Puget Sound Technical Recovery Team Technical Comments: Combined Template and Probabilistic Network Analysis (PNA)

East Kitsap

This technical feedback has three components:

- Brief summary of results of our review concerning certainty, and discussion and recommendations of factors we believe are critical to address in order to improve certainty of your plan;

- Consolidation of technical reviewers' composite and detailed comments on your June 30th draft; and

- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

The "near-term steps" suggested in Section 1 of the feedback should occur by April 30th, because they will help you finalize your draft chapter. The "long-term steps" should generally occur as you implement your adaptive management program.

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of our probabilistic network analysis (for description of the approach, see *Section III* of this document.) We view using this certainty analysis in an iterative fashion, to help you in guiding plan revisions. This analysis also will help us strategically track the elements of your plans and how information at each step affects the overall certainty that the proposed actions in your plan will contribute to population and ESU recovery. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of your plan. You will notice that several questions within each "H" encourage us to check how well the habitat, hatchery and harvest strategies are integrated in the plan. We fully expect that the certainty in your plan's outcomes can be increased by providing more information and documentation—we have highlighted areas we think would be particularly fruitful to focus on in near-term revisions in each section below.

1. *Did the analysis use one or multiple independent models to understand potential fish responses to habitat actions? What is the nature of the analytical support for the model linking population status to changes in habitat-forming processes and in-stream habitat conditions?*

Analytical support for the model is low. A single, qualitative *stressor* model is used as the conceptual recovery framework. This model, from Williams and Thom, is logically robust and provides a good, and potentially useful, framework for linking a variety of stressors (including land use, processes, or habitat structure) to population responses. This has not been done, however, and the model remains in the conceptual stage. The model is documented only in the work of Williams and Thom; there may be more documentation of assumptions, model structure and the parameters but it does not appear in the recovery plan. There is no sensitivity analysis although that may be possible given the model structure, and there has been no empirical test or calibration to local conditions. The City of Bainbridge Island has data on nearshore conditions that could serve as a starting point for an empirical test or calibration of some aspects of the model, however.

Near-term steps to improve certainty:

- Include further documentation of the model assumptions, structure and parameters in the recovery plan;
- Assemble the existing data from Kitsap County and the City of Bainbridge Island for as many of the attributes of the model as possible.

Long-term steps to improve certainty:

- Use the empirical data assembled above to test the logic and relationships of the qualitative model;
- Collect habitat and salmon data from the nearshore in order to fill in the model and move it toward more quantification.

2. *How well supported are the hypotheses for (1) the VSP parameters most limiting recovery and (2) the habitat-forming processes or conditions that are limiting the population response? What is the nature of the watershed-specific data used to support (either of) these hypotheses?*

The hypothesis that serves as a basis for the East Kitsap Recovery plan appears to be: the East Kitsap nearshore is important to a variety of populations of Puget Sound Chinook; land use and direct modification of salmon habitats has altered habitat-forming processes (e.g., hydrology in freshwater systems) and structure (especially through filling and armoring in the nearshore) that has reduced the ability of these habitats to support salmonids, especially juveniles.

Overall, support for the hypotheses is low. The hypotheses do not include the VSP parameters directly and there is little quantitative data provided to show distribution of Chinook along the East Kitsap nearshore. There is considerably more data to support the habitat hypothesis and the discussion of habitat structure, function, and process is quite useful. The nearshore discussion derives from the conceptual model and has led to some shoreline mapping and evaluation by the City of Bainbridge Island (COBI), with a further analysis based on geophysical properties of the shoreline to follow in both COBI and Kitsap County. There is as yet no direct empirical support for changes in VSP attributes and little data that links structural change in the nearshore to process degradation. There is inventory data in the COBI to show the extent of fills and shoreline modifications that is now being overlain with habitat classifications. It is not yet at the mechanistic, cause-response stage, however, that can be related to VSP attributes.

Near-term steps to improve certainty:

- If there is more data on the nearshore of East Kitsap, whether in the form of inventory data, historical information, shoreline characterizations, etc, bring it forward in the plan to support the hypotheses;

- Even if it is based on expert opinion, use the conceptual model to link the changes in habitat volume and structure to VSP attributes by probable life stages utilizing the nearshore and tributaries. These will become additional hypotheses subject to testing.

Long-term steps to improve certainty:

- Apply the COBI inventory and analysis techniques to the entire East Kitsap shoreline as a basis for a "change" evaluation;
- Begin a systematic program to collect salmonid data in the nearshore based on the hypothetical links in the conceptual model and the hypothesis of multiple population use.

3. *Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?*

The strategy for recovery in the East Kitsap is not consistent with the (implied) recovery hypotheses discussed in the plan. The plan has no explicit goals for either habitat or VSP attributes, so a long-term strategy is problematic. However, a general strategy is discussed but there is insufficient specificity in the strategy concerning spatial priorities and sequencing of actions, and there is no link to VSP attributes. The general strategy of education, protection and restoration, and incentives includes the critical elements for recovery but seems quite opportunistic. It is difficult to see how the elements in the plan combine to confidently recover habitat conditions and VSP attributes in the future. If inventory and evaluation of habitats and VSP attributes can be accomplished in a timely manner, the programs within the strategy could be made much more specific to the geography of salmon recovery. For example, what shoreline habitats are most in need of protection; which of restoration? How will they combine to influence spatial structure of the population(s) rearing along or migrating through the nearshore? How much of the nearshore will be preserved (by any means) in a functional condition?

Implicit in the strategy is an understanding of the current path of land use and the future effects on habitat and VSP but there is no analysis by which to judge the effects of this or some alternative path. Thus, the assumption of the sufficiency of the current regulatory path is unsubstantiated by empirical evidence or evaluation of these effects.

Near-term steps to improve certainty:

- Develop explicit goals for habitat conditions in both freshwater and nearshore habitats of East Kitsap. Using the conceptual model, extend these goals to VSP attributes associated with the habitat goals;
- Conduct a current path analysis to predict the spatial and temporal effects of land use affecting the East Kitsap nearshore;
- Clarify the assumptions that support the current regulatory path;
- Use the basic recovery model to (qualitatively) evaluate the elements and test the assumptions of the general strategy. This should allow gaps in the strategy to be evaluated and some predictions to be made about population response.

Long-term steps to improve certainty:

- Develop an evaluation strategy to assess the effects of the educational and incentive elements of the recovery strategy.

4. *Does the habitat recovery strategy preserve options for recovery of all four VSP parameters across all Hs?*

The strategy does not preserve options for the recovery of all VSP parameters. The strategy does not reference the desired outcomes for the VSP parameters and has not integrated either the harvest or hatchery assumptions with the habitat work. Neither is there a well-developed adaptive management program to test the elements of the strategy. This is particularly important since there are a number of critical assumptions upon which success of the strategy is based.

Near-term steps to improve certainty:

- Obtain the harvest and hatchery assumptions (available from the Suquamish Tribe, we assume) and clarify them in the plan. Use these assumptions to evaluate the interaction of harvest and hatchery actions with the habitat strategy;
- Clarify the desired outcomes for the VSP parameters relative to the East Kitsap nearshore (this will require conversations with other watersheds whose populations use the East Kitsap nearshore).

Long-term steps to improve certainty:

- Further develop the adaptive management strategy to support recovery. Include these elements: decision model(s), decision criteria, monitoring targets and protocols, data requirements, evaluation methods, timelines for data collection and analysis, and decision points.

5. *Are the habitat recovery actions consistent with the recovery strategy?*

Given the elements of the general strategy, the actions are generally consistent. The action list is incomplete, however, in so far as the incentive programs and the suite of restoration actions necessary are either undeveloped or have not been included in the plan.

Near-term steps to improve certainty:

- Develop restoration actions and incentive programs linked to the strategy.

6. *How well have the habitat actions been shown to work?*

There is moderate empirical support for the habitat actions put forward in the plan.
The protective actions based on acquisition—the reserve program—has good empirical support from similar actions Sound-wide. The effectiveness of the current regulatory path to provide protection is much less certain; little empirical support is available (Whatcom County has used the EDT model to evaluate regulatory effectiveness as a first step) and the program will require monitoring and evaluation as part of the adaptive management program. Nearshore restoration actions have a mixed history probably due to our general lack of knowledge of nearshore

processes. The educational components of the strategy, while assumed to be of critical importance, should also be made part of the adaptive management program.

Near-term steps to improve certainty:

- Carry out an analysis of the regulatory framework that reveals gaps in protection and evaluates effectiveness of current regulatory protections;
- Develop a list of strategic recovery actions to be included in the plan;
- Provide empirical evidence of the actions' effectiveness for improving habitat conditions and VSP attributes.

Long-term steps to improve certainty:

- Include the evaluation of the regulatory, incentive, and educational actions in the adaptive management plan.

II. Consolidated Comments on Technical Review Template

REVIEW TEMPLATE FOR TECHNICAL REVIEW OF DRAFT WATERSHED PLANS

Reviewer's Name: **PSTRT and adjunct Technical Reviewers**

Watershed Plan: **East Kitsap**

Populations or ESUs considered: **No independent populations**

Summary

Overview of Shared Strategy questions and how well the watershed plans address the technical aspects of those questions. In particular, what is the watershed's technical basis to the answer to the questions from the Shared Strategy: (1) What are the major physical and biological changes necessary to meet the population planning targets? And (2) What are the expected changes in H's and fish population responses over the next 5-10 years?

Review of Plan—Overview

Overall summary of approach, scope of plan (geography, species, populations, ESUs, included), stated goals, participants in plan development, etc.

The approach to achieving the (stated) goal of sustaining salmon populations combines protection and restoration activities with education and incentives. Few details are provided, but the approach generally relies on programs, projects and policies already in place or underway in Kitsap County (KC) and the City of Bainbridge Island (COBI). No new initiatives are proposed in this plan specifically to address Chinook viability. This plan relies on the successful implementation of these existing elements: KC and COBI Comprehensive plans and CAOs; the Kitsap Refugia study; and the Kitsap Peninsula (KP) Salmon Recovery Strategy. No argument is made, however, for the effectiveness of the various elements of the program, particularly the regulatory elements.

The use of complementary ecological frameworks for assessment and action development shows great promise as a logical and integrative framework. It has not been tied to the third necessary framework, that of Viable Salmonid Population (VSP) conservation.

The plan includes the drainages and nearshore habitats of Kitsap County that drain only to the main basin and south basin, and all drainages and nearshore habitats of Bainbridge Island. It does not include the drainages that flow to Hood Canal. This is a multi- species plan and does not focus on Chinook since there are no independent populations of Chinook present in East Kitsap County. However, the plan adopts as its goals the general goals of the Kitsap County and Bainbridge Island Comprehensive Plans, both of which emphasize the restoration of anadromous fish runs. A somewhat more specific goal that (we assume) is adopted by the plan appears in the Kitsap Peninsula recovery strategy and states: "Restore healthy, self-sustaining populations of wild salmon species native to the streams and shorelines of the Kitsap Peninsula". There are no specific goals for any VSP attribute and there are no explicit goals for habitat protection or restoration other than a brief reference to Properly Functional Conditions for effects analysis and a general goal for ecosystem performance.

The plan is very conceptual at this time despite (or as a result of) the ecological framework and the range of actions already undertaken for protection. The plan seems to advocate a largely opportunistic approach to recovery; there is no cohesive strategy that serves to integrate the various elements of the approach or of the actions (see also the Probabilistic Network Analysis (PNA) for further comments. A strategy would assist in developing a coordinated set of actions that are arrayed in space and time to most effectively address the limiting factors described in the plan.

The plan was developed by Kitsap County in cooperation with the City of Bainbridge Island, the Washington Dept. of Fish and Wildlife, the Puget Sound Action Team, Washington Sea Grant, and the Suquamish Tribe. There was no stakeholder participation.

Brief narrative of how well the plan addresses the following; including strengths and weaknesses:

1. **What biological and physical changes does the plan state are required for the population(s) in the watershed to achieve their targets?**
For watersheds without targets, what biological and physical changes are needed for the habitat to be considered functioning for anadromous fish?

   Although the plan presents an excellent general ecological model to evaluate conditions and assess results, there are no specific changes called out in the plan. The description of the physical changes required is very general, and largely unquantified at this time. Properly functional conditions are alluded to several times and the background report on refugia calls out limiting factors and makes recommendations for removal of shoreline protection and placement of LWD, among other recommendations. It also indirectly asserts that the protection and restoration of class A and B refugia will be minimally necessary to support viable core populations. No quantification of these recommendations is evident but given the references to PFC, perhaps those standards are the targets. Still, there is no analysis that would suggest the magnitude of change necessary to attain functioning habitat.

   There are no specific (quantifiable) population-based biological goals established in the plan and no goals have been provided by either Shared Strategy or the PSTRT. One reviewer suggests that certain "proxy" species such as chum and coho in the freshwater systems, and chum, herring, and smelt in the nearshore could be useful for establishing functional goals and therefore, biological goals.

2. **What biological goals does the plan aim to achieve (in 5-10 years and over longer term).**
What are fish-based and habitat, hatchery or harvest management-based goals?

   No biological goals are specified in terms of VSP parameters. Rather, the long-term goal (without a time horizon) is "healthy, self-sustaining wild populations…".The plan seems to focus on reducing the effects of human-caused stressors on habitat processes and thus to habitat conditions. One reviewer suggests developing acreage-based goals for specific nearshore habitat types.

3. **What is the biological RATIONALE for identified actions in all of the H's (i.e., is the "hypothesis-strategy-action" logic presented in the watershed guidance document used?)**

   (a) What is the population's current status for all 4 VSP (this should come out under the hypotheses)?

No VSP parameters have been evaluated although such an analysis could, presumably, be performed for East Kitsap Chinook aggregations. If it were known which independent populations used the East Kitsap nearshore, the VSP analyses from those populations could be employed here.

It should be possible to evaluate habitat conditions in such a way that some indications of change in habitat/population distribution, or in habitat/productivity, or in habitat/population diversity could be hypothesized for this watershed. There is a beginning of that in the refugia study and the COBI shoreline evaluation. It should even be possible to provide some indication of habitat/abundance relationships although that is probably so variable that it would not be particularly valuable.

This evaluation is important to resolve two issues: 1) What role do the streams in this watershed play in the persistence of the ESU?; and 2)What role does the nearshore play in this persistence?
A corollary question might be: Do the hatchery and harvest elements in this watershed compromise the the functions of the nearshore for non-natal populations?

(b) What is the population's predicted status for all 4 VSP over the short- and long-term?

A tacit prediction for the long term seems to be self-sustaining (i.e., viable) for the runs native to the East Kitsap. There are no formal predictions for VSP parameters, however.

(c) What are critical threats affecting the populations? Have all been identified and considered in the stated hypotheses? Are there potential threats that are missing from the plan? Be explicit about each threat or potential factor limiting recovery.

All three Hs do a credible job of laying out the threats to Chinook.
Key habitat stressors are: shoreline development; shoreline fills; dredging/conversion of shallow water to deep water habitats; alteration of inter-tidal vegetated habitat; loss of riparian vegetation in the nearshore and along streams; water quality in streams as a result of urban development and as a result of historic contamination. Key harvest stressors include: insufficient escapements, selective harvest; key hatchery stressors include inbreeding depression, swamping, competition for habitat and food supplies.
Two gaps exist in this discussion, however: 1) the role of large woody debris in the nearshore. This may be important for trapping organic material that serves as a food source for a variety of invertebrate that are potential prey for juvenile Chinook; 2) the role of the small streams in the watershed and their use by hatchery salmon rather than by native Chinook.

The plan does not formulate explicit hypotheses that address each stressor or even a class of stressors (e.g. water quality). There are certainly actions to address particular examples of the stressors but these are not grounded in spatially distinct, VSP-based predictions of the outcomes. The model to accomplish this, while conceptually robust, is not developed completely enough to link stressor to action to predicted outcome. The general assertions (backed up by some useful inventory data in a few cases) will require evidence to validate them, and testable hypotheses to relate actions to VSP outcomes.

One reviewer suggests that an important missing stressor is the reduction of nutrients in freshwater and in the nearshore caused by the reduction of salmon as vectors for ocean-derived nutrients. This is an area of uncertainty that should be addressed in the plan since it could easily affect all H management in the watershed.

(d) Is the strategy for H management changes consistent with the identified hypotheses for current population status, desired future population status, and primary threats? What elements of the strategy are missing? Be explicit about each threat or potential factor limiting recovery.

The strategy is not organized according to the TRT guidance; rather, it is largely opportunistic except for the refugia work which ranked the most important habitat areas to assure core population viability. But this is a relatively small part of the necessary overall habitat strategy given the stressors listed above. Although there are both hatchery and harvest strategies in the plan, the habitat strategy is not well-integrated with them. There is sufficient information in the plan for hatchery and harvest to evaluate the implications for the habitat strategy.

It is unclear from the plan whether the other elements of the habitat strategy (regulatory, educational, and incentives) will be sufficient to address the threat posed by the current stressor conditions, without regard for the future path of these stressors. If both the hypotheses and the strategy derived from them were more explicit, such an evaluation could be carried out and could inform the strategies for the other Hs as well.

(e) How are actions in the H's linked to fish population status? Both existing and future/planned H actions should be addressed. Are these links based on empirical or modeled estimates or both? Be explicit about each threat or potential factor limiting recovery.

H actions are not expressly linked to population status in this plan. That is recognized as a major shortcoming by the authors and should be remedied in further iterations of the plan.

(f) What are the plan's stated assumptions about existing habitat conditions or actions outside of the WRIA jurisdictional boundaries covered in the plan (freshwater and estuarine/nearshore)?

Two assumptions are made: The nearshore habitat to the east of the plan boundaries is more degraded than within the plan boundaries—this places a greater burden on the nearshore habitats within the plan boundaries; actions outside the plan boundaries will be required to reach sustainability.

(g) Are future options preserved in the proposed strategy-action links? How so? Be explicit about each threat or potential factor limiting recovery.

It is unlikely that options are preserved in this plan. Although the plan adopts a monitoring-evaluation-modification approach, there are no contingencies for errors in management or assessment, and the use of adaptive management alone does not necessarily preserve options. Nevertheless, a well-developed adaptive management plan will be needed to evaluate the management outcomes and feed the information into a decision-making model. However, without clear hypotheses linked to VSP, and without a clear strategy that integrates the Hs, it is difficult to evaluate the long term outcomes of management actions; the hypotheses and strategy, in effect, constrain and direct the actions and avoid a more random, "see what works" approach. For many populations, such an approach would likely lead to greater harm before useful knowledge is gained.

4. What is the empirical or modeled SUPPORT for the answers to question #3? How well do the assessment data for the population status and the H's support the hypotheses proposed?

(a) What is the population's current status for all 4 VSP (this should come out under the hypotheses)?
NA

(b) What is the population's predicted status for all 4 VSP over the short- and long-term?
NA

(c) What are critical threats affecting the populations? Have all been identified and considered in the stated hypotheses? Are there potential threats that are missing from the plan? Be explicit about each threat or potential factor limiting recovery.

Three major assessments form the empirical basis for the actions outlined in the plan: the WRIA 15 Limiting Factors Analysis, East Kitsap Refugia Study and the COBI Shoreline Assessment and Evaluation. No modeling work has been undertaken to quantify the critical threats. These threats are not directly addressed in either hypotheses or directly-linked actions.

(d) Is the strategy for H management changes consistent with the identified hypotheses for current population status, desired future population status, and primary threats? What elements of the strategy are missing? Be explicit about each threat or potential factor limiting recovery.

Since no evaluation of population status has been undertaken, nor has any desired future status (other than the genera “self-sustaining”) been declared, it is difficult to analyze the strategy proposed in the plan. Assuming that the population attributes (of those animals using the Kitsap system) demonstrated very little necessary change, then the strategy proposed might be useful. However, given the described alterations in shoreline ad stream habitats, a more directed strategy is necessary.

(e) How are actions in the H’s linked to fish population status? Are these links based on empirical or modeled estimates or both? Be explicit about each threat or potential factor limiting recovery.

No explicit links are made to population status at this time. The plan indicates that little empirical data is available and no models have been employed to hypothesize the links.

(f) What are the plan’s stated assumptions about existing habitat conditions or actions outside of the WRIA jurisdictional boundaries covered in the plan (freshwater and estuarine/nearshore)?

The plan draws on the WDNR shoreline inventory work to make the assumption that nearshore habitat in the central and south basins outside of East Kitsap has been greatly altered and, therefore, East Kitsap nearshore habitat may play an even larger role than it did historically.

(g) Are future options preserved in the proposed strategy-action links? How so? Be explicit about each threat or potential factor limiting recovery.

Future options are not considered except in so far as they may arise from regular review of the policies and programs, and projects described in the plan.

5. **How are the individual and interacting effects of the H’s on the 4 VSP parameters considered for each population? How likely is it that the proposed suites of H actions will achieve the short- and longer-term stated goals? How certain are we in their translation into effects on salmon population VSP?**

Be sure to make note of the assumptions the plan makes about the effects of hatchery and harvest management, existing habitat actions, and survival in the nearshore/ocean, for example.

Only the habitat effects have been considered in any detail in the plan. The effects of harvest and hatchery programs are assumed to be benign, largely because of the application of the HSRG recommendations and of the Harvest Management Plan for Puget Sound Chinook developed by NOAA Fisheries, WDFW and the Tribes.

However, the increased appearance of Chinook in some of the larger tributaries of the East Kitsap suggests that the enhancement programs have the potential to interact with wild Chinook juveniles in the nearshore and stream environments. But no discussion is apparent.

In the sense that it is described by the TRT in the guidance document, integration of the Hs has not occurred. It would seem a useful step to examine the refugia study and the recovery strategy for spatial interactions among wild and enhanced stocks to evaluate the potential for competitive overlap. Given the lack of integration and the absence of clear goals for the elements proposed in the plan, it is difficult to say just what will be achieved by this plan. An exception to this is the refugia study which at least provides a conceptual link between population viability and refugia.

6. **How does the plan acknowledge uncertainties and how are they factored into decisions, future actions?**
   (a) Uncertainties in data and information?

   The plan acknowledges significant gaps in knowledge about population status, population use of shoreline and stream habitats, and status of nearshore habitats outside of the COBI. Without such information, it states that evaluating the effectiveness of actions will be difficult to judge. It does, not, however, offer much in the way of incorporating that awareness into actions and management except through the current mechanisms of plan and regulatory updates. The plan does propose further assessments of nearshore habitats for the remainder of Kitsap County, and implementation of the WDFW Kitsap Peninsula Habitat Assessment to gain further information. It could be assumed that this information would then make its way into a re-evaluation of programs and policies in the comprehensive plans, the CAOs and the recover strategy.

   (b) Uncertainties in environmental conditions in the future?

   This has not been explicitly considered in the plan and no management strategies are tied to this.

   (c) Uncertainties in effectiveness of actions?
   There is not an explicit adaptive management strategy developed in the plan that would address the uncertainty in proposed actions or in the effectiveness of those actions

7. **Reviewer: What is the estimated overall level of risk for the population(s) included in this plan, relative to low-risk (i.e., viable) population criteria? What is your rationale for this risk estimate? How certain are you in the estimation for each VSP parameter?**
   The probabilistic network analysis (PNA) should help inform the answer to this question.

8. **Make any suggestions for approaches or methods for addressing concerns mentioned above or reducing gaps in the plan.**

1. Using a method similar to the COBI work, conduct a shoreline assessment to determine ecological impairment;
2. Selectively sample the existing nearshore habitats to determine the use of these habitats by juvenile Chinook;
3. Expand the conceptual model to include VSP parameters and use this linkage work to evaluate the current list of projects for their effect on particular VSP parameters;
4. Use the hypothesis-strategy-action guidance to identify actions and outcomes more explicitly. Thios could be easily applied with the Refugia study and in the Recovery Strategy.

See the PNA for more information.

III. Probability Network Analysis

Analyzing Certainty of Biologically Effective Recovery Plans

All watersheds in the Puget Sound are unique. Not surprisingly, different watershed planning groups identify different long-term and short-term goals and propose different suits of actions to achieve those goals. The certainty that the actions in every watershed will be biologically effective in moving the populations towards recovery is a key factor in the recovery of the whole evolutionarily significant unit (ESU). Consequently, the Puget Sound Technical Recovery Team (TRT) has focused its analysis of watershed recovery plans on identifying ways to increase the certainty of the plans. The TRT hopes that these analyses will encourage watershed groups to improve the certainty of plans before the TRT does it analysis of the final plans next year.

To provide these analyses, the TRT used a probabilistic network (PN). A probabilistic network is a graphical model that shows how different states of the world of interest—in this case the scientific factors that provide certainty of biologically effective actions—are related (Figure 1). The basic approach is to assess certainty by applying conditional probabilities, which can be expressed as "Given event *b*, the likelihood of event *a* is *x*." In Figure 1, for example, the states of the variables in boxes that point to another variable (e.g. "Use of Independent Models" and "Analytical Support") are the events that condition the likelihood of the states for the latter variable (e.g. "High", "Moderate", and "Low" in the Certainty of the General Fish Response Model). Users provide evidence for the initial conditioning events (or diagnostic nodes); software for PNs use a set of sophisticated algorithms for recalculating the joint probability distributions for all the potentials based on tables of conditional probabilities provided by the analyst (Jensen 2001). Using a PN gave the TRT a rigorous, transparent, repeatable method of analyzing certainty across watershed plans and habitat, harvest, and hatchery management sectors.

Methods

The Puget Sound Technical Recovery Team (TRT) used the PN in Figure 1 to assess separately the certainty of biologically effective actions for each plan in four management sectors, 1) freshwater habitat, 2) nearshore habitat, 3) hatchery production, and 4) harvest. Each assessment also considered how well integrated actions were across categories and how the actions affected characteristics of viable salmonid populations (McElhany et al. 2003). The network graphically shows the logic of how different scientific variables affect the biological certainty of effective recovery plans. The model is based on the TRT's *Integrated Recovery Planning for Listed Salmonids: Technical Guidance for Watershed Groups in the Puget Sound* (http://www.sharedsalmonstrategy.org/files). The network shows that the overall biological certainty of an effective recovery plan depends on the certainty of the recovery strategy (Recovery Strategy), the robustness of the strategy (Preserves Options), and the expected effectiveness of actions chosen to implement the strategy. The certainty of the recovery strategy in turn is conditioned by the certainty of how well we understand the biological, physical, and chemical processes that affect the population (i.e. Recovery Hypothesis), which depends on well recognized sources of scientific uncertainty (Lemons 1996), such as model uncertainty (Use of Independent Models), framing uncertainty and stochasticity (Analytical Support), and empirical support for the hypothesis (Watershed Data Quality). After identifying the model structure, the TRT identified and defined different states of the variables (Tables 1-6).

Conditional probabilities may be derived from frequencies from empirical data, simulation results, or subjective probabilities. When data are too few to parameterize simulation models, use of subjective probabilities is important (Bedford and Cooke 2001) and analysts have developed methods for estimating these (e.g. Ayyub 2001). Using experts to estimate subjective probabilities has inherent biases that can be difficult to control (Kahneman et al. 1982, Otway and von Winterfeldt 1992). Using estimates of conditional probabilities within a logical, transparent model such as a PN

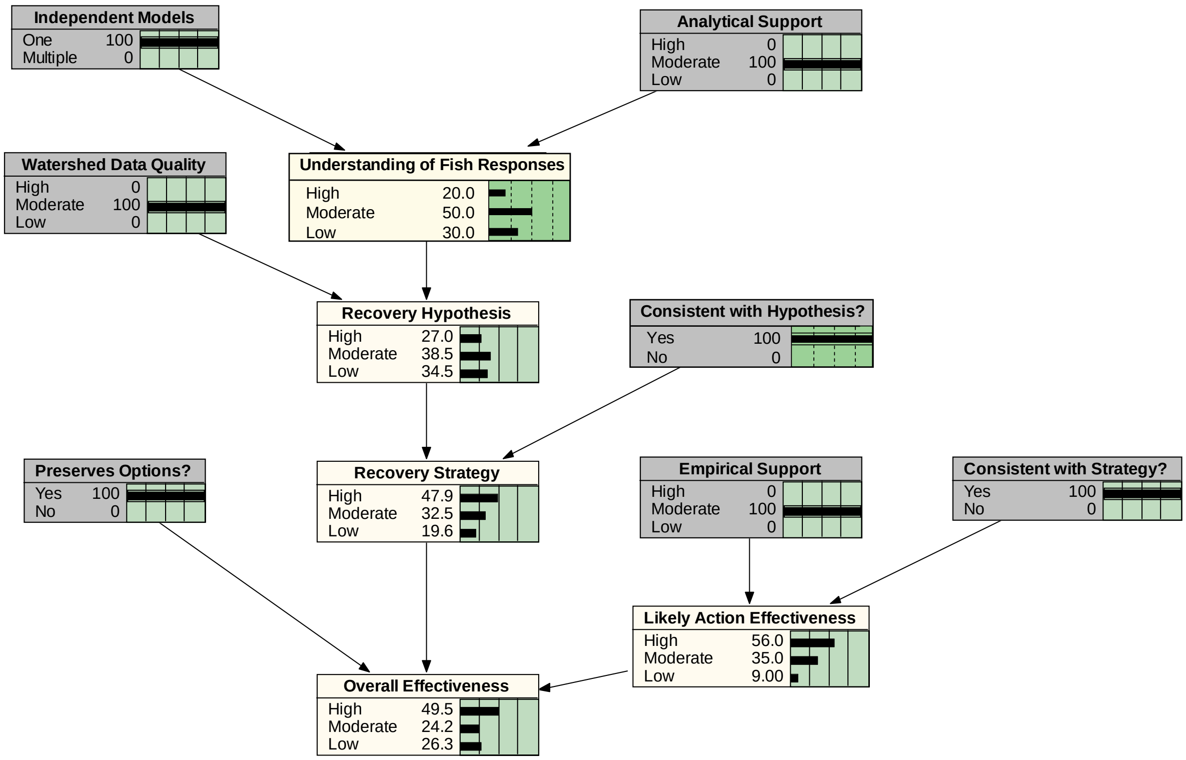

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

may reduce these problems compared to asking experts to provide absolute certainty estimates directly without a model. The TRT estimated conditional probabilities using a Delphi process (Helmer 1968, Ayyub 2001) in which TRT members iteratively estimated conditional probabilities individually; the distributions of the results were compiled and shared; and new estimates were generated. Sensitivity of the model was evaluated using the mutual information index (Pearl 1988) which measures the reduction in entropy of variable *A* due to a finding at *B*.

The TRT qualitatively assessed the states of seven diagnostic variables (box titles in parentheses) that address these questions:

1. Did the analysis use one or multiple independent models to understand potential fish responses to actions? (Independent Models)
2. How well supported is the model? (Analytical Support)
3. How well supported is the recovery hypotheses with watershed specific data? (Watershed Data Quality)
4. Is the recovery strategy robust by preserving options for recovery? (Preserves Options)
5. Is the recovery strategy consistent with the recovery hypothesis? (Consistent with Hypothesis)
6. Are the recovery actions consistent with the recovery strategy? (Consistent with Strategy)
7. How well have the recovery actions been shown to work? (Empirical Support)

The possible answers to these questions are in Tables 1-6. Reviewers usually choose one state, but if this is not possible because of uncertainty, reviewers could assign probabilities to different states (e.g., “Low” = 10%; “Moderate” = 90%). Analyses were performed using Netica (Norsys Software Corporation, Vancouver, BC; http://www.norsys.com).

Interpreting the Results

Even the best recovery plan is inherently uncertain because the future is so difficult to predict. Consequently, the quantitative estimates of certainty generated by the TRT are less important than the relative improvement that watershed planners need to make. For similar reasons, the quantitative estimates of certainty generated by the TRT are not relevant to analyses of certainty performed by regulatory agencies, which depend on a different interpretation and standard of certainty. Based on the TRT analyses, watershed planners may be able to increase the certainty of biological effectives several fold by focusing on several key factors. These are described in individual watershed analyses.

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Table 1. Attributes for different states of analytical support for models.

Analysis	Total Score	Attributes (Maximum Possible Score)
Habitat Models High Moderate Low	 0.60 -1.00 0.21 - 0.60 0 - 0.20	• Qualitative and/or quantitative description of the relationship landscape processes, land use, and habitat condition – (0.1 for each analysis) • Qualitative and/or quantitative description of the relationship between habitat condition and population viability (VSP) characteristics – (0.1 for each analysis; 025 for each VSP characteristic) • Model structures and parameters for each VSP characteristic documented; assumptions discussed and defended – (0.2) • Sensitivity of model to changes in parameters known – (0.2) • Model tested empirically and calibrated to watershed – (0.2)
Harvest Models High Moderate	 0.60 -1.00 0.21 - 0.60	• Qualitative and/or quantitative description of link between demographic processes, harvest effects, and population viability (VSP) characteristics– (0.2 for each analysis; 0.05 for each VSP characteristic)

Low	0 - 0.20	• Model structures and parameters for each VSP characteristic documented; assumptions discussed and defended – (0.2) • Sensitivity of model to changes in parameters known – (0.2) • Model tested empirically and calibrated to watershed – (0.2)
Harvest Models High Moderate Low	 0.60 -1.00 0.21 - 0.60 0 - 0.20	• Qualitative and/or quantitative description of link genetic and ecological processes, hatchery effects, and population viability (VSP) characteristics – (0.2 for each analysis; 0.05 for each VSP characteristic) • Model structures and parameters for each VSP characteristic documented; assumptions discussed and defended – (0.2) • Sensitivity of model to changes in parameters known – (0.2) • Model tested empirically and calibrated to watershed – (0.2)

Table 2. Attributes for different states of the quality of watershed data (support for hypotheses)

States	Attributes
High	• Used empirical population, habitat, and management data from the local watershed at multiple spatial scales to support hypotheses; sources clearly documented; assumptions explained
Moderate	• Used empirical population, habitat, and management data for watersheds or populations within the species' range OR used local watershed data but data highly uncertain or assumptions not well explained
Low	• Used theoretical support for hypothesis or expert opinion based on biological principles and local knowledge of the watershed

Table 3. Attributes for different states of consistency of recovery strategy with recovery hypothesis.

States	Attributes
Yes	Clear and logical relationship between the recovery hypothesis based on processes and conditions for habitat, harvest, and hatcheries and the recovery strategy as evidenced by • Main elements of strategy organized around dominant recovery hypotheses • Elements of strategy reflect spatial attributes of recovery hypotheses • Elements of strategy reflect temporal attributes and action sequencing of recovery hypotheses
No	No clear and logical relationship between recovery hypotheses and strategy; one or more of attributes listed above missing

Table 4. Attributes for different states of preservation of options in the recovery strategy

States	Attributes
Yes	• Strategy protects existing population viability (VSP) structure and opportunities for future improvement in habitat, harvest, and hatchery conditions; adaptive management & monitoring program maintains options for implementing strategy

No	• Strategy does not protect existing VSP structure or opportunities for future improvement in habitat, harvest, and hatchery conditions; adaptive management & monitoring program does not maintain options for implementing strategy

Table 5. Attributes for states of consistency of actions with recovery strategy.

States	Attributes
Yes	• Clear and logical relationship between the short-term and long-term actions and recovery strategy recovery hypothesis • Elements of strategy reflect spatial attributes of recovery hypotheses • Elements of strategy reflect temporal attributes and action sequencing of recovery hypotheses • No strong relationship between fish response models and recovery hypothesis
No	• Actions generally consistent with recovery strategy but major actions are missing or staging of major is inconsistent with recovery hypothesis • Little relationship between actions and strategy; major short-term and long-term actions do not follow from the recovery hypothesis and strategy

Table 6. Attributes of empirical support of recovery actions.

States	Attributes
High	• Evidence for effects of suites of actions (in habitat, harvest, or hatcheries) is clear and unambiguous; broad applications have been tested with similar results; uncertainty incorporated in assessments
Moderate	• Some empirical evidence of effectiveness in similar settings; few tested applications; some conflicting results; predictions of effect do not incorporate uncertainty
Low	• Little or no empirical evidence of the action being effective or appropriate