Appendix F

SacEFT Analyses Results

1.1 Background Information

Note: this appendix is **not** a stand-alone document. Context for this material is provided in Section 2.3 of the Sacramento River Ecological Flows Study Final Report (and references therein). Readers are strongly encouraged to read Section 2.3 of the Final Report prior to this appendix.

SacEFT possesses unique strengths that complement and advance other tools like the Ecosystem Functions Model (EFM) (USACE 2002) and Indicators of Hydrologic Alteration (IHA) (Richter et al. 1996) (Table F–1).

Table F–1. Comparison of SacEFT with related tools for evaluating ecological flow regimes.

	Scale	Ecological Emphasis	Notes
SacEFT	Keswick to Colusa at mixed spatial resolution (index segments, reaches, cross sections) Mainstem only - tributaries not presently included Daily time-step	6 focal species, 35 habitat-centered performance measures links flow, water temperature, gravel augmentation (substrate condition) and channel revetment states with focal species performance *Not* a predictive salmon life-history model; emphasizes representation of a wide range of ecological processes	▪ A single computer program ▪ Interpretation of biological significance automated through "traffic light" indicator ratings† tied to specific biophysical relationships ▪ Emphasizes communication with non-specialists ▪ Builds in non-flow actions for gravel augmentation and channel revetment states ▪ Emphasizes identification of preferred flow, temperature, substrate and channel characteristics rather than precise quantification of focal species life-history outcomes
Ecosystem Function Model (EFM)	Applied reach-by-reach, site specific – not Sacramento River as a whole	15 biological relationships	▪ Links to several other USACE tools through a sequenced analysis & manual interpretation process ▪ GIS map focus ▪ Tightly linked to hydraulic modelling at site scale
Indicators of Hydrologic Alteration (IHA)	Stream gage level data analysis –viable at a reach to segment scale	~32 statistical parameters of hydrologic change (scorecard); no explicit representation of biological outcomes (though IHA parameters known from ecological theory / first principles to be biologically relevant)	▪ Focused on pre- vs. post-alteration comparisons ▪ Does not directly address potential biological significance of hydrologic alterations
DRIFT	Focused on specific index cross sections	Biophysical and socioeconomic consequence data entered as textual statements based on expert opinion, not calculated in a simulation (e.g., "Plants at back of zone under increasing stress; roots unable to develop because of insufficient water")	▪ Expert system; requires synthesis and interpretation of individual lookup statements ▪ Includes socio-economic considerations
SALMOD	Keswick Dam to Red Bluff Diversion Dam More attention to meso-habitat characteristics and local hydraulic properties; spatially explicit simulation of movement of cohorts from one habitat unit to another Weekly time-step	Winter, spring, fall and late fall Chinook salmon Model processes include spawning (with redd superimposition), incubation losses (such as redd scour or dewatering), growth (including egg maturation), mortality due to water temperature and other causes. End prediction is Chinook salmon outmigrant abundance	▪ Chinook salmon freshwater life history model ▪ Parameter intensive, deterministic, predictive model. ▪ Tracks spatially distinct cohorts that originate as eggs and grow from one life stage to another as a function of water temperature and flow in a computation unit. ▪ Software and data file configuration geared towards expert technical modellers ▪ For Chinook salmon, SacEFT uses some of the same source datasets and assumptions as those found in SALMOD

† Sometimes referred to synonymously as "hazard ratings" or "severity ratings".

1.1.1 CALSIM-SRWQM data disclaimer

As noted in the Final Report for the NODOS-AF2B, FNA2 and Shasta flow scenarios (see Section 1.1.6 for scenario definitions) daily flow disaggregation *below* Red Bluff Diversion Dam (RBDD) is known to be flawed; although temperature estimates are not thought to suffer from this numerical problem. Therefore, these modeled flows are used to illustrate contrasting flow regimes for model testing of the sensitivity of the ecological performance measures to the flow patterns, but do not represent the actual flows below RBDD following hydrosystem operations under the NODOS-AF2B, FNA2, or Shasta scenarios. These flows below RBDD **are for testing and demonstration purposes only.** Model results for performance measures calculated at sites *above* RBDD represent legitimate flow comparisons.

1.1.2 SacEFT: assumptions in underlying physical models

SacEFT includes a variety of physical data sets that originate from several high-profile planning models. The intent is to leverage the extensive existing efforts made in these systems to supply key inputs necessary to calculate focal species performance measures. In addition to these models, select mainstem Sacramento River gauging records have been used for river discharge and water temperatures. Using data from models and stream gauges allows multiple prospective and retrospective analyses. Approximately 66 years of daily historical records were gathered in this manner and used in a retrospective historical scenario. Care is taken to identify scenarios that have fundamentally consistent internal assumptions vs. runs using historical flows which embed a range of hydrosystem configurations, operations and levels of human water demands.

SacEFT prospective daily flow datasets are based on 2005 baseline assumptions as simulated using the CALSIM – SRWQM – HEC5Q modeling complex. The Common Assumptions team has agreed that the daily flow disaggregation results from SRWQM *below* RBDD are flawed. Hence, it is important to emphasize that in SacEFT, records below RBDD were used for testing and demonstration purposes. DWR is working on an updated disaggregation algorithm intended to resolve the flow stability concerns below Red Bluff. When completed and tested, this new disaggregation methodology will be built into the CALSIM Daily Operations Model (CALSIM DOM). The timeline for this updated product is not clear.

Over the course of model development DWR provided several sets of daily disaggregated discharge data for a variety of scenarios. Three of these, NODOS-A2FB (North-of-the-Delta Offstream Storage), Shasta (raise Shasta Dam 18.5 ft) and FNA2 (Future No Action) were selected. Although these scenarios are preliminary and the daily flow disaggregations below RBDD are in development, they offered our study team the best opportunity to explore contrasting flow regimes for model testing of the sensitivity of the ecological performance measures to the flow patterns.

Fremont cottonwood initiation is currently the only consideration in SacEFT driving the choice of matched stage-discharge and ground surface elevation data. During our reconnaissance leading up to the model design workshop in December 2005, three sites examined during the 2003 Beehive Bend study (Roberts et al. 2002, Roberts 2003) met our selection criteria:

- RM172
- RM183
- RM192

These sites are assumed to be generally representative of the Colusa to Red Bluff section of the Sacramento River. SacEFT's riparian initiation submodel is applied to these 3 sites.

Stillwater Sciences has developed The Unified Gravel-Sand (TUGS) model to simulate how bed mobilization and scour affect grain size distribution, including the fraction of sand, of both the surface and subsurface (Appendix E). The model can be used to assess the effects of different management scenarios (e.g., gravel augmentation, flow releases to increase the frequency of bed mobilization and scour, reduction in fine sediment supply) on salmonid spawning habitat. The TUGS model simulates how flow and sediment transport affect grain size distribution, including the fraction of sand, in both the surface and subsurface components. SacEFT imports TUGS outputs for use in estimating the benefits of gravel augmentation for spawning WUA.

UC Davis researchers have developed a model of meander migration (Larsen 1995, Larsen and Greco 2002, Larsen et al. 2006) using MATLAB software to calculate channel migration using a simplified form of equations for fluid flow and sediment transport developed by Johannesson and Parker (1989). One version of the meander migration model predicts meander migration as a function of a single, representative, geomorphically effective discharge ("characteristic discharge"). The model has been modified to consider the effects of a variable hydrograph on meander migration rates. This is believed to provide a more accurate depiction of the conditions in which meander migration occurs. The underlying hypothesis is that bank migration rate is linearly related to the sum of the cumulative excess stream power. The meander migration model applied and configured for SacEFT focuses on three river segments located between RM 170-185, RM 185-RM 201, and RM 201-218. The finest unit of resolution of interest in SacEFT is a bend.

Additional details on the assumptions of the meander migration model are available in the Meander Migration Final Report (Appendix D) and in the TUGS Final Report (Appendix E).

1.1.3 SacEFT: Matching physical to focal species locations of interest

Each focal species model in SacEFT is designed to accommodate the temporal framework of its input data: daily for flow and temperature and annual for TUGS and MM data. SacEFT accepts inputs that may be point-based (e.g. discharge and temperature) or segment-based (e.g., TUGS data). It links these inputs to performance measures (PMs) that may themselves be point-based (e.g. GS1 – Green Sturgeon spawning locations) or segment-based (e.g. CS1 – Chinook spawning WUA).

The guiding principle for this linkage is to first fill gaps that may be present in the input data. The second principle is to use the input data that is nearest to the location where the PM is modeled. To do this SacEFT uses the concept of a neighbor zone: any input data located within a user-defined river mile tolerance zone is considered a perfect match. Failing a match within the tolerance zone the nearest upstream data is usually selected. In some cases, such as the riparian initiation submodel, flows are interpolated based on the nearest available upstream and downstream source of flow data for the cross-section of interest.

Some matches require overlaying segment-based data from multiple sources (e.g. TUGS data and salmonid spawning segments). When this occurs, segments that are completely-contained and segments that overlap are weighted by the proportion of their length contained in the common segment. For example, if a short TUGS segment is completely contained in a longer spawning segment along with an adjacent TUGS segment that is half in the spawning segment, the sediment data from the first segment are given a weight of 1.0 and the data from the second segment a weight of 0.5.

In the unique case of salmonid rearing habitat there are some rearing-reaches without spawning and therefore without any natural way to predict the egg-emergence that eventually follows spawning and marks the initiation of rearing. In these cases the average emergence of the *upstream* segments is used to create an egg-emergence distribution for the downstream rearing segment.

SacEFT: Extending TUGS locations to Chinook and steelhead locations

When applying TUGS data for Chinook and steelhead spawning WUA calculations it was generally necessary to apply annual location-based TUGS results to portions of the river that are outside the area where TUGS was calibrated. In accordance with our nearest-neighbor principle, the predicted substrate composition of the most downstream of the five TUGS simulation segments (near RM 289) was mapped to the downstream segments used by the Chinook and steelhead submodels each year for each of the 8 combinations of 4 flow scenarios and 2 gravel scenarios. In the case of fall Chinook, the most distant segment extends downstream over 70 miles to Vina (RM 218), implying that the distribution of surface substrate size classes (sand through boulder) is comparable across this entire range. It also assumes that gravel injection simulations at upstream locations can be plausibly extended at the downstream locations. The further this spatial extrapolation, the more tenuous this assumption becomes. Going forward, the solution is to obtain TUGS simulation results calibrated and tested for these more downstream reaches of the Sacramento River. This requires additional input data to calibrate the TUGS model, such as natural sediment loading information from major tributaries (Appendix E).

1.1.4 Assumptions and uncertainties in indicators used in SacEFT

For detailed descriptions of SacEFT's 35 focal species performance measures and their assumptions, readers are referred to ESSA Technologies (2007) (available from the "SacEFT Design Guidelines" link on http://www.delta.dfg.ca.gov/erp/sacriverecoflows.asp). Table F–2 summarizes the major assumptions for key focal species' performance measures.

Table F–2. Summary of major assumptions and uncertainties in SacEFT indicators.

Performance measure (and key sub-component(s))	Major assumptions and limitations
Spawning and rearing WUA	The Chinook and steelhead spawning WUA models are based on Mark Gard's habitat preference models (U.S. Fish and Wildlife Service 2003, 2005a, 2005b). Gard's results are based on the River-2D hydrodynamic model. Inherent Instream Flow Incremental Methodology (IFIM) assumptions, strengths and weaknesses. Habitat suitability curves (weighted useable area vs. discharge) for current velocity, substrate and depth accurately reflect habitat preference and these preferences truly confer differential survival (rather than summarizing a mode of differential selection that has no true significance for survival). Rearing WUA is not affected by substrate conditions. Index locations and sampling periods provide a representative snapshot of true habitat conditions and run-type preferences. The cross-sectional data used to parameterize WUA relationships are a snapshot in time of conditions in the mainstem, and mainstem habitat locations may change slowly or episodically as a result of high flow events, sediment transport and channel migration. Habitat is therefore assumed to be in an equilibrium state in which the spatial arrangement of particular habitats may change, but the segment-wide non-spatial proportions do not. Habitat preferences for spring Chinook are not available and we assumed they followed those of fall Chinook (Mark Gard, pers. comm.). Because parameterized relationships were not always available for every desired study location, relationship mapping was carried out by assuming that relationships parameterized for a race or location could be applied to another race or location (Mark Gard, pers. comm.). For example, based on USFWS (1995), the distribution of rearing habitat for spring-run Chinook is almost entirely concentrated below Battle Creek but uses fall-run rearing WUA relationships. Likewise, rearing WUA relationships are not available for downstream from Battle Creek, and currently make use of upstream WUA relationships.
Temperature-salmon egg emergence	Temperature-emergence timing for Chinook/steelhead has been taken from relationships published for the SALMOD model (Bartholow and Heasley 2006). The relationship we adopted is not strictly egg-maturation, but covers the period to free swimming emergence.
Temperature-salmon egg mortality	During the design of SacEFT in 2005 we anticipated using the USBR egg mortality model, but later adopted the mortality ATU models used by SALMOD, since the SALMOD formulation reports and corrects some mathematical errors that may be present in the USBR model.
Chinook/steelhead redd scour	Flows above 20 kCFS trigger a fair hazard (yellow), with flows above 32 kCFS required to trigger a poor indicator rating (red). The model couples these hazard categories to each race's spawning distribution and uses a temperature-driven emergence function to create an aggregated egg distribution for each day of the egg development period. The daily proportion of redds exposed to scour incorporates the joint influence of the original spawning distribution, temperature driven egg-development distribution and the proportion of total spawning WUA available in the river segment.
Chinook/steelhead redd dewatering	The model makes use of Gard's redd dewatering research (U.S. Fish and Wildlife Service 2006b), which estimates proportional decrease in redds over the period between spawning and the emergence of juveniles. Gard's results do not include time explicitly. Rather, his model estimates proportion of spawning redds lost (if any) at each location between the time a day-cohort is spawned and the end of the cohort's egg development period. Based on discussions with Gard, we adapted this relationship in a way that is mathematically consistent with the original results, but which can be disaggregated to the daily scale of the dewatering model. If there is no decline in flow then no loss occurs. To calculate the daily PM, the model compares the previous day's flow with the current day. If there is a drop, then some proportion of eggs are potentially dewatered, and bilinear interpolation is used to calculate the loss. Gard's tabular results include fall- and winter-Chinook salmon and steelhead trout only, and relationships for spring- and late-fall Chinook salmon are mapped from fall-run Chinook.

Performance measure (and key sub-component(s))	Major assumptions and limitations
Chinook/steelhead juvenile stranding	The performance measure uses Gard's juvenile stranding research (U.S. Fish and Wildlife Service 2006b) to estimate the proportional decrease in habitat over the period between juvenile emergence and the end of the juvenile residence period. Mark Gard's raw system-level results were disaggregated to the segment level used by SacEFT. As Gard's results do not include time explicitly, we adopted a method that calculates daily losses from the day of emergence through to the end of the residency period. The model compares the previous day's flow with the current day. If there is a drop, then some proportion of juveniles are potentially stranded, and bilinear interpolation is used to calculate proportional losses between the tabular values found in Gard's tables (U.S. Fish and Wildlife Service 2006b). Although races are modeled separately in SacEFT, all use a single all-species flow-decline relationship.
Green sturgeon – water temperature tolerances	The impact of water temperature on green sturgeon eggs/larvae is modeled using two temperature breakpoints: 17°C and 20°C, to mark temperature excursions into zones of moderate and high risk. Each day the model tracks spawned eggs over a fixed development period of 14 days, tracking each spawning day separately. The simplicity of the model stems from the lack of information about temperature-based mortality, referring instead to the categorical evaluation created by Cech et al. (2000, cited in (NMFS 2003)) to assign "healthy", "moderate" and "lethal" outcomes. Other important measures of green sturgeon life history (e.g., flow-habitat; juvenile entrainment; fishing and poaching, discharge-migration cues and needs) were found to be lacking in quantitative knowledge and therefore are not included in SacEFT.
Bank swallows	Because the habitat model is very simplified, it has no memory of flow over time, and the BASW2 indicator does not capture the possible cumulative effects of changes in discharge, nor the role of bank height in predicting bank sloughing. The 'length of newly eroded bank' generated by $L_b = \frac{A}{W}$ using meander migration data does not account well for the **depth** of bank erosion. Lengths predicted by this formula can also in some cases be artificial, having a trivial depth of erosion along a relatively long length. Soil type is known to be a critical factor in determining whether newly eroded banks are suitable for Bank swallows. The present version of SacEFT does not implement this component of habitat suitability (as this information was not made available to our modeling team).
Fremont cottonwood initiation	Standard recruitment box model Sampled cross section nodes, if non-uniform, are representative of the overall cross-sectional characteristics. Tap root growth rate = 29 mm/day Drought tolerance of 2 days (roots can be out of contact with water table for 2 days without being declared dead) Fixed capillary fringe height of 30 cm (a very site specific parameter based on soil type) Cottonwood seedlings whose roots reach a depth of 45cm are assumed to be successful in reaching some type of ephemeral groundwater moisture sufficient to keep them alive through the remainder of their first year (based on dialogue with John Bair, McBain and Trush, pers. comm..). **Note**: all these assumptions are fully configurable in the SacEFT database.
Western Pond turtles	The lack of contrast in meander migration results did not merit calibration and implementation of Western Pond turtles in SacEFT v.1.00.018 (i.e. the key drivers did not vary sufficiently).

Performance measure (and key sub-component(s))	Major assumptions and limitations
Chinook/steelhead: general	The six performance measures are intentionally simplified and generally do not attempt to account for interactions that will naturally occur. For example, redd dewatering, temperature-driven egg mortality and redd scour risk all occur during the incubation period and the processes together would predict a different outcome than each process taken alone. SacEFT does not track movement of juveniles between reaches, and instead they are assumed to remain in the proportions occurring at the time eggs were spawned. Lengthening of the egg development and juvenile growth window via lower water temperatures also lengthens the cumulative exposure to other potential mortality sources, a set of processes not accounted for in SacEFT.
Overall	Indicator ratings (“hazard ratings” or “severity ratings”) represent biologically significant thresholds.

1.1.5 Methodology for determining thresholds: green, yellow & red

The hazard threshold boundaries that define indicator ratings (“green”, “yellow” and “red”) are a key feature of SacEFT’s design, and are fully configurable in the SacEFT database. Because these thresholds are assigned at up to 3 different levels of spatial and temporal aggregation (daily, over an entire life history stage and annually) and often include weighting calculations based on life-history distributions and area coverages (spawning WUA), an understanding of these units and scales is essential before changing the threshold break-points.

The threshold values used for SacEFT’s initial demonstration are calibrated using a full 66 year historical scenario (WY 1939–2004) and then found from tercile break-points (top 1/3 of years “good”, bottom 1/3 “poor”, middle 1/3 “fair”) or obvious shifts in zones of performance following inspection of the all year results. As indicated in meta-data comments provided in the SacEFT database, this approach may under- or over-estimate the biological significance of performance measure results, and they have been identified as a subject for further peer reviews.

The recommended approach for changing thresholds is to have each performance measure reviewed by a small group of knowledgeable and reputable biologists, who form a consensus or majority opinion. Now that the SacEFT prototype is available, such an evaluation is a highly recommended next step.

1.1.6 Water management scenarios evaluated

Subsequent to the completion of the first version of this report, DWR provided revised flow and water temperature simulations that included a Future No Action (FNA2) baseline scenario that can be used in comparisons with modified hydrosystem operations. The NODOS-AF2B scenario includes select restoration targets and constraints in its alternative operation plan; and the FNA2 scenario provides a “Future No Action” alternative in order to make internally consistent comparisons with the NODOS-AF2B scenario. As a rule, SacEFT comparisons of focal species response under the NODOS-AF2B alternative must, by definition, be only made versus the FNA2 scenario. This comparison includes common assumptions, and Appendix F results are updated to reflect this consistent scenario comparison. The Shasta alternative is not compared to anything as we were not provided a future no action Shasta scenario against which to compare the Shasta alternative. Therefore, due to differences in hydrosystem operations and demands between both the historical and Shasta scenarios and the FNA2 scenario, it is understood that direct comparisons can only be made between the FNA2 and NODOS-AF2B scenarios. Readers are advised that this document may show SacEFT results for historical flows to illustrate the results used in calibrating species performance measures’ hazard threshold boundaries.

Scenario 1 (Historical)
Historical flows (WY 1939–2004) used principally to calibrate the tercile-breakpoints that underlie the biophysical hazard threshold boundaries described above. While historical flows embed a range of hydrosystem configurations, operations and levels of human water demands and thus do not have internally consistent assumptions, they nevertheless illustrate the true measured flow regime. These flows typically provide the widest range of contrasts, a desirable property when calibrating hazard threshold boundaries.

Scenario 2 (NODOS Future No Action, or FNA2)
As part of the Surface Storage Investigations, the CALFED Bay-Delta Authority, California Department of Water Resources and U.S. Bureau of Reclamation developed a Common Assumptions process to provide peer review of analytical tools and baseline conditions for planning analysis, including a NEPA Future No Action simulation of 2020 operations and hydrology (based on an 80 year historic streamflow record). FNA2 includes the current Common Assumptions FNA assumptions, documented as Common Model Package 8d.

Scenario 3 (NODOS Future Action Alternative, or NODOS-AF2B)
The North-of-the-Delta Off Stream Storage Investigation (NODOS) AF2B scenario is a hydrosystem simulation developed jointly by the California Department of Water Resources and Bureau of Reclamation, to evaluate the potential benefits and consequences of the new off-stream Sites Reservoir near Maxwell, California. The investigation is evaluating a number of multi-objective scenarios[1] for improved water supply reliability and Delta water quality, and enhanced survival of anadromous fish. The AF2B scenario was selected based on its emphasis on select restoration targets and constraints in its scenario operation plan. The NODOS-AF2B operational rules and hydrology are the same as FNA2 (2020 facilities, demands, and operations), but includes the new offstream Sites Reservoir. This allows a direct comparison of AF2B and FNA2 scenarios by providing a dataset depicting common assumptions about the streams, reservoirs, Delta, and operations of the central valley water resources systems including the Central Valley Project and State Water Project.

Scenario 4 (Shasta)
In this scenario (WY 1922–1994) the Bureau of Reclamation is investigating the water delivery consequences of raising Shasta Dam 18.5 feet to increase the reservoir's storage capacity.

Detailed definitions of the simulations are provided in the main body of the Final Report (Section 2.3.2).

1.2 Key questions

Considering that our goal with this work is to facilitate the inclusion of a broader suite of ecological considerations in water planning exercises, we developed a series of questions to demonstrate the added value of SacEFT. We formulated the questions to test whether effects of potential water infrastructure projects and their effects to hydrology and water temperature (as reflected by CALSIM-SRWQM-HEC5Q output) would be revealed through our focal species and associated functional relationships. These "proof of concept" questions were as follows:

Question 1: *Of the two internally consistent flow management scenarios considered in the Study, how much difference do they make to the six focal species? Re-stated, how sensitive are the focal species performance measures to the NODOS-AF2B scenario relative to the FNA2 baseline? What do we learn about focal species sensitivity by looking at the Shasta scenario and variation in historical flows alone from 1939 to 2004?*

Example 1: Green sturgeon egg survival

Focal species performance measures varied widely in their sensitivity to the alternative flow scenarios. An attempt is made to present results in increasing order of sensitivity to flows. Least sensitive was green

[1] These restoration objectives are described in detail in Section 2.3.2 of the Main Report.

sturgeon egg survival risk (Figure F–1). In all scenarios, green sturgeon eggs never encountered water temperatures above 17°C to 20°C during the egg development period.

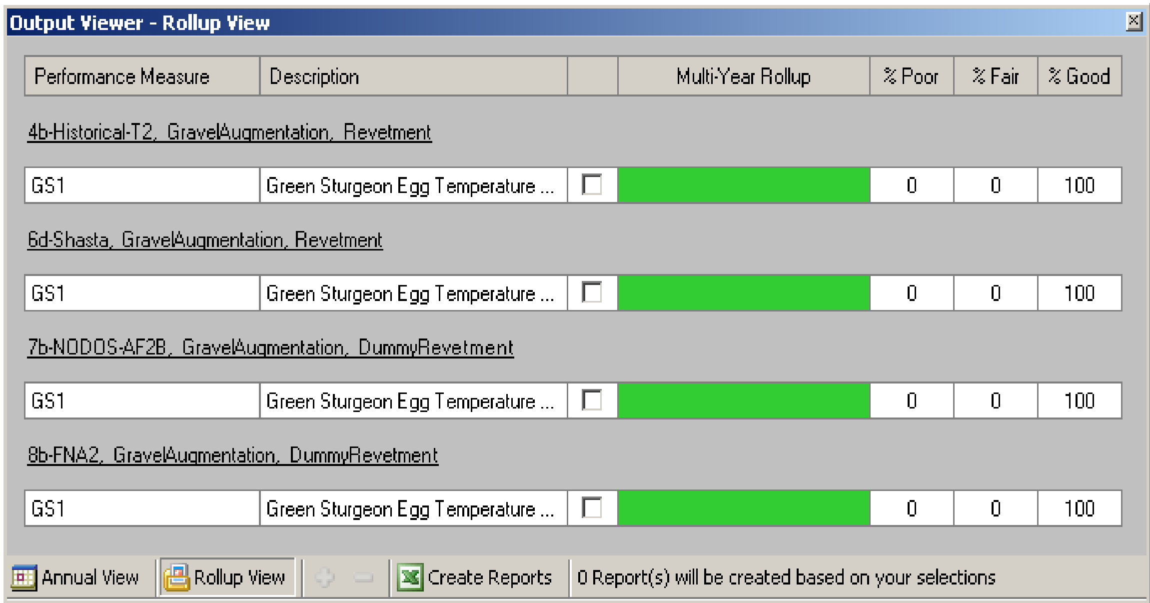
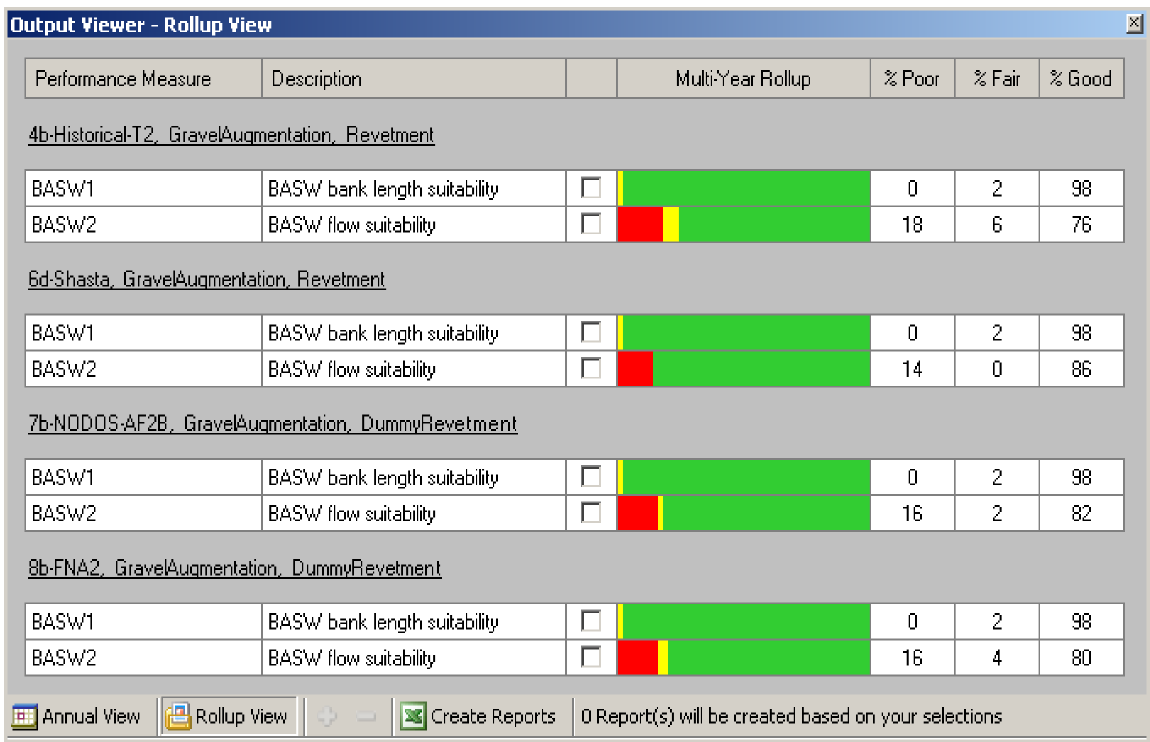


Figure F–1. SacEFT multi-year rollup results for green sturgeon egg survival risk for historical and 3 flow scenarios.

Example 2: Bank swallow length of newly eroded banks

Bank swallow performance measures were also relatively insensitive to the three flow scenarios (Figure F–2). Under the NODOS-AF2B scenario the incidence of desirable flows during nesting (BASW2: % Good) is very slightly improved compared to the FNA2 scenario. Differences of 2-3% represent a change in annual suitability scores in 1-3 years of the simulation period and likely do not translate to statistically significant differences. The length of newly eroded banks (BASW1) was unchanged across all flow scenarios. At present, this is known a modeling artifact caused by an inability to supply newly eroded bank information from the Meander Migration model at the scale required by BASW1. The reason for this outcome is discussed further under Question #3.

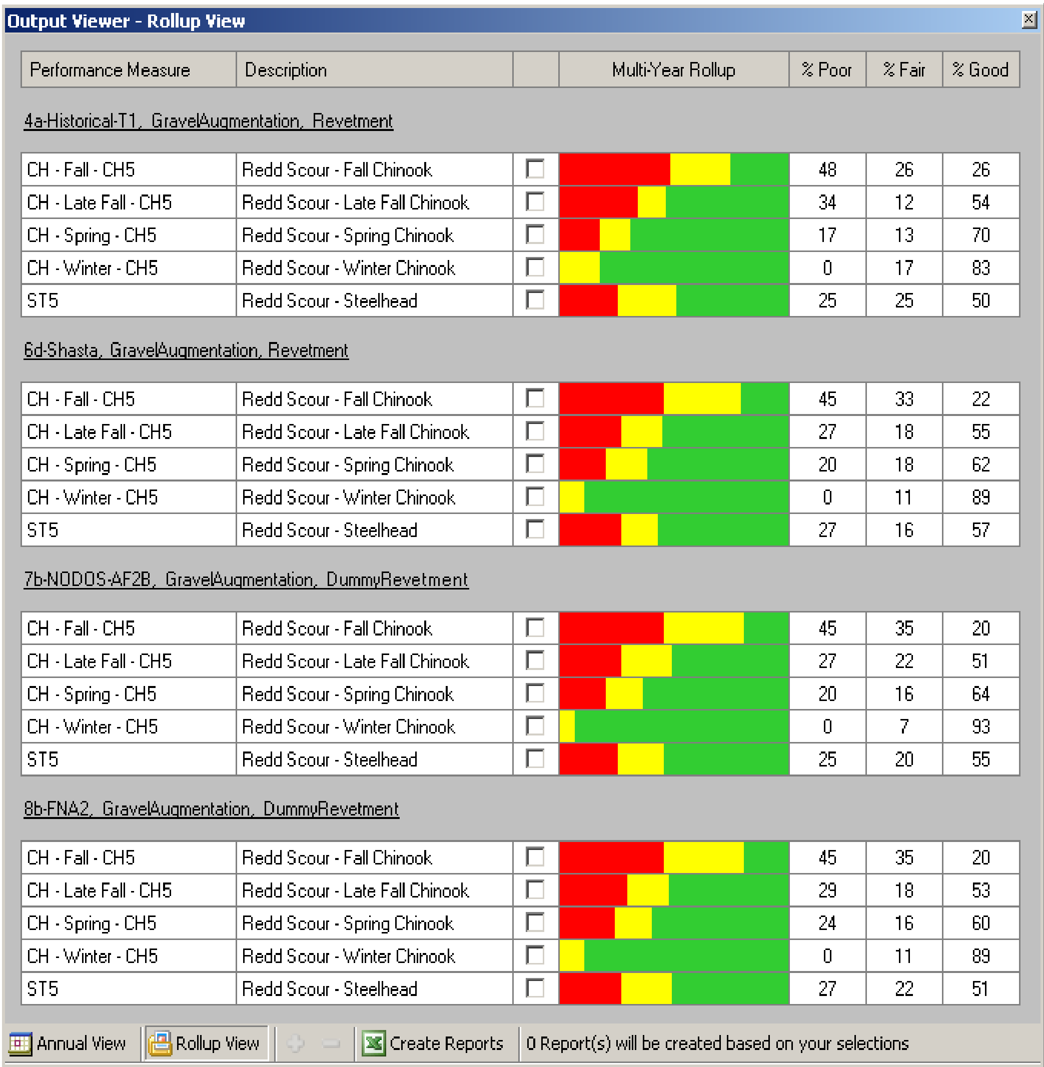


Performance Measure	Description		Multi-Year Rollup	% Poor	% Fair	% Good
4b-Historical-T2, GravelAugmentation, Revetment						
BASW1	BASW bank length suitability			0	2	98
BASW2	BASW flow suitability			18	6	76
6d-Shasta, GravelAugmentation, Revetment						
BASW1	BASW bank length suitability			0	2	98
BASW2	BASW flow suitability			14	0	86
7b-NODOS-AF2B, GravelAugmentation, DummyRevetment						
BASW1	BASW bank length suitability			0	2	98
BASW2	BASW flow suitability			16	2	82
8b-FNA2, GravelAugmentation, DummyRevetment						
BASW1	BASW bank length suitability			0	2	98
BASW2	BASW flow suitability			16	4	80

Figure F–2. SacEFT multi-year rollup results for bank swallow length of newly eroded banks (BASW1) and peak flows during the nesting period (BASW2), for historical and 3 flow scenarios.

Example 3: Chinook and steelhead redd scour risk

Chinook and steelhead redd scour risk was slightly lower under the NODOS-AF2B scenario relative to FNA2 flow (Figure F–3). Increased storage capacity reduced the frequency of flow events greater than 20,000 cfs responsible for redd scour. While there was relatively little difference amongst the three flow scenarios, the potential for improving conditions to limit redd scour was relatively high, as indicated by the frequency of poor performing years for some races, regardless of overall scenario assumptions.



Output Viewer - Rollup View

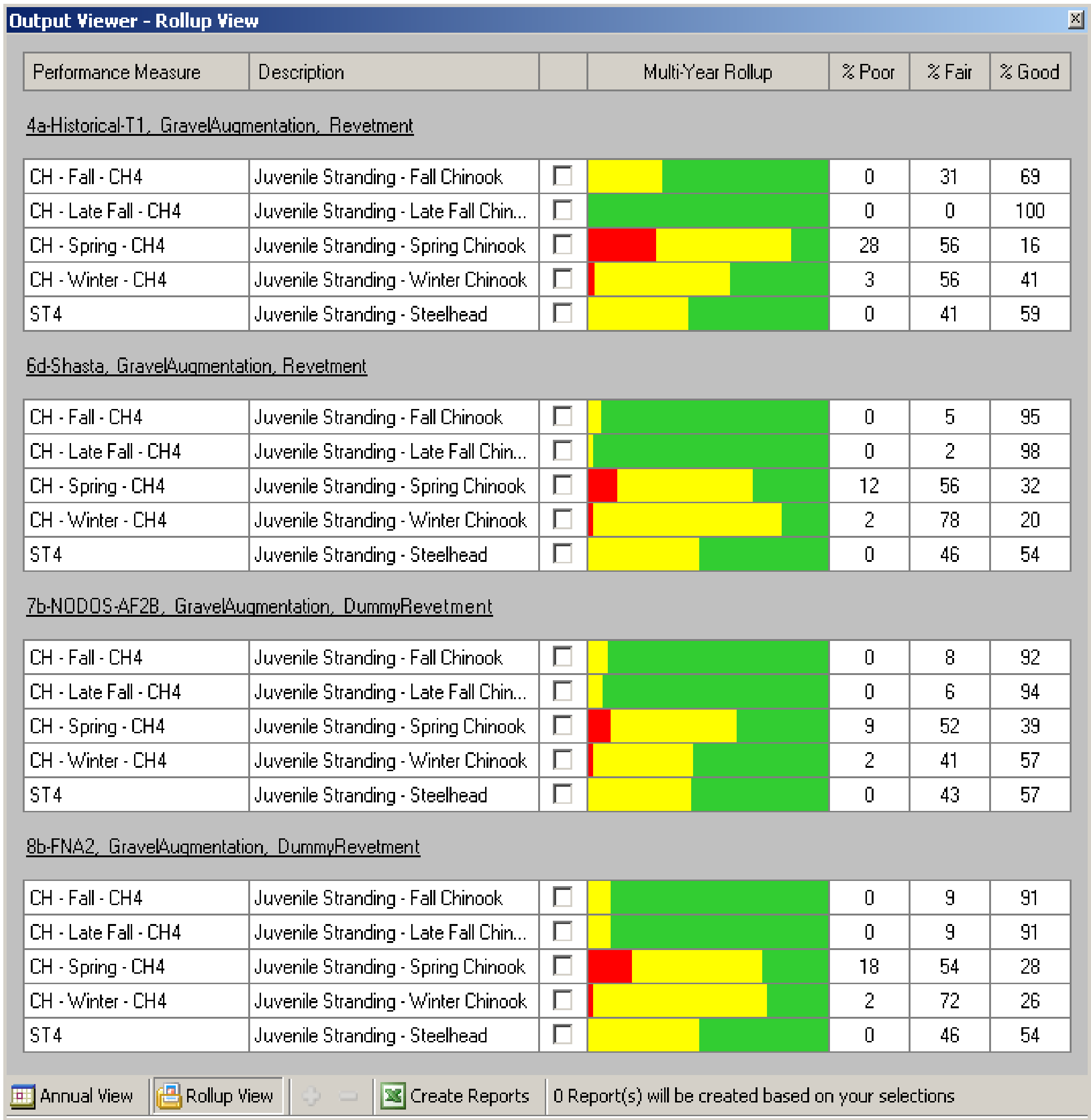
Performance Measure	Description		Multi-Year Rollup	% Poor	% Fair	% Good
4a-Historical-T1, GravelAugmentation, Revetment						
CH - Fall - CH5	Redd Scour - Fall Chinook			48	26	26
CH - Late Fall - CH5	Redd Scour - Late Fall Chinook			34	12	54
CH - Spring - CH5	Redd Scour - Spring Chinook			17	13	70
CH - Winter - CH5	Redd Scour - Winter Chinook			0	17	83
ST5	Redd Scour - Steelhead			25	25	50
6d-Shasta, GravelAugmentation, Revetment						
CH - Fall - CH5	Redd Scour - Fall Chinook			45	33	22
CH - Late Fall - CH5	Redd Scour - Late Fall Chinook			27	18	55
CH - Spring - CH5	Redd Scour - Spring Chinook			20	18	62
CH - Winter - CH5	Redd Scour - Winter Chinook			0	11	89
ST5	Redd Scour - Steelhead			27	16	57
7b-NODOS-AF2B, GravelAugmentation, DummyRevetment						
CH - Fall - CH5	Redd Scour - Fall Chinook			45	35	20
CH - Late Fall - CH5	Redd Scour - Late Fall Chinook			27	22	51
CH - Spring - CH5	Redd Scour - Spring Chinook			20	16	64
CH - Winter - CH5	Redd Scour - Winter Chinook			0	7	93
ST5	Redd Scour - Steelhead			25	20	55
8b-FNA2, GravelAugmentation, DummyRevetment						
CH - Fall - CH5	Redd Scour - Fall Chinook			45	35	20
CH - Late Fall - CH5	Redd Scour - Late Fall Chinook			29	18	53
CH - Spring - CH5	Redd Scour - Spring Chinook			24	16	60
CH - Winter - CH5	Redd Scour - Winter Chinook			0	11	89
ST5	Redd Scour - Steelhead			27	22	51

Annual View | Rollup View | Create Reports | 0 Report(s) will be created based on your selections

Figure F–3. SacEFT multi-year rollup results for Chinook and steelhead redd scour risk for historical and 3 flow scenarios.

Example 4: Chinook and steelhead juvenile stranding

Chinook and steelhead juvenile stranding occurred slightly less frequently under the NODOS-AF2B scenario compared to FNA2, particularly for spring-run Chinook (Figure F–4).



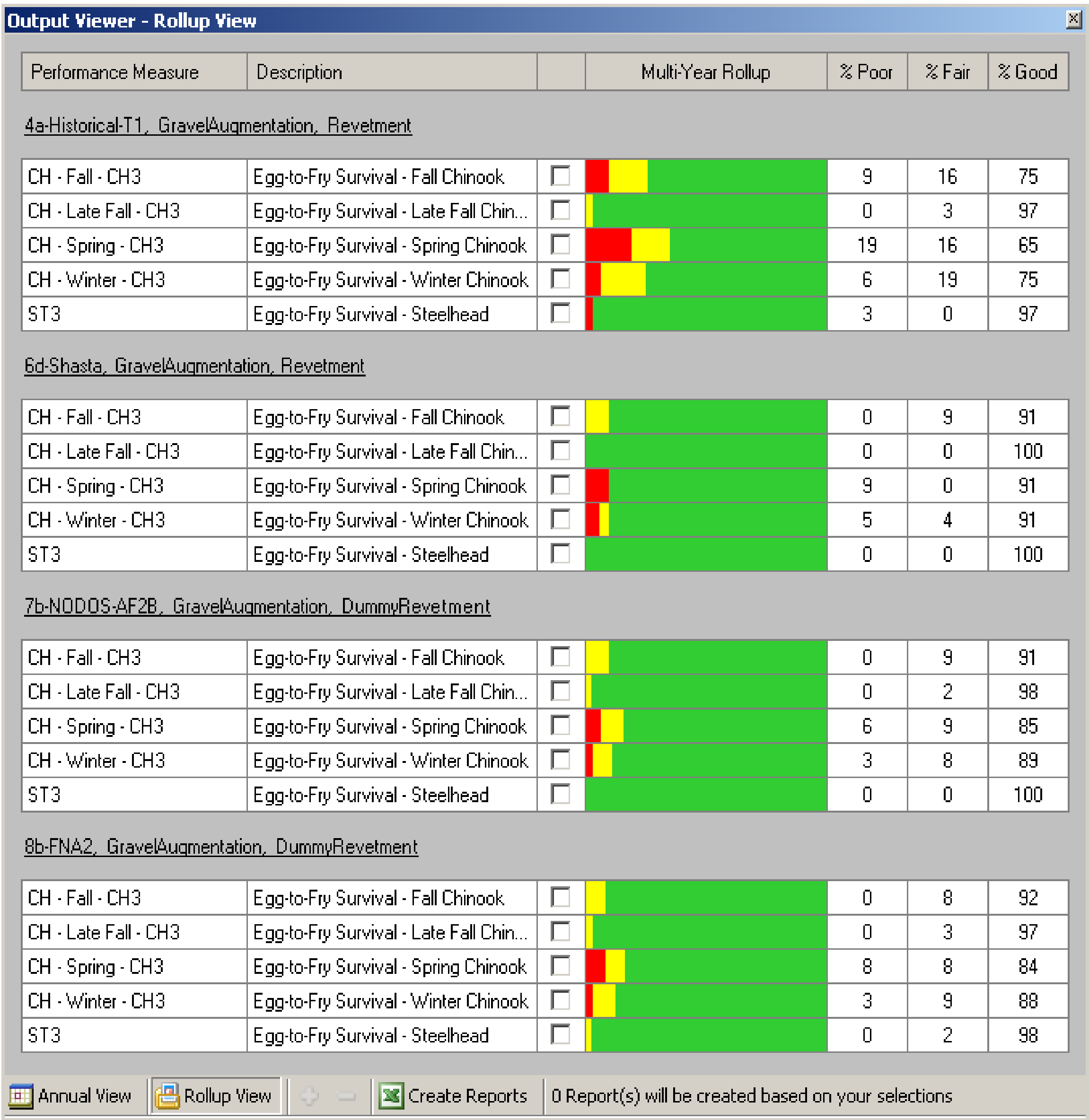
Output Viewer - Rollup View

Performance Measure	Description		Multi-Year Rollup	% Poor	% Fair	% Good
4a-Historical-T1, GravelAugmentation, Revetment						
CH - Fall - CH4	Juvenile Stranding - Fall Chinook			0	31	69
CH - Late Fall - CH4	Juvenile Stranding - Late Fall Chin...			0	0	100
CH - Spring - CH4	Juvenile Stranding - Spring Chinook			28	56	16
CH - Winter - CH4	Juvenile Stranding - Winter Chinook			3	56	41
ST4	Juvenile Stranding - Steelhead			0	41	59
6d-Shasta, GravelAugmentation, Revetment						
CH - Fall - CH4	Juvenile Stranding - Fall Chinook			0	5	95
CH - Late Fall - CH4	Juvenile Stranding - Late Fall Chin...			0	2	98
CH - Spring - CH4	Juvenile Stranding - Spring Chinook			12	56	32
CH - Winter - CH4	Juvenile Stranding - Winter Chinook			2	78	20
ST4	Juvenile Stranding - Steelhead			0	46	54
7b-NODOS-AF2B, GravelAugmentation, DummyRevetment						
CH - Fall - CH4	Juvenile Stranding - Fall Chinook			0	8	92
CH - Late Fall - CH4	Juvenile Stranding - Late Fall Chin...			0	6	94
CH - Spring - CH4	Juvenile Stranding - Spring Chinook			9	52	39
CH - Winter - CH4	Juvenile Stranding - Winter Chinook			2	41	57
ST4	Juvenile Stranding - Steelhead			0	43	57
8b-FNA2, GravelAugmentation, DummyRevetment						
CH - Fall - CH4	Juvenile Stranding - Fall Chinook			0	9	91
CH - Late Fall - CH4	Juvenile Stranding - Late Fall Chin...			0	9	91
CH - Spring - CH4	Juvenile Stranding - Spring Chinook			18	54	28
CH - Winter - CH4	Juvenile Stranding - Winter Chinook			2	72	26
ST4	Juvenile Stranding - Steelhead			0	46	54

Figure F–4. SacEFT multi-year rollup results for Chinook and steelhead juvenile stranding for historical and 3 flow scenarios.

Example 5: Chinook and steelhead egg-to-fry thermal mortality

Chinook and steelhead egg-to-fry thermal mortality occurred less frequently under the NODOS-AF2B scenario compared to FNA2, particularly for steelhead, spring- and late fall-run Chinook (Figure F–5). Lengthening of the egg development window through reduced river temperatures also lengthens the cumulative exposure to other potential mortality sources, a set of processes not accounted for by Figure F–5.

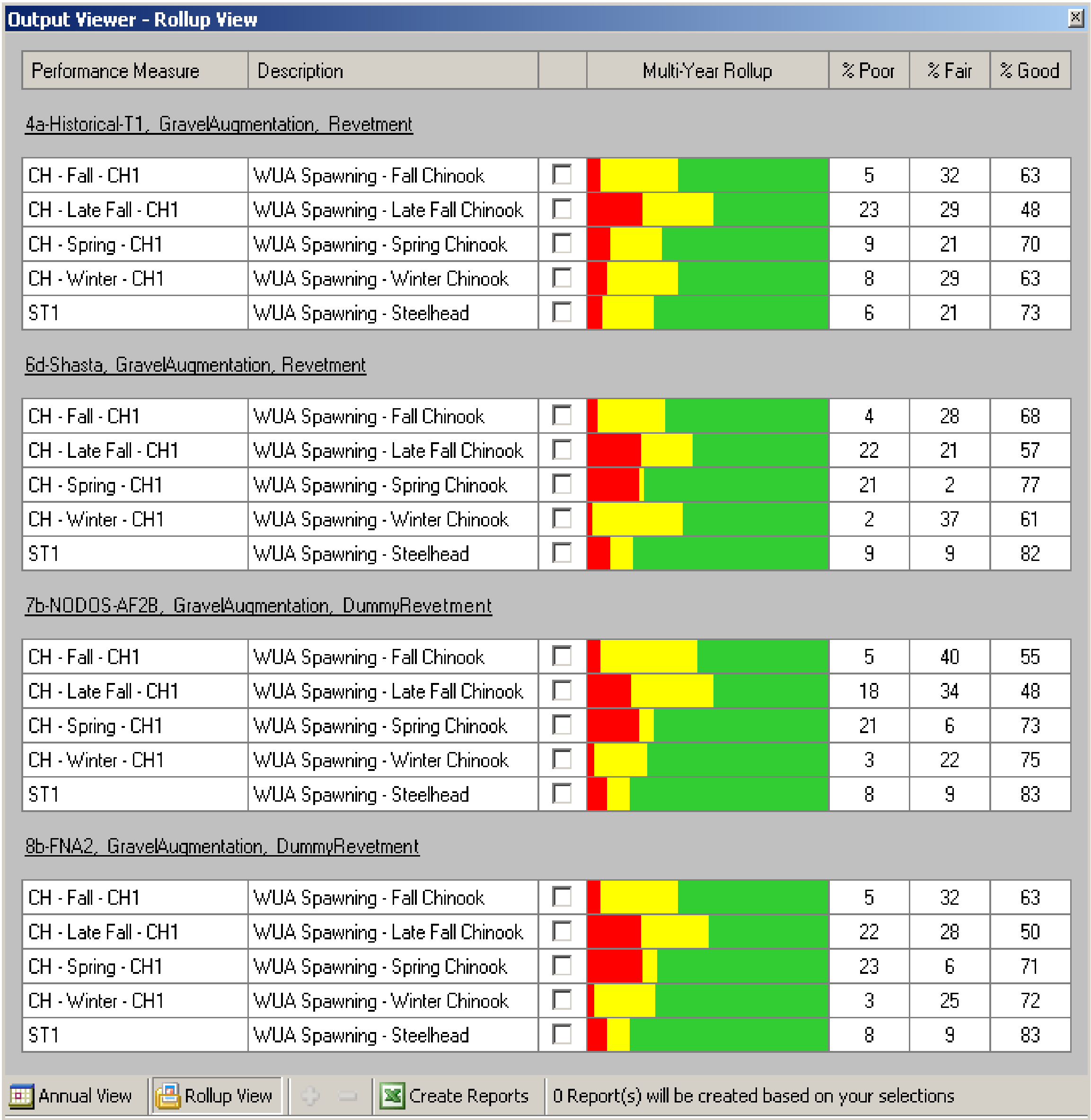


Performance Measure	Description		Multi-Year Rollup	% Poor	% Fair	% Good
4a-Historical-T1, GravelAugmentation, Revetment						
CH - Fall - CH3	Egg-to-Fry Survival - Fall Chinook			9	16	75
CH - Late Fall - CH3	Egg-to-Fry Survival - Late Fall Chin...			0	3	97
CH - Spring - CH3	Egg-to-Fry Survival - Spring Chinook			19	16	65
CH - Winter - CH3	Egg-to-Fry Survival - Winter Chinook			6	19	75
ST3	Egg-to-Fry Survival - Steelhead			3	0	97
6d-Shasta, GravelAugmentation, Revetment						
CH - Fall - CH3	Egg-to-Fry Survival - Fall Chinook			0	9	91
CH - Late Fall - CH3	Egg-to-Fry Survival - Late Fall Chin...			0	0	100
CH - Spring - CH3	Egg-to-Fry Survival - Spring Chinook			9	0	91
CH - Winter - CH3	Egg-to-Fry Survival - Winter Chinook			5	4	91
ST3	Egg-to-Fry Survival - Steelhead			0	0	100
7b-NODOS-AF2B, GravelAugmentation, DummyRevetment						
CH - Fall - CH3	Egg-to-Fry Survival - Fall Chinook			0	9	91
CH - Late Fall - CH3	Egg-to-Fry Survival - Late Fall Chin...			0	2	98
CH - Spring - CH3	Egg-to-Fry Survival - Spring Chinook			6	9	85
CH - Winter - CH3	Egg-to-Fry Survival - Winter Chinook			3	8	89
ST3	Egg-to-Fry Survival - Steelhead			0	0	100
8b-FNA2, GravelAugmentation, DummyRevetment						
CH - Fall - CH3	Egg-to-Fry Survival - Fall Chinook			0	8	92
CH - Late Fall - CH3	Egg-to-Fry Survival - Late Fall Chin...			0	3	97
CH - Spring - CH3	Egg-to-Fry Survival - Spring Chinook			8	8	84
CH - Winter - CH3	Egg-to-Fry Survival - Winter Chinook			3	9	88
ST3	Egg-to-Fry Survival - Steelhead			0	2	98

Figure F–5. SacEFT multi-year rollup results for Chinook and steelhead egg-to-fry thermal mortality for historical and 3 flow scenarios.

Example 6: Chinook and steelhead spawning weighted useable area (WUA)

Spawning weighted useable area (WUA) showed mixed results in comparisons of the NODOS-AF2B scenario relative to FNA2: fall-run Chinook fared worse, with mixed results for other Chinook races.



Output Viewer - Rollup View

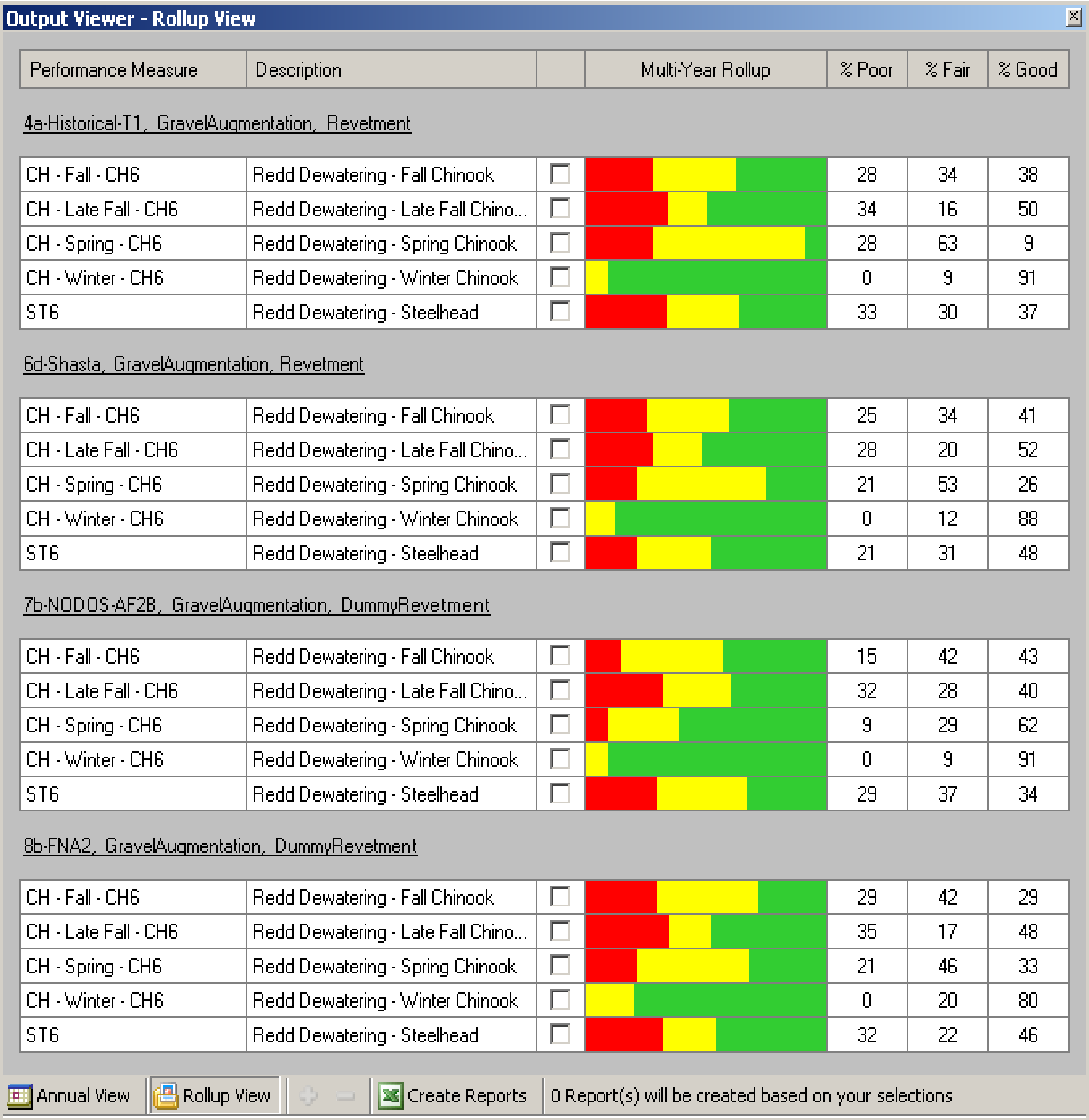
Performance Measure	Description		Multi-Year Rollup	% Poor	% Fair	% Good
4a-Historical-T1, GravelAugmentation, Revetment						
CH - Fall - CH1	WUA Spawning - Fall Chinook			5	32	63
CH - Late Fall - CH1	WUA Spawning - Late Fall Chinook			23	29	48
CH - Spring - CH1	WUA Spawning - Spring Chinook			9	21	70
CH - Winter - CH1	WUA Spawning - Winter Chinook			8	29	63
ST1	WUA Spawning - Steelhead			6	21	73
6d-Shasta, GravelAugmentation, Revetment						
CH - Fall - CH1	WUA Spawning - Fall Chinook			4	28	68
CH - Late Fall - CH1	WUA Spawning - Late Fall Chinook			22	21	57
CH - Spring - CH1	WUA Spawning - Spring Chinook			21	2	77
CH - Winter - CH1	WUA Spawning - Winter Chinook			2	37	61
ST1	WUA Spawning - Steelhead			9	9	82
7b-NODOS-AF2B, GravelAugmentation, DummyRevetment						
CH - Fall - CH1	WUA Spawning - Fall Chinook			5	40	55
CH - Late Fall - CH1	WUA Spawning - Late Fall Chinook			18	34	48
CH - Spring - CH1	WUA Spawning - Spring Chinook			21	6	73
CH - Winter - CH1	WUA Spawning - Winter Chinook			3	22	75
ST1	WUA Spawning - Steelhead			8	9	83
8b-FNA2, GravelAugmentation, DummyRevetment						
CH - Fall - CH1	WUA Spawning - Fall Chinook			5	32	63
CH - Late Fall - CH1	WUA Spawning - Late Fall Chinook			22	28	50
CH - Spring - CH1	WUA Spawning - Spring Chinook			23	6	71
CH - Winter - CH1	WUA Spawning - Winter Chinook			3	25	72
ST1	WUA Spawning - Steelhead			8	9	83

Annual View | Rollup View | Create Reports | 0 Report(s) will be created based on your selections

Figure F.6. SacEFT multi-year rollup results for Chinook and steelhead spawning weighted useable area (WUA) for historical and 3 flow scenarios with gravel augmentation.

Example 7: Chinook and steelhead redd dewatering

Dewatering of Chinook and steelhead spawning redds showed mixed results in comparisons of the NODOS-AF2B flow scenarios relative to FNA2. Steelhead and late fall-run Chinook declined under the NODOS-AF2B scenario, while other Chinook races, most notably spring-run, improved. (Figure F–7).

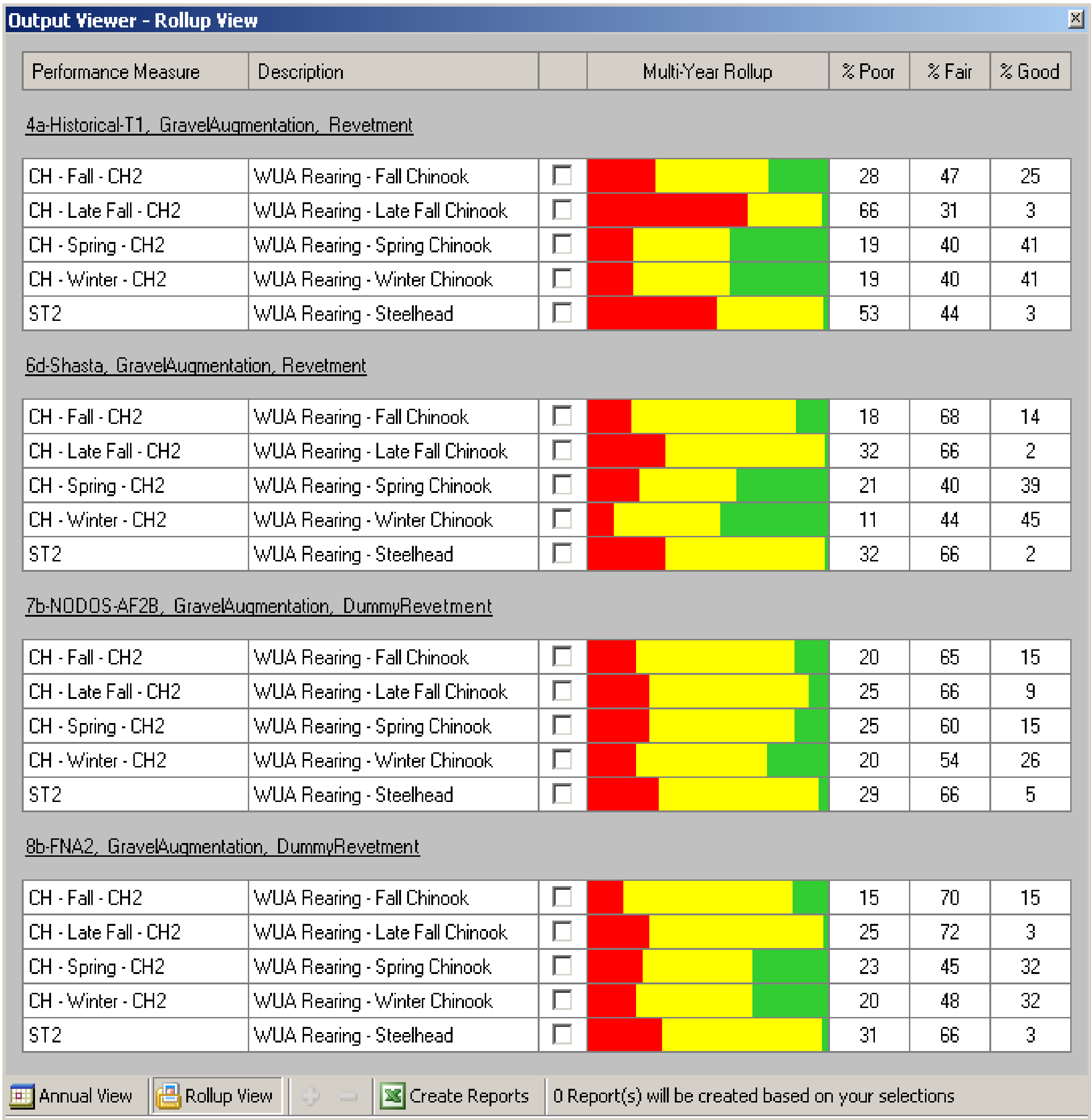

Output Viewer - Rollup View

Performance Measure	Description		Multi-Year Rollup	% Poor	% Fair	% Good
4a-Historical-T1, GravelAugmentation, Revetment						
CH - Fall - CH6	Redd Dewatering - Fall Chinook			28	34	38
CH - Late Fall - CH6	Redd Dewatering - Late Fall Chino...			34	16	50
CH - Spring - CH6	Redd Dewatering - Spring Chinook			28	63	9
CH - Winter - CH6	Redd Dewatering - Winter Chinook			0	9	91
ST6	Redd Dewatering - Steelhead			33	30	37
6d-Shasta, GravelAugmentation, Revetment						
CH - Fall - CH6	Redd Dewatering - Fall Chinook			25	34	41
CH - Late Fall - CH6	Redd Dewatering - Late Fall Chino...			28	20	52
CH - Spring - CH6	Redd Dewatering - Spring Chinook			21	53	26
CH - Winter - CH6	Redd Dewatering - Winter Chinook			0	12	88
ST6	Redd Dewatering - Steelhead			21	31	48
7b-NODOS-AF2B, GravelAugmentation, DummyRevetment						
CH - Fall - CH6	Redd Dewatering - Fall Chinook			15	42	43
CH - Late Fall - CH6	Redd Dewatering - Late Fall Chino...			32	28	40
CH - Spring - CH6	Redd Dewatering - Spring Chinook			9	29	62
CH - Winter - CH6	Redd Dewatering - Winter Chinook			0	9	91
ST6	Redd Dewatering - Steelhead			29	37	34
8b-FNA2, GravelAugmentation, DummyRevetment						
CH - Fall - CH6	Redd Dewatering - Fall Chinook			29	42	29
CH - Late Fall - CH6	Redd Dewatering - Late Fall Chino...			35	17	48
CH - Spring - CH6	Redd Dewatering - Spring Chinook			21	46	33
CH - Winter - CH6	Redd Dewatering - Winter Chinook			0	20	80
ST6	Redd Dewatering - Steelhead			32	22	46

Figure F–7. SacEFT multi-year rollup results for Chinook and steelhead redd dewatering for historical and 3 flow scenarios.

Example 8: Chinook and steelhead rearing weighted useable area (WUA)

Chinook and steelhead rearing WUA showed mixed to poor results in comparisons of the NODOS-AF2B scenario relative to FNA2, with a lower frequency of "% Good" years in comparison with other performance measures. Most Chinook races fared more poorly, with the possible exception of late fall-run Chinook and steelhead (Figure F–8).



Performance Measure	Description		Multi-Year Rollup	% Poor	% Fair	% Good
4a-Historical-T1, GravelAugmentation, Revetment						
CH - Fall - CH2	WUA Rearing - Fall Chinook			28	47	25
CH - Late Fall - CH2	WUA Rearing - Late Fall Chinook			66	31	3
CH - Spring - CH2	WUA Rearing - Spring Chinook			19	40	41
CH - Winter - CH2	WUA Rearing - Winter Chinook			19	40	41
ST2	WUA Rearing - Steelhead			53	44	3
6d-Shasta, GravelAugmentation, Revetment						
CH - Fall - CH2	WUA Rearing - Fall Chinook			18	68	14
CH - Late Fall - CH2	WUA Rearing - Late Fall Chinook			32	66	2
CH - Spring - CH2	WUA Rearing - Spring Chinook			21	40	39
CH - Winter - CH2	WUA Rearing - Winter Chinook			11	44	45
ST2	WUA Rearing - Steelhead			32	66	2
7b-NODOS-AF2B, GravelAugmentation, DummyRevetment						
CH - Fall - CH2	WUA Rearing - Fall Chinook			20	65	15
CH - Late Fall - CH2	WUA Rearing - Late Fall Chinook			25	66	9
CH - Spring - CH2	WUA Rearing - Spring Chinook			25	60	15
CH - Winter - CH2	WUA Rearing - Winter Chinook			20	54	26
ST2	WUA Rearing - Steelhead			29	66	5
8b-FNA2, GravelAugmentation, DummyRevetment						
CH - Fall - CH2	WUA Rearing - Fall Chinook			15	70	15
CH - Late Fall - CH2	WUA Rearing - Late Fall Chinook			25	72	3
CH - Spring - CH2	WUA Rearing - Spring Chinook			23	45	32
CH - Winter - CH2	WUA Rearing - Winter Chinook			20	48	32
ST2	WUA Rearing - Steelhead			31	66	3

Figure F–8. SacEFT multi-year rollup results for Chinook and steelhead rearing weighted useable area (WUA) for historical and 3 flow scenarios.

Example 9: Fremont cottonwood initiation success

In a comparison of the NODOS-AF2B flow scenario relative to FNA2, Fremont cottonwood initiation success improved (Figure F–9).

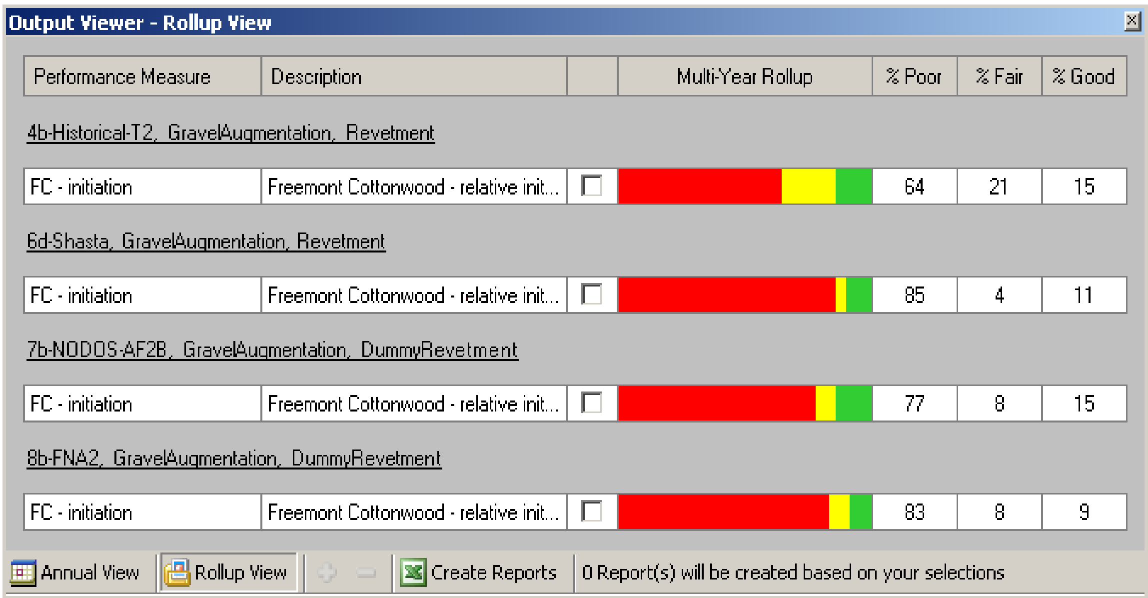


Figure F–9. SacEFT multi-year rollup results for Fremont cottonwood initiation success for historical and 3 flow scenarios.

Example 10: Chinook and steelhead performance measures shown for the historical flows scenario

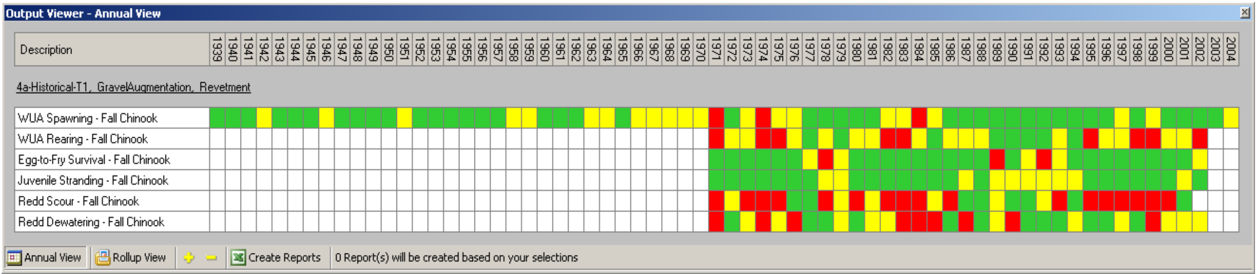


Figure F–10. SacEFT annual rollup results for fall-run Chinook performance measures shown for historical flow. The absence of results for non-spawning performance measures prior to WY 1971 is due to the lack of early historical temperature data. Temperature provides the timing information which is necessary to drive maturation and the rearing stages represented by these performance measures.

Question 1 Summary

From simple inspection of the historical flow record (WY 1939-2004), we can observe from the frequency of poor, fair and good cases in SacEFT that many focal species performance measures are sensitive to flow. While this sensitivity is in part driven by choices related to hazard threshold boundaries, modeling results showed many performance measures nevertheless exhibit considerable contrast in their raw values.

Question 2: *How much difference does ‘no channel action’ vs. ‘full channel action’ make? Is gravel augmentation more significant than channel revetment? For what focal species?*

Note: “No channel action” refers to the ‘ng’ and ‘cc’ conditions while ‘g+’ and ‘r^3’ refer to “Full channel action” conditions defined in Table 2.3 of the Final Report.

As detailed in the SacEFT design document (ESSA Technologies 2007), 3 performance measures depend on in-channel actions:

Gravel augmentation	Revetment removal and channel migration
Chinook & Steelhead: WUA spawning (CH1)	Bank Swallows: length of newly eroded banks (BASW1) Western Pond Turtles: Area of off-channel habitats, indexed by creation of newly orphaned channels (WPT1)

Example 11: newly eroded banks

For BASW1 that depends on meander migration rate, we did not observe a measureable response whether select revetment removal was implemented or not (Figure F–11). The reason for this outcome is discussed further under Question #3.

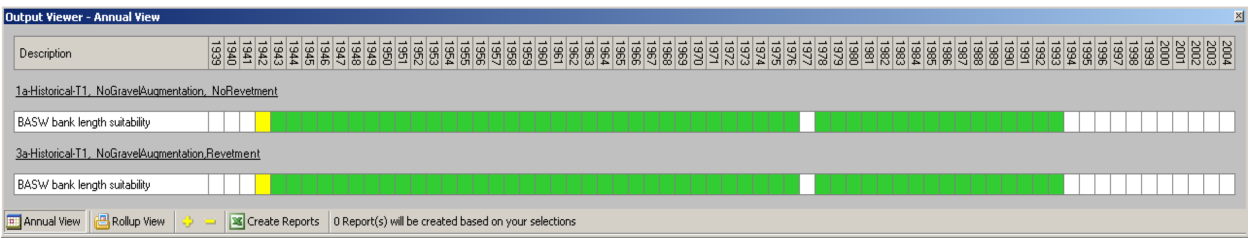
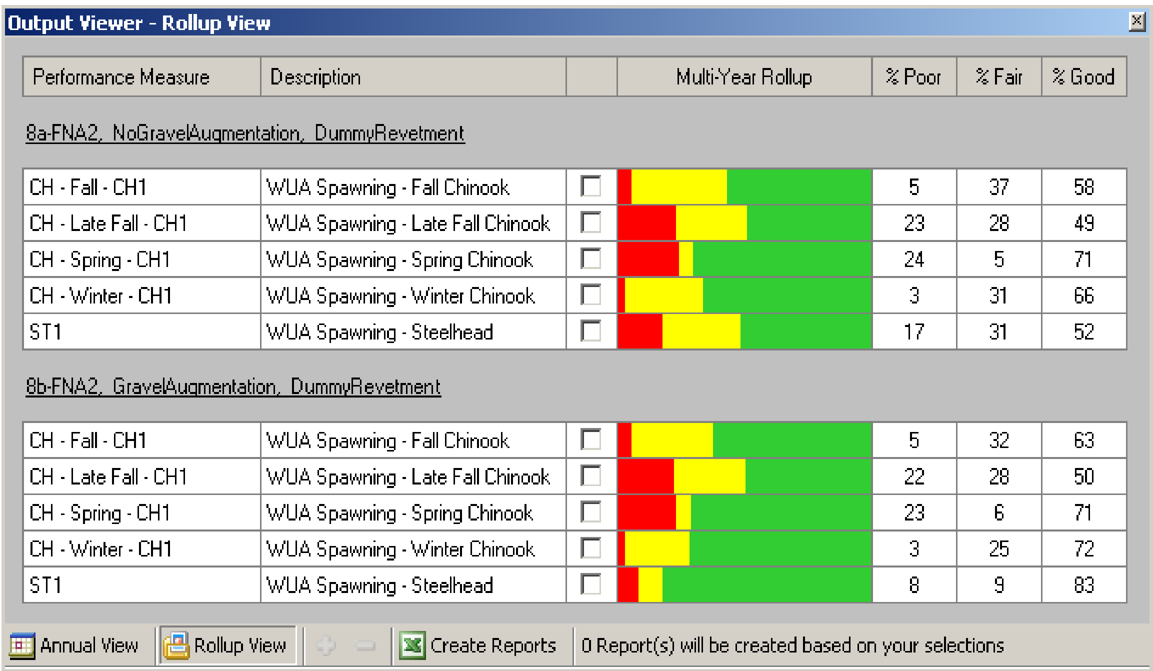


Figure F–11. SacEFT annual rollup results for the length of newly eroded banks (BASW1) shown for historical flow with and without revetment. Missing and incomplete years in 1942 and 1977 are due to numerical instability in the meander migration model, which drives the creation of the BASW1 performance measure

Example 12: Chinook and steelhead spawning weighted useable area (WUA)

Chinook and steelhead WUA (CH1) improved for all races in response to gravel augmentation under the FNA2 flow scenario, particularly steelhead and winter-run Chinook (Figure F–12). Under the NODOS-AF2B and Shasta scenarios (Figure F–13) steelhead and winter-run Chinook spawning WUA were often improved compared to FNA2 with the same “ng/g+” treatment, with steelhead leading the way in greatest improvement. This finding highlights the interaction between flow and substrate conditions that should be taken into account when interpreting WUA predictions. The steelhead finding makes sense, as augmented gravel (g+) includes a relatively high proportion of smaller substrate preferred by steelhead. As substrate preferences are quite similar for Chinook, their spawning WUA performance was more largely driven by flow conditions.

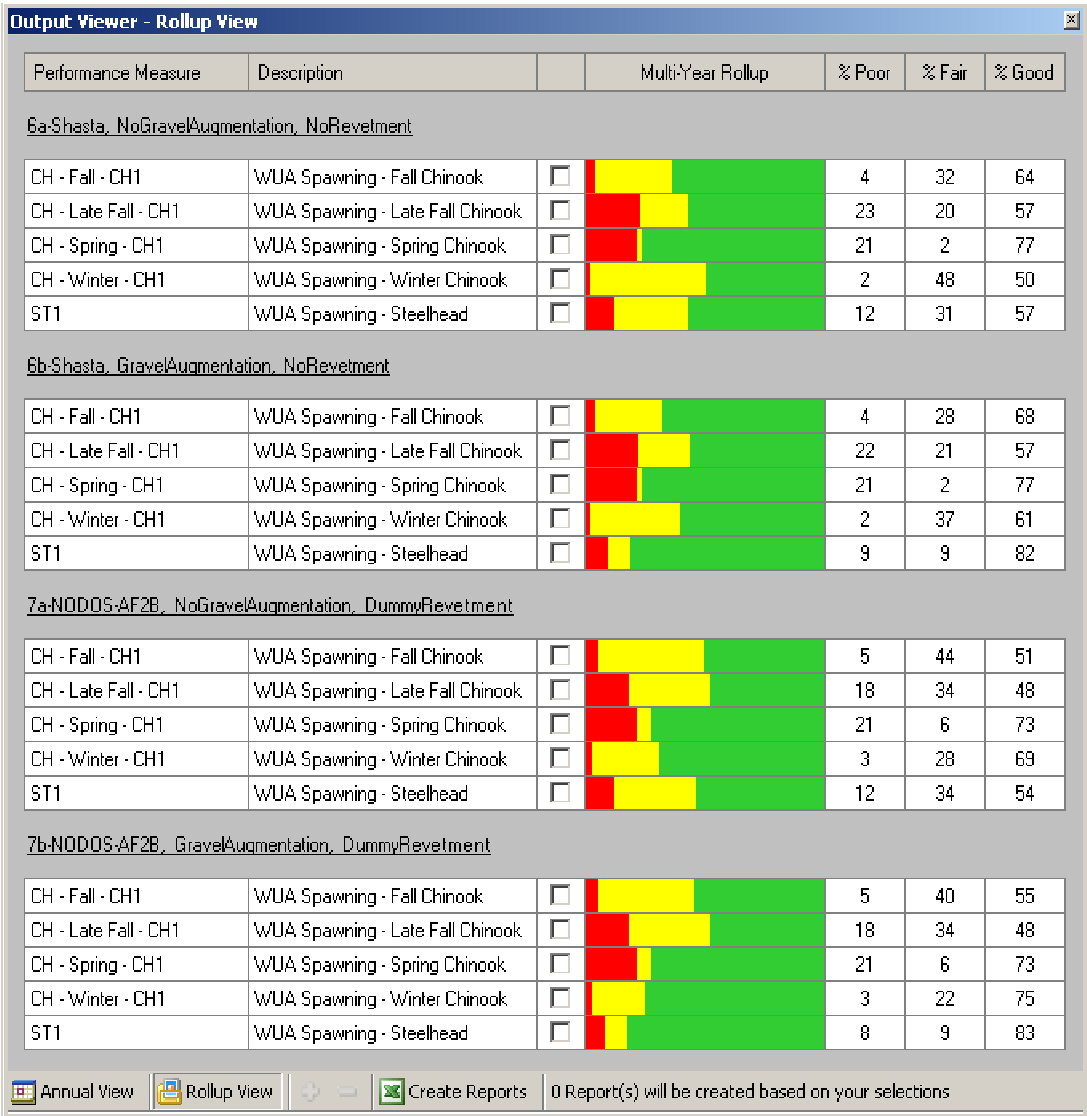

Output Viewer - Rollup View

Performance Measure	Description		Multi-Year Rollup	% Poor	% Fair	% Good
8a-FNA2_NoGravelAugmentation_DummyRevetment						
CH - Fall - CH1	WUA Spawning - Fall Chinook			5	37	58
CH - Late Fall - CH1	WUA Spawning - Late Fall Chinook			23	28	49
CH - Spring - CH1	WUA Spawning - Spring Chinook			24	5	71
CH - Winter - CH1	WUA Spawning - Winter Chinook			3	31	66
ST1	WUA Spawning - Steelhead			17	31	52
8b-FNA2_GravelAugmentation_DummyRevetment						
CH - Fall - CH1	WUA Spawning - Fall Chinook			5	32	63
CH - Late Fall - CH1	WUA Spawning - Late Fall Chinook			22	28	50
CH - Spring - CH1	WUA Spawning - Spring Chinook			23	6	71
CH - Winter - CH1	WUA Spawning - Winter Chinook			3	25	72
ST1	WUA Spawning - Steelhead			8	9	83

Annual View | Rollup View | Create Reports | 0 Report(s) will be created based on your selections

Figure F–12. SacEFT multi-year rollup results for Chinook and steelhead spawning weighted useable area (WUA) for the FNA2 flow scenario. The panels show results with (bottom) and without (top) gravel augmentation.

Example 13: WUA spawning with and without gravel augmentation for the NODOS-AF2B and Shasta scenarios.



Output Viewer - Rollup View

Performance Measure	Description		Multi-Year Rollup	% Poor	% Fair	% Good
6a-Shasta, NoGravelAugmentation, NoRevetment						
CH - Fall - CH1	WUA Spawning - Fall Chinook			4	32	64
CH - Late Fall - CH1	WUA Spawning - Late Fall Chinook			23	20	57
CH - Spring - CH1	WUA Spawning - Spring Chinook			21	2	77
CH - Winter - CH1	WUA Spawning - Winter Chinook			2	48	50
ST1	WUA Spawning - Steelhead			12	31	57
6b-Shasta, GravelAugmentation, NoRevetment						
CH - Fall - CH1	WUA Spawning - Fall Chinook			4	28	68
CH - Late Fall - CH1	WUA Spawning - Late Fall Chinook			22	21	57
CH - Spring - CH1	WUA Spawning - Spring Chinook			21	2	77
CH - Winter - CH1	WUA Spawning - Winter Chinook			2	37	61
ST1	WUA Spawning - Steelhead			9	9	82
7a-NODOS-AF2B, NoGravelAugmentation, DummyRevetment						
CH - Fall - CH1	WUA Spawning - Fall Chinook			5	44	51
CH - Late Fall - CH1	WUA Spawning - Late Fall Chinook			18	34	48
CH - Spring - CH1	WUA Spawning - Spring Chinook			21	6	73
CH - Winter - CH1	WUA Spawning - Winter Chinook			3	28	69
ST1	WUA Spawning - Steelhead			12	34	54
7b-NODOS-AF2B, GravelAugmentation, DummyRevetment						
CH - Fall - CH1	WUA Spawning - Fall Chinook			5	40	55
CH - Late Fall - CH1	WUA Spawning - Late Fall Chinook			18	34	48
CH - Spring - CH1	WUA Spawning - Spring Chinook			21	6	73
CH - Winter - CH1	WUA Spawning - Winter Chinook			3	22	75
ST1	WUA Spawning - Steelhead			8	9	83

Annual View | Rollup View | Create Reports | 0 Report(s) will be created based on your selections

Figure F–13. SacEFT multi-year rollup results for Chinook and steelhead spawning weighted useable area (WUA) for the NODOS-AF2B and Shasta scenarios, with and without gravel augmentation.

Question 2 Summary

In answer to Question #2, gravel augmentation was more significant to steelhead and Chinook spawning than channel revetment was to bank swallow nesting habitat and western pond turtle habitat creation for the indicators we used. As addressed in Question #3 below, in the case of bank swallows and western pond turtles, this may owe to limitations in the physical driving models and simplifying assumptions used for these indicators rather than be a true approximation of what is occurring in nature.

Question 3*: What are the most and least sensitive focal species performance measures? To what actions? For focal species which appear to be insensitive, is this likely to occur in nature, or is this due to simplifying assumptions in the SacEFT models?*

Table F–3 provides a summary evaluation of least and most sensitive focal species performance measures emerging from the initial application of SacEFT to the scenarios in Section 2.3.2.

Table F–3. Least and most sensitive focal species indicators mapped to SacEFT's major classes of actions when comparing relative change over scenarios. These results should be interpreted in the context of the flow and channel actions evaluated in the initial pilot application of SacEFT (Table 2.3, Section 2.3.2) rather than as general statements.

Action	Least Sensitive	Most Sensitive
Water temperature	Green sturgeon egg survival risk (GS1)	Chinook and steelhead incubation and early rearing performance measures (lower water temperatures increase period of vulnerability)
	Chinook and steelhead egg-to-fry thermal mortality (CH3)	
Flow	Bank swallow - peak flow during the nesting period (BASW2)	Fremont cottonwood - initiation success (FC)
	Chinook and steelhead juvenile stranding (CH4)	Chinook and steelhead rearing weighted useable area (WUA) (CH2)
	Chinook and steelhead spawning weighted useable area (WUA) (CH1)	Chinook and steelhead redd scour risk (CH5)
	Chinook and steelhead redd dewatering (CH6)	
Rip rap removal (channel migration)	Area of off-channel habitats, indexed by creation of newly orphaned channels (WPT1)*	n/a
	Bank swallow - length of newly eroded banks (BASW1)*	
Gravel augmentation	n/a	Chinook and steelhead spawning WUA (CH1)

* Lack of sensitivity most likely due to simplifying assumptions in indicator formulation or lack of resolution or contrast in incoming meander migration datasets.

The corollary to Question 2 is: "*for focal species which appear to be insensitive, is this likely to occur in nature, or does this owe to simplifying assumptions in the SacEFT models*?"

There are two different ways of thinking about this question: (i) in terms of the performance measure results themselves and (ii) more broadly in terms of the overall focal species and its full set of life-history requirements. SacEFT is not a population life-history model, but rather, focuses on discrete habitat-based indicators. As such, component 'ii' is outside the scope of SacEFT's design (though Chinook and steelhead do have multiple indicators that cover different freshwater life-history stages, albeit unlinked). We therefore address this question in terms of component 'i' – the contrast and sensitivity found in the results for the performance measures themselves.

The indicators in Table F–3 marked with a "*" are most likely insensitive (showed little if any contrast in results) because of simplifying assumptions in the formulation of the indicator in SacEFT or lack of contrast in incoming physical datasets.

For example, the meander migration model provides annual estimates of meander migration rate (*W*) and area of floodplain reworked (*A*) for each of up to 14 modeled bends (*b*) in each of three river segments

(Larsen 2007). From these two indicators, the length of newly eroded bank in each bank is approximated by the *simple* geometrical approximation:

$$L_b = \frac{A}{W}$$

Example 14: Average length of newly eroded banks

In BASW1, banks that are newly eroded to 20m or more receive a suitability weighting of '1'. The choice of a fairly small length-scale (13m-20m) for assessing the suitability of newly eroded banks is therefore poorly matched to the scale at which the Meander Migration model is parameterized: almost all newly eroded bend areas were longer than 500m, and therefore the suitability weight value assigned was almost always 1.0. Coupled with the low variability in year over year lengths of newly eroded bank, this creates a performance measure with very low contrast (Figure F–14).

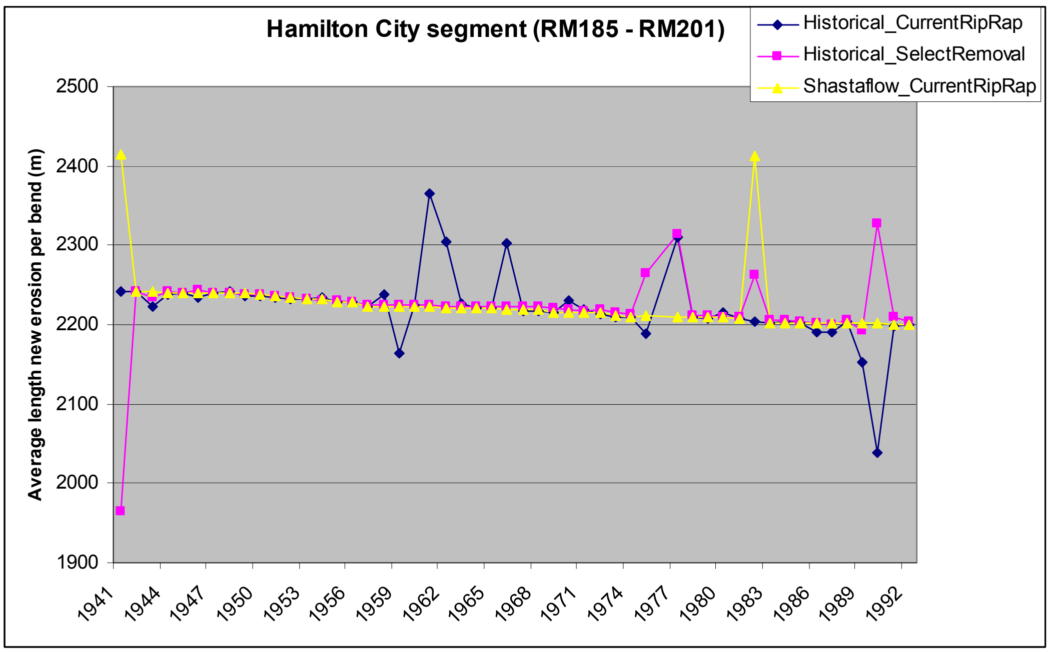


Figure F–14. Average length of newly eroded banks, per bend, predicted by the Meander Migration model, for 3 different scenarios.

We also note that the 'length of newly eroded bank' generated by $L_b = \frac{A}{W}$ also does not account for the depth of this bank erosion along the bend. Thus, lengths predicted by this formula will in some cases be artificial, having a trivial depth of erosion along the length (<1 cm).

In the case of creation of newly orphaned channels (WPT1), the meander migration model predicted only two events. These occurred in WY 1939 and 1941 only, reshaping Bend 5 of the most-downstream segment (see Table 2.3 in ESSA (2007)) and adding 2070 m^2 and 425 m^2 of new orphaned channel habitat in the process. These events occurred under all three flow regimes (historical, NODOS[2] and Shasta) when revetment (rip rap removal) was simulated, and also under the NODOS flow regime when no revetment (no rip rap removal or current rip rap) was simulated.

The fact that the major cut-off event occurred during the first simulation year and across all three flow regimes strongly suggests that the bend morphology became unstable once rip-rap was removed. However, once this event took place, the newly aligned bend and other bends simulated were subsequently insensitive to variations over the following half century of flow variation.

Question 3 Summary

Taken together these results show that simulated revetment removal can cause channel realignment in cases where the bed morphology has reached a point of instability, but that such events are infrequent under the current channel morphology even when rip-rap is removed at select sites. This is not a reflection of lack of sensitivity of the WPT1 indicator itself per se, but reflects the overall lack of contrast in meander migration results.

Finally, we point out that green sturgeon egg survival risk (GS1) was insensitive to the temperatures included in our SacEFT scenarios. Water temperatures that lead to elevated rates of egg mortality in green sturgeon (17°C - 20°C) were rarely if ever encountered for the scenarios we evaluated (including historically reconstructed temperatures) and hence, given the simplicity of the indicator, its results are not in dispute. We recognize that representation of this focal species would benefit from a more complete formulation looking at other life-history stages and biophysical relationships, possibly including relationships that address flow-habitat; juvenile entrainment; fishing and poaching, discharge-migration cues. These factors were considered during the original SacEFT design workshop, but subsequently found to be lacking in quantitative knowledge for modelling.

Question 4: *Does SacEFT suggest directions for adaptive management experiments and/or research to test the real-world benefits of different actions for focal species?*

At the present stage of development, we do not feel SacEFT is in a suitable position to recommend *specific* adaptive management experiments. Instead, the most important next steps are:

a. reviewing our focal species indicators for the demonstration scenarios and refining them (including obtaining final FNA2, NODOS-AF2B and Shasta daily flow datasets below Redd Bluff);
b. convening several small technical meetings with qualified biologists to refine the indicator (or hazard) thresholds used to signify the biological significance of different outcomes (‘poor’, ‘fair’, ‘good’); and
c. considering whether other focal species indicators (including life-history components) and important biophysical linkages not presently represented in SacEFT should be added based on Linkages Report and Field Study results.

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[2] Following the acceptance of the first version of this report DWR provided two updated scenarios: NODOS-AF2B and FNA2, to allow more comparable simulations of different hydrosystem facilities and configuration. For time and budgetary reasons, it was not possible to update the revetment simulations using these new simulations. Therefore there are no corresponding revetment simulations for the FNA2 scenario, and the NODOS-AF2B scenario makes use of an earlier NODOS scenario.

However, even with this important additional review and refinement, residual uncertainties will always remain around various modeling assumptions and parameters. It goes without saying that the proffered biological benefits of SacEFT's target (and avoidance) flows should be tested in the field through focused (preferably high precision) monitoring techniques. However, waiting for perfect or highly certain knowledge is a recipe for inaction that is incompatible with "reasonable and prudent action." Water operators, biologists, restoration ecologists and river engineers should use our findings to experimentally generate purposefully timed contrast in flows, gravel additions, and rip-rap removal actions to better gage geomorphic and biological significance. "Outside the box" flow and in-channel experiments are critical for generating these fresh insights and overcoming the lethargy inherent in passive approaches.

In the meantime, managers of water operations should not wait to be told that the divergent community of river restoration specialists has reached a consensus on what should be done. We encourage all sincere water planners, engineers, restoration ecologists and operators to seriously consider the Flows Team's leading hypotheses and advice on ecological flow targets and begin to pilot these flows alongside planned short-term flow experiments and focused monitoring activities. A number of specific ideas in this regard are listed in Chapter 10 of the Linkages Report (Appendix A).

Question 4: *Are there any glaring differences with leading hypotheses and management advice identified in the Linkages Report (Appendix A)?*

Table F–4 addresses this sub-question.

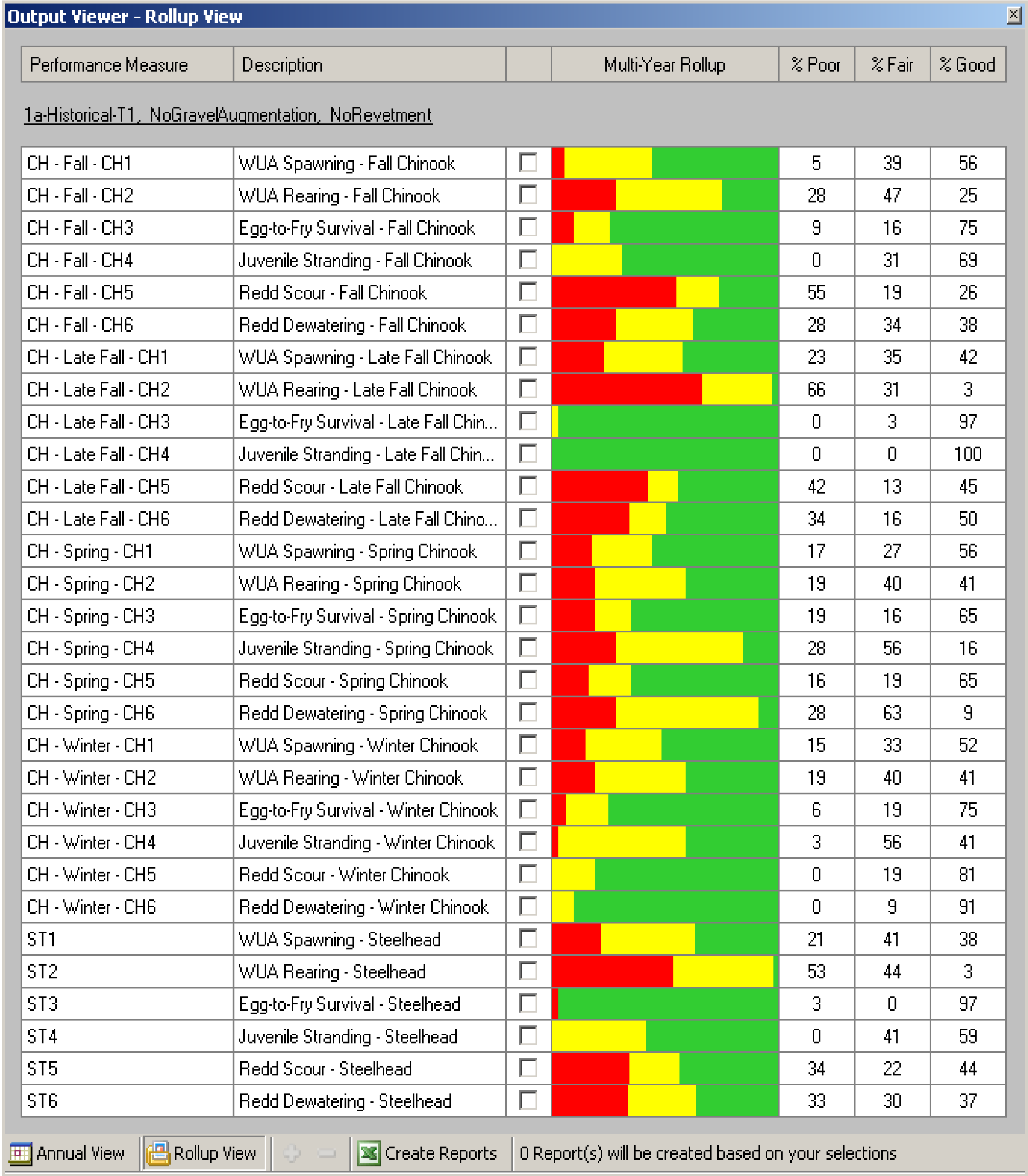
Table F–4. Comparison of leading hypotheses and management advice in the Linkages Report (Stillwater Sciences, 2007a) with overall SacEFT modeling results. Details of SacEFT functional relationships are provided in ESSA Technologies (2007).

	Linkages Report	**SacEFT***
Chinook/Steelhead: *general*	Shasta Dam has generated a cumulative gravel deficit of more than 7.6 million m^3 relative to the augmented volumes of 191,000 m^3 since 1978. Though patches of favorable spawning gravel from these injections have been helpful, it has done little to expand spawning habitat significantly and reverse the process of bed coarsening. Application of gravel injection in upstream reaches is most effective as that is where the bed is most coarse and where migrating salmon concentrate in highest densities.	Includes performance measures for spawning and rearing weighted useable area, scour, egg desiccation, juvenile stranding and temperature preferences of incubating eggs. SacEFT links gravel augmentation effects to changes in spawning WUA.
Winter-run Chinook	Limited by spawning gravel. Bed coarsening following dam construction (generally true for all Chinook runs). Also identifies reductions in frequency/duration of overbank flows and loss of microhabitats. Juvenile rearing habitat may be the key limiting factor. Inundation of shallow water habitats within the bankfull channel is thought to be of value, so long as it does not lead to stranding. RBDD gate operations that promote upstream migration should remain a top priority to limit predator pit losses by pikeminnow, striped bass and birds in this area. Recommend Sep-Oct flows that inundate shallow water habitats within the bankfull channel (that do not lead to stranding).	Considering historical flow case, rearing WUA for winter run Chinook was not the worst performing relative to other runs (and steelhead). However, rearing WUA was the indicator for winter-run that had the highest count of "poor" rated (red) years (Figure F–15). Winter-run did show improvement in spawning WUA with the addition of spawning gravel, though not as pronounced as steelhead and spring Chinook. After spring Chinook, winter-run exhibited the highest risk of juvenile stranding in SacEFT (Figure F–15). SacEFT does not presently include any components that address RBDD gate operations.
Spring-run Chinook	Shasta Dam cut off access to historical habitat. Dam also eliminated spatial segregation from fall-run Chinook. Due to lack of spatial segregation, fall-run Chinook have the advantage as their eggs are deposited subsequent (and often over top of- spring-run). Hybridization with fall-run has virtually eliminated the spring-run as a distinct run. Spatial segregation from fall-run fish is an important component of restoring spring-run in mainstem Sacramento River. Operation of ACID Dam an important component for realizing this segregation. Without some means to re-constitute the spatial segregation between fall-run and spring-run salmon spawning, the spring-run population is likely to receive little benefit from any restoration or management measures aimed at improving spawning habitat availability.	The effect of spatial segregation on spawning success is not presently included in SacEFT. Of the indicators included in SacEFT, juvenile stranding and redd dewatering were the greatest risk areas (Figure F–15). WUA spawning for spring-Chinook was not noticeably different from levels of success/challenge faced by other run types.
Fall-run Chinook	Largely supported by hatchery supplementation. Life-history strategy of fry emigrating at small size before water temperature stress builds requires prolific egg production and survival of juveniles. Thus, requires abundant spawning habitat. Competition for spawning habitat may be the most likely source of DD mortality (redd superimposition). Recommend flows Feb-Mar that inundate shallow water habitats within the bankfull channel (that do not lead to stranding).	Hatchery vs. wild component of the run not distinguished in SacEFT. Redd superimposition is not presently included in SacEFT. Relative to the other run types, WUA spawning for fall-Chinook was amongst the least challenged (fewest "poor" (red) rated years). Only late-fall Chinook had a lower risk of juvenile stranding than fall-run. Of the indicators included in SacEFT, redd scour was the greatest risk area (Figure F–15).

	Linkages Report	SacEFT*
Late fall-run Chinook	An artifact of Shasta Dam construction and operations. Cold water from Shasta has created over-summering habitat where it did not previously exist. Water temperatures the most significant factor controlling over-summering habitat.	Of the indicators included in SacEFT, rearing WUA was the poorest performing indicator (Figure F–15).
Steelhead	The availability of steep, high-elevation reaches of Sacramento tributaries most important type of habitat, but is unavailable. Biggest limiting factor is the amount of suitable summer and winter rearing habitat for age 1+ and 2+ juveniles. Fry prefer shallow, low-velocity habitats. Velocity refugia to improve overwinter survival. Not as sensitive to spawning gravel limitations because juveniles grow larger and fair better vs. some predators.	Of the indicators included in SacEFT, rearing WUA was the poorest performing indicator (Figure F–15). Redd dewatering was the next indicator to receive the most poor and fair ratings. In terms of spawning WUA, steelhead exhibited the strongest improvement following gravel augmentation.
Green sturgeon	Replacement of Redd Bluff Diversion Dam with a structure that facilitates upstream passage of adults. (Currently mid-May closure of gates may prevent late migrants form accessing preferred upstream spawning sites). Reduce targeted and incidental harvest. More research on distribution and spawning preferences – little is known (though present belief is most spawn above RBDD). Current temperature controls (for winter-run Chinook) probably provide a favorable water temperature regime for larvae.	One of the least sensitive indicators in SacEFT. Green sturgeon egg/larvae survival risk (GS1) was insensitive to the temperatures included in our SacEFT scenarios. Water temperatures that lead to elevated rates of egg mortality in green sturgeon (17°C - 20°C) were rarely if ever encountered for the scenarios we evaluated (including historically reconstructed temperatures).
Bank swallow	Bank armoring projects have reduced breeding habitat sites. High flow events during nesting can lead to bank collapse and even inundation which can produce significant mortality. Note: bank swallow nesting coincides with timing of preferred high flows for riparian recruitment. Natural bank erosion is necessary to expose soils that can be excavated by the birds; but this is best if it occurs outside breeding and nesting period. This habitat renewal by erosion is an important benefit of high flow events. Remove rip rap and retire bank armoring in locations were meanders are likely to migrate into soils suitable for nesting colonies. It will be difficult to recover bank swallows without more extensive rip rap removal (~10%-20%). These sites must have appropriate soil conditions.	The length of newly eroded banks (BASW1) that depends on meander migration rate, we did not observe a measureable response whether select rip rap removal was implemented or not. These results were also largely unchanged amongst the historical and flow scenarios evaluated. Lack of sensitivity in BASW1 most likely due to simplifying assumptions in indicator formulation or lack of resolution or contrast in incoming meander migration datasets. Under NODOS–AF2B scenario, the incidence of undesirable flows during nesting (BASW2) was slightly reduced compared to the FNA2 scenario. In SacEFT, this indicator was more sensitive than BASW1.

	Linkages Report	**SacEFT***
Western pond turtle	Loss of off-channel water bodies (through human encroachment and terrestrialization) Hypolimnetic reservoir releases above Redd Bluff may have reduced summer water temperatures too much for WPT. Introduced predators a concern (largemouth bass and bullfrogs) A key potential limiting factor is the relationship between water level and flow in off-channel water bodies during summer incubation. Incubating eggs are extremely sensitive to increased soil moisture. High incubation mortality is likely if summer flows inundate off-channel water bodies. These same flows are beneficial however at other times for driving channel migration and chute-cutoff processes.	SacEFT does not include a relationship addressing flow in off-channel water bodies during summer incubation. In the case of creation of newly orphaned channels (WPT1), the meander migration model predicted only two events. These occurred in WY 1939 and 1941 only and adding 2070 m^2 and 425 m^2 of new orphaned channel habitat in the process. These events occurred under all three flow regimes when rip rap removal was simulated, and also under the NODOS flow regime when no rip rap removal was simulated. Taken together these results show that simulated rip rap removal can cause channel realignment in cases where the bed morphology has reached a point of instability, but that such events are infrequent under the current channel morphology even when rip-rap is removed. This is not a reflection of lack of sensitivity of the WPT1 indicator itself per se, but reflects the overall lack of contrast in meander migration results.
Fremont cottonwood	Management of recession limb of hydrograph in wet years to promote seedling establishment. Research by TNC and CDWR suggest that recruitment events may have a recurrence interval on the order of 20 years on the Sacramento River. The recurrence interval for riparian vegetation recruitment on many other similar western rivers is order 5 years. Recruitment flows are not necessary every year, but instead need occur once every 5 to 10 years. Recruitment flow should be in the range of 22,000 to 37,000 cfs during the peak of the cottonwood seed release period (end Apr-beginning June). Promotion of channel migration to create new seedbeds through scour and fine sediment deposition. Control of invasive plant species	SacEFT's riparian initiation model does not consider channel migration, floodplain fine sediment deposition, nor succession. For historical flows, SacEFT predicts approximately 9-10 'significant' recruitment events in 65 years; approximately 4 in 65 years if successful recruitment events require a normal to wet year in the year following an acceptable recession limb. For good (green) rated years in SacEFT, the recruitment flow (measured at Hamilton City) between Apr-14 and May-15 averaged 20,000 cfs, and ranged between 15,000 cfs and 40,000 cfs.
Geomorphic processes: *general*	Implementation of the meander zone concept is advocated. River migration critical to the formation and preservation of off-channel habitats as well as exchange of sediment from the channel to the floodplain. Migration is fundamental to formation of numerous types of habitats that are critical for multiple species. Gravel augmentation will be required indefinitely, because surface coarsening and downstream transport will remove injected gravels that cannot be replaced naturally due to the sediment supply deficit caused by Shasta Dam. Gravel bed restructuring to remove coarse surface layer should accompany gravel augmentation. This approach is however very labor intensive.	Gravel augmentation was more significant (to Chinook and steelhead spawning) than channel revetment was to bank swallow nesting habitat and western pond turtle habitat creation for the indicators we used. In the case of bank swallows and western pond turtles, this may owe to limitations in the physical driving models and simplifying assumptions used for these indicators rather than be a true approximation of what is occurring in nature.
Flow management: *general*	Well-timed spring pulse flows that reconnect seasonally inundated habitats with the mainstem increase habitat area and quality. These flows are desirable so long as they do not lead to stranding juvenile salmonids. Use ACID Dam to re-distribute salmonid spawning if redd superimposition is found to be a limiting factor.	SacEFT uses USFWS stranding site survey data. Based on historical flow data alone, this survey information suggests that spring and winter Chinook experience the highest risk of stranding (Figure F–15). We present a number of specific target and avoidance flows in Section 2.3.4 of the Final Report.

* All statements are based on the historical flow scenario, unless otherwise indicated.



Output Viewer - Rollup View

1a-Historical-T1, NoGravelAugmentation, NoRevetment

Performance Measure	Description		Multi-Year Rollup	% Poor	% Fair	% Good
CH - Fall - CH1	WUA Spawning - Fall Chinook			5	39	56
CH - Fall - CH2	WUA Rearing - Fall Chinook			28	47	25
CH - Fall - CH3	Egg-to-Fry Survival - Fall Chinook			9	16	75
CH - Fall - CH4	Juvenile Stranding - Fall Chinook			0	31	69
CH - Fall - CH5	Redd Scour - Fall Chinook			55	19	26
CH - Fall - CH6	Redd Dewatering - Fall Chinook			28	34	38
CH - Late Fall - CH1	WUA Spawning - Late Fall Chinook			23	35	42
CH - Late Fall - CH2	WUA Rearing - Late Fall Chinook			66	31	3
CH - Late Fall - CH3	Egg-to-Fry Survival - Late Fall Chin...			0	3	97
CH - Late Fall - CH4	Juvenile Stranding - Late Fall Chin...			0	0	100
CH - Late Fall - CH5	Redd Scour - Late Fall Chinook			42	13	45
CH - Late Fall - CH6	Redd Dewatering - Late Fall Chino...			34	16	50
CH - Spring - CH1	WUA Spawning - Spring Chinook			17	27	56
CH - Spring - CH2	WUA Rearing - Spring Chinook			19	40	41
CH - Spring - CH3	Egg-to-Fry Survival - Spring Chinook			19	16	65
CH - Spring - CH4	Juvenile Stranding - Spring Chinook			28	56	16
CH - Spring - CH5	Redd Scour - Spring Chinook			16	19	65
CH - Spring - CH6	Redd Dewatering - Spring Chinook			28	63	9
CH - Winter - CH1	WUA Spawning - Winter Chinook			15	33	52
CH - Winter - CH2	WUA Rearing - Winter Chinook			19	40	41
CH - Winter - CH3	Egg-to-Fry Survival - Winter Chinook			6	19	75
CH - Winter - CH4	Juvenile Stranding - Winter Chinook			3	56	41
CH - Winter - CH5	Redd Scour - Winter Chinook			0	19	81
CH - Winter - CH6	Redd Dewatering - Winter Chinook			0	9	91
ST1	WUA Spawning - Steelhead			21	41	38
ST2	WUA Rearing - Steelhead			53	44	3
ST3	Egg-to-Fry Survival - Steelhead			3	0	97
ST4	Juvenile Stranding - Steelhead			0	41	59
ST5	Redd Scour - Steelhead			34	22	44
ST6	Redd Dewatering - Steelhead			33	30	37

Annual View | Rollup View | Create Reports | 0 Report(s) will be created based on your selections

Figure F–15. SacEFT results for all Chinook and steelhead performance measures, for historical flows and water temperatures, without gravel augmentation.

1.3 Examples of Within-Year (Daily) SacEFT Results

MS Excel graphs and tables serve as the primary output format for SacEFT's detailed within year results. An example of SacEFT's spawning weighted useable area report (WUA) is given in Figure .

Example 15: SacEFT's spawning weighted useable area (WUA) report

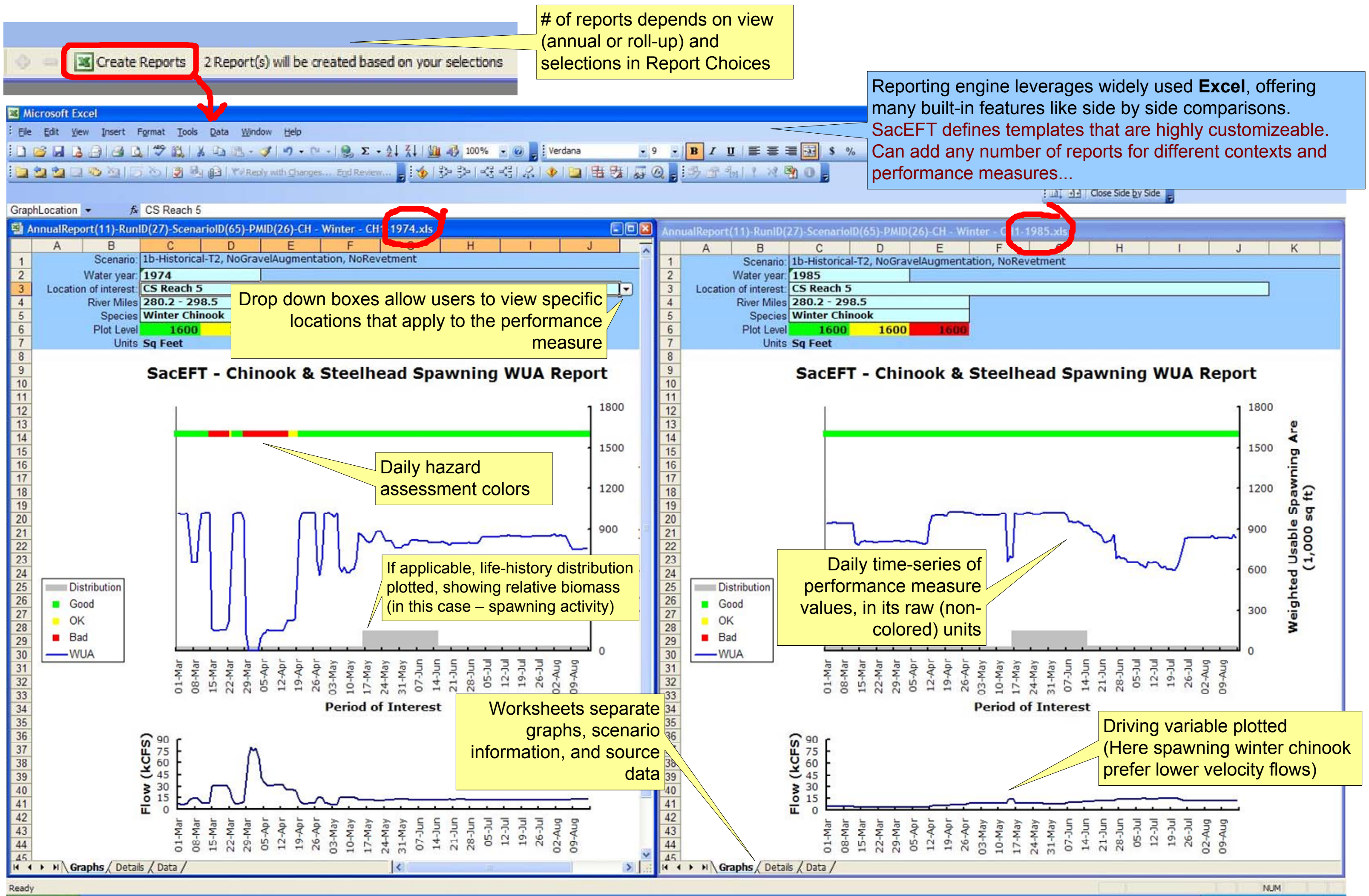


Figure F–16. SacEFT provides detailed output on a scenario × year × performance measure basis in Excel. Here, managers and scientists can examine the detailed results in the performance measure's raw units, alongside its driving variable (e.g., flows).

Example 16: SacEFT's redd dewatering report comparing a good year and a poor rated year

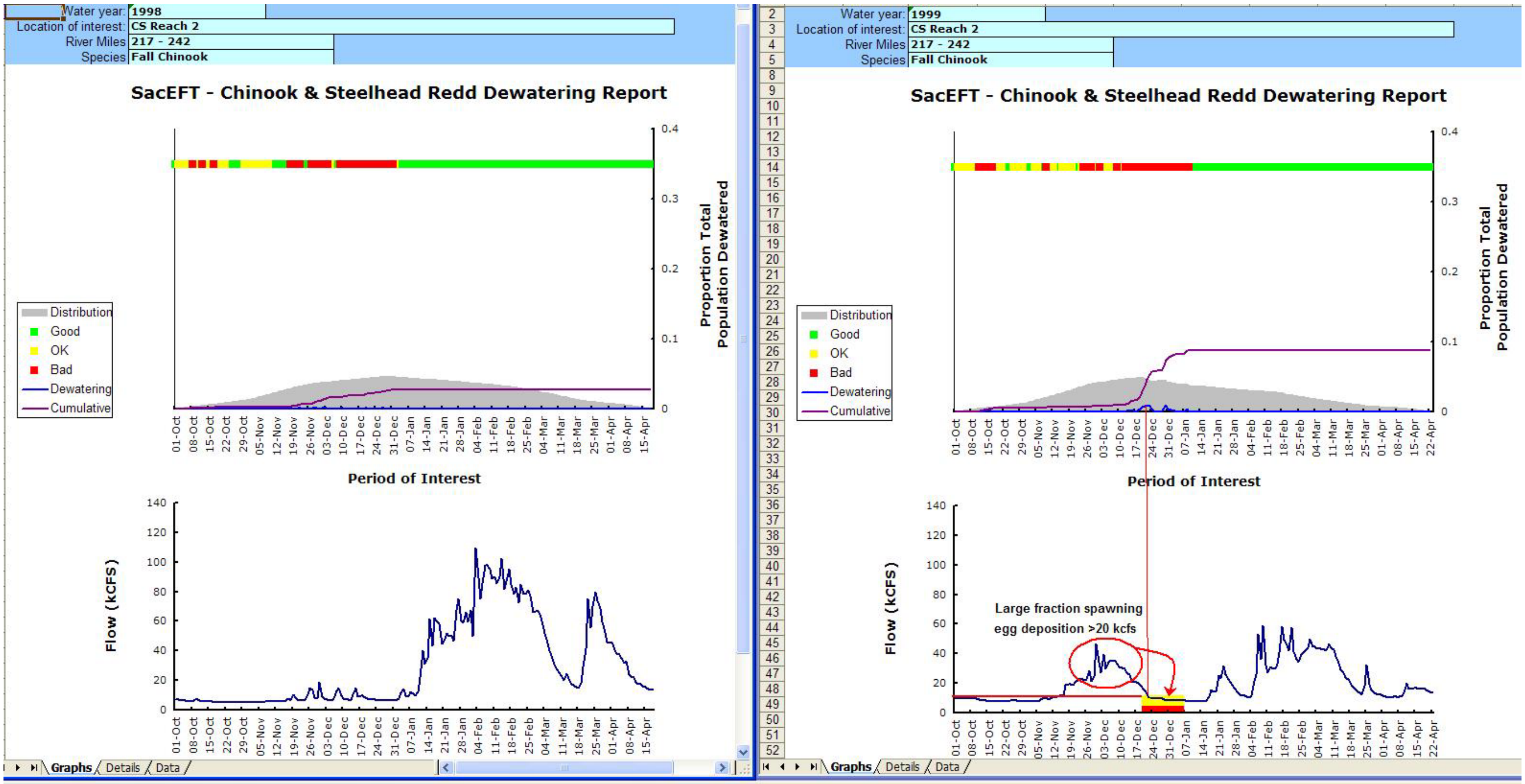


Figure F–17. An example of SacEFT's redd dewatering report comparing a good rated year (left) with a poor rated year (right).

Example 17: SacEFT's juvenile stranding report comparing a good rated year with a poor rated year

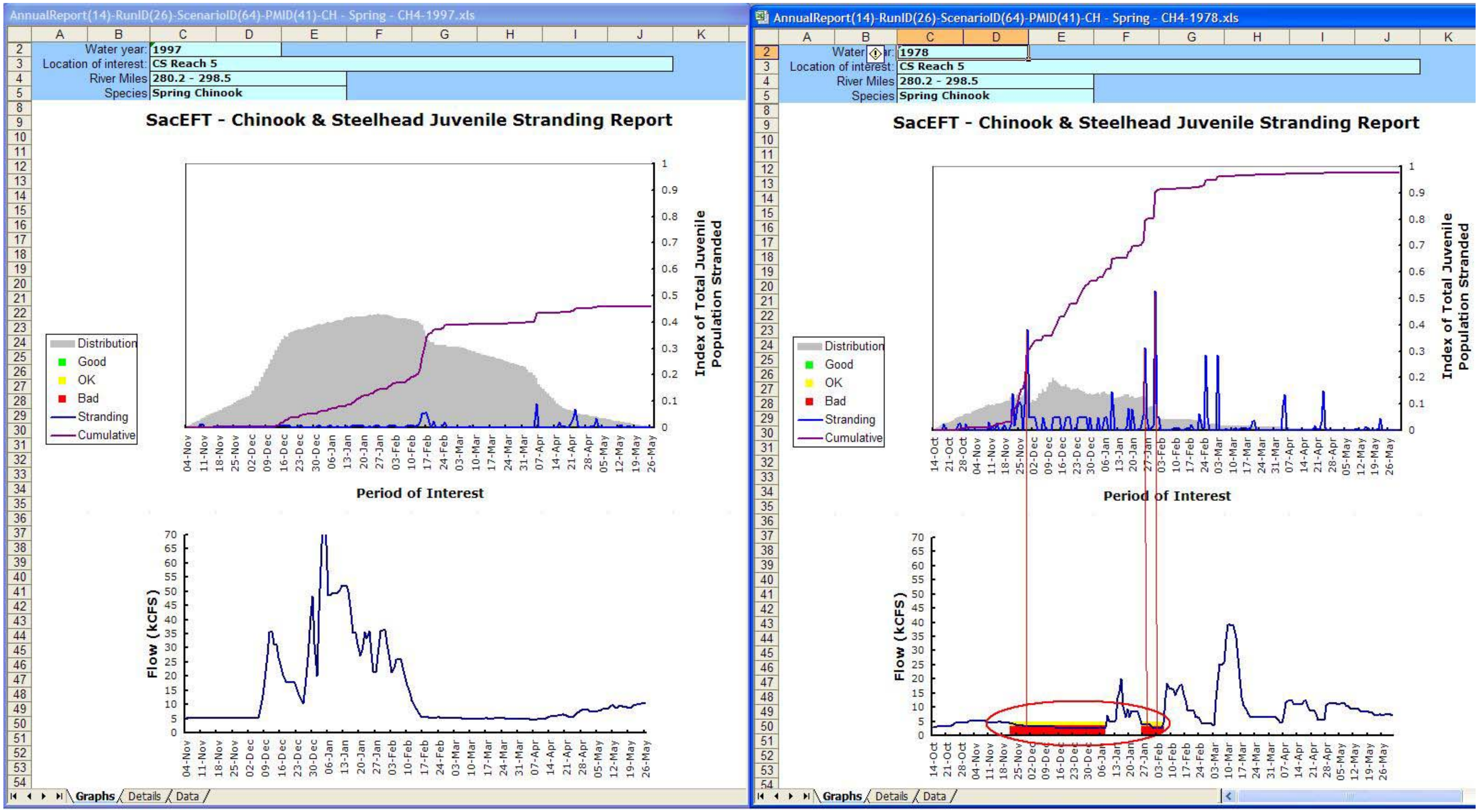
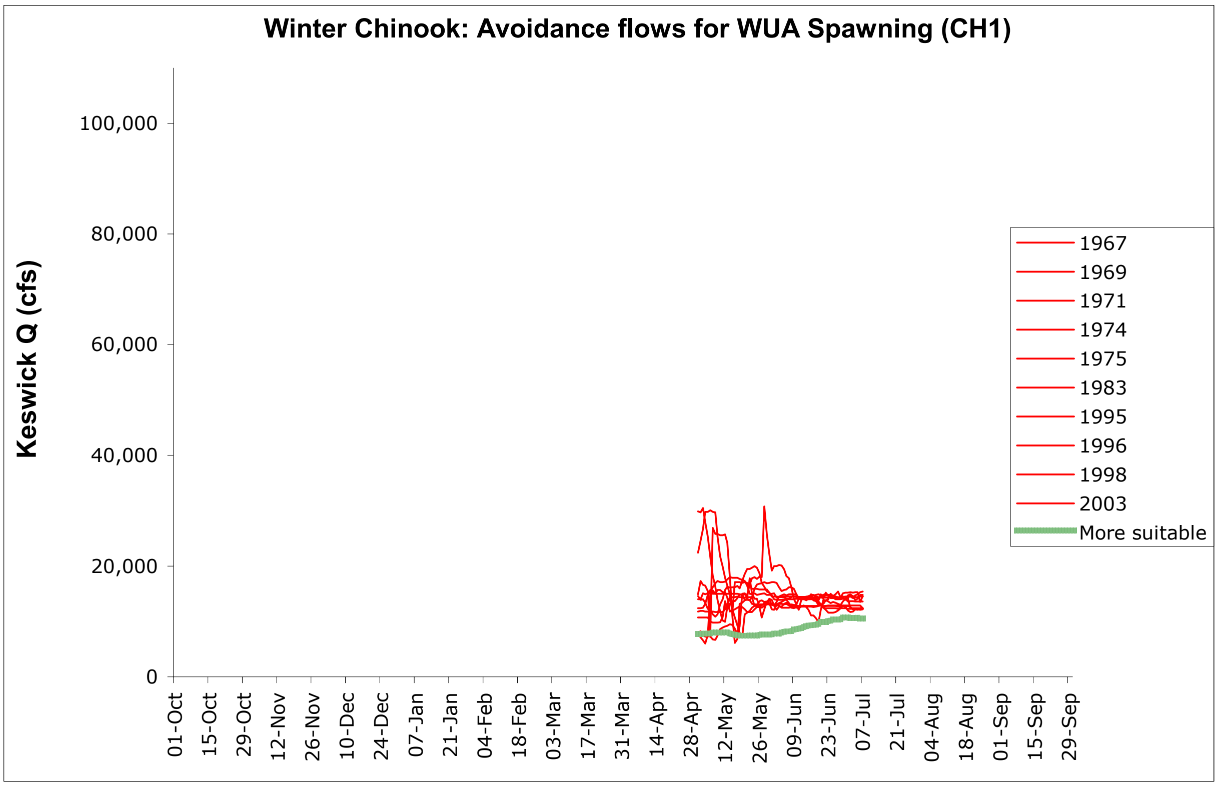
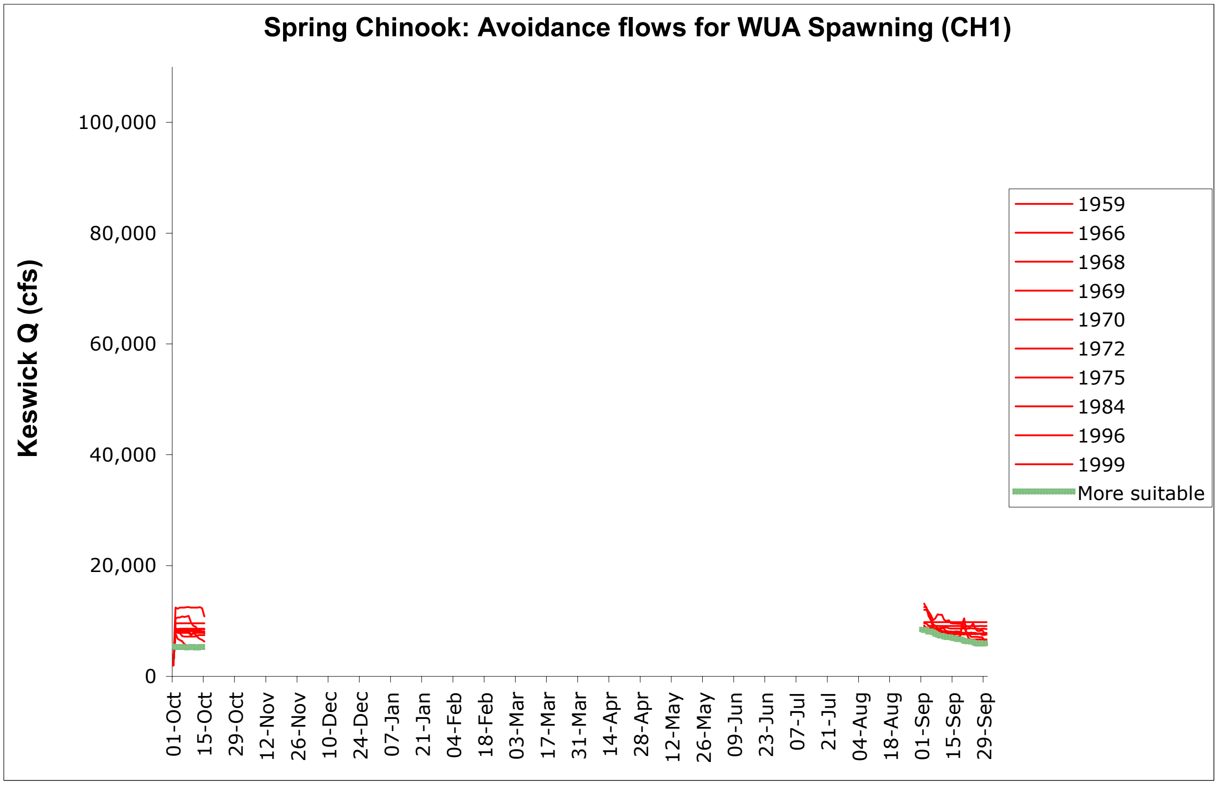


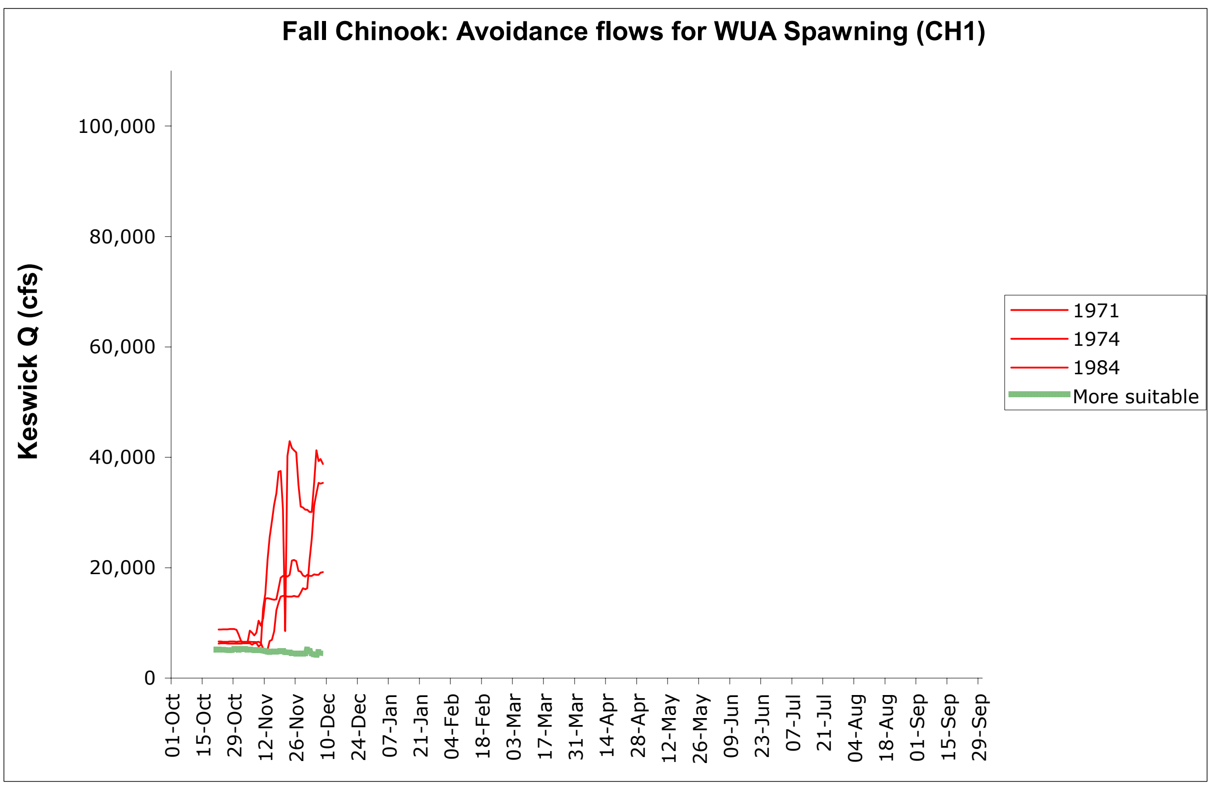
Figure F‑ 18. An example of SacEFT's juvenile stranding report comparing a good rated year (left) with a poor rated year (right).

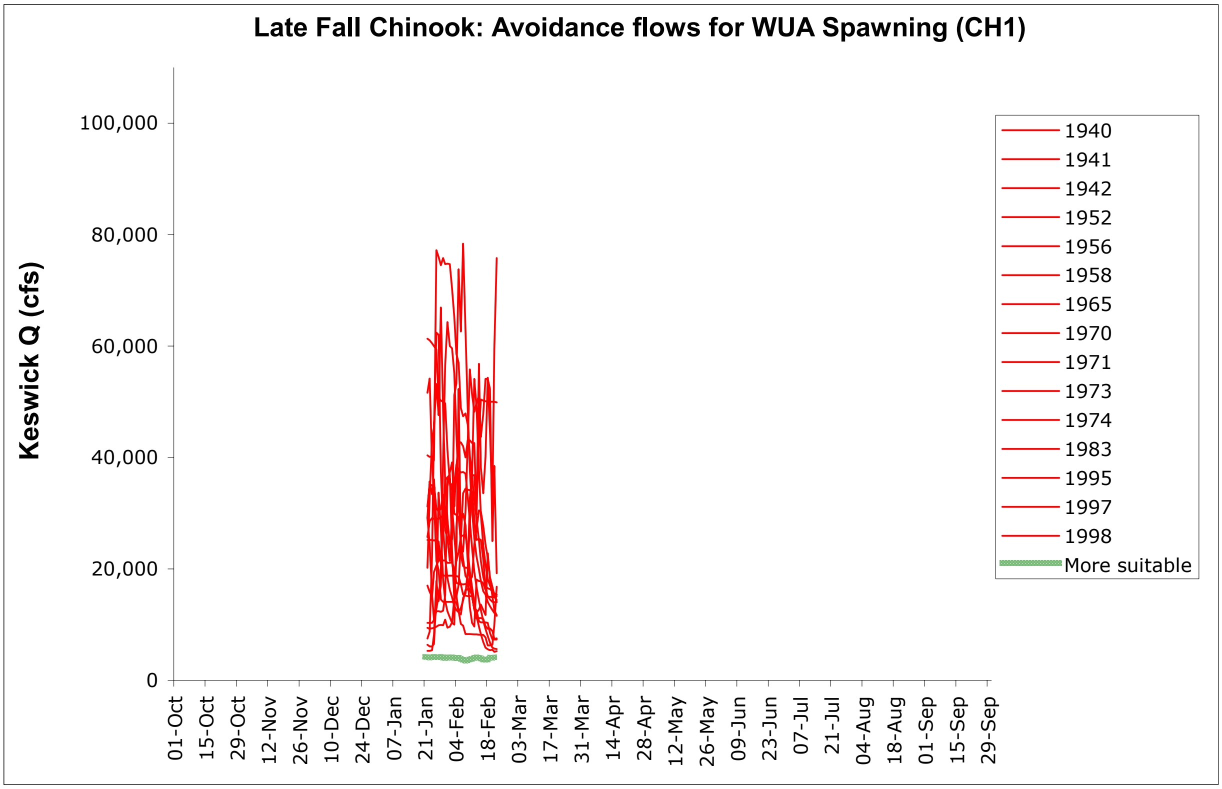
1.4 SacEFT's recommended target and avoidance flow ranges (zoom magnification)

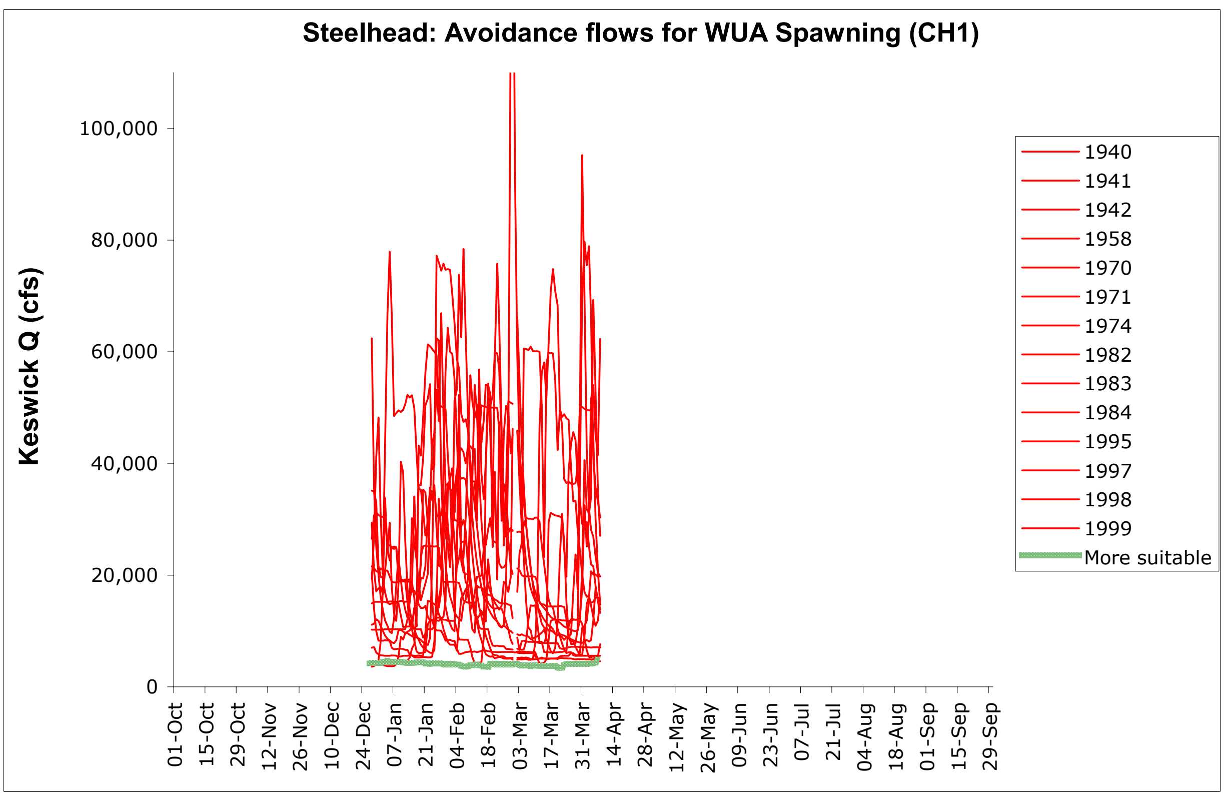
This section provides the same information as that given in Figure 2–1 of the Final Report, but at 'zoom' magnification for individual focal species (and where relevant, Chinook run-types). These target and avoidance flows were derived by taking the historical flow scenario (WY 1939-2004), Run ID 26, and selecting all the good (green) performing years ('target' or 'desired' flow) or poor (red) performing years ('avoidance' flow). "More suitable" flow lines represent the median of all good (green) performing years found in the historical model simulation. Given this approach, some "target" flows for some Chinook run types may in reality reflect the "least worst" flows observed historically rather than a true target flow.

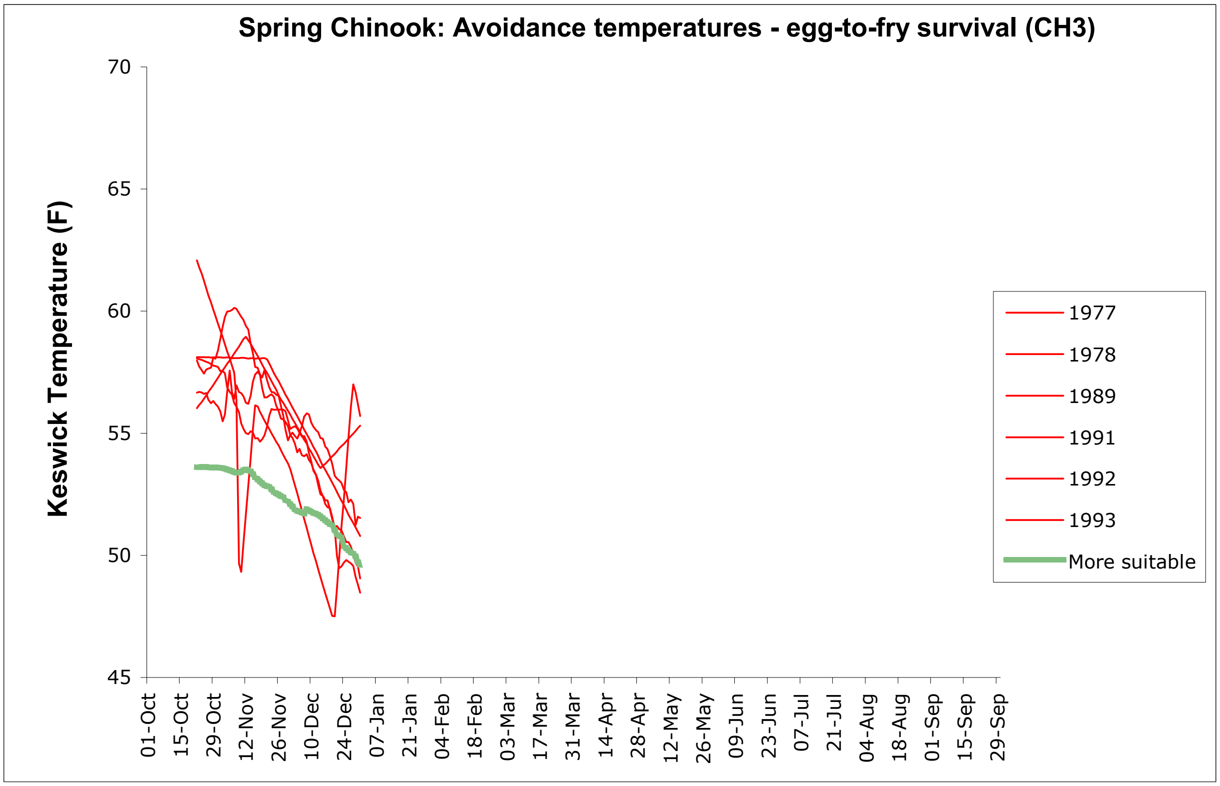


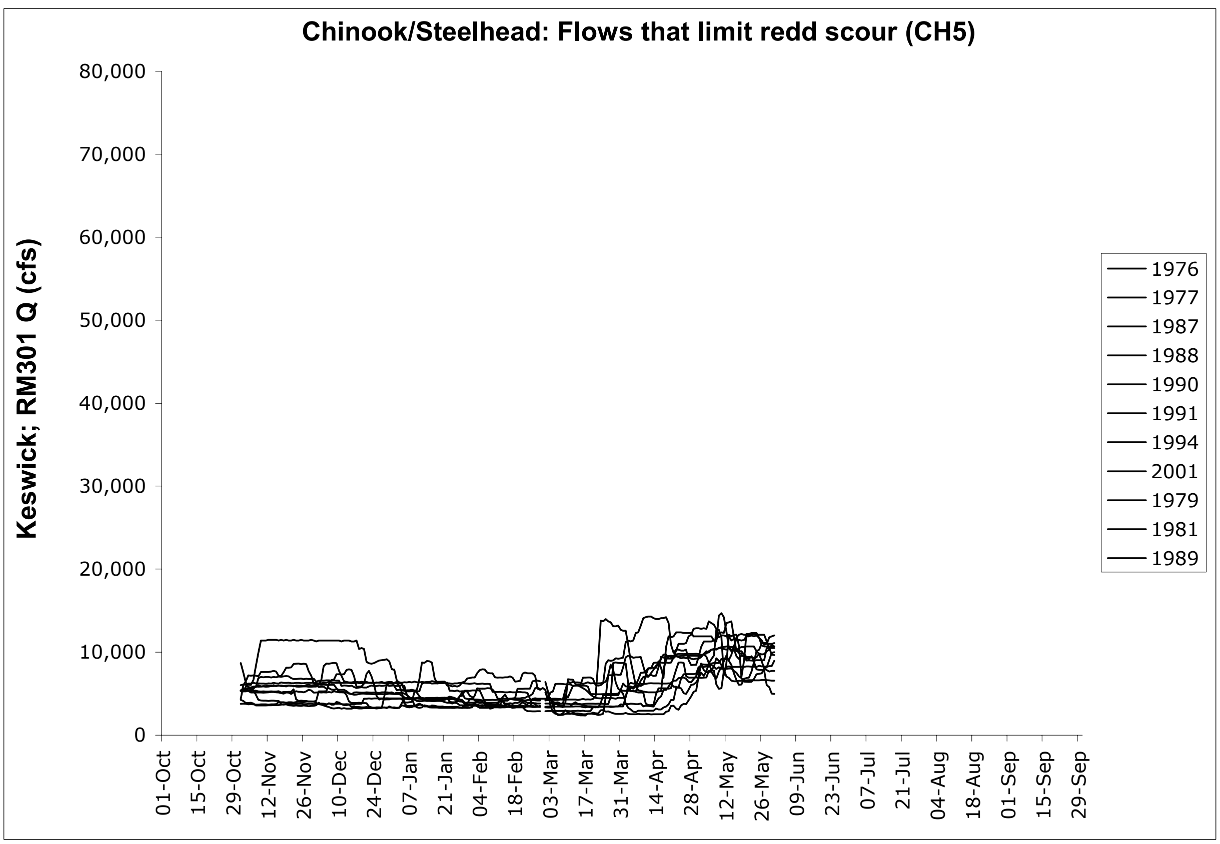

Spring Chinook: Avoidance flows for WUA Spawning (CH1)
Keswick Q (cfs)
100,000
80,000
60,000
40,000
20,000
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1959
1966
1968
1969
1970
1972
1975
1984
1996
1999
More suitable


Fall Chinook: Avoidance flows for WUA Spawning (CH1)
Keswick Q (cfs)
100,000
80,000
60,000
40,000
20,000
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1971
1974
1984
More suitable


Late Fall Chinook: Avoidance flows for WUA Spawning (CH1)
Keswick Q (cfs)
100,000
80,000
60,000
40,000
20,000
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1940
1941
1942
1952
1956
1958
1965
1970
1971
1973
1974
1983
1995
1997
1998
More suitable


Steelhead: Avoidance flows for WUA Spawning (CH1)
Keswick Q (cfs)
100,000
80,000
60,000
40,000
20,000
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1940
1941
1942
1958
1970
1971
1974
1982
1983
1984
1995
1997
1998
1999
More suitable


Spring Chinook: Avoidance temperatures - egg-to-fry survival (CH3)
Keswick Temperature (F)
70
65
60
55
50
45
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1977
1978
1989
1991
1992
1993
More suitable


Chinook/Steelhead: Flows that limit redd scour (CH5)
Keswick; RM301 Q (cfs)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
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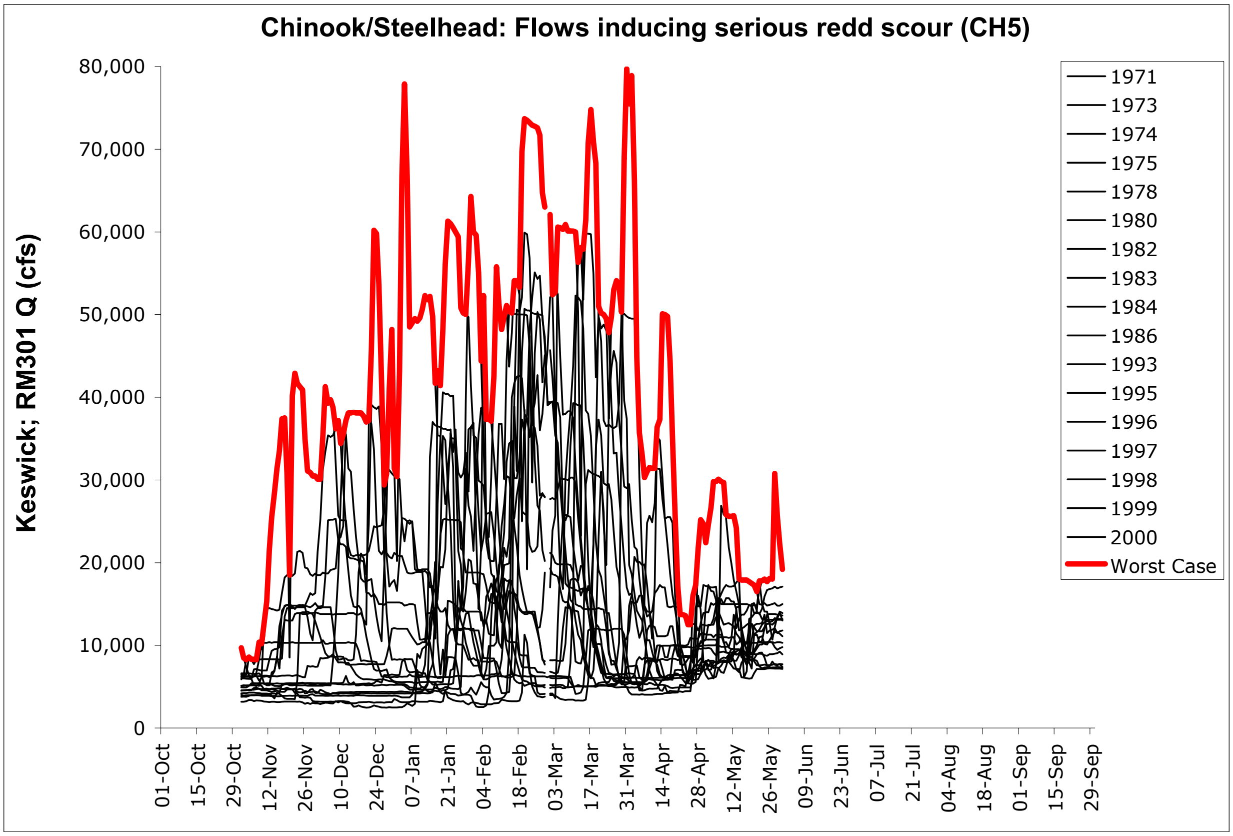
01-Sep
15-Sep
29-Sep
1976
1977
1987
1988
1990
1991
1994
2001
1979
1981
1989


Chinook/Steelhead: Flows inducing serious redd scour (CH5)
Keswick; RM301 Q (cfs)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1971
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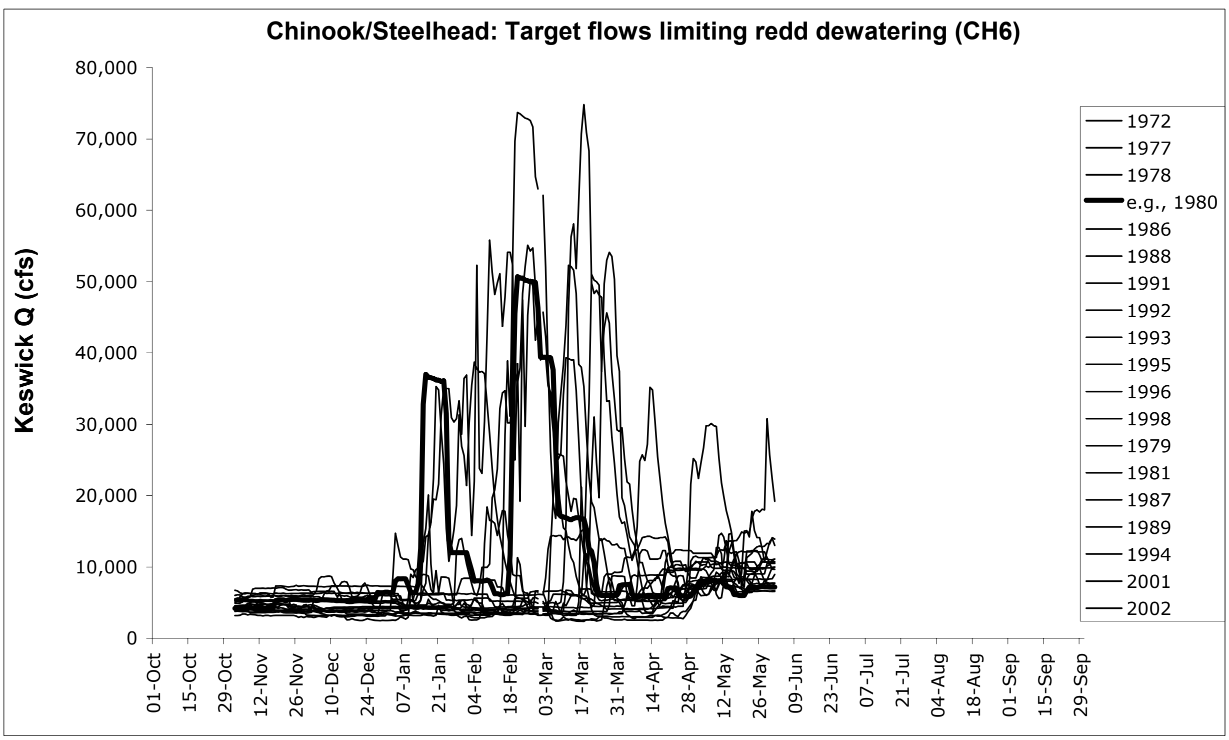
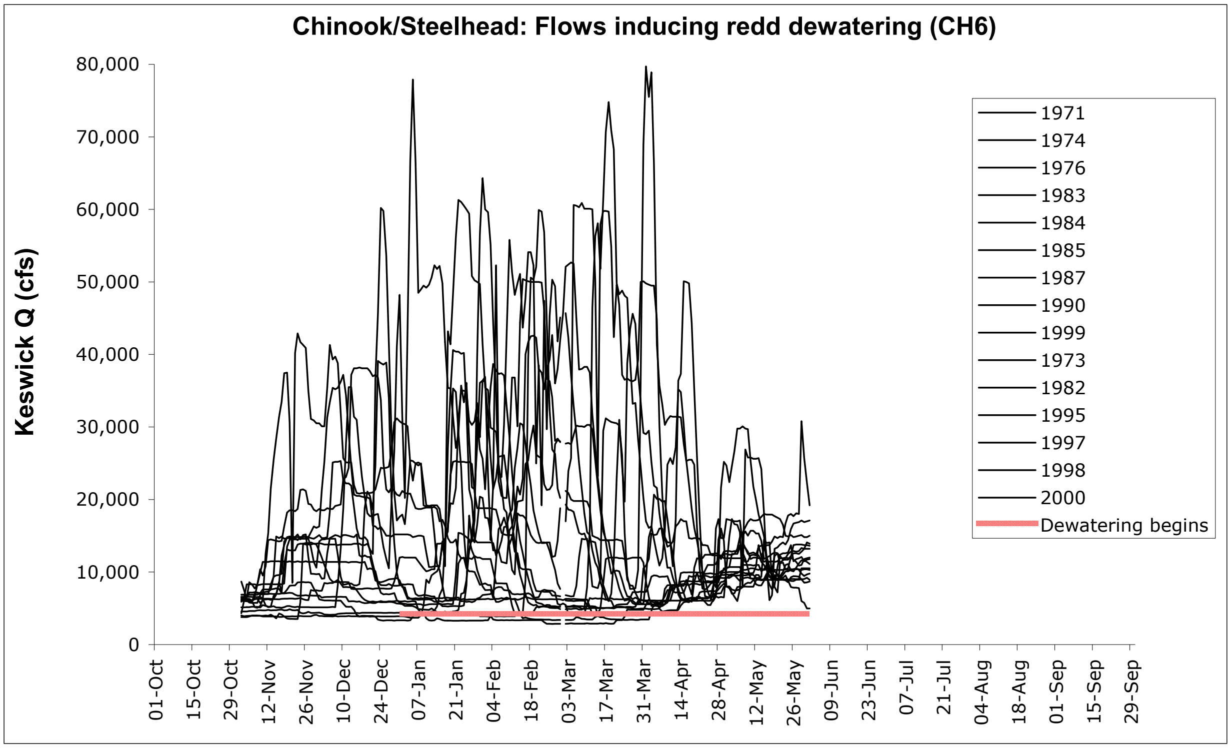
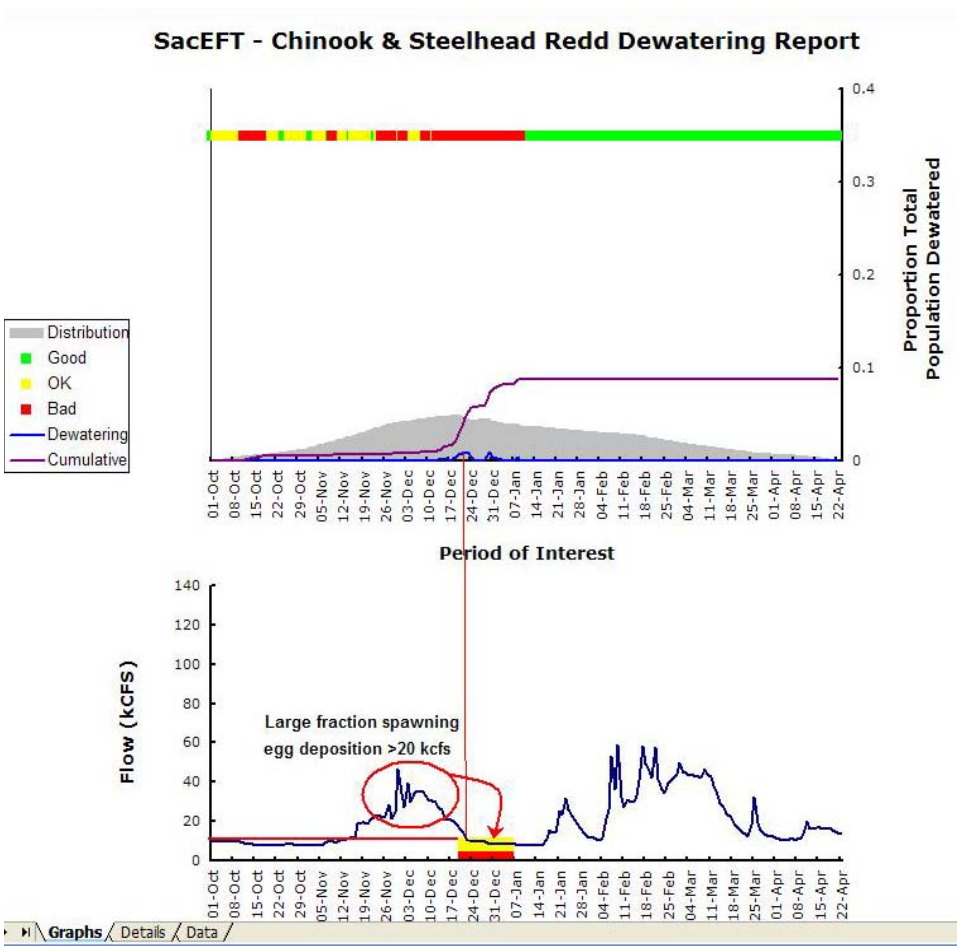
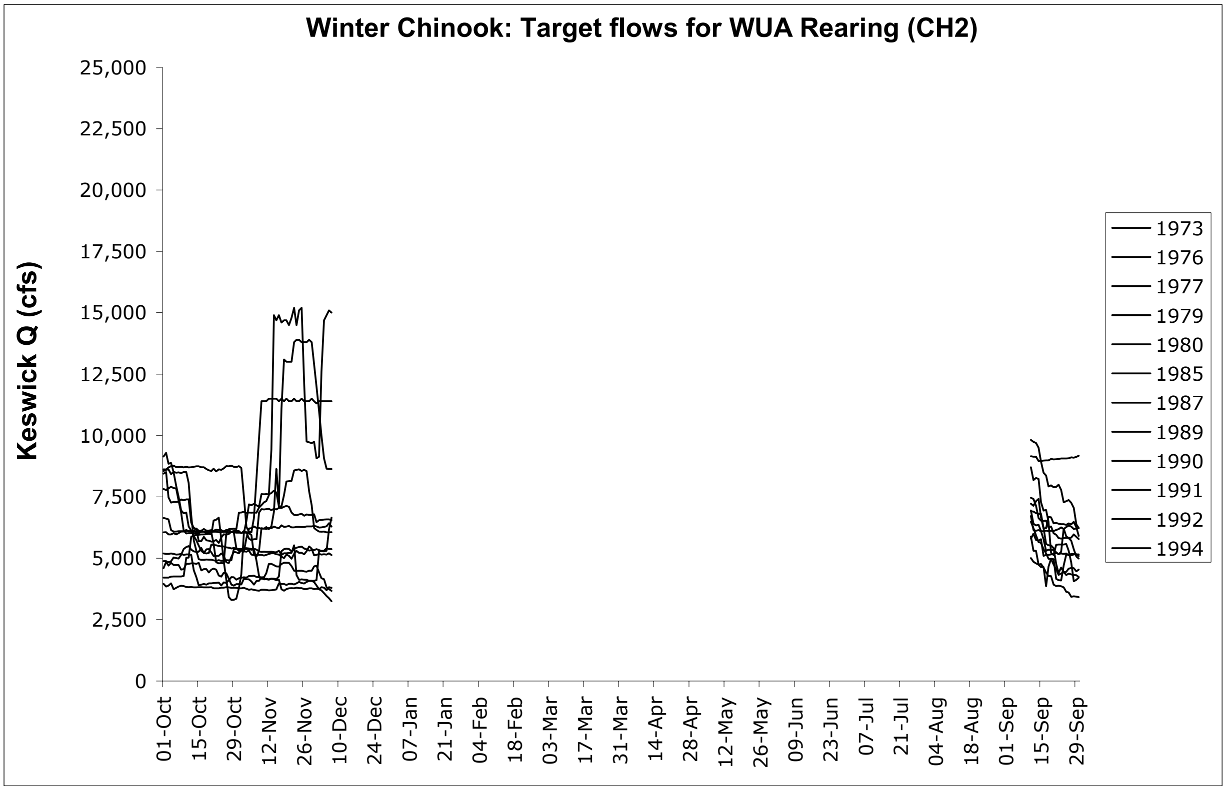
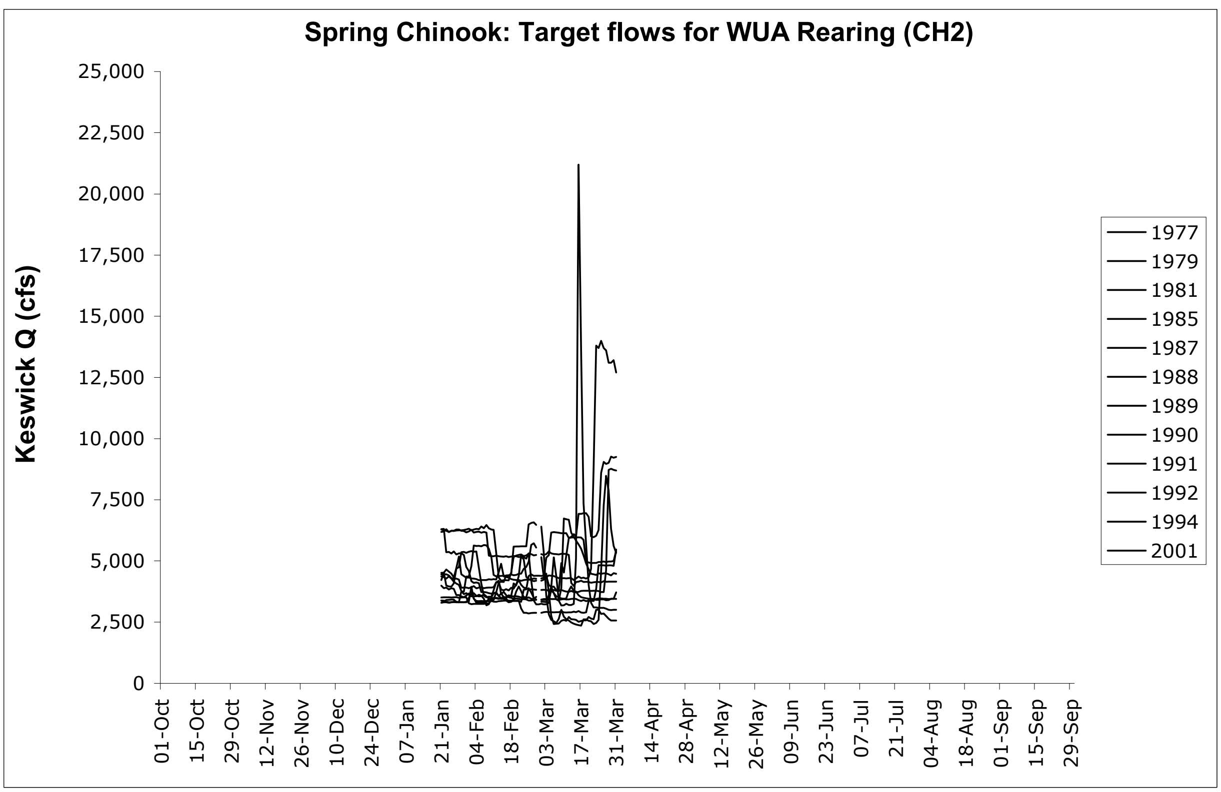
1984
1986
1993
1995
1996
1997
1998
1999
2000
Worst Case

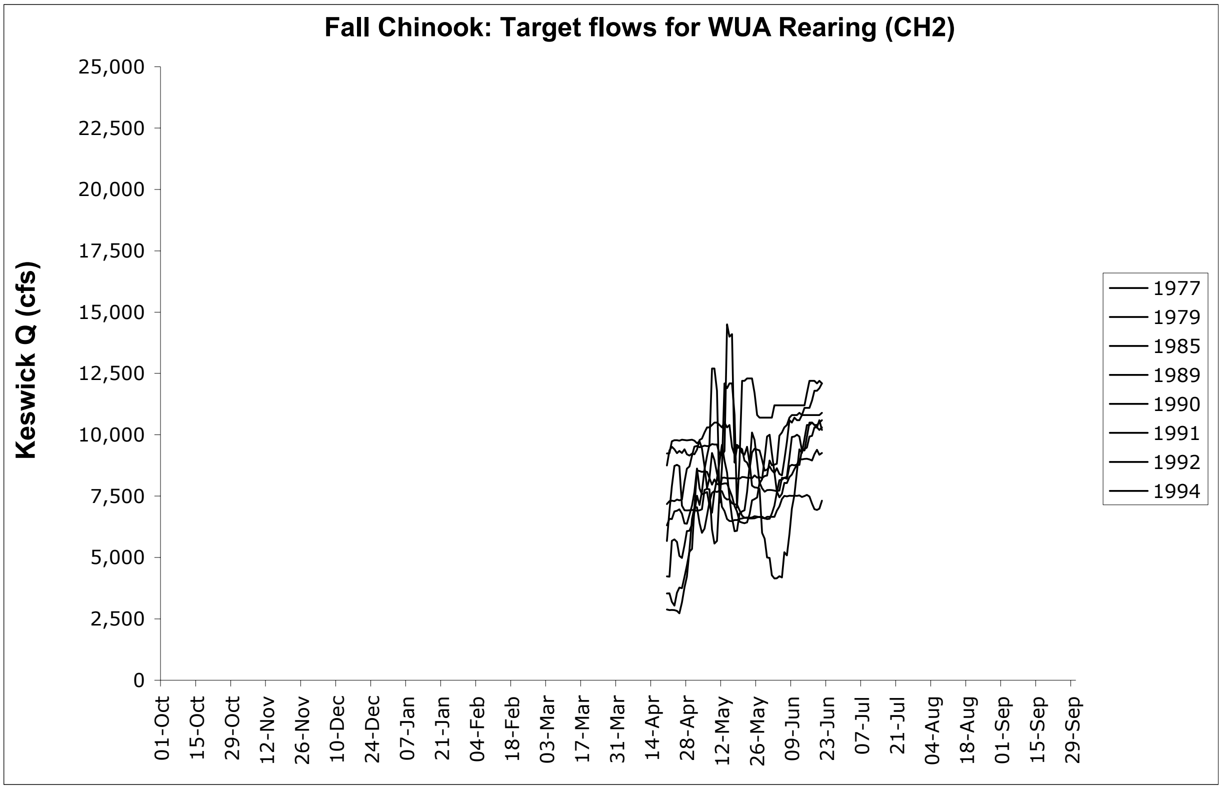

Chinook/Steelhead: Target flows limiting redd dewatering (CH6)
Keswick Q (cfs)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1972
1977
1978
e.g., 1980
1986
1988
1991
1992
1993
1995
1996
1998
1979
1981
1987
1989
1994
2001
2002

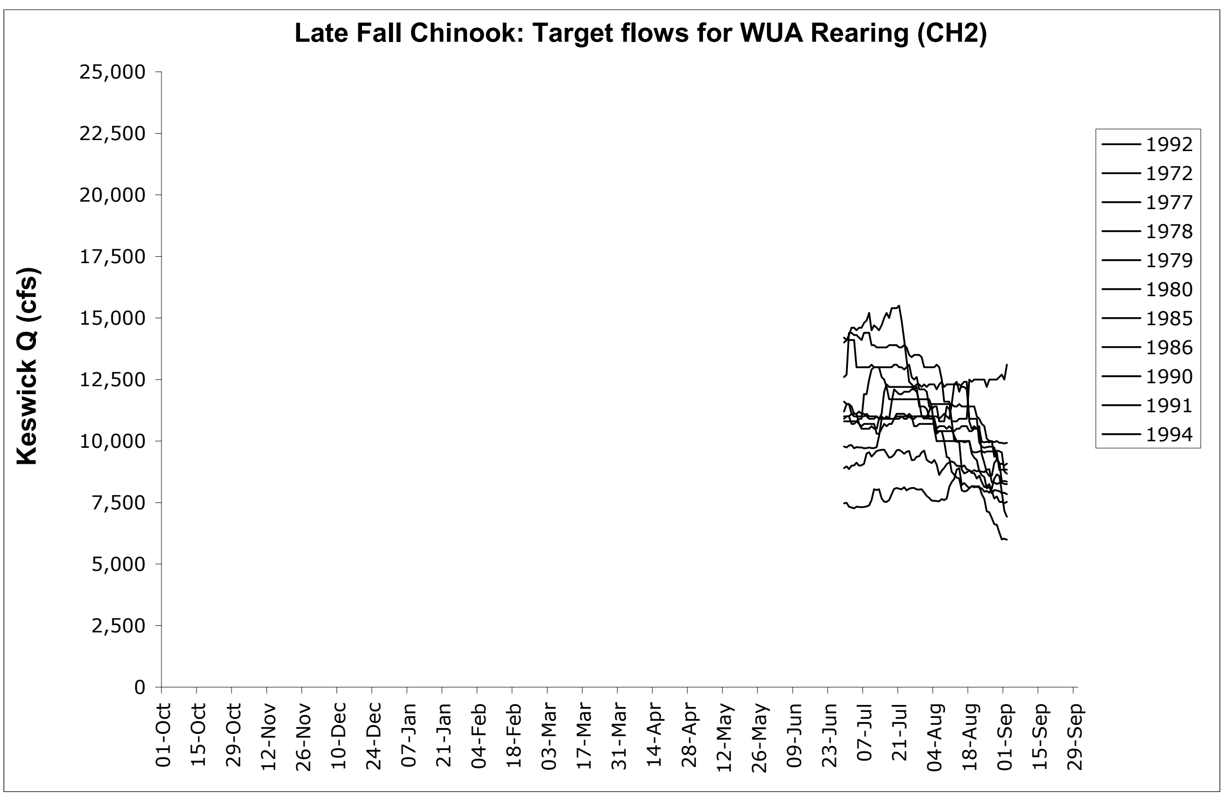

Chinook/Steelhead: Flows inducing redd dewatering (CH6)
Keswick Q (cfs)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1971
1974
1976
1983
1984
1985
1987
1990
1999
1973
1982
1995
1997
1998
2000
Dewatering begins

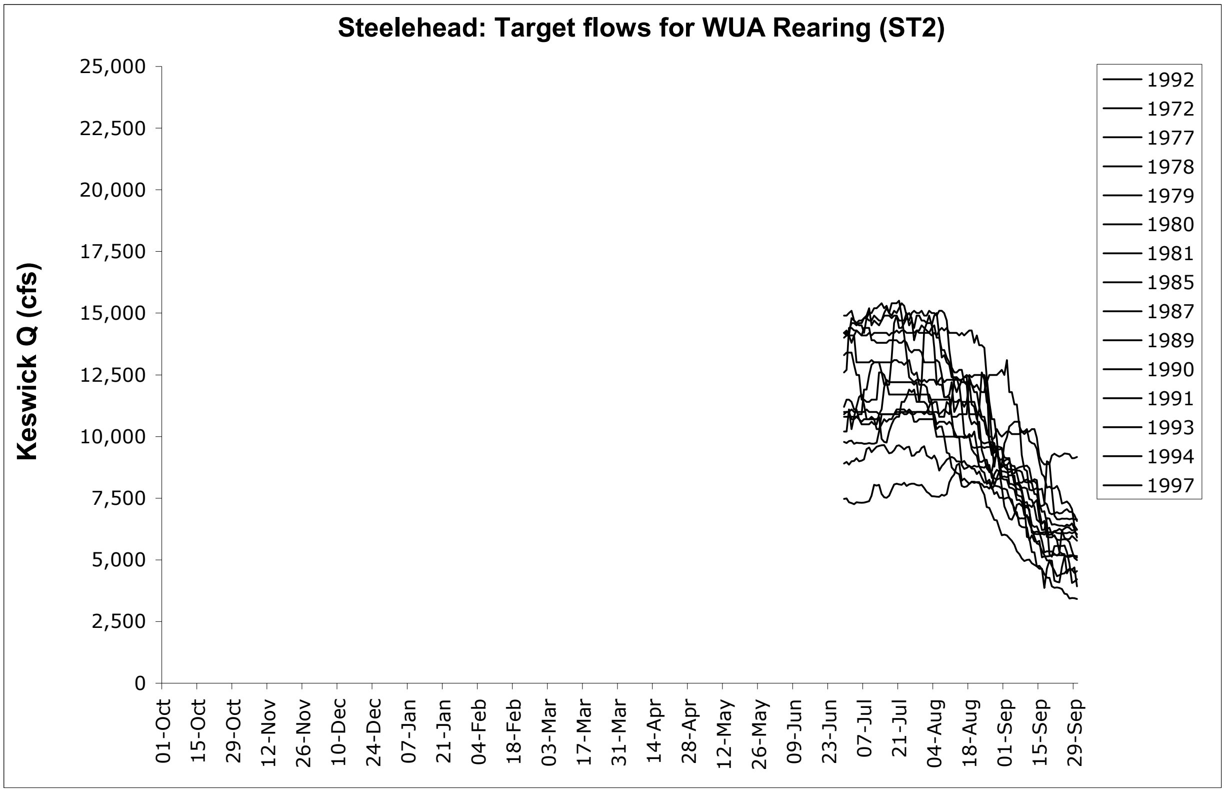

SacEFT - Chinook & Steelhead Redd Dewatering Report
Distribution
Good
OK
Bad
Dewatering
Cumulative
0.4
0.3
0.2
0.1
0
Proportion Total Population Dewatered
01-Oct
08-Oct
15-Oct
22-Oct
29-Oct
05-Nov
12-Nov
19-Nov
26-Nov
03-Dec
10-Dec
17-Dec
24-Dec
31-Dec
07-Jan
14-Jan
21-Jan
28-Jan
04-Feb
11-Feb
18-Feb
25-Feb
04-Mar
11-Mar
18-Mar
25-Mar
01-Apr
08-Apr
15-Apr
22-Apr
Period of Interest
Flow (kCFS)
140
120
100
80
60
40
20
0
Large fraction spawning
egg deposition >20 kcfs
Graphs
Details
Data

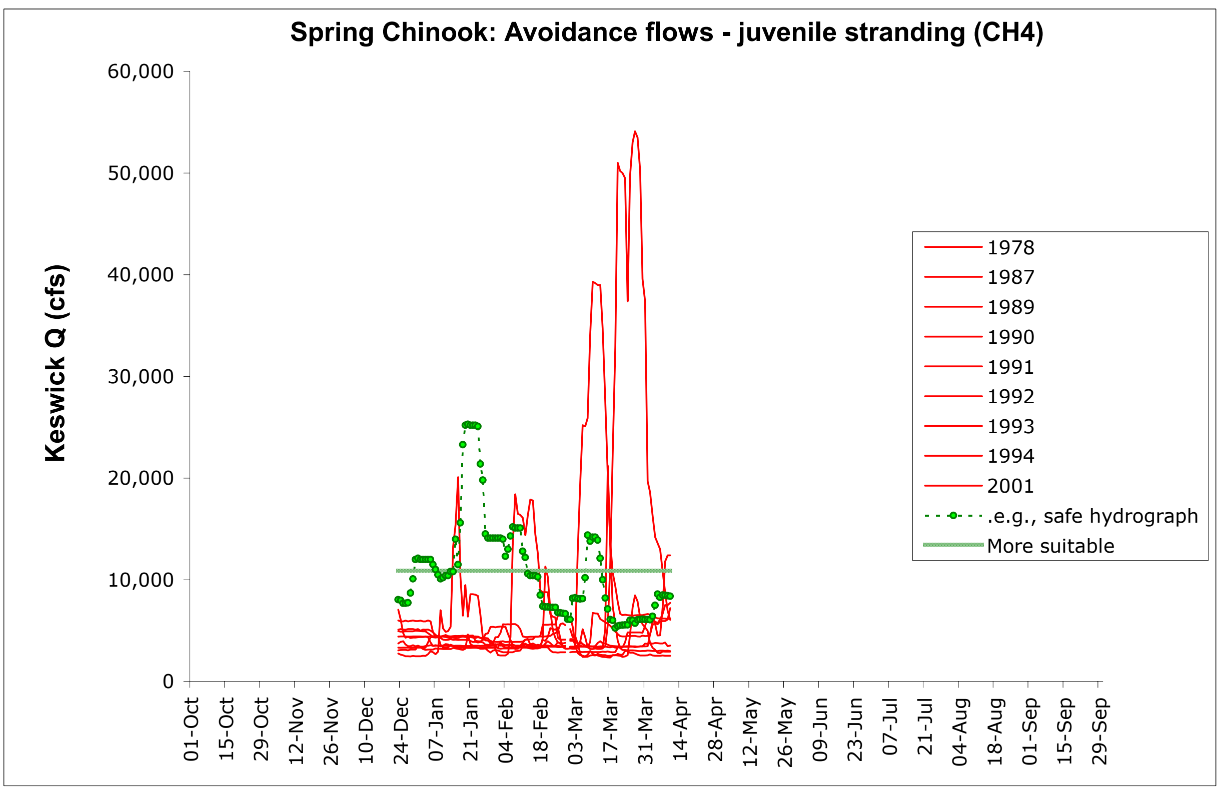

Winter Chinook: Target flows for WUA Rearing (CH2)
Keswick Q (cfs)
25,000
22,500
20,000
17,500
15,000
12,500
10,000
7,500
5,000
2,500
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1973
1976
1977
1979
1980
1985
1987
1989
1990
1991
1992
1994

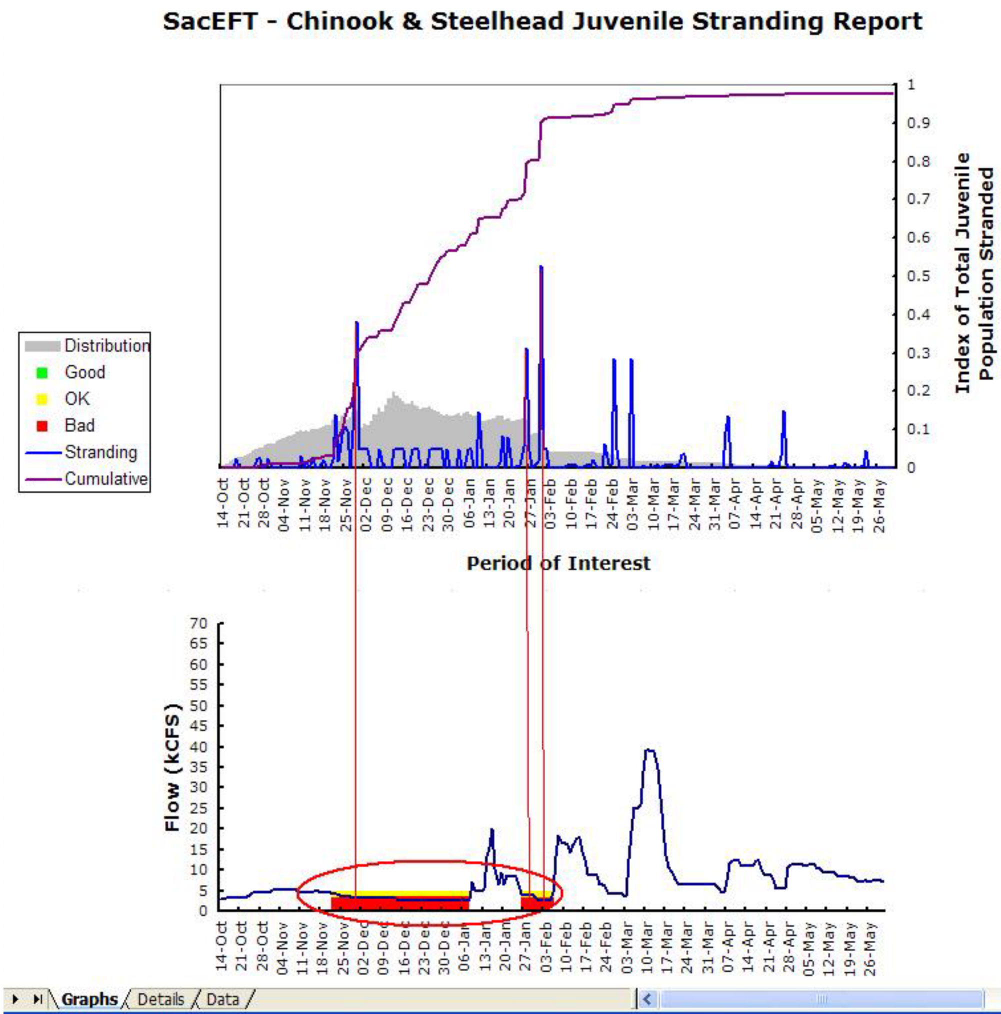

Spring Chinook: Target flows for WUA Rearing (CH2)
Keswick Q (cfs)
25,000
22,500
20,000
17,500
15,000
12,500
10,000
7,500
5,000
2,500
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1977
1979
1981
1985
1987
1988
1989
1990
1991
1992
1994
2001

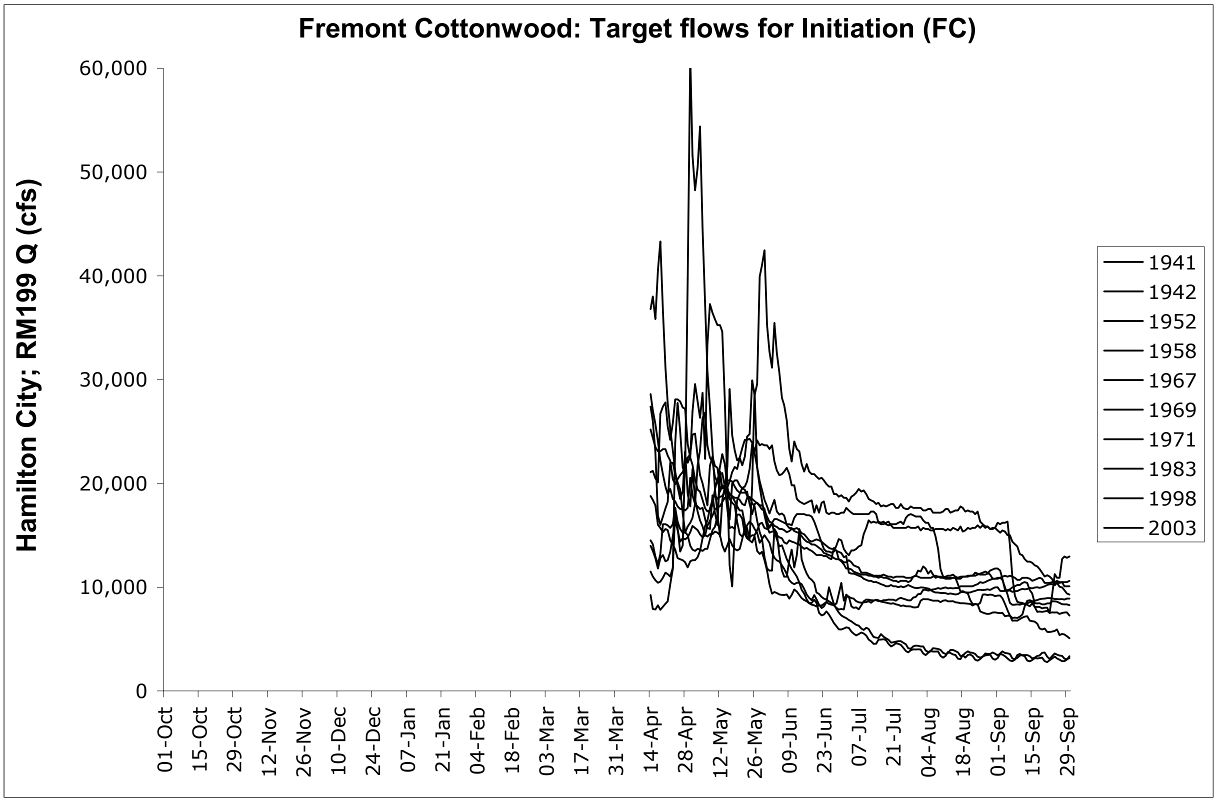

Fall Chinook: Target flows for WUA Rearing (CH2)
Keswick Q (cfs)
25,000
22,500
20,000
17,500
15,000
12,500
10,000
7,500
5,000
2,500
0
01-Oct 15-Oct 29-Oct 12-Nov 26-Nov 10-Dec 24-Dec 07-Jan 21-Jan 04-Feb 18-Feb 03-Mar 17-Mar 31-Mar 14-Apr 28-Apr 12-May 26-May 09-Jun 23-Jun 07-Jul 21-Jul 04-Aug 18-Aug 01-Sep 15-Sep 29-Sep
1977
1979
1985
1989
1990
1991
1992
1994

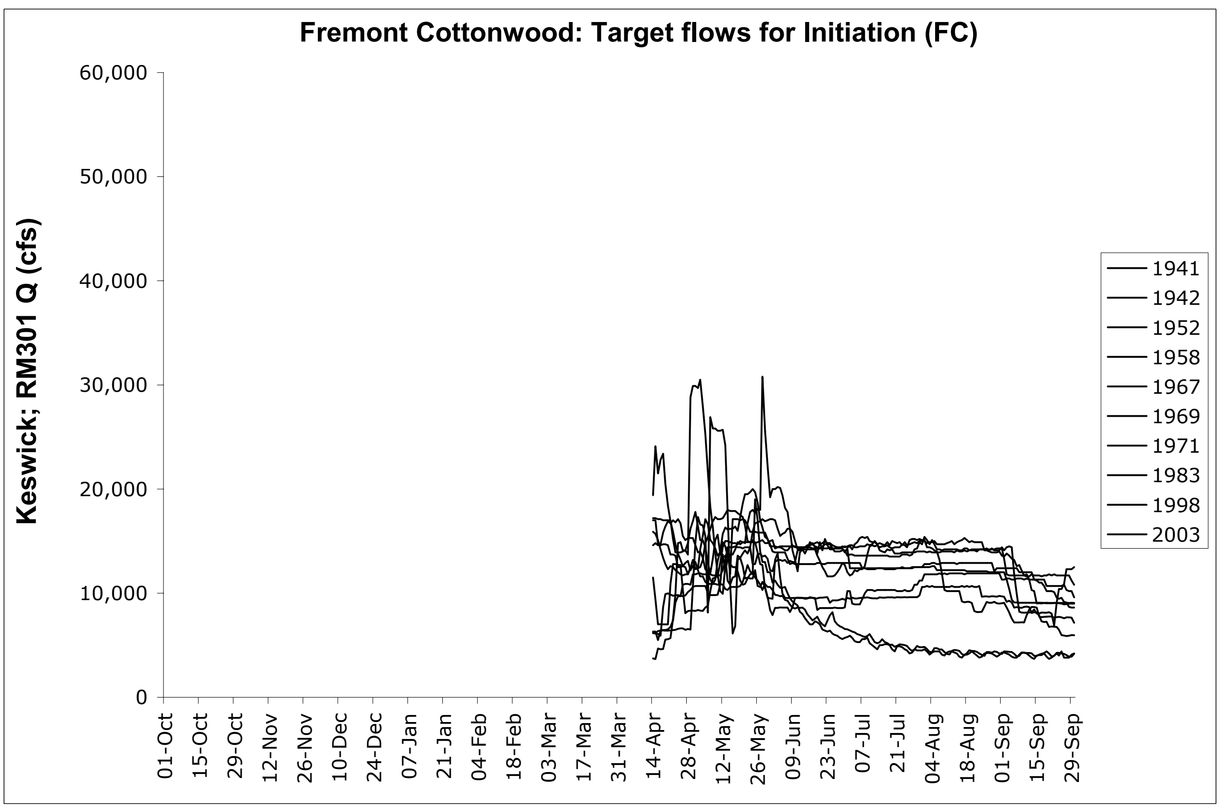

Late Fall Chinook: Target flows for WUA Rearing (CH2)
Keswick Q (cfs)
25,000
22,500
20,000
17,500
15,000
12,500
10,000
7,500
5,000
2,500
0
01-Oct 15-Oct 29-Oct 12-Nov 26-Nov 10-Dec 24-Dec 07-Jan 21-Jan 04-Feb 18-Feb 03-Mar 17-Mar 31-Mar 14-Apr 28-Apr 12-May 26-May 09-Jun 23-Jun 07-Jul 21-Jul 04-Aug 18-Aug 01-Sep 15-Sep 29-Sep
1992
1972
1977
1978
1979
1980
1985
1986
1990
1991
1994

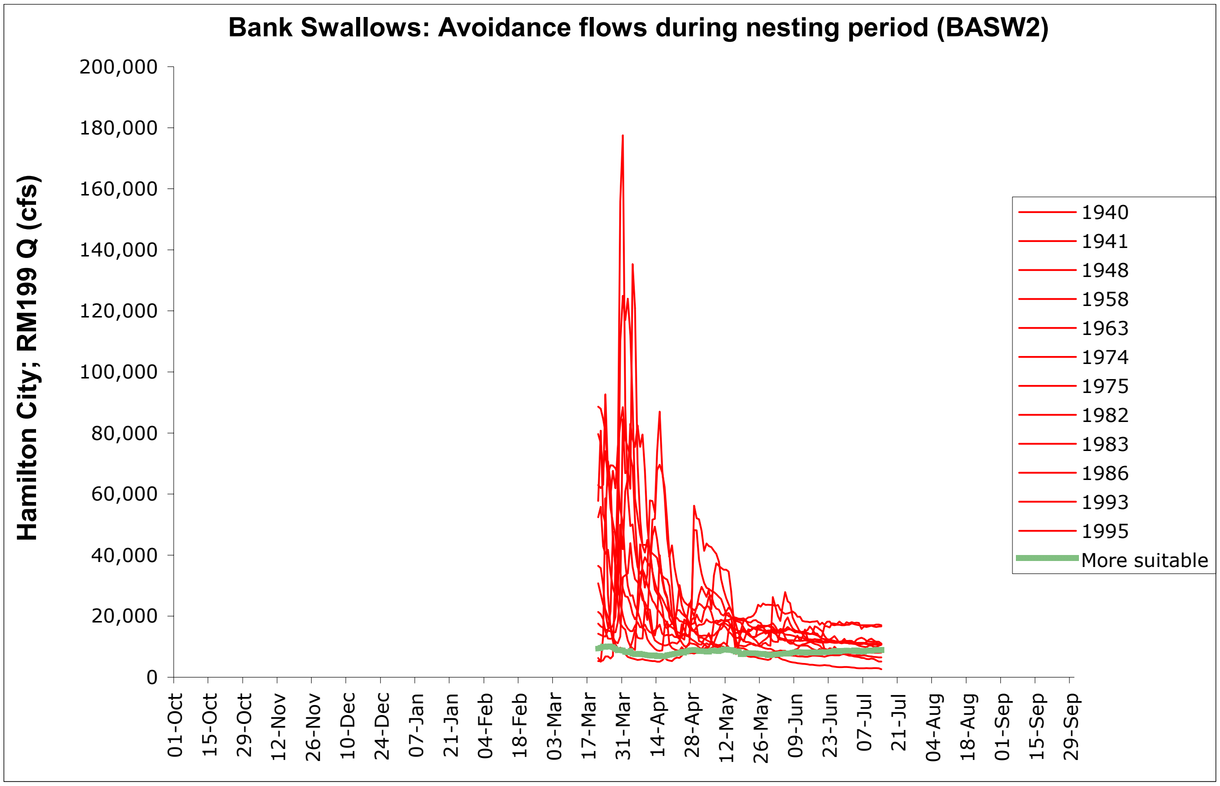

Steelehead: Target flows for WUA Rearing (ST2)
Keswick Q (cfs)
25,000
22,500
20,000
17,500
15,000
12,500
10,000
7,500
5,000
2,500
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1992
1972
1977
1978
1979
1980
1981
1985
1987
1989
1990
1991
1993
1994
1997


Spring Chinook: Avoidance flows - juvenile stranding (CH4)
Keswick Q (cfs)
60,000
50,000
40,000
30,000
20,000
10,000
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1978
1987
1989
1990
1991
1992
1993
1994
2001
.e.g., safe hydrograph
More suitable


SacEFT - Chinook & Steelhead Juvenile Stranding Report
Distribution
Good
OK
Bad
Stranding
Cumulative
Index of Total Juvenile Population Stranded
Period of Interest
Flow (kCFS)
Graphs
Details
Data


Fremont Cottonwood: Target flows for Initiation (FC)
Hamilton City; RM199 Q (cfs)
60,000
50,000
40,000
30,000
20,000
10,000
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1941
1942
1952
1958
1967
1969
1971
1983
1998
2003


Fremont Cottonwood: Target flows for Initiation (FC)
Keswick; RM301 Q (cfs)
60,000
50,000
40,000
30,000
20,000
10,000
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1941
1942
1952
1958
1967
1969
1971
1983
1998
2003


Bank Swallows: Avoidance flows during nesting period (BASW2)
Hamilton City; RM199 Q (cfs)
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec
07-Jan
21-Jan
04-Feb
18-Feb
03-Mar
17-Mar
31-Mar
14-Apr
28-Apr
12-May
26-May
09-Jun
23-Jun
07-Jul
21-Jul
04-Aug
18-Aug
01-Sep
15-Sep
29-Sep
1940
1941
1948
1958
1963
1974
1975
1982
1983
1986
1993
1995
More suitable