Urbanization, Flow Regime, and Salmon Populations in the Puget Sound Basin

or

Recent Experiences with the Instream Flow Assessment Pilot Project

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I think the best we can do in the compressed amount of time is provide some highlights of this project for Puget Sound Shared Strategy and the WA Dept. of Ecology. Our report is in peer review and I expect that a draft will soon be made available by our clients on the web.

Project Goals

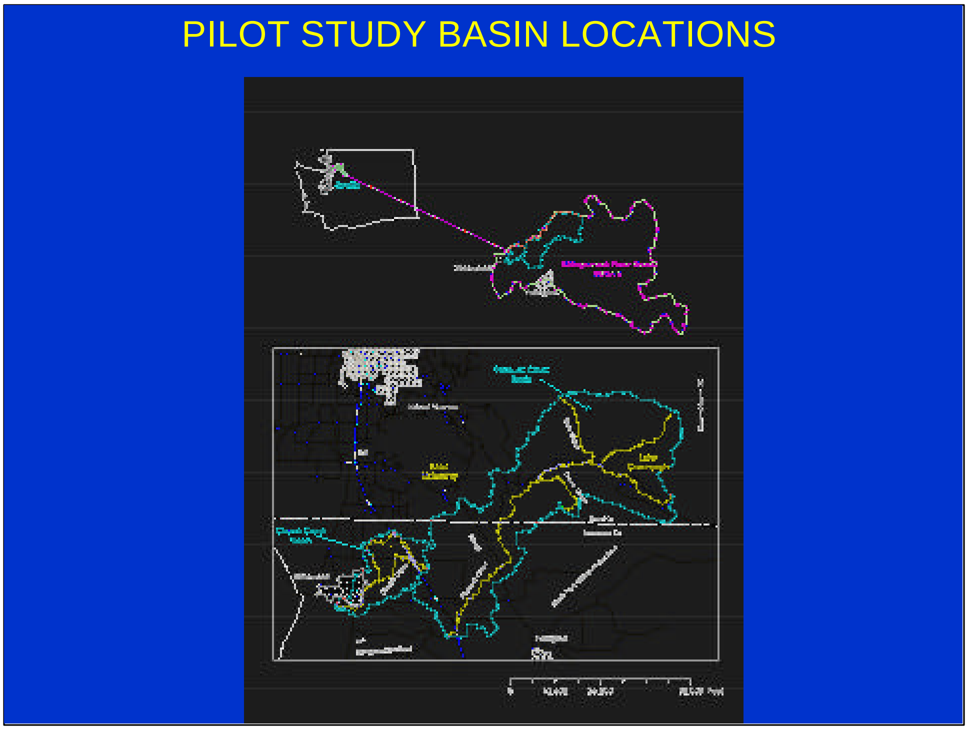
- Develop, document, demonstrate a method to:
  1. Quantify land use and water management actions on changes to stream flow regime
  2. Relate those changes to aquatic habitat and salmon population change
- Help answer the “how much water for fish” question

Our team was charged with developing a method to analyze the impacts of water and land management actions on stream flow regime and in turn the effect of stream flow regime changes on habitat and salmon populations.

Project Approach

1. Select Pilot Basins
2. Define illustrative modeling scenarios
3. Quantify Land Cover and Basin Water Management
4. Perform HSPF modeling of stream flow and temperature
5. Extract hydrologic statistics as inputs to EDT
6. Perform EDT simulation of salmon populations
7. Compare population responses across scenarios
8. Document our application and critique methodology

Our overall approach was to select relevant pilot stream basins and…



Our pilot basins are both tributary subbasins of the greater Stillaguamish River watershed. The river rises in the Cascades and discharges to Puget Sound. The western, lower end of the pilot area is traversed by Interstate-5 near the City of Stanwood, about 50 miles north of here.

Church Creek- typical small P.S. stream draining an urbanizing basin

- 11 square miles, currently mixed rural and urban use
- Primary impacts- current and future urbanization (flashier, peakier storm flows), groundwater pumping to meet growth demand (base flow depletion)
- used by coho salmon, sea-run cutthroat, and chum salmon.
- Coho selected as focal species for ecosystem modeling

Church Creek is a typical 3rd order Puget Sound stream transitioning from a pastoral to a suburban landscape. It is typical of the many of the small, low elevation coho streams in the Puget Sound basin. We selected coho as the focal species in evaluating scenarios for Church Creek.

An example of poor riparian conditions lacking conifer cover and LWD.

City of Stanwood's Bryant Well House on the bank of Church Creek – affect of pumping on creek is flow not universally agreed upon

The City of Stanwood pumps most of its water supply from these wells a mere few yards from the Church Creek.

Pilchuck Creek drains a larger basin in industrial forestry and rural use

- 76 square miles drainage, r.o.s. and rain-dominated hydrology
- Chinook and coho use lower mainstem, coho use both lower mainstem and smaller tributaries. Both were modeled.
- Current and Future Land Use- rural and forest production
- Assumed human impacts on habitat:
  - Industrial forestry basin wide
  - Current and future tributary water withdrawal and export
  - Future urbanization in one small tributary near Church Creek

Pilchuck Creek is a 4th order tributary to the Stillaguamish river. Chinook use the mainstem and coho use both the mainstem and smaller tributaries. Pilchuck Creek basin is dominated by industrial forest land use. Land use plans suggest it that with few exceptions, this pattern will continue in the future.

Lower Pilchuck Creek, January 2005

Sub-Bankfull Condition (Q2 ~3000 cfs)

Winter base flow on Pilchuck Creek.

Modeling assumptions

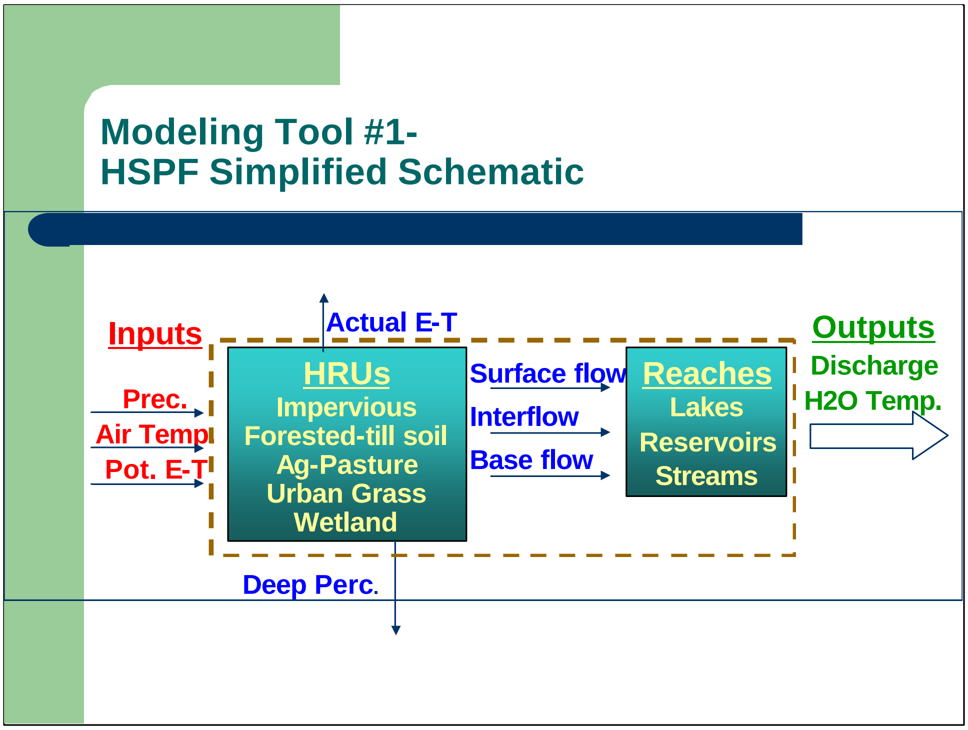
- Pristine estuary, riparian, LWD, habitat structure- all scenarios (not realistic)
- Continuity of municipal wells and exempt wells with streams (based on available info)
- No Stormwater Control for any scenario Included in Simulations (realistic for Current scenario)

In order to narrow the variables in our study, we assumed pristine, historic, riparian conditions, LWD debris loading, and habitat structure for all modeled scenarios. This allowed us to focus on upland land use change and water management.

Scenarios

- Historic/"Template"- fully forested, no human water consumption
- Current as indicated by 2001 LANDSAT-based land cover, population data, and water use records
- Future 1- as indicated by Land Use Plans
- Future 2- intense urbanization of Church Creek basin with population similar to Seattle mixed use neighborhoods

Four scenarios were modeled, but since pristine historic or template conditions were used as a reference condition to normalized results from the other scenarios, we really generated 3 sets of relative results. Current land and water management conditions, planned future conditions per current zoning and growth plans, and a 2nd future assuming heavy urbanization along I-t and to the and west- at levels found currently within some Seattle neighborhoods.



We used the Hydrologic Simulation Program Fortran (HSPF) to convert land use and water management scenarios to stream flow and stream temperature hydrographs. In HSPF, watershed areas are classified into a set of hydrologic response units that each exhibit particular runoff patterns. Simulated runoff is routed in the stream network and a timeseries of discharge, and optionally temperature and pollutants can be produced for virtually any location within the watershed.

HSPF outputs to EDT inputs

- 50-yr hourly timeseries of Q and T to EDT statistics:

  Q(t)? Relative Peak Q, Relative Base Q, Stage Fluctuation, Relative Storm Flashiness

  T(t)? Frequency of extreme Tmax and Tmin events of specified level and duration

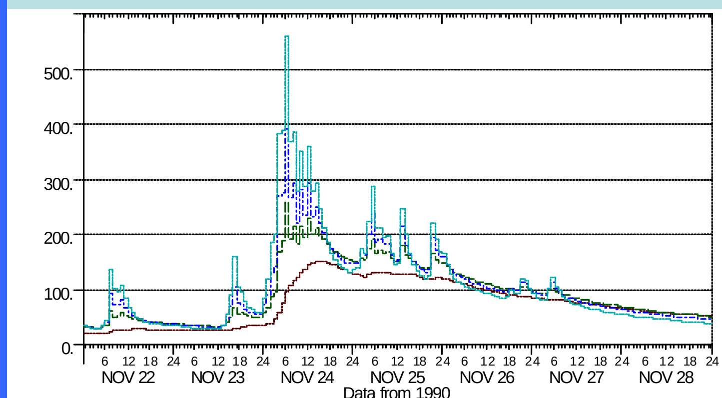
In our study we used approximately 50-years of hourly input data to simulate flow from rainfall and snowmelt in the two pilot basins. From these data, flow and temperature statistics needed for habitat modeling with Ecosystem Diagnosis and Treatment (EDT) were extracted.

Church Creek nr Stanwood

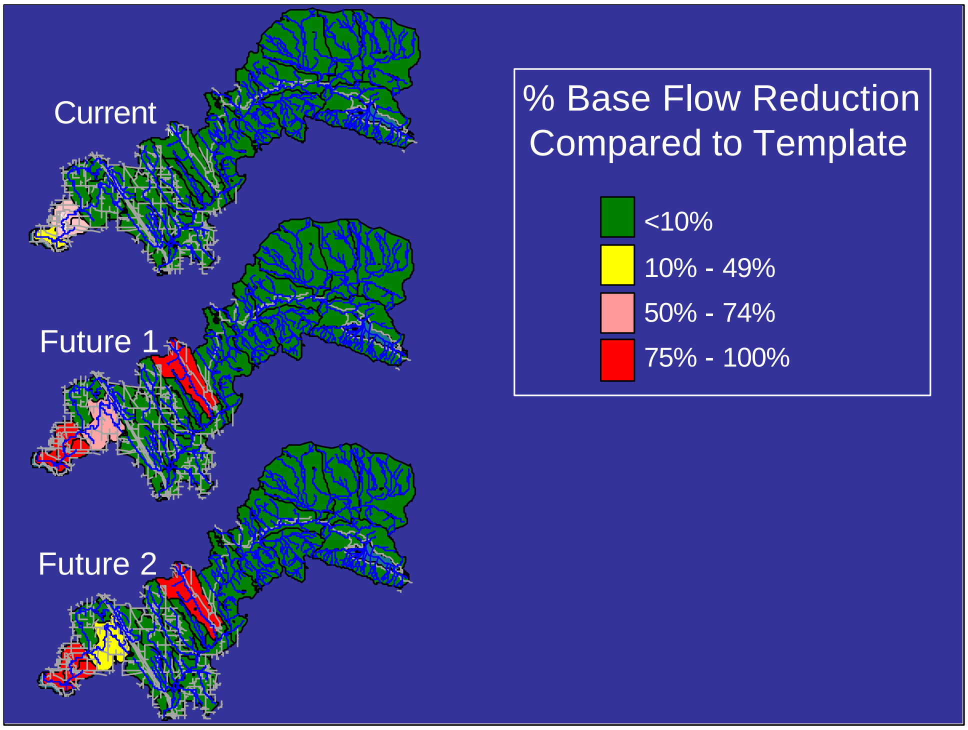
Simulated Effect of Urbanization on Storm Flows

Ratios of 2-yr peaks to template:

Current =	1.7
Future 1=	2.4
Future 2=	3.2

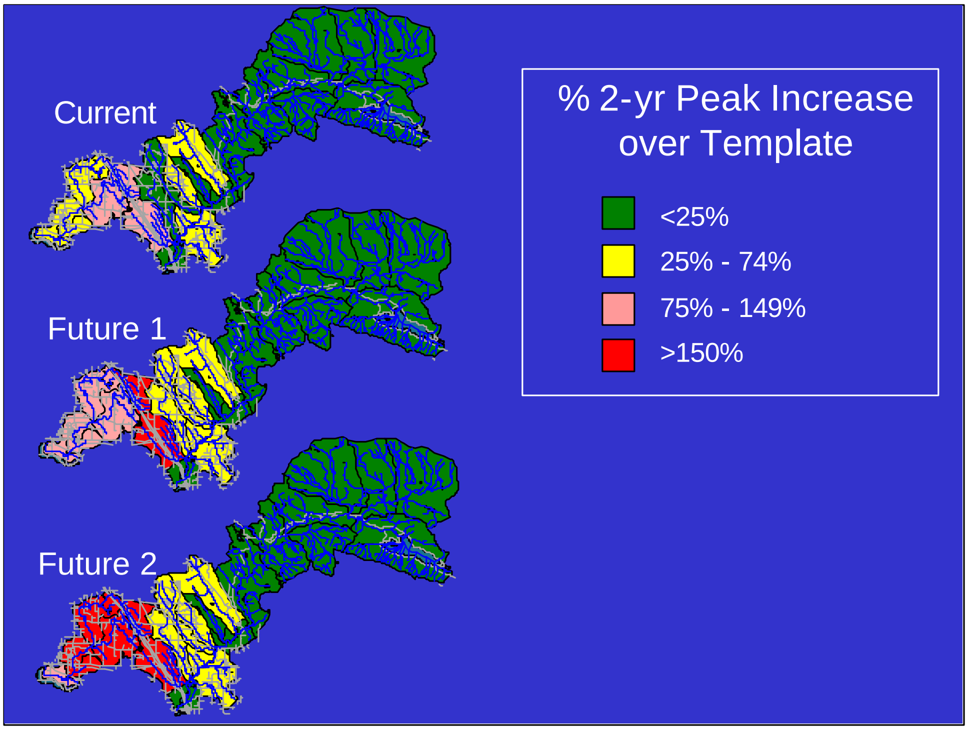


These are examples of simulated hydrographs for all scenarios showing greatly increased peaks and flashiness under current and future conditions in lower Church Creek.



Timeseries output are digested into summary statistics. Here the spatial distribution of summer base flow reductions show progressive an increasingly severe base flow loss as population increases with each scenario. The lower portion of the basin will go chronically dry in the future as indicated by the red area.

Pilchuck Creek is currently unaffected, but will suffer a large local reduction of base flow in subbasin 8 in the future as public wells are fully exploited to supply growth in the Stanwood urban growth area.



On the basis of peak flow increases, again Church Creek is currently more affected than Pilchuck Creek. This trend continues in the future with stream reaches along the I-5 corridor and to the west in Church Creek exhibiting peak discharges that are more than 2.5 times as large as their historical values. The Pilchuck mainstem experiences only moderate increases from a predominantly forest-covered drainage basin upstream.

Tool 2- Ecosystem Diagnosis and Treatment Model (EDT)

- Rates habitat quality and quantity on a reach by reach basis in terms of focal species P, C, A, and D or “Viable Salmon Population” parameters.
- Used to plan habitat restoration and basin management actions with the goal of meeting VSP targets

EDT rates habitat from the perspective of a focal salmon species by calculating population parameters and comparing those values to historical or “template” conditions. VSP parameters include intrinsic Productivity, P, a measured of habitat quality, Capacity, C, a measure of habitat quantity, Diversity, D, based on the number of life history trajectories available to the population, and A represents abundance, the number of fish a modeled basin tends to equilibrate to given a certain set up of assumptions about marine survival and harvest.

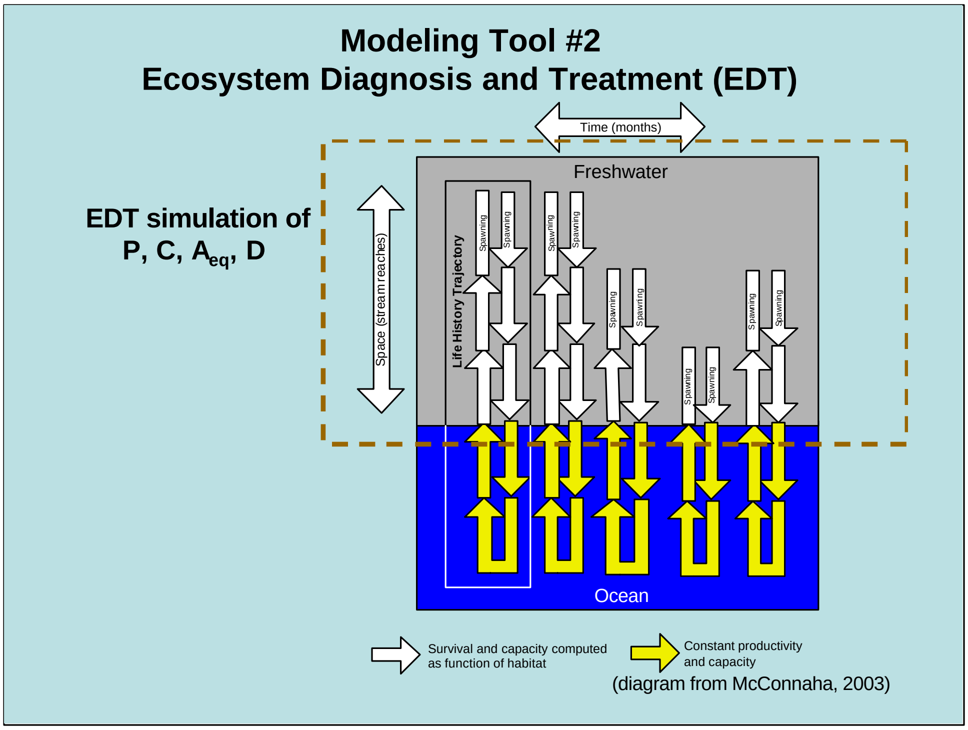
Additional EDT Inputs from other sources

- Bed scour depth in spawning areas
- Intra-gravular Fine Sediment in spawning areas
- Pollutants (e.g. adsorbed and dissolved metals, D.O.)
- Riparian Function
- LWD loading
- Relative Predator Abundance

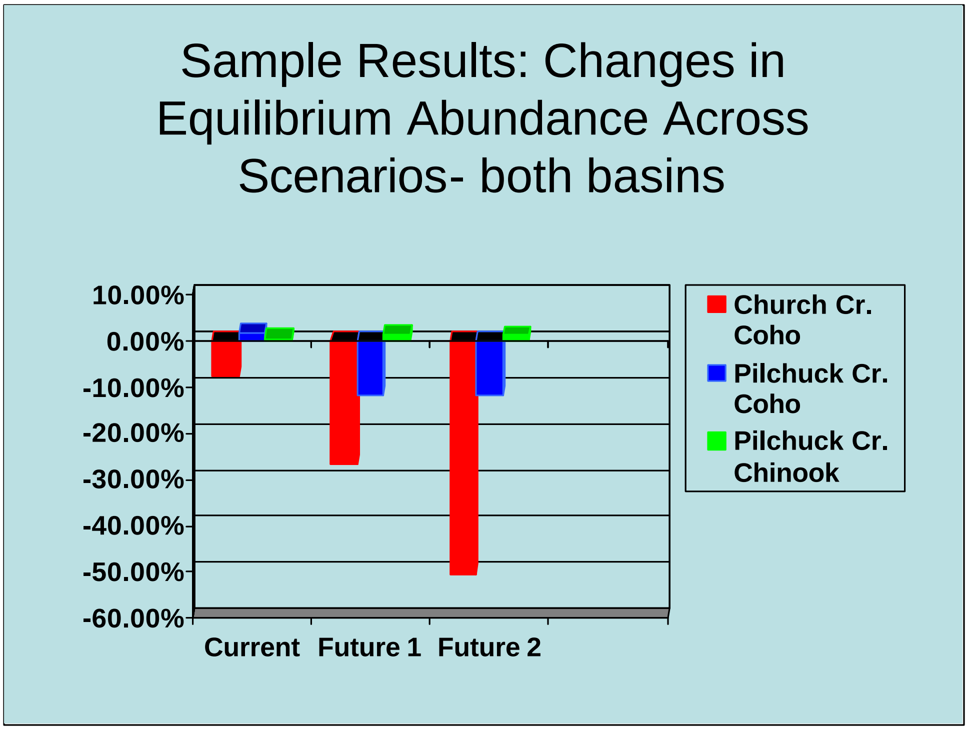
- Habitat area by types per reach
- Geomorphic confinement
- Average Reach Gradient

- …Kitchen Sink…and Tire Loadings…per reach

In addition to flow parameters and temperature information, the user must assign a raft of other input values that characterize habitat in each reach including stream stability, fine sediment deposition, water quality, riparian function, LWD, food, predation, surface area of different habitat types, etc. There are total of 46 “level 2” inputs.



EDT uses rules to define different life history trajectories appropriate for the selected focal species. It tracks salmon at various locations and life stages in the freshwater environment and calculates their survival at each stage (spawning, egg incubation, rearing, migration) based on the user's inputs describing habitat quality and quantity.



Here are sample results showing modeled departures in fish abundance from template conditions for current and future scenarios. Church Creek coho are shown in red, Pilchuck Creek coho are shown in blue, and Pilchuck Creek Chinook are shown in green.

Church Creek Coho- shows progressive steep decline with urbanization. Based on detailed model output and sensitivity analysis, these declines are most strongly influenced by unfavorable bed scour and fine sediment loading inputs that were linked by us to peak flow increases and TIA respectively.

Modeling predicts Pilchuck Creek coho suffer moderate declines in future scenarios associated with scour and fine sediments (peak flow and urbanization) in the single urban subbasin number 1 and subbasin and the dewatered subbasin number 8.

The model indicates Pilchuck Creek Chinook are largely unaffected. They only use the mainstem of the creek that drained predominantly by forest cover currently and in the future scenarios. The mainstem flow is not affectgedy are not much affect by withdrawals or urbanization in relatively small tributary basins. Note that all results reflect assumptions of template conditions with respect riparian vegetation and function, LWD, and habitat structure- far from the actual situation in either stream system.

Assuming we have confidence in our models and method, some reasonable inferences are:

- Biggest problems are scour and fine sediments
- Control runoff peak and duration to prevent scour
- High riparian function, LWD mitigate base flow depletion. Church Creek could lose 40% of base flow with less than a 20% hit on reach survival.
- Higher rates of water depletion in Future 1 and Future 2 wipe about habitat area and reduce population diversity
- Forestry is not a problem- with caveats (channel protection, LWD, riparian buffers/function road density limits..)
- We have a method to assess land and water management impact on habitat and fish.

If we trusted our methods, we would focus on controlling bed scour in spawning areas as well as fine sediment deposition. We would make control of runoff peaks and storm durations a priority in order to reduce the scour potential of urban storm runoff. We would make protection and restoration of stream buffers and natural riparian functions a high priority. We might relax instream requirements of near-natural natural summer base flows- especially where riparian vegetation and LWD loadings approach template conditions.

We would accept industrial forestry as a relatively benign land use as long as natural riparian vegetation, and LWD loads are maintained, road density is limited, and fish passage is not impaired.

Finally, if we trusted these models and their application in this pilot study, we might assert that we have a valid method to manage land use, mitigate storm water impacts, and designate instream flows to meet salmon habitat restoration goals.

Some reasons for caution...
Low EDT sensitivity to direct flow inputs

Direct EDT Flow Input	Source of Input	Confidence in Input Value	Sensitivity of VSP in EDT (study conditions)	Confidence in EDT Approach
Rel. Peak Q	HSPF Model	High	Low	Medium
Stage Fluctuation	HSPF & HEC RAS	Medium	Negligible	Low
Rel. Flashiness	HSPF model	High	Negligible	Low
Rel. Base Flow	HSPF with assumptions	Low	Low	Low

But caution is called for. Of the four main direct EDT flow inputs that were derived from water supply surveys, plans, and watershed modeling, none were strong drivers of EDT output. Although very large increases in peak flow were estimated by HSPF, these inputs had little direct influence on salmon population response modeled by EDT. Additionally, strong assumptions were required to simulate the current and potential future impacts of groundwater pumping for public water supply on summer base flows.

Concerns...continued

Indirect Flow-Related Input	Source of Input	Confidence in Input	Sensitivity of EDT-based VSP parameters	Confidence in EDT Approach
Bed Scour (spawning areas)	Assumed f(Q2-ratio)	Low	*Very High*	High
Fine Sediment (in spawning gravels)	f(%TIA)	Low	*High*	Medium

Outputs Sensitive to Uncertain Inputs

In contrast, the most influential determinants of EDT output of VSP parameters were inputs for bed scour depth and fine sediment. In the case of bed scour, EDT input for each reach was based on an assumed relationship with peak flow that can be described as "qualitatively reasonable" at best.

A similarly low level confidence applies to our Fine Sediment input values which were determined based on total imperviousness of the contributing area.

In sum...

- Salmon habitat restoration planning often applies models like EDT that calculate VSP parameters
- We know implicitly that flow regime is a major driver of habitat quality and salmon survival
- Yet current analysis tools are not numerically reliable for assessing impact of flow changes
- Therefore: act conservatively now, refine and improve knowledge, adjust later

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  - Stillaguamish Tribe Natural Resource Department
  - Keta Waters

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