involve developing a tiered list of metrics (in a carefully organized tabulation) ranking those that are robust and those that are less robust.

A revised report must carefully define what it means for a flow metric to be modeled “well enough.” It is important to establish reliability of modeled hydrologic metrics, a standard of reliability say at 95% confidence. It seems likely that some metrics can be modeled better than others. Which hydrologic metrics can be modeled most successfully? Are those metrics relevant to the current analysis?

In short, these comments point to a crucial issue: the need for a statistically robust comparison of the hydrologic metrics generated by simulated results and gage data for the same site(s). This need was noted in our earlier reports, and its absence will undermine any future efforts to use the project’s results.

2. We urge project leadership to focus on a rational subset of hydrologic measures. The exploration of a rich array of hydrologic measures has been important in defining new indicators as well as in seeing hydrologic issues in new ways. Unfortunately, the report seems to hang onto the rather larger list of hydrologic measures without any culling. Nowhere in this document is there an attempt to reduce the number of hydrologic metrics necessary for evaluation. SRT #4 identified seven promising metrics, and it further recommended that the number be *reduced* after excluding “those metrics that show high correlation with each other and that measure very similar flow attributes” (p. 9). The current report does not provide any evidence that this has been done; instead, this report has recommendations such as “[include] a full set of these metrics [to] allow managers to evaluate hydrologic changes that have already occurred and those that may occur in the future” (p. vii; restated on p. 81). Indeed, this report advocates including yet additional

metrics, including those that have not shown any useful predictive or correlative powers at all. Given that the ultimate goal of this project is to achieve an operational management tool, this framing in the report has moved in the wrong direction. Although these efforts have been useful in defining correlations among factors, they are not adequate yet to define the mechanisms of interaction of the major variables studied. That important task remains, but it is not necessary to document those mechanisms before understanding of the connections between hydrology and biology can be used to improve management. Data at hand offer ample opportunity to narrow further analyses and discussion to a smaller, more efficient and robust subset of the large collection of flow metrics initially considered.

3. The matching of hydrologic and biological data in the analysis depends on the proximity of the location of points of interest (POI) and the paired sites where biological data were collected. For each site analyzed, what is the stream distance between those two points? For sites separated by only a short distance, this probably does not create a problem. (What might that “short distance” threshold be and how is that distance selected?) For sites more separated in space, the analysis will be less rigorous and reliable, especially where landscape heterogeneity occurs between the two sites. How heterogeneous are those landscapes for POI and biological data sites that are separated by some distance? This is potentially important information that could be used as a “covariate” in an analysis that attempts to explain residual variation in hydrology-biology relations.

4. As one final example, consider the tendency in the report to avoid making clear statements about what has been learned in this project and how it might be used today. The limited data available for this effort leads one logically to note the limitations of the study. But in many places, the text makes reference to the "preliminary" nature of this study, perhaps suggesting that one might gain more insight from continued analysis of these data, or by seeking more examples of the same kinds of data But we do not see these results as preliminary in that context. Rather we believe that many of the patterns discovered in this report point to the need for the county to explicitly consider flow issues in stream and river management if the goal is to protect salmon populations and river health. The study also provides insight about what flow parameters might be the focus of management concern, and future research on how riparian conditions can influence the biological consequences of flow alteration. These results are important and should be clearly recognized and carried forward. This emphasis is consistent with the high level of resources already invested by the County and the previously articulated goals of this study.

As these comments convey, we believe that a stronger report is both possible and needed.

Clarifications

1. The goals and objectives of the overall project have been lost in this document, and they need to be recovered. The original document from the County on the Normative

Flow Project (February 5, 2002) states the following "key objectives" among its full list of eight:

- "Develop a valid and defensible river and stream assessment method, employing and testing Normative Flow concepts, for use in King County rivers and streams.
- "Formulate flow management recommendations based upon the assessment and analytical methods.
- "Use the flow management recommendations to inform technical, regulatory (e.g., permitting), and policy decisions specific to King County.
- "Monitor and evaluate the effectiveness of management actions based upon Normative Flow concepts and make appropriate recommendations for course corrections in action and analysis as a result."

Contrast this list with statements in the current document, particularly: "The Normative Flow Project (NFP) seeks to enhance understanding of the relationship between flow patterns and other ecological parameters in PSL streams" (p. 1). What were once stated as the key objectives of this project in 2002 are then summarized as "the ultimate goal of this project," relegating them to essentially unattainable status. Is this really what the project team wants to project as the primary outcome of the effort? Is the goal really unattainable? Is the failure due to lack of data or to some other factor(s)? What are those factors? If the original objectives were impossible, that should be stated and supported. If the work is substantive but incomplete, then state clearly the conclusions that are substantive.

2. If this report is to have the effect that is desired, for example, to ensure that flow is considered as a primary variable to guide water resource management decisions by King County, the most significant findings of this study must be extracted and highlighted for all to see and understand. To illustrate this point, modeling efforts that focused attention on hydrologic factors such as peak flows and low flows were not well connected to flow as a primary variable influencing biological condition. In contrast, it appears that the importance of the onset of flow (the fall rise in flow) and biology is strong. The concept of trajectory change is an important stimulus in living systems. This is reflected in identification and exploration of flow metrics relating to flow pulse, onset of flow, and rise metrics. Though perhaps not biologically surprising in some ways, a focus on these temporal dimensions of flow transition seems to be new in the scientific arena. These dimensions of flow are worth pursuing despite the fact that they are typically overlooked in management and conservation efforts.

By showing major areas of progress managers and county leaders can define where to go with this effort in the future. We see some potential and more important a need for improved understanding of how to use flow in local and regional decision making. We are reluctant, however, to recommend a specific approach or future to this effort in the current situation.

3. Another issue that generated vigorous discussion was the extent to which the project should look beyond flow. On one side is the view that the charge has been to focus on flow, with next steps being outside those bounds. Proper use of this report is to say what

are the next steps, given a reasoned approach to the mandate of this study. The other side might suggest that careful exploration of the role of important co-variates such as sedimentation, water quality, and physical habitat structure is appropriate at this time. In either case, more can be gleaned from existing information than is reflected in the current report and current data are simply not sufficient to explain everything. The inclusion of the riparian condition variable (as suggested by SRT #4) illustrates the value (even necessity) of systematically incorporating important non-flow variables that are known to influence biological condition as co-variates or contingent factors. The point should be made in the report that isolating the independent effects of flow regime on biological metrics can best be inferred across sites where riparian condition or other important co-variates do not vary substantially. The present post-hoc design did not allow for as careful controls as might be useful.

This point reinforces an early caveat of SRT discussions, namely to not assume that a flow-based approach ALONE will be adequate to define comprehensive management recommendations in a landscape with highly variable land cover and use. Many other variables are also important direct and indirect (through flow relations) determinants of biological condition in streams and rivers.

4. Be sure that terms, concepts, and contexts used in the report are clearly defined and consistently used throughout. This is essential for effective communication among members of the project team and, even more importantly, in communications with broader audiences of elected officials and citizens.

- Clearly define how TIA and EIA are estimated, including references to the use and effectiveness of those estimates.
- Clarify when and why specific time steps were selected for flow analyses (i.e. 15-minute vs. hourly vs. daily).
- Document and describe the logic of the Q2-Q10 approach in the report. The logic used as described in response to a question during our meeting seems sound but it is not explicitly presented in the report.
- Clarify how and when replicate invertebrate samples were combined to achieve minimum sample sizes for analysis. Perhaps this should be included in a table of data used in the study. How often was this done and how many sites were not used because of the application of the 300- or 500-individuals-in-sample rule? This would provide a valuable archive for any future studies that wish to repeat the methods used here.
- Decision rules including how variables were chosen need to be more explicitly stated. If this isn't done, repeatability will suffer.
- The analytical approach in the current report that constrains the regression of model with real data to go through the origin needs elaboration. Is this constraint appropriate? Why or why not? What are the consequences of that constraint? What effect does relaxing that constraint have on our ability to detect and document differences in slope and intercept in these regressions?
- The collective efforts of the interdisciplinary team yielded results that are stronger than might have been possible without that interdisciplinary context. Yet the report does not highlight this reality.

5. Another concern is the use of modeled streamflows (HSPF) versus measured streamflows. A significant advantage of the simulated streamflows is that they represent watershed conditions (1995) near the time benthic invertebrates were sampled to determine site-specific B-IBIs (1994-2002 in Table 2) and are a consistent time series of streamflows. In contrast, the measured streamflows represent changing watershed conditions and do not necessarily represent the conditions at the time the B-IBIs were determined. This is an important consideration that must be addressed in the report. An example of this importance is the relation between B-IBI and TQ Mean shown for observed data in Figure 11 (page 64, lower right) and for the simulated results in Figure 11 (page 62, lower left). The differences in the correlation coefficients are significant being 0.10 for the observed flows and 0.57 for the model streamflows; also there is a clear limit for the modeled streamflows and none for the measured results. The difference may be partly because the definition of TQ Mean may have changed. The definition in Table 5 uses the number of days over the 'average baseline-forested flow rate'. The forested baseline-flow rate is unknown for the measured streamflow time series. Every hydrologic metric present in either Figure 10 or Figure 11 should have the same metric in the other figure; there should also be a summary table. Consider limit analysis for the various metrics (a limit is very clear for the TQ mean in figure 10).

6. The discriminant function analyses generated wide-ranging discussion. Important points raised in those discussions include the following.

- Strengthen the multivariate analysis with discussion of what is learned from its use, what might be learned from more or different use of these methods, and how to effectively communicate those insights to diverse audiences. Generally, multivariate analyses are of limited use to managers, unless the (discriminant function) axes have some clear interpretation. If this can't be achieved, remove this section from the report.
- The analysis would likely be better if redundant predictor variables were removed (see point #2 under "Major Needs for Additional Data Mining and Evaluation" above). This would remove multi-collinear variables from the analysis, as well as probably allow for greater interpretation of multivariate axes.
- The inclusion of EIA as an independent (predictor) variable is inappropriate: it is not a hydrologic measure. We suggest removing impervious area to look more narrowly at hydrologic factors. Mixing land-cover and hydrologic variables may improve the correlations but they don't provide any physical insight or allow much physical interpretation into the results.
- Care must be taken to ensure that information in Tables 7 and 8 matches the analyses depicted in Figures 16 and 17, since this was not the case during the oral presentation at the SRT meeting.

7. The SRT encourages King County to prepare a report from this project for submission to a peer-reviewed publication. In its current form, it is too large and not as clearly focused as it should be with that goal in mind. People in other areas can benefit from this work, but only if the issues raised above are adequately dealt with. However, the viability of any such peer-reviewed publication will depend on addressing the several

specific shortcomings mentioned above (e.g., confidence in simulated flow variables and others).

Key Questions for SRT on Streams Analysis, as raised by King County:

W*hat questions does SRT have about what we did, why we did it, and how we have interpreted our analysis?* A number of items relating to these issues are outlined above. Two of the more important are 1) make the most significant findings of the study more explicit and 2) improve the presentation of the measured versus modeled streamflows metrics.

Do you have recommendations for validation steps (e.g., particular analytical approaches)? The results need to be further refined and digested before there will be anything to "validate." Much winnowing still needs to occur to reduce the number of hydrologic metrics, for example, for use in both decision making and in the design and execution of future work. Some data from the Kitsap Peninsula may be available for this purpose, but most of the regionally available data has already been used for developing the relationships presented here.

Given the analysis we have done, what types of management guidance can we establish now? In particular, with respect to the County's proposed performance measures? The SRT believes that there are useful management guidelines buried in these results. The next work on the project should be to develop management actions that can change the hydrological parameters in the direction that improves the biology of the streams.

What additional steps or approaches would you recommend for developing management guidance from this work, given the limited data available for testing flow-biology relationships in smaller rivers and streams? This question presupposes that there's not enough information already available. While we agree that there is never enough information, we also believe that it is possible to extract some meaningful and useful results from the current analysis and this should be done as soon as possible. The first step is to clean up the details of this report and proceed with the work needed to transform the results to date into a useful management tool – this should be done before additional studies are made. We emphasize the need to use the small set of hydrological variables identified in the report along with stratifying existing data to "control" for variation in riparian condition (as in Figure 12) or other factors. Using this approach is crucial because it requires that flow be put into context.

What recommendations do you have for defining "hydrologic" stream types for the purposes of comparing hydrologic alteration across streams (to limit natural variability and detect impacts of flow alteration)? Aside from the obvious issues suggested by inspection of the data and discussed *at some length* at SRT 4, sites were pre-selected to minimize the variability of this factor. The analysis completed to date, because of the relative homogeneity of the streams included in the analysis, avoids this issue. If this is a new objective for the NFP, then a new data set would need to be explored. As it is, most

of the streams analyzed appear to be relatively homogeneous in both physiographic setting and hydrologic response (by design at least for the streams from which biological data (B-IBI) were collected). Variability in some factors such as the spacing and distance downstream of sample sites, however, does complicate the comparison of sites.

We have not attempted to deal with the impacts of climate change on our metrics or how we estimated flow alteration recommendations for incorporating climate change analysis into our use of these metrics, or for detecting signals of climate change plus urbanization effects? Because this project initially did not incorporate this issue as a core project goal, and because our comments above suggest that more needs to be done to strengthen accomplishments related to those original goals, expanding the scope of this project to encompass climate change issues is ill-advised at this time.

Have we addressed comments/issues from SRT4 meeting to your satisfaction? The SRT #4 summary of "next steps" (bulleted and indented brown text) and our commentary on them (italics) follow. As we indicated at the meeting, we believe some progress has been made but the need for additional effort is clear from the comments above and these comments on the "next steps" defined in SRT#4.

- Data quality and homogeneity must be addressed before any further analyses are run. As part of that effort, the hydrologic data should be tested systematically for dependence on the time step used and for differences between simulated vs. gage data.

We do not recall any analysis of the time-step dependency, although that may have occurred. It's not in the present document. The simulated vs. gage analysis has been run, and it seems to reinforce the concerns expressed by the SRT. These concerns have not been adequately addressed in the present document. The time step used is dependent on the method used to generate the time series – simulated (modeled) data should not be used for short time (e.g., daily) steps.

- Cull the biological data to yield a homogeneous, high-quality set, using defined rules for selection that acknowledge the range of applicability for the metrics and methodology of the Puget Lowland B-IBI.

This appears to have been done, although the discussion in the text of October-collected data seems oddly remorseful of the loss of non-protocol data. We already commented on the need for more specificity on when and how often the combining of samples was necessary to provide adequate numbers of individuals in invertebrate replicate samples.

- Evaluate conditions at those sites with the least degree of recognized non-hydrologic disturbance. Focus this analysis on local riparian conditions, anticipating that grouping sites by their degree of local riparian cover will identity these least-impaired sites. Also consider chemical and other physical conditions, to the extent that data are available.

This has largely been done, but some of this conceptual framework for the approach has been lost in the document's description of this work. That should be easily rectified. We also note that other factors (including both local conditions [water quality, in- channel

physical habitat conditions] and landscape context [stream size (order), subbasin grouping, and distance between sampling point and POI]) could be explored beyond riparian condition with existing data sets, and that some of those explorations could be initiated by a more careful analysis of outliers in the data plots.

- Evaluate the intercorrelation of the various metrics, particularly hydrologic. Exclude those metrics that show high correlation with each other and that measure very similar flow attributes.

This has not been pursued with any vigor, and in fact the document seems to advocate adding yet additional metrics to those already identified, including those that have shown no discernible relationship to biological response. Wasn't the goal to use existing data to reduce the overwhelming array of hydrologic parameters through study of available data? Failure to remove redundant variables makes interpretation (and any management implementation) more difficult.

- Describe how to operationalize the hydrologic metrics; determine whether continuous hydrologic modeling should be (or is) necessary to apply them.

This has not been done in the report at either of two levels important to the county. First, the report does not highlight in positive terms the conclusion that selected flow conditions and contexts are important to river biology. Second, it does not provide guidance on next steps necessary to translate that general conclusion to into carefully formulated but not overly simplistic management guidance. As a result, the County lacks management tools after 3 years of work on this project. We urged the group at our meeting to think carefully about the key findings of the study. Which of those key findings involve metrics that you might have some confidence in?

- If the County is planning to move forward with these recommendations, an experimental and analytical design should be presented to the SRT for review as soon as available.

This was an SRT #4 recommendation. We urged the development and presentation of an experimental and analytical design BEFORE the project team embarked on this "analysis," not after they had already generated a complete draft of the report. The plan we asked for last year was the one that might have guided the work in the present report, and whose existence might have avoided some of the problems we are articulating here.