Review of the
Alameda Creek Habitat Conservation Plan Modeling Strategy

Prepared for
San Francisco Public Utilities Commission
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by
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FORWARD

This report represents the independent scientific review of physical and biological models developed to inform the San Francisco Public Utility Commission's (SFPUC) Alameda Watershed Habitat Conservation Plan (AWHCP). The physical models address hydrologic, hydraulic, and temperature conditions in Alameda Creek, and this information is then used as input to the biological (EDT) model. The physical models were developed through a collaborative effort between the SFPUC and Alameda County Water District in coordination with the Alameda Watershed Fisheries Restoration Workgroup (Workgroup).

The SFPUC's AWHCP has been under development for the last several years to provide compliance with the federal and state Endangered Species Acts for SFPUC's maintenance and operations activities within the watershed. Although the Alameda Creek watershed is not currently available to returning anadromous adult fishes due to physical barriers in the flood control channel, efforts are underway to provide passage upstream and downstream of these barriers. The biological model reviewed here was developed to compare the relative potential for different watershed conditions to support steelhead. The results from the model will guide selection of conservation measures to be included in the SFPUC AWHCP. The SFPUC commissioned this review to help the SFPUC, resource agencies, and other stakeholders better understand and apply these models.

The SFPUC hired Dr. Johnnie Moore from the University of Montana to lead the independent scientific review, panel formation, and development of the panel charge. With input from the Workgroup, Dr. Moore reviewed names and resumes of potential panel members that represent the various specialties reflected in the modeling work and selected four scientists for the panel. Dr. Moore also sought the input of the Workgroup on the panel charge, which is described below on page 4.

The results of this scientific review will be used by the SFPUC to further the development of the hydrologic, hydraulic, temperature, and biological models – and to inform the conservation measures as the AWHCP moves toward completion. We also hope that the Workgroup members will find this review useful in the larger context of steelhead restoration to the Alameda Creek watershed.

The SFPUC wants to thank the panel members, Dr. Johnnie Moore, the panel coordinator Barbara McDonnell (MWH, Inc.), the staff from the California Department of Fish and Game, U.S. Fish and Wildlife Service and National Marine Fisheries Service, and the other Workgroup members for their time and insight. We also wish to thank the staff and consultants who put together the papers and presentations that were the subject of the review process. We also express our appreciation to Robin Grossinger

from SFEI for sharing the early results from their historical ecology work in the watershed and to Pete Alexander from the East Bay Regional Park District who hosted the Panel meeting at the Richard C. Trudeau Training Center.

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San Francisco Public Utilities Commission

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Alameda Watershed HCP Independent Science Review Panel Report

Charge to the Independent Science Review Panel (ISRP)

The ISRP was charged with reviewing efforts by the San Francisco Public Utilities Commission (SFPUC) to evaluate the impact of the proposed Alameda Watershed HCP (AWHCP) conservation and mitigation measures applicable to steelhead trout (*Oncorhynchus mykiss*) populations. In concert with the National Marine Fisheries Service, U.S. Fish and Wildlife Service, California Department of Fish and Game, and Alameda Creek Fisheries Restoration Workgroup, the San Francisco Public Utilities Commission (SFPUC) continues to evaluate a range of flow and fish passage improvements that hold promise for restoring anadromy to the *O. mykiss* population in Alameda Creek. Three white papers had been prepared to describe the modeling process used by the SFPUC staff and its consultants to analyze potential impacts of the AWHCP on steelhead populations. The reports are:

I.   *Overview of Methods, Models, and Results to Develop Unimpaired, Impaired, and Future Flow and Temperature Estimates Along Lower Alameda Creek for Hydrologic Years 1996-2009* by A.S. Dhakal, E. Buckland, and S. McBain. This analysis provides hydrology, hydraulic and temperature inputs to the EDT model. April 13, 2012

II. *Modeling Steelhead Life Histories in Alameda Creek Using Ecosystem Diagnostics and Treatment* by ICF International. April 2012

III. *Ecosystem Diagnostics and Treatment Modeling for the San Francisco Public Utilities Commission Alameda Watershed Habitat Conservation Plan* by ICF International. This paper combines descriptions of the EDT model structure, its assumptions, the scenarios it considered, its relationships to other models, and its results. May 2012

After reviewing these documents, the ISRP met for three days to inspect the Alameda Creek Watershed (for one day), listen to updated presentations of modeling efforts by SFPUC staff and consultants, and to hold discussions with the consultants and among themselves. The panel also heard a presentation on *The Historical Ecology of Alameda Creek Watershed* by Robin Grossinger of the San Francisco Estuary Institute, a report commissioned by the SFPUC in conjunction with the HCP development. The ISRP was also asked to make comments on the relevance of this activity to the ACWCP. We have added this task as item IV in the following report.

ALAMEDA WATERSHED HCP INDEPENDENT SCIENCE REVIEW

I: Methods, Models, and Results to Develop Unimpaired, Impaired, and Future Flow and Temperature Estimates Along Lower Alameda Creek for Hydrologic Years 1996-2009

The report describes methods used for prediction of average daily flows, hydraulic conditions, and average daily water temperatures in each reach of Alameda Creek and San Antonio Creek. Flows from Arroyo de la Laguna and other tributaries, along with flows at various import and export locations such as the Hetch Hetchy and the South Bay Aqueduct, are not predicted but are defined by gauge measurements as boundary conditions for the Alameda Creek flow model.

The intention was to predict hydrology, hydraulics, and water temperatures for three conditions, defined as:

(i)   unimpaired conditions (considered for this purpose to involve natural flows modulated by the current reservoirs and their operation, -- a condition that never existed but used as a base condition for designing a flow regime for the HCP);

(ii)   currently impaired conditions; and

(iii)   future conditions (under the HCP flow release agreement).

The strategy employed in the modeling of streamflow was to assimilate measured values of daily flow from various gauging stations throughout the watershed and to estimate daily flow volumes at ungauged locations and times from nearby stations. The model interpolates flows between measurement locations and dates. Storage and delay of flows within channel reaches are ignored, which is likely to influence results only during flashy high flows that are not a major concern in determining habitat potential in this case. Thus, the computation requires only addition, subtraction and algebraic partitioning of flows from each source and into each sink. Calculations are conducted in a spreadsheet (illustrated in Figure 3 of the report). The number of stations available in any one period has varied, and was particularly small for the unimpaired flow period. Records from fourteen stations were available for varying periods during 1996-2009, so the modeling is restricted to flow conditions sampled during that period.

An initial attempt to utilize the widely implemented modeling tool, HEC-HMS, to predict daily streamflows was abandoned because the model was not able to accurately predict low flows that are critical for habitat analyses. This is not surprising because low flows in Alameda Creek watershed, being supplied to a significant degree from groundwater, are affected by strongly segmented hydrogeological conditions of fault blocks and sedimentary basins within the watershed. Low-flow patterns are further complicated by flow releases from reservoirs, the Hetch Hetchy Aqueduct, and the State Water Project, and by local disruptions resulting from ground water extraction and gravel mining in Sunol Valley. The ground water reservoir module of HEC-HMS is not structured to represent such influences.

The spreadsheet budgeting strategy was first implemented for the period of measured,

impaired flows (Scenario 4). It was then used to compute unimpaired flows that would have been expected for the period 1996-2009 with no watershed or flow disturbances (Scenario 2) and with watershed disturbance in Arroyo de le Laguna but without reservoir operations (Scenario 1). These simulations were intended to provide historical context for comparison with predictions of the modern era. The report authors note that the 1996-2009 measured flows from the limited unimpaired parts of Alameda Creek watershed, along with adjustments based on very sparse records from 1912-1930 used for these simulations, were not truly unaffected by land use and so the results provide only an approximate historical context. However, this approximation seems unlikely to constitute an impediment to the use of these simulated flow records, given the other approximations employed. Finally, simulations were conducted of flows identical to those measured during 1996-2009, but with three proposed future operational conditions (Scenarios 3, 5 and 6). In all but the unimpaired scenarios (1 and 2) assumptions were made about infiltration of flow into the streambed based on a short record in the important Sunol Valley reach (about which we will comment later).

The complexity of the computational steps and the subtleties of differing data sources and operating rules for the various scenarios make it difficult to encompass and summarize the results in a manner that is useful for non-hydrologists who need to evaluate and use them. It would facilitate interdisciplinary communication and planning, as well as communication with the public, if --- now that the computational details have been worked through and documented -- a simple, clear presentation of the most salient aspects of the flow simulations could be provided.

The report authors acknowledge that it was necessary to make many approximations and weakly constrained assumptions to compensate for the reliance on the sparse empirical records, and this limitation makes it impossible to conduct a formal quantitative assessment of uncertainties in predicted values, especially for the future scenarios. However, it is difficult to think of an alternative prediction strategy for future streamflows in such a hydrologically disturbed, geographically complex, and data-sparse environment.

The most general expectation about flows, derived from the modeling, is that discharges will be higher in the future under the proposed HCP flow releases, and even higher than the estimated 'unimpaired' historical condition at some seasons. The effect is particularly large upstream of Sunol Valley, and in drier years. However, the flow through Sunol Valley (represented by Node 5 in the simulation domain) will continue to be severely constrained by infiltration into valley-floor gravels, especially during summers and in dry years. Considerable uncertainty remains about how continued gravel-pit deepening and proposed seepage cutoff walls in this reach will affect flow losses from this reach. SFPUC personnel have initiated a field study of seepage in the reach, but the measurements have not yet been analyzed. Clearer understanding of the likely magnitude of this infiltration effect on flow and habitat potential will require analysis of the field data on streamflow losses, water-table elevations, and pumping schedules from the pits. It is also likely that a groundwater modeling study will be necessary to evaluate the effects of both

continued lowering of pit elevations and several designs of the seepage cutoff walls, which have been proposed to minimize flow losses.

Downstream of Sunol Valley, both current and future flows are predicted to be generally higher than the estimated unimpaired flows because of the SFPUC flow releases, expected hydrological changes in Arroyo de la Laguna watershed, and the intermittent contributions of imported water from the State Water Project that are being conveyed to the ACWD groundwater recharge sites in the lower watershed.

The Consultant Team then used the flows estimated from the spreadsheet model to calculate average streamflow depths and widths at various discharges along each channel reach in Alameda Creek. Both width and depth were utilized in turn to calculate water temperatures. The reach-averaged flow widths were also used in the EDT modeling of habitat potential (see later). Channel and floodplain topography was surveyed by SFPUC personnel at 229 cross sections for this purpose, combining field survey and LIDAR techniques. Water-surface elevations at gauging stations and visual estimates of hydraulic roughness parameters were also obtained by standard procedures. The computations of stream width and average depth were then accomplished with the widely employed HEC-RAS flow routing program, calibrated and validated using measurements from gauging stations.

HEC-RAS was also used for computing water temperatures in each reach and flow scenario. Because of the temporal variation of flows and energy-balance components affecting the temperature of water as it flows downstream, this step required significantly more data specification, computation and calibration. In particular, it was necessary to run HEC-RAS with flow varying each day, as specified by the various modeled scenarios described above. Meteorological data from nearby weather stations and water temperatures of incoming flows were also required from monitoring stations or other estimates, and a separate calibration and validation exercise was necessary. Some of the estimates of water temperature inputs involved approximations based on sparse data. Because of the many feedbacks in the energy balance affecting water temperature we could not evaluate, from this report alone, the degree to which the predicted results might be sensitive to the approximations made. However, the results were constrained by local temperature records.

The model calculated hourly values of water temperature in each reach and for each flow scenario, and the results were aggregated to daily average temperatures. If there is a need for finer-scale analysis of temperature effects on fish, the higher-resolution calculations are available. Prediction errors for a comparison with measurements from the Niles Canyon gauging station ranged up to 2°C with no obvious bias. Predicted water temperature changes in Alameda Creek are more sensitive to flow regime upstream of the Arroyo de le Laguna confluence than are predictions for downstream of the confluence. Water from that tributary has a large influence on both the flow and temperature regimes downstream.

General Comments on Flow, Hydraulics, and Water Temperature Modeling

The overall strategy of building an empirical streamflow model, based directly on measurements within the Alameda Creek watershed, has an advantage that it is unlikely to create large errors for the current condition and for the prescribed flows under the HCP proposal. Substantial inaccuracies are possible for the unimpaired condition, as the authors point out. However, since those results are utilized only for approximate indications of baseline conditions that never actually existed, these potential inaccuracies do not seem to be important, and are unlikely to be improved upon given the available streamflow records.

A limitation of the empirical modeling approach, based on such short and fragmented records, is that the resulting model cannot represent well an important feature of California hydrology, which is the occurrence of enduring droughts. The rivers of the state experience multiple years of strongly below-average flows, which tend to stress aquatic ecosystems, particularly those from which flows have been diverted. In this case, a certain amount of low-flow protection is provided by the proposed HCP flow releases from reservoirs and by limitations on diversions. However, the presence of flow losses from the channel in Sunol Valley and the fact that upper Alameda Creek watershed does not supply the majority of spring and summer water for lower Alameda Creek suggests that lower Alameda Creek flows could be strongly affected by multi-year droughts, as well as reductions in State Water Project supplies. The same could be said for impacts of climate change, although we do not know of any sufficiently secure regional climate-change predictions over the next 30 years to make consideration of this influence revealing for the present purpose.

Because of the potential importance of multi-year droughts on fish populations (and subject to any analysis of this issue with EDT), there seems to be some value in continuing to re-visit a process-based streamflow modeling strategy (HEC-HMS or other option). If such a model could be reliably calibrated to the hydrogeological conditions of the Alameda Creek watershed, it could be used with the longer precipitation records of the region to examine the streamflows to be expected in California's persistent droughts. Such an exercise might also be valuable when and if the hydrology of Arroyo de la Laguna watershed and its effects on flows and water quality along lower Alameda Creek are assessed.

Considerable uncertainty persists about the future of streamflows and associated riparian shade in Sunol Valley between nodes 4 and 5, because of the planned deepening and enlargement of gravel pits. This issue is the subject of ongoing field investigations by SFPUC personnel, and cannot be fully assessed at this time. Experience elsewhere in California indicates that floodplain mining operations have significant influences on flow, temperature, and physical habitat quality of *O. mykiss* and other species that inhabit a flashy winter flow environment and stressful summer rearing conditions. In its present form, the EDT habitat potential modeling

methodology is capable of investigating the significance of conditions in this reach as they propagate throughout the life history of the fish, and therefore of illustrating how significantly conditions in this reach affect the fish population potential of the entire watershed. But the combination of the low resolution with which EDT represents local effects of this kind and the continuing uncertainties about the future hydrology of the reach as gravel mining continues suggest that it would be useful to refine the EDT representation of habitat potential locally. Such refinement might involve the field investigations of flow losses and higher-resolution modeling of habitat conditions in the reach, including detailed topographic surveys, flow modeling, and energy-balance modeling of temperatures. The potential for riparian shade management and channel-margin structures to promote pool development could also be investigated by this means, if the EDT modeling and field surveys of fish use of the reach indicate that such improvements would lead to population-scale survival benefits.

Apart from the effect of flow losses, other potentially deleterious effects of mining on habitat conditions in Sunol Valley did not receive much attention in the various reports. For example, the panel did not get a clear idea of plans for the management of fine sediment and the quality of water returned to Alameda Creek at the downstream end of the reach. These factors, along with flow and shade suggest that mining outcomes should be a component of the HCP discussion.

Another opportunity for improved habitat investigations is provided by the channel cross-section data and stream gauging data collected for hydraulic modeling and already processed within HEC-RAS. Although flow depths and velocities are not utilized by the EDT model for assessing habitat potential, these flow-dependent characteristics are widely used elsewhere for assessing habitat suitability for fish passage, spawning, and juvenile rearing.

The water temperature calculations that have been made also constitute a resource that one day might prove useful for habitat assessment beyond their use in EDT up to this time. EDT uses only daily average temperatures, ignoring potentially important diurnal temperature swings that might become crucial for fish growth and survival near the boundaries of the species' range. Although it may not be necessary to utilize these data in the current stage of habitat assessment, the data are available for complementary, higher-resolution analyses.

II: Modeling Steelhead Life Histories in Alameda Creek Using Ecosystem Diagnosis and Treatment

The Alameda Creek Watershed Habitat Conservation Plan (AWHCP) Independent Science Review Panel (ISRP) was charged with evaluating the efficacy of Ecosystem Diagnosis and

Treatment (EDT) modeling to assess take and mitigation for the anadromous component of *O. mykiss.*

The EDT methodology is founded on a set of assumptions about target species' life histories. *O. mykiss* life history is represented by a set of life-history trajectories that define how an individual fish will transition (survive) in space and time from one life stage to another. This strategy allows computation of the value of each channel reach and time period to the outcome of a population of migrating or resident fish under a wide range of starting conditions and habitat scenarios (such as flow regimes and water temperatures). The model thus computes the implications of each anticipated set of spatial and temporal conditions for the population outcome, identifying the significance of bottlenecks to survival.

Though originally developed for use in the Pacific Northwest, the EDT model contains parameters that can be adjusted to reflect a species' survival as it uses local environmental conditions. Throughout their range, *O. mykiss* display a high degree of phenotypic plasticity. This plasticity creates a diverse array of life history tactics and allows populations to survive in highly variable environments. In coastal central California, *O. mykiss* experience extremes in intra- and inter annual hydrologic conditions marked by flashy, high, winter flow events and prolonged periods of summer drought with low, often intermittent, streamflow. The hydrologic conditions in Alameda Creek, a San Francisco Bay drainage set in a semi-arid Mediterranean climate, are typical of many central California streams. Inter-annual and seasonal diversity in streamflow demand that *O. mykiss* express a wide range of life history tactics in Alameda Creek. Because anadromy has been limited by fish passage barriers for 40 years, empirical data are lacking for judging which life history tactics are most productive for the steelhead component of the Alameda Creek *O. mykiss* population. In the absence of these data, the Consultant Team relied on reports and published literature to construct a set of life history tactics that *O. mykiss* might employ to establish a viable population in Alameda Creek.

Due to variable conditions in Alameda Creek and the dearth of available fish population data, the Consultant Team identified the need to examine EDT model life history assumptions prior to evaluating the habitat potential of proposed HCP flow scenarios. Based largely on work by McBain and Trush (2008), the Life History White Paper posits seven potential life history tactics that include *O. mykiss* rearing in several reaches of the stream and smolting at age one or two (Table 5, Page 19). The EDT model was run for each of these tactics using unimpaired flows from the wet/normal 1998 water year. Life history Tactic 4 (fry remain in their spawning reach, rear in that reach during summer and winter, then smolt at age 1+) had the highest productivity (returns per spawner) and was the only tactic forwarded to the full EDT analysis of water year types and HCP scenarios.

The Life History White Paper (on pages 7 and 8) states that current, past, and possible future conditions in the Alameda Creek watershed would be compared against a range of life history

tactics. The report states that "It is likely that the eventual steelhead [we believe this should read *O. mykiss*] population will include a variety of tactics that will allow the population to cope with the high degree of environmental variability and frequently marginal conditions in Alameda Creek". However, information presented in the three white papers to date, does not compare the performance of multiple life history tactics over time and the selection of a single tactic, with fish smolting at age 1+, gave several ISRP members pause and raised questions about the validity of assumptions regarding life stage trajectories. More specifically panel members questioned the timing (life stage duration and transitions), seasonal movements among reaches, and the potential for winter rearing and growth on the success of life history tactics in EDT. Furthermore, panel members concluded that an *O. mykiss* management strategy that focuses exclusively on anadromy would limit future management. An approach that identifies a potential population encompassing a range of strategies, from complete anadromy to complete residency, will provide greater opportunities for long-term success in this endeavor. Recent literature from coastal central California, forwarded to the Consultant Team by the panel, may shed some light on potential steelhead life history strategies in Alameda Creek.

Smolt Age

ISRP members' experiences and recently published literature, suggest that most steelhead in central California coastal streams smolt at age 2+ (Satterthwaite et al. 2012; Sogard et al. 2009). Low flows and limited feeding opportunities during summer suppress growth rates and necessitate two years of freshwater residency before smolts attain a threshold size (generally >150 mm FL) for survival in the ocean (Sogard et al. 2012). We presume that the EDT modeling predicted Tactic 4 to be more profitable than Tactic 7 (a second summer and winter of rearing with smoltification at Age 2) because EDT assumes juveniles are inactive, grow slowly, and suffer higher mortality rates in winter. While survival is often lower during winter, in coastal California streams, mild winter temperatures and higher stream base flows afford enhanced feeding and growth opportunities. If adjustments to model inputs such as life stage duration and transition could be made to reflect enhanced use of habitat in winter, reduced winter survival may still yield EDT results that show higher potential performance of Tactic 4. However, if fish fail to achieve a threshold size for smoltification after only one summer of rearing, it is unlikely this tactic will be expressed. We are concerned that EDT results contrasting water year or management scenarios using Tactic 4 may set unrealistic expectations for future productivity of an anadromous steelhead population in Alameda Creek.

Juvenile Seasonal Movements

Juvenile fish trajectories in EDT start in a spawning reach and progress downstream over time. Allowing only downstream movement among seasonal habitats constrains the seven life history tactics evaluated in Alameda Creek. Recent research from central California streams demonstrates the importance of downstream and upstream movement of juvenile steelhead.

Hayes et al. (2008) and Fuller (2012) described tactics that involved age 0 and age 1+ fish rearing in estuaries during summer then moving upstream in fall to overwinter. These multidirectional movements allow fish to exploit seasonally productive environments and maximize growth. The ISRP recommends incorporating multidirectional movements in life history tactics.

It is not clear if any of the seven life history tactics considered active rearing of age 1+ or 2+ fish during winter in Niles Canyon following a period of summer rearing in the estuary or upper Alameda Creek. We appreciate that low streamflow in the Sunol Valley reach and high water temperature in the Niles Canyon and Niles Cone reaches limits rearing potential and movement from late spring to fall. However, as mentioned previously, winter rearing may be an important component of steelhead life history in Alameda Creek and EDT should allow greater flexibility in seasonal movements. If computational limitations in EDT preclude adding greater flexibility to seasonal movements, the Consultant Team should consider subjecting the full EDT analysis (i.e., comparison of water years and HCP scenarios, White Paper #3) to a number of life history tactics as opposed to only forwarding Tactic 4. While this might not demonstrate multidirectional juvenile movement per se, it might present a more varied depiction of potential steelhead performance. This theme will be explored in greater detail in the section of this report describing EDT Implementation.

Timing – Life State Duration and Transitions

Life stage transition dates and durations are key parameters in EDT (Table 2, Page 7). In addition to modifying these transition dates and durations to reflect winter rearing and multi-directional movements, the ISRP also recommends a refined view of smolt emigration and adult immigration timing. Figure 4 on Page 10 shows approximate timing of major stages in the potential life history of Alameda Creek steelhead. The smolt emigration period is shown to range from February to May with a peak between March and April. This timing is generally supported by recent literature in central California streams (Hayes et al. 2008; Sogard et al. 2009) but in some ISRP members' experience sampling challenges limit out-migrant data collection in late winter/early spring (thereby biasing many accounts of out-migrant timing) and the smolt outmigration peak should extend to February. Likewise, some panel members felt the January to mid-February spawning period was too short and recommend extending the assumed spawning period into March.

Evaluation of Life History Tactics

While the Life History White Paper included a clear and generally well-supported presentation of life history characteristics for a potential Alameda Creek steelhead population, the document contained little information to support the comparison of performance among the seven tactics. To evaluate the effect of limiting factors on fish performance for each tactic, the

ISRP recommends contrasting results using the life stage/attribute/survival factor tables found in Figures 22-29 on pages 62-69 of the EDT Implementation Paper (White Paper #3). Because this analysis will rely on modifying benchmark survival rates using stage specific survival factors, it would also be helpful to include discussion about benchmark survival estimates for Alameda Creek steelhead. Benchmark values for EDT are presented on page 12 of White Paper #3 and appear to be supported by literature review and professional judgment from Pacific Northwest streams. It would be helpful to include this information, and any refinements to benchmark values based on recent work in central California, in the Life History White Paper.

III: Ecosystem Diagnostics and Treatment Modeling for the San Francisco Public Utilities Commission Alameda Watershed Habitat Conservation Plan

General comments

Some members of the review panel, having considerable modeling experience, were initially skeptical of the 'black box' nature of the EDT model during preparation for the review. Our concerns were moderated by discussions with the modeling Consultant Team, who emphasized that the model is designed to predict biological performance as the outcome of the spatial and temporal pattern of habitat quality during variable environmental conditions in a river network. In particular, the model propagates the effects of fish survival potential through each month of the species' life history and each reach that the species needs to exploit. This is an important facility in modeling the expected response of fish populations to natural and management scenarios.

The panel concluded that, in a general and qualitative way, EDT can inform managers of the patterns of potential outcomes of important ecosystem changes such as returning flow to previously depleted stream reaches. It also portrays the variability of population responses that can reasonably be expected to result from the variability of habitat conditions and the plasticity of a species' responses to habitat availability and quality. The strategy of modeling a distribution of spatially explicit life-stage trajectories is particularly attractive for this purpose.

EDT is a life-cycle model of habitat potential, based on the extent and characteristics of the aquatic environment in an entire stream network (subject to constraints on accessibility) as experienced by a migrating salmonid. The quantity and quality of habitat in each stream reach and month of a fish's particular life-history trajectory affect the productivity[1] and capacity[1] (maximum density) of salmonids using that pathway through space and time. The model results

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[1] The terms "productivity" and "capacity" are defined in the two-parameter Beverton-Holt stock-recruitment relationship (Beverton and Holt, 1957). The term "productivity" is a density-dependent survival for each life-cycle stage, and "capacity" is the asymptotically approached maximum density for that stage.

can then be disaggregated to examine the effects of changes in individual reach-scale attributes at particular seasons, as they might be affected by natural conditions and management actions.

The model relates capacity and productivity to ratings of habitat conditions (ordinal-scale, integer (0-5) scores). Thus, the productivity at a particular life stage is the arithmetic product of a benchmark survival (for a rating of 0, representing no degradation of survival due to habitat quality) multiplied by a survival factor that varies with the actual habitat quality score for the reach and month. The benchmark productivity has been established for "optimal environmental conditions" (Blair et al., 2009, Appendix A of the report) and hard-wired into the model before its implementation in Alameda Creek. This makes the benchmark productivity critical to the *numerical* outcome of each simulation, and it was based on "available literature and consulting biologists" (Blair et al, 2009, p. 7), and the ISRP has no way of evaluating their relevance to Alameda Creek. The survival factors represent the decrease from the benchmark productivity resulting from habitat characteristics such as sedimentation conditions, in-channel wood, water temperature, etc., etc. These survival factors, which are crucial to the eventual prediction of fish production potential of the habitat, have been related by the model designers to multivariate relationships among "more specific, measurable attributes of the environment" (p. 8 of the report.)

The structure of the model by which survival is calculated and the nature of the parameterization methods introduce the major uncertainties about how, and the quantitative degree to which, the model results can be interpreted. For example, the survival factor related to "sediment" consists of a multiplication of three component survival factors based on "fine sediment in riffles", "embeddedness", and "suspended sediment". Not only does the defining appendix of the report never define *why* these three variables should be multiplied together to obtain the percent survival factor, but the assignment of the scores (0-5) to the range of (say) embeddedness is never defended. Even the basis for including each variable is only defended by anecdotal literature review, which does not illustrate for the reader *how* the scores were assigned. The same argument could be made for each parameter in the model. Environmental attributes such as "change in inter-annual variability in high flows", "change in inter-annual variability in low flows", "intra-daily diel flows" are categorized in ways that can only be described as conceptual rather than quantitative; yet they are then given scores which reduce the survival quantities of fish in the governing equation. Furthermore, when single samples of data from particular Pacific Northwest field sites are used, the issue of how well a relationship was quantified by the original study is never addressed. Even if that relationship has been or could be reproduced elsewhere, by how much would the parameter vary?

Thus, the model can best be described as an attempt to capture and loosely quantify the accumulated wisdom and experience of the community of fish biologists (mainly) in the Pacific Northwest. Given the complex nature of predicting the cumulative fish-producing potential of

complex, time-varying stream networks, this is considerable achievement. However, it would be easy to conclude from the report and related documents that EDT is predicting annual returns of (say) 40 to 125 adult *O. mykiss* to Alameda Creek watershed under the scenarios and water-year conditions represented in Figure 12 of the report. As the Consultant team emphasized in their presentation, this is not really a prediction of fish numbers but of the fish-producing potential of the stream network habitat under the various management scenarios. The implication is that although resource managers cannot promise to deliver a certain number of fish (because of, for example, the influence of ocean conditions on survival), managers might be expected to maintain habitat quality at a certain level that has the potential to support a desired number of fish. Nevertheless, graphs such as Figure 12 on predicted equilibrium abundance of returning *O. mykiss* and Figure 13 on the predicted "take" and "mitigation" do raise the question of whether the reasonable expectation is for tens, hundreds, or thousands of fish to return to Alameda Creek. Another reasonable interpretation of the modeling, illustrated in Figure 16 of the report, is that a considerable amount of variability should be expected in the response of individual fish on account of their spawning in different reaches at a range of dates and requiring access to different reaches during their growth and migration.

Although it is not possible to say that the structure of the EDT model and its parameter estimation methods are "weaknesses" of the modeling strategy, they are certainly worthy of debate, especially about the accuracy and precision of the model's predictions (both the quantities and the patterns). We support the use of EDT as a "planning model" appropriate for predicting changes in patterns of a habitat's (such as an entire stream network or watershed) potential for supporting a fish population resulting from management alternatives. However, by presenting its results in the form of fish numbers returning to a river, the model invites overly confident and optimistic misinterpretation, despite its potential for wise use.

Of course, the model has been widely analyzed, debated, and verified to varying degrees in the Pacific Northwest, and it is not our intent to re-open those debates. However, the dependence of the model on an exceedingly complex structure and parameter estimation strategy does create considerable uncertainty about the numerical values of any results. This is not to say that the *patterns* of the results are unreliable, or that the quantitative uncertainties in the process necessarily vitiate use of the model for its intended planning purpose in Alameda Creek watershed. However, it would be wise to keep a skeptical eye open for situations where the limitations of applying such a model in a new environment --- like the hydrologically episodic, warm, and non-oligotrophic, Mediterranean environment of Alameda Creek ---might lead to some unforeseen or easily overlooked mis-identification of process or habitat limitation. Ways to reduce this risk include assimilating local biological results into the parameterization, and even structure, of EDT, and combining the coarse-grained predictions of EDT with higher –resolution habitat analyses in reaches or seasons that have been identified by EDT as particularly critical to the predicted outcomes.

One example of the latter strategy could be to integrate the results of the unfinished "Number of Good Days" model, which was briefly described to us, with EDT's capability for propagating the consequences of habitat limitation at one location and season through the whole freshwater life history of the fish. Another example of where increasing the resolution of the analysis beyond what EDT seems to be designed for is illustrated in the three panels of Figure 1, which illustrate habitat conditions and ecological processes that are fundamental to project success in Mediterranean climates and mountainous terrain in Central California. This reach, between Little Yosemite and the Alameda Creek Diversion, appears to provide one of the best opportunities to enhance habitat for the anadromous component of *O. mykiss* in the watershed. It was not clear to the panel that EDT is designed to represent such features, which are nevertheless vital to creating and maintaining this habitat. Recent observations (June 2) by one of the panel members revealed a drying channel with desiccated spawning gravels (Figure 1c). Yet, relatively large pools supporting young *O. mykiss* and other fish species occurred throughout the reach (Figures 1 a, b). These pools are created by forcing elements, such as large boulders, bedrock outcrops, and sycamore trees throughout the reach. Such pools, if deep enough, might create temperature and flow refugia to support rearing and resident *O. mykiss* during the stressful low flow summer and fall periods. Flow depth, created by these forcing elements and key to maintaining temperatures, is not treated by the EDT model. Identifying whether these features meet over-summer requirements and what long-term riparian management strategies are required to maintain these features seem very important since Strategy 4 appears to rely on this stream section.

Figure 1: Examples of forcing features in the reach upstream of Little Yosemite: (a) a large boulder, (b) a sycamore root wad, (c) small boulders in a desiccating riffle immediately downstream of a forced pool.

Detailed Suggestions for Improvements of the Analysis

The following is a more detailed and specific set of suggestions of how model implementation could be improved, extended, or interpreted.

EDT is used here to examine specific habitat responses to proposed flow changes and fish access modifications. This is understandable from a contractual perspective but is not the best use of a predictive model. Why not use EDT to make recommendations for the most potentially successful *O. mykiss* strategies that might historically have been present, and to characterize the most productive historical habitat? This is not to argue for a "no-project scenario, but simply to inform the process about what realistic *O. mykiss* strategies could occur within this geographical range. Similar concepts are being used on river systems where salmonid populations have been extirpated and re-introduction is being considered (e.g. the Lower San Joaquin Restoration Program).

Members of the panel have concerns about using the modified hydrograph to inform the model for the selection of the "dominant life stage". Because an altered flow dictates the strategy of the fish rather than allowing the appropriate, natural strategy for a fish within this latitude and historic hydrology, constraining the range of flow regimes examined creates a circular argument that constrains the model in expressing the population's potential richness and diversity.

Temperature effects on *O. mykiss* success have been and will continue to be hotly debated. We understand that at some point in a modeling strategy, modelers have to choose a temperature threshold and move forward. However, the threshold(s) chosen will have significant effects on the modeled outcomes. Report III indicates that the temperature parameters chosen originated from research conducted in the Pacific Northwest, suggesting a conservative approach when these parameters are applied in Central California. However, if temperature thresholds are overly sensitive, they might suggest that a particular life strategy might fail when, in fact, it would not or does not. Use of both broadly applied conservative temperature criteria and reach-specific temperature criteria might produce useful insights.

Take and mitigation are legal definitions, and we understand that those terms are the subject of negotiations among the parties in developing the HCP.   The panel is concerned that take has not been accurately defined for all of the impacts associated with the PUC's facilities and operations. For example, the reservoirs inundate large areas of habitat and block access to much of the watershed, disrupting not only fish passage but also the flow and continuity of water, sediment, wood and nutrients to the downstream environment. Gravel mines in the Sunol Valley reach are also diminishing and putting at risk what may have been valuable gravel-bed habitat for salmonid spawning and rearing. The water table in today's pumped-down condition reduces in-channel flows and dries out habitat under a range of flows that would otherwise provide habitat.   There are temporal as well as spatial reductions in habitat resulting from this resource use, which is under the control of the SFPUC.   These negative effects may be as

profound as a dam in disconnecting habitat and stream flow from an important part of the Alameda Creek catchment.

The panel realizes that a clear description of the goals and proposals of the HCP has not been fully developed at this time. Given that, we recommend that the initial EDT results, tempered by the concerns and recommendations made in this review, be considered as information to refine and focus the HCP in defining the best cost-benefit actions. For example, a clearer definition of a successful outcome and how it will be measured would assist with focusing the interpretation of the EDT modeling.

Several recommendations for improving the approach and utility of the model were identified that we would like to highlight.

1. Communicating more clearly how the model works and what its results represent would illuminate the utility of the modeling exercise for those who are charged with interpreting and implementing its results. The ISRP members found that understanding the structure and appropriate interpretations of the model depends on some very subtle vocabulary and manifold arithmetic manipulations of "scores" that are originally assigned on the basis of both quantitative, site-specific and laboratory measurements and on qualitative rankings of environmental conditions. It would be helpful, for example, to illustrate the use of one or two survival factor scores and the logic and stepwise calculation from input to result and its appropriate interpretation.

2. EDT results should avoid converting habitat into fish numbers. The HCP should quantify habitat, and take and mitigation should be related to that metric.

3. Test the sensitivity of the model structure by varying individual parameters selected for Alameda Creek. This could naturally lead to identification of the most influential parameters, and may facilitate a streamlined model. It would also inform the model results and allow for describing the significance of results. The Northwest Fisheries Science Center performed a sensitivity analysis of EDT. It would be good to incorporate their ideas into the work performed here. [http://www.nwfsc.noaa.gov/research/divisions/fed/wpg/sensitivity _analysis.cfm]

4. Test the sensitivity of the model to the environment one action at a time, to a range of potential management actions in the watershed (e.g. flow augmentation, temperature augmentation, barrier modification, habitat enhancement, Sunol Valley restoration). This could lead to identification of factors limiting habitat and could identify optimal

actions. Recommendations 3 and 4, when fully developed, would unbind the 'diagnosis' tool that EDT promises.

5.   Model cycles of hydrologic years; as discussed in the hydrology comments, average conditions or single water years can be meaningless in California. We recommend modeling sequences of year types that would include prolonged droughts and floods consistent with ENSO and Pacific Decadal Oscillation climate cycles. The hydrology sub-group could develop representative climate sequences.

6.   Model the seven different steelhead life strategies with a multi-year hydrologic framework recommended in #5, above.

7.   Recommendations #4 and #5, when fully implemented, would produce a 'results matrix' of life strategies and hydrologic sequences that would be particularly robust and edifying.

8.   Let model results feedback to management scenario definition and optimization.

9.   Run a bootstrap-type analysis of results to provide confidence intervals for using EDT evaluation of the HCP.

10. Utilize the EDT model to explore the potential of the non-anadromous behavior in the resident population. Model runs under HCP proposals "fail" if connectivity with the ocean is not established. However, in the modeling context it would be possible to leave in the present barriers and examine the predicted habitat potential with the proposed HCP flows. Then, barriers could be removed to compare the habitat potential with the resident-only condition.

11. The application of EDT in the Sunol Valley reach should be informed with a physical model of groundwater-surface water interactions (explained in greater detail in the hydrology section of our report). The effects of deep pit mining and the associated depletion of the groundwater in the valley have profound effects on habitat that may have been vital to salmonids for spawning and rearing.

12. The EDT model could be used to examine how improvements in riparian shade might be used to ameliorate water temperatures. This analysis could include the prospects for such improvements in the gravel-mined reach of Sunol Valley, where sequences of air photos indicate that the riparian tree cover has been significantly diminished as the water table has fallen as gravel pits have been deepened and extended.

13. There is likely to be value in integrating EDT with the "Number of Good Days" model of local habitat conditions in four critical reaches. However, we were briefed only quickly about the latter model, and though the two approaches seem to be complementary, the integration will not remove all information gaps, and we have to reserve our judgment on the final value of that effort.

14. **The model appears to use a single individual when tracking the success of a given life strategy. ISRP members have been grappling with the idea that this incorrectly emphasizes failure for a strategy. For example, if a single female (strategy A) returns to spawn, that strategy is considered less successful than strategy B, where two females return. This choice of a successful outcome misses the possibility that another successful outcome would be if a female from strategy A spawns with a resident male (a mixing of strategies). What if strategy A and B become more successful if they are allowed to share genetic material? In short, how does the model, or more broadly the conceptualization of the conservation potential in Alameda Creek Watershed, account for mixed strategies?**

IV: Historical Ecology of Alameda Creek Watershed

Historical ecology is becoming more widely used as a means of informing the construction of landscape restoration and management plans. The method can indicate what conditions "were actually like before the changes that restorationists seek to undo or mitigate" (from the Consultant's presentation). However, the activity can yield several other products useful for the goals of HCPs, even in a watershed that has been so radically altered that ecosystem planning is unlikely to return the landscape anywhere close to original conditions. For example, it can identify habitat patterns, connectivity, and processes that no longer exist but that be re-established even within modern constraints. It can document secular changes in vegetation patterns, sediment supplies, or channel conditions that have not been sampled in the instrumental record of environmental change. It can document the relative magnitude and quality of habitat loss or transformation in various parts of a river system, such as in the two main tributary watersheds of Alameda Creek, highlighting the potential importance of seeing an HCP in the context of other positive and negative trends that might influence the effectiveness of the conservation plan. Combined with modeling, this aspect of historical ecology constitutes one form of cumulative watershed effects analysis. An example of such analysis occurs when mapped land cover changes reflect changes in the water balance of groundwater recharge, leading to desiccation or waterlogging of riparian zones downstream. Observations of this type might indicate the potential for unwelcome surprises or changes that landowners wish to avoid, no matter how natural they might be.

The consultant team from the San Francisco Estuary Institute has documented landscape change since the late-18th century in the entire Alameda Creek Watershed, including the watershed of the larger tributary, Arroyo de la Laguna. The data sources are diverse in nature and reliability, and mainly qualitative, but when recorded in consistent ways, compiled by time period, and geo-referenced, they can reveal patterns and persistent changes, which when interpreted by people with training in landscape functioning can produce important insights for conservation planning. Early data sources tend to comprise descriptions and other records at places or on small areas of land, although early instrumental surveys or even sketched maps are surprisingly widespread and can be digitally geo-referenced. The record became significantly enriched beginning in the 1920s with the introduction of aerial photographic surveys of increasing scale and quality, many of which are now published directly in digital form. The increasing wealth of data, however, does not diminish the level of interpretive skill required to convert these subtle spatial records into understanding of landscape patterns and change.

A crucial step in assimilating the diverse data sources is to recognize the fingerprint of landscape processes, such as how patterns of ground water flow relate to topography, geological structure, and surface water bodies, and thereby create patterns of water flow and availability that sustain plant communities and the activities of people. The magnitude and role of flooding and the density and intricacy of water bodies are other important recognizable landscape features. Another potential of the method is the documentation of rates of processes, such as the spread of plants and other aspects of succession. One of the limitations of the reconstructions, however, is that they often can involve only qualitative identification of processes, habitat potentials, or ecosystem services. Thus, it is valuable to combine the results with quantitative estimates based on process models or statistical characterizations from elsewhere.

Although the historical documentation and interpretation of the Alameda Creek watershed is not yet complete, it has already yielded important insights which suggest both conceptual models for restoration but also targets for quantitative interpretation through mathematical modeling of hydrology, hydraulics, and ecosystem functioning. The most widespread and significant targets of this work have been outside of the parts of Alameda Creek watershed involved in the current HCP. Relevant features within the HCP domain include natural and anthropogenic influences on channel morphology and riparian vegetation in the Sunol Valley reach, and channel simplification and pool eradication in the flood-control reach downstream of Niles. These results emphasize that the critical ecological role of those two reaches should be closely addressed by EDT and other habitat modeling exercises involving flow, channel morphology, and water temperature.

The historical analysis also points to wider issues that would favor aquatic ecosystem improvements in the longer term, building on the fruits of the HCP. Examples include the former

role of extensive marshlands in providing fish habitat and turbidity control along Arroyo de la Laguna. Another is the original denser and more intricate network of tidal channels with pools and shade provided by tree-covered natural levees and securely watered channels, sustained by artesian ground water immediately upstream from them. These channels probably provided extensive rearing habitat for anadromous fish throughout the year, and the historical documentation suggests analyzing the potential yield of partial restoration. This larger historical spatial context provides a strong foundation for SFPUC to play an important role in ecosystem management by promoting the expansion of its current approach of monitoring and modeling in support of its HCP.

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