Trinity River Restoration Program

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MEMORANDUM

TO: TRINITY MANAGEMENT COUNCIL (TMC), JENNIFER FALER, INTERIM EXECUTIVE DIRECTOR, TRINITY RIVER RESTORATION PROGRAM (TRRP)

FROM: ERNIE CLARKE, SCIENCE PROGRAM COORDINATOR, TRRP

CC: 2010 KLAMATH LATE-SUMMER FLOW AUGMENTATION EVALUATION WORKING GROUP

SUBJECT: KLAMATH RIVER SPECIAL FLOW RELEASES

DATE: AUGUST 30, 2010

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1) Background.

   a) In September 2002, a significant fish die-off occurred in the lower Klamath River. Though estimates vary, the US Fish and Wildlife Service reported that over 34,000 adult fish died, comprised primarily of fall-run Chinook Salmon. Carcasses were observed between September 18 and October 1, 2002 within the lower 36 river miles, extending from the estuary upstream to Coon Creek Falls.

   b) In the 2004 report released by the California Department of Fish and Game, the die-off was attributed to the pathogens *Ich* and *Columnaris*, though several other contributing factors were cited, including an above-above average run size, low flow rates, and correspondingly high river temperatures.

   c) Because hydrologic conditions in late August and early September of 2003 and 2004 appeared somewhat similar, Reclamation, in cooperation with the tribes and regulatory agencies, sought to identify and implement measures to prevent a similar die-off. Water was released from Trinity Reservoir in both those years, with volumes totaling 34,000 acre-feet and 36,000 acre-feet, respectively.

   d) A multi-agency group was formed by the TMC on March 31/April 1, 2010 to consider special flow releases to reduce the risk of another epizootic disease outbreak in fall run Chinook salmon in the lower Klamath River. The TMC assigned the group six specific objectives. The response to each objective is included in Attachment A.

e) The projected in-river fall Chinook salmon run for 2010 is 110,700 adults, slightly above the mean from 1978 to 2009.

f) The working group met on April 19, May 10, June 28, July 12, and August 10, 2010.

g) Working group participants and dates of participation are listed in Attachment B.

2) 2010 Recommendation –The group's work culminated in the development of criteria and protocols for special flow releases for 2010.

a) General information.

i) Location – discharge triggers are associated with U.S. Geological Survey Site #11530500 (Klamath River near Klamath, California).

ii) Period of concern – coincides with the migration season for fall Chinook salmon which is from the last week of August through the third week of September. This period could be adjusted to accommodate abnormal circumstances (e.g. exceptionally late run).

iii) Water source – is considered unimportant for successfully preventing an Ich outbreak. Water may be provided from the Bureau of Reclamation facilities on the Klamath or Trinity Rivers or by PacifiCorp on the Klamath River.

b) Preventative releases – designed to avert a fish die-off.

i) IF flows are below 2,500 cfs in the lower Klamath during the migration season THEN release water to increase base flows to at least 2,500 cfs.

ii) Forecasts and real-time discharges will be monitored by TRRP staff to determine if releases need to be augmented. Projected flows will be determined by the National Weather Service Advanced Hydrologic Prediction Service 5-day forecast for Klamath near Klamath, CA available online at: http://water.weather.gov/ ahps2/index.php?wfo=eka. Real-time flows are measured by the USGS Gauge #11530500 Klamath River near Klamath, CA available online at: http://waterdata.usgs. gov/ca/nwis/current/?type=flow.

iii) Based on present forecasts, it is anticipated that lower Klamath flows will exceed 2,500 cfs during the period of concern in 2010.

c) Emergency releases –designed to decrease the severity of a fish die-off if real-time monitoring indicates a rapid spread of the incidence of Ich. It appears unlikely that emergency flows can impact prognosis for individual, diseased fish. Emergency releases must be made within hours of triggering conditions.

i) IF there are multiple severe confirmed Ich infections THEN immediately release water to double pre-existing base flows in the lower Klamath. Double flows will be maintained for seven days. Multiple is defined as more than one fish. Severity is judged by disease experts with the Yurok Tribal Fisheries Program and U.S. Fish and Wildlife Service's California-Nevada Fish Health Center

ii) A single incidence of Ich will lead to greater effort and confirmation by fish disease experts.

iii) The Yurok Tribal Fisheries Program, in cooperation with U.S. Fish and Wildlife Service's California-Nevada Fish Health Center, will monitor and report on the incidence and severity of Ich.

3) Supporting Documentation – the working group prepared several documents while addressing TMC objectives and developing a 2010 recommendation. These are included as attachments to this memo.

   a) Attachment C – Josh Strange's report "Summary of Scientific Evidence to Guide Special Flow Releases to Reduce the Risk of Adult Fall Chinook Salmon Mass Disease Mortality in the Lower Klamath River".

   b) Attachment D – Joe Polos' memorandum "Summary of Klamath Fall Chinook salmon runs and fall flows in the lower Klamath River, 1978-2009".

   c) Attachment E – Eric Peterson's report "Forecasting flows on the lower Klamath River in late summer with empirical models".

   d) Attachment F - Instructions for the National Weather Service discharge forecast tool.

   e) Attachment G - Meeting summaries (April 19, May 10, June 28, July 12).

4) Future Years.

   a) The results of the previous year's recommendations/actions will be summarized in an after-action report.

   b) The 2010 recommendation will serve as a starting point.

   c) Release criteria and protocols will be reviewed annually to incorporate new information and data as appropriate, including the results of annual adult Chinook salmon pathology monitoring.

   d) The group will consider two-step proactive criteria where the flow threshold depends on the projected run size.

   e) National Weather Service discharge forecast will be used to predict flows.

5) Policy Concerns – members of the working group identified several important concerns that, while beyond the scope of our effort, may impact the execution of special flow releases. We therefore bring these to the TMC's attention:

   a) There needs to be clarification of the need to purchase water stored and how the 50,000 acre-feet of Humboldt County water may be used to address flow needs in excess of those identified in the Record of Decision.

   b) Flow conditions in the Klamath River below the Trinity River confluence are influenced by operation of Reclamation facilities including those on Trinity River mainstem, Upper Klamath Lake and Klamath mainstem, and in Klamath River tributaries including Jenny Creek and Fourmile Creek. Given the influence of these federal projects on Klamath flows, Reclamation staff from the Klamath Project, Rogue River Basin Project and Trinity River Division of Central Valley Project are fundamental in planning for flow management.

   c) Carryover of fishery water supply has not been possible to date. There are instances in which "banking" of water behind Trinity Dam would provide flexibility in meeting fishery needs in subsequent years.. There is therefore a need to reconsider the policy on carryover storage for fishery water volumes.

Attachment A

TMC Objectives with Responses

1. Compile available information (e.g. CDFG Causative Factors Report, FWS Fish Die Off report, Yurok report) (this effort should be exhaustive)

RESPONSE: The working group assembled the available information and considered it in formulating its recommendation. Attachment B, Josh Strange's report "Summary of Scientific Evidence to Guide Special Flow Releases to Prevent Adult Fall Chinook Salmon Mass Disease Mortality in the Lower Klamath River", includes a list of references.

2. Review triggers established previously and determine if they were beneficial.

RESPONSE: While the working group reviewed the triggers used in previous years, the criteria and protocols suggested for 2010 are based on the evidence available and the professional judgment of the group.

3. Develop forecast for the lower Klamath at Turwer to determine if triggers are likely to be tripped

RESPONSE: Forecasts were made utilizing two different forecasting strategies (Attachments D and E). Based on both forecasts, it appears that discharges in the lower Klamath will exceed proactive flow thresholds. Regardless, the team will use short-term forecasts and real-time flow information to maintain desired levels.

4. If so, what would alleviate the problem? Consider solutions on both sides.

RESPONSE: The water source is considered unimportant for successfully preventing an Ich outbreak. Water may be provided from the Bureau of Reclamation facilities on the Klamath or Trinity Rivers or by PacifiCorp.

5. If so, would it be helpful to release additional Trinity water?

RESPONSE: Please see the response to objective 4.

6. If so, how?

RESPONSE: For a proactive release, flows would be maintained above 2500 cfs in the lower Klamath. For an emergency release, flows would be immediately doubled for a duration and maintained at that level for a period of seven days.

Attachment B

Working Group Participants

Participant	Meeting Date				
	04/19/10	5/10/10	6/28/10	7/12/10	8/10/10
Andrea Davis (HVTF)		x			
Buford Holt (Reclamation NCAO)		x		x	
Charlie Chamberlain (USFWS Arcata)	x				
Danny Jordan (HVT)			x	x	
Don Reck (Reclamation NCAO)					x
Eric Wiseman (USFS)	x	x	x		
Ernie Clarke (USFWS Weaverville)	x	x	x	x	x
George Kautsky (HVTF)			x		
Joe Polos (USFWS Arcata)		x	x		
John Hicks (Reclamation KBAO)	x	x			
Josh Strange (YTFP)		x	x	x	x
Keith Schultz (Reclamation KBAO)					x
Larry Hanson (Ca. DFG)		x		x	
Mike Belchik (YTFP)					x
Mike Berry (Ca. DFG)		x	x	x	
Mike Orcutt (HVTF)			x	x	x
Robert Franklin (HVTF)	x		x	x	
Scott Foott (USFWS Fish Health Center)	x				
Seth Naman (NOAA Fisheries)		x	x	x	
Thomas Weseloh (TAMWG / Ca. Trout)				x	
Tim Hayden (YTFP)	x		x	x	

In addition to the meeting participants listed above, others provided input:

1. Eric Peterson of Reclamation / TRRP and Robert Hartman of the National Weather Service provided a flow forecasting tool
2. Nina Hemphill of Reclamation / TRRP and Nick Hetrick and Tom Shaw of USFWS / Arcata reviewed working group products
3. Rod Wittler of Reclamation / TRRP provided operational considerations

Attachment C

Josh Strange's report "Summary of Scientific Evidence to Guide Special Flow Releases to Reduce the Risk of Adult Fall Chinook Salmon Mass Disease Mortality in the Lower Klamath River"

Summary of Scientific Evidence to Guide Special Flow Releases to Reduce the Risk of Adult Fall Chinook Salmon Mass Disease Mortality in the Lower Klamath River

Joshua Strange, Yurok Tribal Fisheries Program
August 16th 2010

Executive Summary

Klamath and Trinity basin adult fall-run Chinook salmon are especially vulnerable to *Ichthyophthirius multifiliis* (Ich) infections due to their tendency to hold and congregate extensively in the lower Klamath River (i.e. below the confluence of the Trinity River) under all river flow conditions. Given restoration targets, achieving large run sizes on a regular basis should be anticipated by managers in fish disease planning. Current temperature dynamics result in warm river conditions during the peak of the fall salmon migration season annually, a situation that can not be ameliorated pending removal of the Klamath River hydroelectric dams or exceptionally large releases from Trinity Dam. Warm water temperatures, while stressful and accelerating, are not necessary for an Ich outbreak. Thus protective, proactive river flows are the only readily available management tool for effectively reducing the risk of catastrophic Ich outbreaks. Fortunately, ensuring sufficiently high river base flows is also the most effective tool for preventing and abating Ich outbreaks.

The key to understanding the 2002 fish kill in the lower Klamath River lies not in the biology of the fish, but in the biology of the parasites, particularly Ich. The key aspect of Ich biology is the probability that its infectious free-swimming life stage can encounter and successfully attach to a fish host during the 72 hour period it can survive without being in a host.

The risk of Ich epizootic fish kills are primarily determined by three probabilities:

- The probability an infectious free-swimming stage of Ich will locate and attach to a fish within 72 hours;
- The probability of susceptibility of that fish to infection and the resulting severity;
- The probability and rate of infection spreading to other fish.

Those three probabilities are in turn are strongly affected by four primary variables: 1) river flow; 2) run size; 3) residence time of the fish in the infectious zone; and, 4) water temperature. No one of these four variables is sufficient by itself to facilitate an epizootic, but in proper combination they can create prime conditions for the rapid spread of severe Ich infections. Each Ich infection in turn produces more infectious parasites and also provides an opportunity for columnaris infection through the Ich entry hole.

The one variable that can be overtly influenced by managers is the flow of the river, with a minimum base flow of 2,500 cfs detailed herein as necessary to avoid another fish kill under most circumstances, and 2,800 cfs necessary at minimum during years of large projected run sizes ($\geq$ 170,000 fall Chinook salmon). Large pulsed flows such as during 2003 and 2004 from the Trinity River are unnecessary since adult fall Chinook salmon tend to ignore pulsed flows, and higher base flows still impede the infectivity and spread of Ich. The key with higher flows is not greater water volume per se but the associated increased water velocities and higher turnover rates of water in holding areas, which disrupts Ich's ability to find and attach to a host fish during its free swimming infectious stage. Sufficiently high water velocities and turnover rates need to be maintained throughout the primary fall Chinook salmon migration season (last week of August through the third week of September under normal circumstances). A proactive, preventative approach is necessary because the time lag between detection of an impending epizootic and arrival of a reactive, emergency flow release could result in no benefit to salmon survival. There will be an inherent risk of using water when conditions are less dangerous than projected, but the tradeoff is the risk of another massive fish kill that could be avoided. The source of water is unimportant even if it contains background levels of Ich parasites.

Introduction

The lethal agent in the 2002 Klamath River fish kill, which resulted in an estimated 32,553 to over 65,000 dead adult Chinook salmon in the lower 58 kilometers (Figure 1), was an epizootic outbreak caused by the protozoan parasite *Ichthyophthirius multifiliis* (Ich) and the bacterium *Flavobacterium columnare* (columnaris) (Foott 2002; Guillen 2003; Belchik et al. 2004; Turek et al. 2004). Minor numbers of other fish species were also killed.

Columnaris is ubiquitous in the Klamath River basin and affects the skin and gills of salmonids. In general, healthy fish are resistant to columnaris (Shotts and Starliper 1999); however, infections can develop due to environmental stress, minor injuries to the skin or gills, or the presence of other pathogens such as Ich (Figure 2). Environmental stress can include overcrowding, capture or pursuit stress, low dissolved oxygen, high temperatures, toxins, and high organic loads (Thune 1993). Columnaris infection is usually secondary to other pathogens that penetrate the epithelium, such as Ich (Plumb 1999).

Ich is a ciliated protozoan parasite (Figure 3) found throughout the world and is presumed to be native to the Klamath River basin. Outbreaks of Ich occur when conditions are favorable for rapid multiplication of the parasite, which spreads horizontally from fish to fish with trophonts attacking gills and other epithelium surfaces resulting in death by asphyxiation. These conditions include, but are not limited to, a suitable environment and susceptible fish. Ich epizootics occur when fishes are stressed and crowded, flows are relatively low, and are worsened by elevated water temperatures (Dickerson and Dawe 1995). For example, Butte Creek spring Chinook salmon experienced severe disease mortality (3,400 out of 16,000 fish in 2002, and 11,200 out of 17,300 fish in 2003) from Ich (and columnaris) during pre-spawn holding (CDFG 2004) in pools with elevated temperatures and artificially low flows. High water temperatures are not necessary for an Ich outbreak, however, as significant Ich mortality has occurred in British Columbia in low flow spawning channels at 13 to 15°C (Traxler et al. 1998). High water temperatures do favor outbreaks by increasing fish stress and Ich reproduction rates (approximately 7 days to complete the life cycle at 20°C) but high temperatures alone cannot trigger an outbreak. For example, Klamath River water temperatures have been favorable for Ich outbreaks in past decades, but 2002 was the only year on record to experience an outbreak, which was also the first ever documented mortality due to Ich in the Klamath River basin (Belchik et al. 2004). Factors such as low flows, high fish densities, and long fish residence times are believed to be the main contributing factors to the disease outbreak of 2002 (Guillen 2003; Belchik et al. 2004; Turek et al. 2004).

Fish Densities and Residence Times

A potential obstacle encountered by all migrating salmon in the Klamath River basin during summer and fall base flow conditions are shallow riffles such as found in the lower Klamath River, which could potentially impede migration and increase fish densities and residence times. The shallow riffle just below Pecwan Creek at rkm 40 is especially notable. In 2006, sonic receivers where placed immediately above and below the Pecwan riffle to determine if there was a slowing in salmon migration rates at the riffle (Strange 2007a). No evidence was found among tagged adult Chinook salmon in 2006 for a decrease in migration rates or migrational delays at the Pecwan riffle (minimum flow of 2,900 cfs). In 2007, this receiver deployment was repeated and again no evidence for a decrease in migration rates or migrational delays at the Pecwan riffle was observed (minimum flow of 2,600 cfs) (Strange 2008). There was also no consistent relationship between river flow and passage rate at Pecwan riffle (Strange 2008).

Another potential obstacle encountered by migrating salmon in the Klamath River basin are excessively high water temperatures. In such cases, migratory movement becomes too energetically and physiologically costly and salmon must suspend migration, and if possible, seek and use cold water thermal refuges (e.g. Goniea et al. 2006). Based on analysis of multiple years of biotelemetry data, mean daily temperatures of 23.0°C represent the upper thermal limit to migration for adult Chinook salmon in the Klamath River basin, with corresponding mean weekly temperatures of 22°C and mean weekly maximum temperatures of 23°C (Strange 2010). Temperatures above these metrics appear to completely block migration in almost all circumstances; however, fish are sensitive to trends in water temperatures and tend to be more conservative in migrating during period of rising water temperatures such as during a heat wave and more aggressive during periods of falling water temperatures such as with the passage of a major storm front (Strange 2010). Water temperatures were below the upper thermal limits to migration prior to and during the 2002 fish kill. Analysis of approximately 50 years of historic water temperature data from the lower Klamath and Trinity rivers revealed that, on average, the last day that mean daily water temperatures exceed 22°C was Sept 1st and Sept 15th for 20°C (YTFP unpublished analysis). Based on coded wire tag recovery data over approximately the last decade, peak estuary entry timing for Klamath hatchery fall Chinook salmon is Julian week 35 (week ending Sept 2nd) and

Julian week 36 to 37 (week ending Sept 16th) for Trinity hatchery fish, thus thermal blocks to migration are not typically an issue for adult fall Chinook salmon migration in the Klamath River basin. Even without thermal blocks, higher temperatures due increase the reproductive rate of Ich and can contribute to physiological stress in fish. There are, however, no readily available means for significantly reducing water temperatures annually in the lower Klamath River, with the exception of removal of the Klamath hydroelectric dams or exceptionally large releases from Trinity Dam. Removal of the Klamath hydroelectric dams is predicted to result in accelerated autumn cooling creating a decreasing thermal gradient as fish migrate upstream in the mainstem Klamath River as opposed to the current conditions wherein the thermal gradient increases as fish migrate upstream (Bartholow et al. 2005). In summary, available evidence does not support migration blockages as an important mechansim affecting fish densities of fall run Chinook salmon in the lower Klamath River.

Run size, however, is a factor that logically affects fish density of fall run Chinook salmon in the lower Klamath River. Examining run size since 1978 illustrates that run size fluctuates widely with an average of approximately 121,000 fish (Figure 4; run size estimates are only available back to 1978). In 2002 the estimated run-size was 170,000 fish, which obviously resulted in fish densities sufficient for an Ich epizootic. In contrast, 1988 had equivalent low flows as 2002 with a run-size of over 200,000 fish and no epizootic. The lowest recorded flows in the lower Klamath River since 1978 occurred in 1994, which had a run-size of approximately 80,000 fish and no epizootic, suggesting that fish densities may have been below a presumptive threshold of fish density necessary for an Ich outbreak in the lower Klamath River. The variability demonstrated by these three years highlights the uncertainty in determining a threshold value of run size that produces fish densities sufficient to allow an Ich outbreak in the lower Klamath River, which coupled with the large error associated with pre-season run-size projections, negates the usefulness of measures of fish density as the primary criteria for determining the need for special flow releases. Furthermore, fish tend to congregate in schools resulting in close inter-fish spacing such as observed among adult Chinook salmon in the lower Klamath River (Figure 5) and Butte Creek (Figure 6) even at relatively low fish densities, which facilitates the fish-to-fish transmission of pathogens such as Ich.

In addition to run size, migration behavior can affect fish residence times and densities. Biotelemetry data from 2003 to 2007 has documented extensive holding in deep pools and slowed migration of adult fall run Chinook salmon in the lower Klamath River between Blue Creek (rkm 26) and the confluence of the Trinity River (rkm 70). Both Klamath and Trinity river fall Chinook salmon stocks have exhibited this behavior (Figure 7). This behavior has occurred consistently during all study years throughout the fall migration season and under a wide range of river flow and temperature conditions, thus providing strong evidence that this behavior is a normative strategy for fall Chinook salmon under current conditions. While this behavior appears normative, it also greatly increases the vulnerability of adult fall Chinook salmon to Ich outbreaks and other contagious pathogens if sufficiently low flows occur concurrently.

River Flows and Special Flow Releases

Flow has been shown to be of paramount importance in controlling and preventing Ich outbreaks in controlled experimental settings (Bodensteiner et al. 2000), and artificially reduced stream flows have been a key component of all known Ich outbreaks among adult Pacific salmon (i.e. Brititsh Columbia, Butte Creek, and Klamath River). Analysis of summer and fall minimum flows in the lower Klamath River basin (at rkm 13) show that flows below 2,500 cfs occur infrequently and flows near or below 2,000 cfs such as during the 2002 fish kill have occurred in only five years since 1978: 1988, 1991, 1992, 1994, and 2002 (Figure 8; only flows since 1978 have been used in this analysis because run size data is only available since 1978 for comparisons). Conversely, flows of approximately 2,500 cfs have occurred frequently since 1978 without any Ich outbreaks including as recently as 2001, 2007, 2008, and 2009. Based on this line of reasoning, flows in the lower Klamath River of 2,500 cfs are the minimum required for a reasonable level of confidence that an Ich outbreak is unlikely to occur with disease risk decreasing as flows increase beyond this minimum threshold. Flows below 2,500 cfs are likely to result in substantial risk of an epizootic with risk increasing as flows further decrease. Flows at or below 2,000 cfs are likely to result in an unacceptable high level of risk of an epizootic under all circumstances. Using a completely different technique, CDFG staff identified ≤ 2,200 cfs at Orleans plus Hoopa (approximately equivalent to 2,500 cfs at Klamath rkm 13 based on mean monthly flow for September at these three sites) as a threshold for substantial fish kill risk and a target for fish kill prevention flows (Turek et al. 2004).

During years with large projected run sizes, even higher base flows are recommended in order to maintain protective conditions as compared to years with smaller projected run sizes. At low flows (i.e. > 2,500 cfs) even the lower fish densities associated with small run sizes could be sufficient to allow for the initiation of an Ich outbreak. Higher fish densities associated with larger runs may not result in higher risk of an Ich outbreak initiating, but larger numbers of fish would logically increase the speed and inertia of the spread of an Ich outbreak due to the higher number of infectious theronts released at the completion of each successive Ich life cycle (e.g. 10,000 infected fish can produced vastly more infectious theronts than 1,000 infected fish). Due to this dynamic, extra caution is needed during years when run sizes are projected to be large (defined as greater than or equal to the run size in 2002 of 170,000 fall Chinook salmon). The higher the flow the lesser the risk of an Ich outbreak (e.g. 3,100 cfs is more protective than 2,500 cfs); however, an additional release of 300 cfs is recommend as the minimum increase required to decrease the level of risk during years with large run sizes. Thus the threshold for special flow releases herein increases from 2,500 cfs to 2,800 cfs during years with a projected run of ≥ 170,000 fall Chinook salmon.

Special flow releases to reduce the risk of epizootics in the lower Klamath River should increase base flows above the threshold levels during the fall Chinook salmon migration season as opposed to a large pulsed flow. Using a higher base flow strategy with trigger thresholds as opposed to a large pulsed flow strategy also has the benefit of reducing the volume of water needed and lessening non-target ecological effects. Higher base flows will not have the effect of flushing more highly infectious water into the lower Klamath

River, since Ich is ubiquitous and background levels of Ich are minimal. Outbreaks occur when environmental conditions lead to an initial localized group of congregating, infected fish shedding parasites and thereby building the abundance of infectious parasites above background levels leading to the beginning of epizootic cycle. The proactive special flow releases prescribed herein are designed to prevent the beginning stage of the Ich epizootic cycle from starting by maintaining sufficiently high base flows in the lower Klamath River.

Special flow releases from Klamath River basin dams have been previously used to reduce the risk of disease outbreaks for fall run Chinook salmon. During late August and early September of 2003 and 2004, a pulse of water was released from Lewiston Dam with the goal of avoiding a repeat of the 2002 fish kill. Scientists and river managers convened by the United States Bureau of Reclamation's Trinity River Restoration Program hypothesized these pulse flows would trigger adult Chinook salmon to migrate out of the lower Klamath River, thereby reducing fish densities and the risk of disease infection and mortality. Based on biotelemetry data from tagged Chinook salmon in 2003 and 2004, upriver movement was not triggered by these pulse flows except for the relatively minor portion of fish that were already holding at en route thermal refuges (i.e. cold creek confluences)(Strange 2003 and 2006; Naman 2005). This conclusion is further supported by results from 2005, a year with no fall pulse flow aside from the two-day Trinity boat dance flow (Strange 2007b). Tagged Klamath fall Chinook migrants in 2005, 2006, and 2007 displayed equivalent movement patterns as Klamath fall Chinook migrants in the 2003 and 2004 fall pulse flow years; both before, during, and after the pulse flows. This relationship was especially apparent for Klamath fall Chinook migrants but also held true for Trinity fall Chinook migrants (Figure 7). The lack of movement associated with pulse flows was also observed during tribal ceremonial flows releases (e.g. boat dance flows) from Lewiston and Iron Gate dams. Given the lack of salmon movement observed in response to the pulse flows of 2003 and 2004, the potential for untimely premature migration into the Klamath River above the Trinity River does not appear likely, as corroborated by boat-based visual surveys during 2003 and 2004 (Stutsman and Hayden 2004; Stutsman 2005). Simply stated, consistent movement patterns with or without pulse flows is compelling evidence that such flows do not trigger upriver movement or substantially alter migration behavior among adult Chinook salmon in the Klamath River basin.

Understanding why there was virtually no response to any of the pulse flows among fall Chinook salmon in the lower Klamath River requires remembering the evolutionary axiom of adaptation to long term average conditions (Gilhousen 1990; Quinn et al. 1997; Hodgson and Quinn 2002). The fall pulse flows were unprecedented in their magnitude and duration for that time of year and thus well outside the range of long term average conditions to which Klamath River basin adult Chinook salmon have adapted. The only natural equivalents are ephemeral and inconsistent flash floods originating in mountainous tributaries.

In the absence of dispersal of adult Chinook salmon in reaction to a pulsed flow, higher flows (i.e. increased base flows) are still the best option for substantially reducing the risk of Ich pathogen transmission and disease mortality. The reduction in Ich risk is accomplished primarily by increasing river flow and secondarily by reducing water temperatures (thermal effects are location and release specific). Most importantly for *Ich*, higher flows increase turnover rates and water velocities that serve to flush out pathogens (ultimately to the estuary where they can't survive in high salinity) and decrease fish-to-fish pathogen transmission (Bodensteiner et al. 2000).

Using a controlled fish culture environment and channel catfish (*Ictalurus punctatus*) as the laboratory animal, Bodensteiner et al. (2000) evaluated fundamental dynamics controlling *Ich* infections and concluded that increasing turnover rates and water velocities are the most effective measure to prevent and stop *Ich* because it disrupted the ciliated free-swimming theront's ability to find and attached to a suitable host within the approximately three day viability period and also flushes theronts our of the fish holding area (Figure 3). The importance of flow will hold true regardless of fish species involved (Bodensteiner et al. 2000). Furthermore, Bodensteiner et al. (2000) found that fish density did not affect *Ich* infection or mortality rates at the densities tested thereby reducing the importance of fish densities in determining Ich risk. One inference of this finding, combined with the biology of Ich, is that fish density likely has an on-or-off threshold relationship (e.g. necessary condition) and not a positive linear relationship with *Ich*. Figure 9 shows the lack of a relationship between Ich mortality and fish density at the densities tested by Bodensteiner et al. (2000), and also illustrates the potential shape of this relationship at fish densities below the threshold necessary for unconstrained Ich mortality. Whether the threshold is abrupt or gradual has management and theoretical implications. Regardless of the true shape of the relationship at lower fish densities, using fish densities as a prediction tool for evaluating the risk of an Ich outbreak is problematic due to the uncertainty in determining the fish density threshold in a given natural setting and because of the substantial and variable error in pre-season run size projections.

Once the true fish density threshold is crossed for a given setting, flow via turnover rates and water velocities are the primary determinants of *Ich* infection and mortality rates (i.e. controlling factors). Given that fall Chinook salmon (Klamath stocks in particular) hold extensively and migrate slowly through the lower Klamath River below the confluence of the Trinity River as part of their apparent normative migration behavior strategy, they are especially vulnerable to *Ich* infection and mortality with pathogen transmission risk increasing as flows decrease. These relationships are consistent with the low flows that occurred before and during the 2002 fish kill as compared to the absence of epizootic outbreaks in years with larger runs but higher flows (Guillen 2003; Belchik et al. 2004; Turek et al. 2004). Run year 1988 is the one exception that had equivalent flows as 2002 with a larger run-size which could indicate the risk of an Ich kill is 50% at such flows or that continued ecological degradation in the Klamath River has increased the risk of Ich outbreaks at such flows. All other years with low flows equivalent or lower than 2002 also had much lower run sizes (e.g. 1994 the next largest run-size at approximately 80,000 fall Chinook salmon), which could suggest that the fish density threshold for an Ich outbreak could be at or above a run of 80,000 fall Chinook salmon for the lower Klamath River.

Since these relationships are likely not field testable in a controlled experimental manner, it is incumbent on river mangers to make risk averse decisions in the face of uncertainty as to the exact turnover rate, water velocity, and fish density thresholds for the lower Klamath River for which there is only one affirmative data point – 2002. Risk adverse decision making is especially critical given on-going cumulative ecological degradation, which could results in increasing disease risk in the future at a given flow. For example, environmental stressors such as high pH, free ammonia, and microcyctins are especially toxic to salmonids and are a known problem during the summer and fall in the Klamath River.

Adult Chinook Salmon Pathology Monitoring

Since 2003, the Yurok Tribal Fisheries Program (YTFP) has conducted real-time monitoring of Ich and columnaris in adult fall Chinook salmon in the lower Klamath River. While columnaris is observed every year and tends to increase with temperatures and maturation level, no Ich has been observed since a few infected fish were documented in 2003 (McCovey 2010). The negligible presence of Ich since 2002 supports the hypothesis of a trigger threshold of flow and run-size for facilitating the degree of fish-to-fish transmission of Ich necessary for an epizootic. The results of this monitoring effort also show that the background levels of Ich are very low within the Klamath River. The adult fall Chinook salmon pathology monitoring project provides an essential long-term data set to evaluate baseline levels of Ich and columnaris infections up to now and into the future, and is vital to assessing the success of any special flow releases. Using data from this real-time pathology monitoring project to provide an early warning system of an impending epizootic is problematic, however, because the time delay between detection in the field, expert confirmation in the lab, implementation of a reactive management action, and arrival of increased flows to the lower Klamath River, which would result in a substantial progression of the epizootic given the warm water temperatures typical during the fall migration season. Thus a proactive, risk adverse management approach is of paramount importance as opposed to reactive, emergency responses.

Criteria and Protocols for Special Flow Releases

Using up-to-date information and analysis, the criteria and protocols for a special flow release from the Trinity River in 2010 to reduce the risk of another epizootic disease outbreak in fall run Chinook salmon in the lower Klamath River are as follows below. Proactive preventative flow releases, as opposed to reactive emergency flow releases, are necessary in order to successfully avert a fish kill although criteria and protocols for an emergency release are included in order to plan for all scenarios. These criteria and protocols will be reviewed annually to incorporate new information and data as appropriate, including the results of annual adult Chinook salmon pathology monitoring. Projected flows for the lower Klamath River (at rkm 13) used in this analysis will be determined by the National Weather Service Advanced Hydrologic Prediction Service 5-day forecast for Klamath near Klamath, CA available online at: http://water.weather.gov/ahps2/index.php?wfo=eka. Real-time flows are measured by the USGS Gauge

#11530500 Klamath River near Klamath, CA available online at: http://waterdata.usgs.gov/ca/nwis/current/?type=flow. The source of water is unimportant for successfully preventing an Ich outbreak. The migration season for fall Chinook salmon defined herein is from the last week of August through the third week of September, but this target period should be adjusted to accommodate abnormal circumstances (e.g. exceptionally late run).

Proactive release

1) Flows projected above 2,800 cfs at rkm 13 during the adult fall-run Chinook migration season = no special flow release;
2) Flows projected below 2,800 cfs at rkm 13 during the migration season and projected run-size at or above 170,000 fish (estimated run size during the 2002 fish kill year) = special flow release to increase base flows to 2,800 cfs during migration season;
3) Flows projected below 2,500 cfs at rkm 13 during the migration season = special flow release to increase base flows to at least 2,500 cfs during migration season regardless of run-size.

Emergency release

1) No preventative release planned;
2) Multiple severe confirmed Ich infections = immediate special flow release with a 7 day duration pulsed spike to double pre-existing base flows followed by a bench release to increase base flows to proactive levels for the remainder of the migration season. A single incidence of Ich would lead to greater effort and confirmation by fish disease experts, which would trigger an emergency release if multiple severe infections were documented. The duration of the 7 day (total duration with ramping) peaked flow release is determined by the life cycle of Ich, which takes 7 days to complete at 20°C.

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Figures

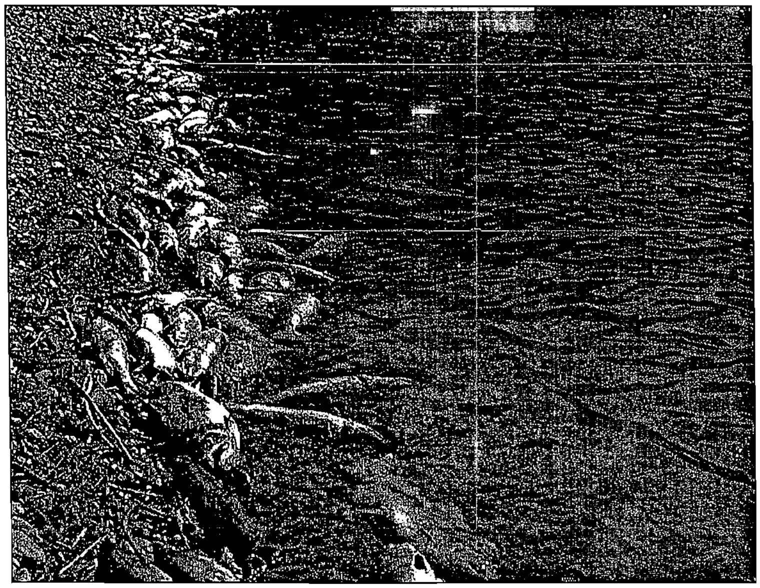

Figure 1. Adult Chinook salmon mortalities during the 2002 fish kill in the lower Klamath River (photo credit: Michael Belchik).

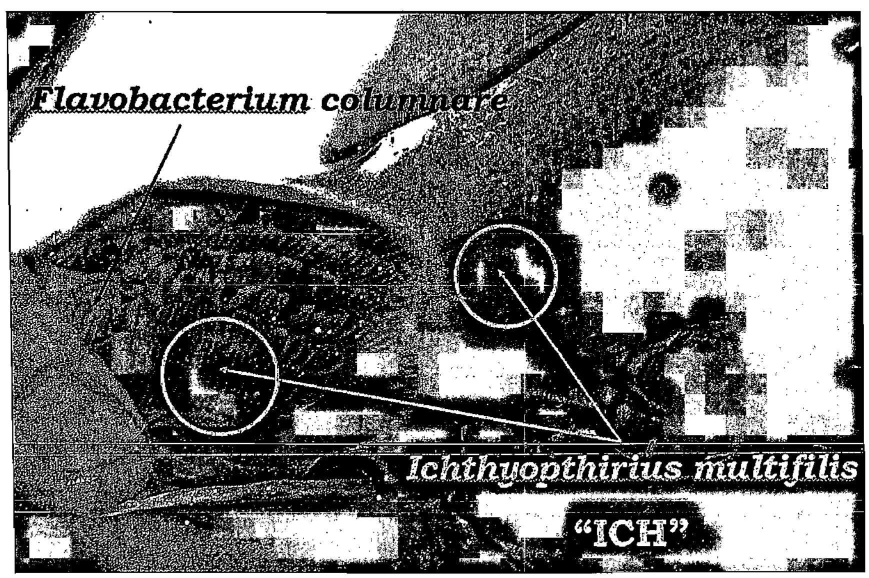

Figure 2. Deceased adult salmonid infected with Ich and columnaris (with secondary fungal infection) during the 2002 fish kill in the lower Klamath River (photo credit: Michael Belchik).

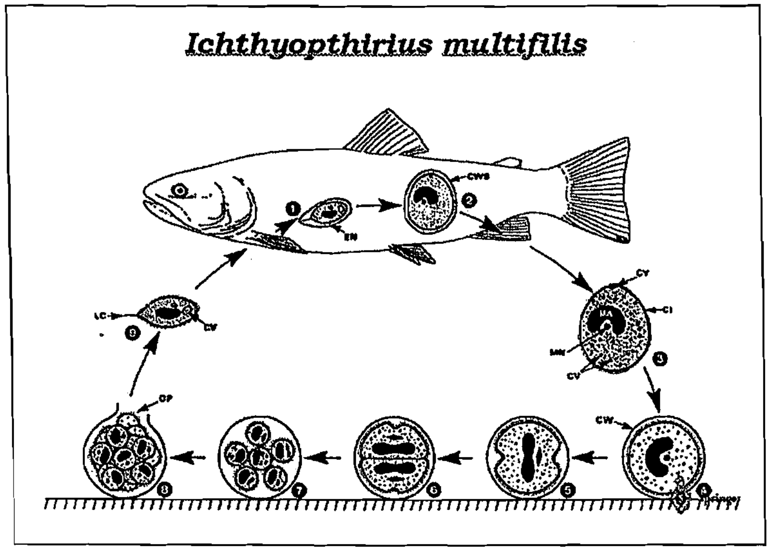

Figure 3. Life cycle of Ich showing the parasitic trophonts stages (#1 and 2), the mature ciliated trophont stage (#3) attaches to benthic substrate before dividing into tomites (#7 and 8), which are then released as the ciliated theront stage (#9) that must actively swim and find a suitable host within approximately 24 to 72 hours.

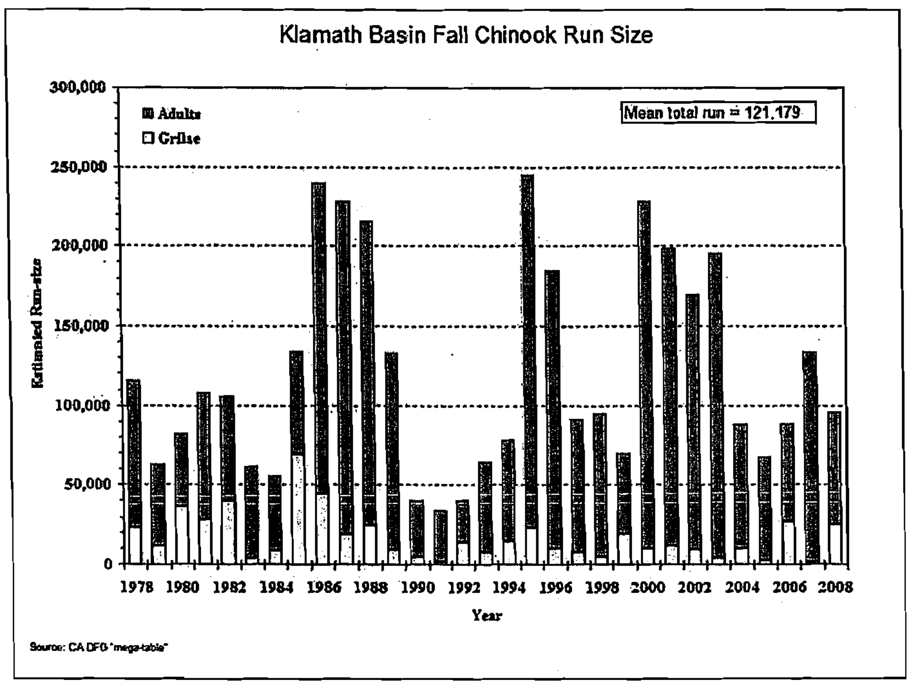

Figure 4. Run size of fall run Chinook salmon in the Klamath River basin from 1978 to 2008. Run years 1988, 1991, 1992, and 1994 had equivalently low base flows as the 2002 fish kill year.

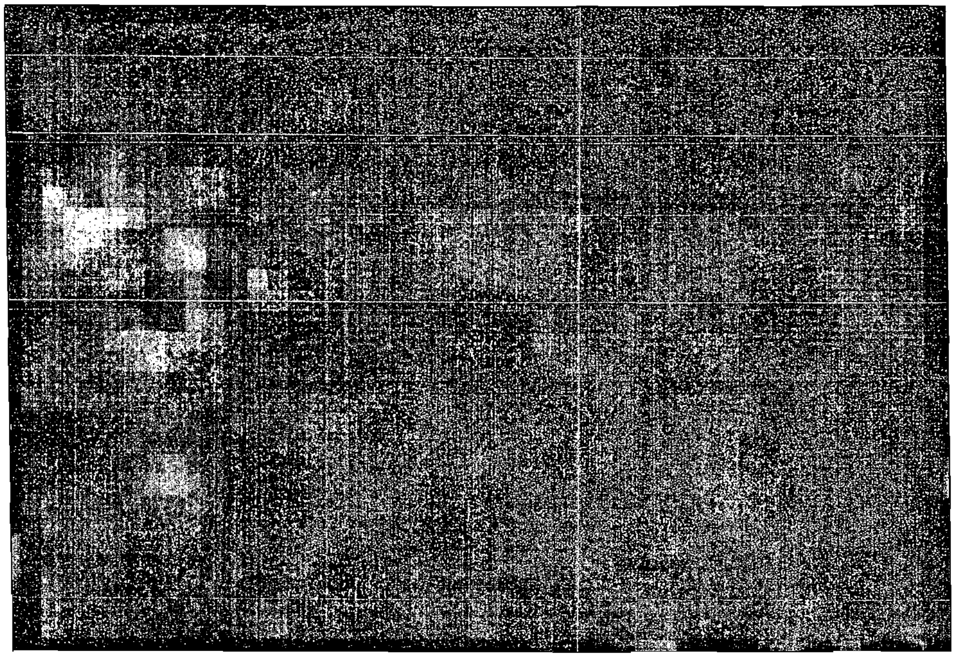

Figure 5. Adult Chinook salmon holding in a lower Klamath River thermal refuge displaying the close inter-fish distance typical of schooling salmon even at low fish densities (photo credit: Barry McCovey Jr.).

Figure 6. Adult Chinook salmon holding in Butte Creek displaying the close inter-fish distance typical of schooling salmon even at low fish densities (photo credit: Thomas Dunklin).

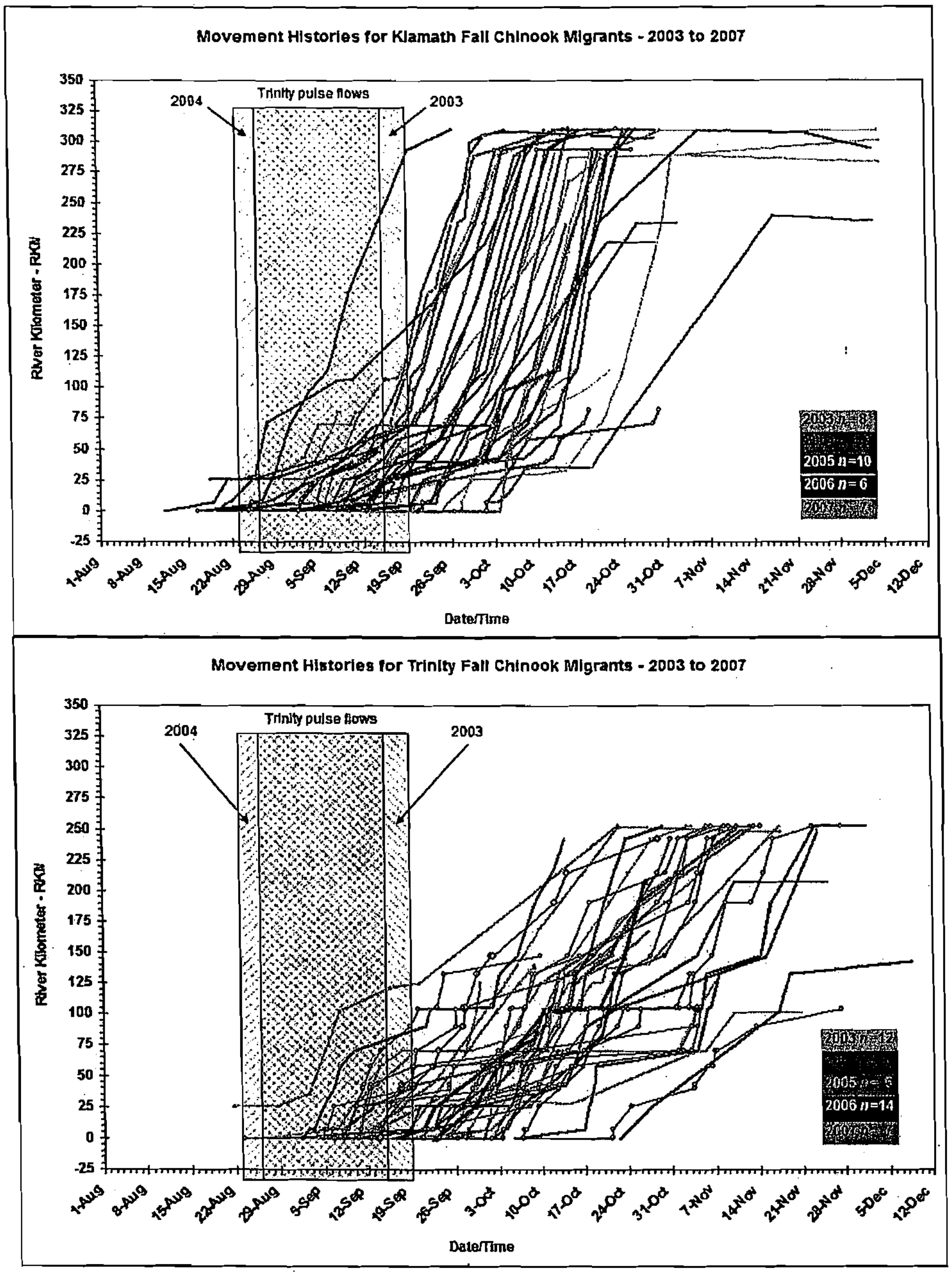

Figure 7. Migration histories of Klamath stock (top graph) and Trinity stock (bottom graph) fall run Chinook salmon determined by biotelemetry from 2003 to 2007 showing the apparently normative slowed migration from rkm 26 to 70 and the absence of movement in response to the large pulse flows of 2003 and 2004 (Strange 2003, 2006, 2007b). There are small pulsed flows of several days annually in late August for tribal ceremonies ("boat dance flows") alternating between the Klamath and Trinity rivers (e.g. 2010 will have a boat dance flow on the Klamath; 2011 on the Trinity).

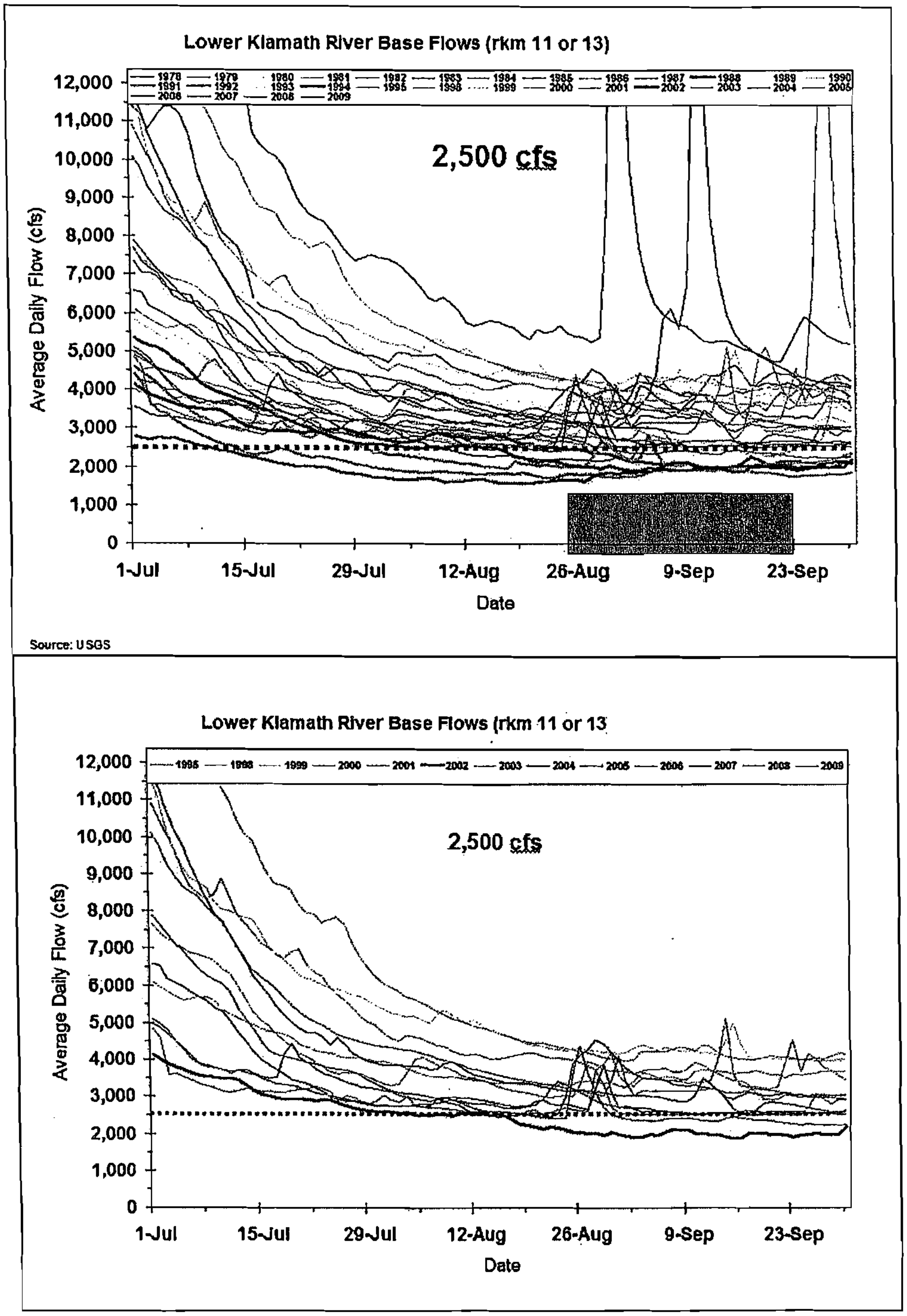

Figure 8. Available flow data for the lower Klamath River (rkm 11 or 13; USGS Gauge #11530500) from 1978 to 2009 (top graph) and from 1995 to 2009 (bottom graph) showing the 2,500 cfs flow threshold below which there is deemed to be a substantial risk of Ich outbreaks regardless of run size. Mean monthly flows for August and September during the period of record are approximately 3,100 cfs.

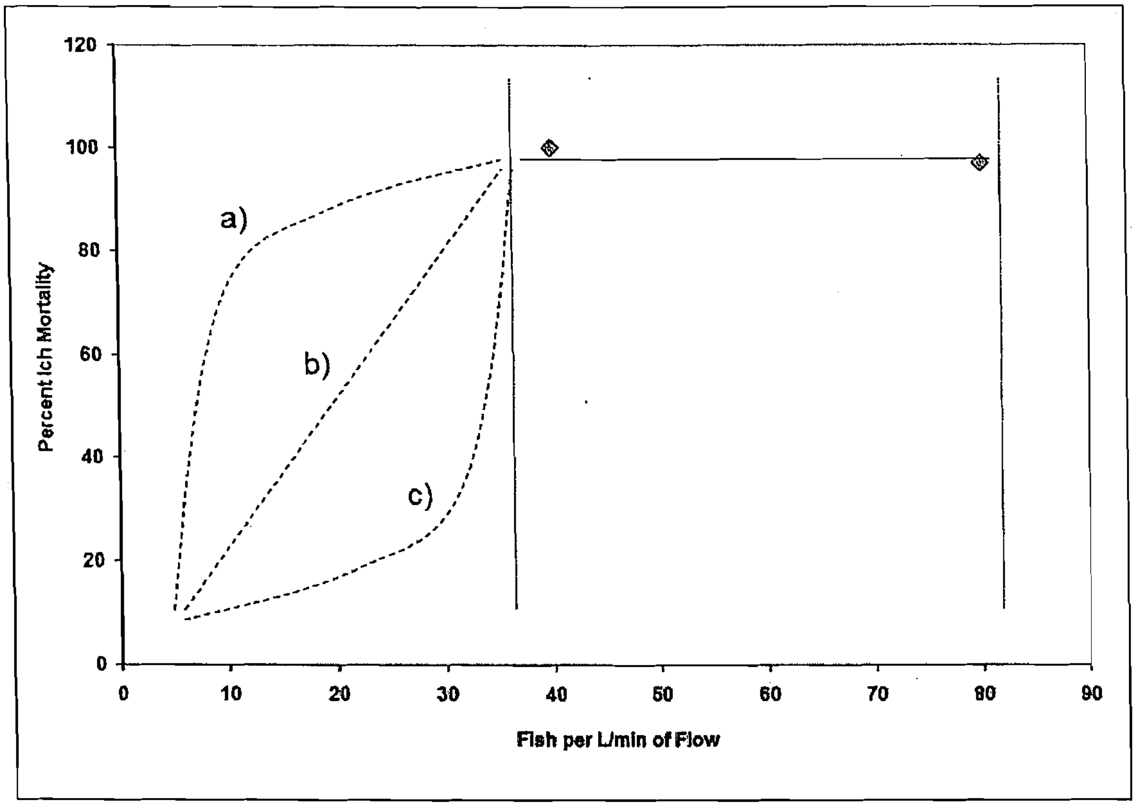

Figure 8. Fish densities at high Ich mortality rates as measured by Bodensteiner et al. (2000) demonstrating the lack of a relationship between fish density and Ich infection at the densities tested due to the paramount importance of flow. Actual fish numbers varied from 200 to 400 fish per unit (for the two points shown above) but the outdoor rearing ponds used in this study had fish numbers of 86,000 to 114,000 fish per unit - 1.06 to 1.4 fish per L/min of flow respectively - with no Ich infections versus heavy infections being produced depending on flow). Fish densities at the lower end approaching zero were not tested in this study; however, hypothetical relationships are illustrated by lines a, b, and c with: a) denoting no on-off threshold, any number of fish above zero can produce high mortality; c) denoting an abrupt on-off threshold relationship that would presumably be situation specific but once a certain threshold number of fish is reached then an Ich outbreak could occur if flow conditions permitted; and, b) denoting any number of possible intermediary more gradual on-off threshold relationships. Which of these possible hypotheses is true is important theoretically but would require more evidence to further inform management strategies.

Attachment D

Joe Polos' memorandum "Summary of Klamath Fall Chinook salmon runs and fall flows in the lower Klamath River, 1978-2009."

June 29, 2010

To: Trinity River Restoration Program, Fall Flow Augmentation Ad Hoc Group

From: Joe Polos, Supv. Fishery Biologist, USFWS-Arcata Fish and Wildlife Office

Subject: Summary of Klamath Fall Chinook salmon runs and fall flows in the lower Klamath River, 1978-2009.

1. Klamath Run Size –

   a. Projections vs Estimated Inriver Run

      Preseason forecast of the Klamath fall Chinook salmon inriver adult run are made by PFMC's Salmon Technical Team while evaluating ocean fisheries. Data available to compare preseason forecasts to post-season inriver run estimates were form 1986-1992 and 2001-2009. While the preseason forecast and post-season inriver run estimate are significantly correlated ($r=0.726$, $n=16$, $p< 0.01$), the relationship is highly variable (Figure 1). The ratio of forecast to the post-season estimated inriver run has ranged from 0.50 to 2.67, with a mean of 1.17 indicating a slight positive bias in the data that were evaluated. Variability in ocean survival rates, age specific maturity rates, and harvest impact rates greatly influence the relationship between the preseason forecasts and the post-season estimates.

   b. Proportion of jacks in the run and estimated total inriver run for 2010.

      The contribution of jacks (age 2 mature fish) to the inriver run is highly variable, ranging from 0.01 to 0.52, with a mean of 0.16 for the 1978 to 2009 return years. There is currently no methodology to forecast the number of jacks expected to return and contribute to the annual inriver run as this age class is not part of the annual stock assessment/harvest management process in determining the inriver run. Since the proportion of jacks in the run compared to the adult run is highly variable (Figure 2), especially at the lower and moderate adult run sizes, regression analyses were not pursued at this time.

      To estimate the number of total inriver run for 2010, including jacks, the forecast inriver adult run (110,700) was divided by the (1-proportion of jacks). Rather than using the mean jack proportion of 0.16 from the 1978 to 2009 dataset, the mean for the proportion of jacks at higher adult run sizes was used as the jack proportion is less variable (ranging from 0.01 to 0.19, mean of 0.07) and somewhat stable at these larger run sizes (Figure 2).

Using this method the estimated total fall Chinook salmon run for 2010 is:

Adult Inriver Forecast/(1-proportion of jacks) =
110,700/(1-0.07) = **119,169**

2. Lower Klamath Flows

   a. Data

   Lower Klamath (USGS gage #11530500) mean monthly flow data were obtained from USGS's National Water Information System: Web Interface for the same period that inriver fall Chinook salmon run data are available (1978-2009). Mean monthly flows for July, August and September were compiled as this is the time period of concern, especially August and September.

   b. Filling in missing data for 1996 and 1997

   Flow data for the lower Klamath are not available for 1996 and 1997. To estimate the monthly mean flow in the lower Klamath relationships between the Klamath flow at Orleans (USGS gage # 11523000) plus the Trinity flow at Hoopa (USGS gage #11530000) to the mean monthly flow in the lower Klamath flow were developed separately for each month of interest (Figures 3-5).

3. Klamath Fall Flow and inriver fall Chinook salmon run size and flow thresholds

   a. Run size and Klamath Fall Flows

   Annual fall Chinook adult (Figures 6-8) and total (Figures 9-11) inriver run and mean monthly lower Klamath River flows to investigate the patterns of run size and flow. Focusing on conditions (run size and lower Klamath flow) that occurred during the fish kill in 2002, in August 1987 and September of 1988 flows were below 2,500 cfs and the runs were fairly large and a fish-kill did not occur. Additionally, in August 1988, August 2001, September 1987, September 2001, and September 2006, flows in the lower Klamath were slightly above 2,500 cfs with moderate to large run sizes without a fish-kill. There have also been years with low Klamath flows (1991, 1992 and 1994, but these low flow conditions coincided with some of the lowest inriver runs. These general patterns are similar for the total run data (Figures 9-11). These data are also presented as scatter plots in Attachment 1.

As discussed at the Flow meeting on June 28, 2010, there are many hypotheses as to why conditions manifested as a fish kill in 2002 when apparently similar conditions have occurred in other years. Some of these include the density of fish early in the run being reduced by the estuary tribal fishery (35,700 harvest in August 1987 and 35,400 harvest in August 1988) inriver run being reduced by a significant, adverse conditions being set-up in 2001 and the low-flow conditions coupled with a large run leading to the fish kill, etc.(should fill this in better).

b. 2,500 cfs

For the period from 1978-2009, mean monthly flows in the lower Klamath River below a 2,500 cfs threshold occurred once (3.1%) in July, five times (15.6%) in August and six times (18.8%) in September (Table 1). As noted above, only in 1988 and 2002 did the flows below this threshold coincide with a large inriver run.

c. 3,000 cfs

For the period from 1978-2009, mean monthly flows in the lower Klamath River below a 3,000 cfs threshold occurred 2 times (6.3%) in July, 14 times in (43.8%) in August and 13 times (40.6%) in September (Table 1). Flows below the 3,000 cfs threshold coincided with large runs five times during August (1986, 1987, 1988, 2001, 2002) and four times during September (1987, 1988, 2001, 2002).

4. Conclusion

Based on the flow and run size data from 1978 and 2009, it appears that a flow threshold to protect the fall Chinook inriver run of 2,500 cfs is appropriate. While flows below this level have not been uncommon in August and September (15.6% and 18.8%, respectively), these low flows have also coincided with low to moderate inriver runs or significant estuary fisheries during larger runs which likely decreased the density of fish in the river. A 3,000 cfs threshold is more conservative but flow below this are common in August and September (43.8% and 40.6%, respectively) and it is unclear if this level of flow is necessary to prevent conditions that could lead to a fish kill in the lower Klamath. While the inriver run forecasts are slightly positively biased, the forecast of the inriver adult run in 2010 is near the long-term average, and substantially smaller than the runs of 1988 and 2002.

Table 1. Frequency of occurrence (percentage in parentheses) of Lower Klamath Flows being lower than thresholds of 2,500 cfs and 3,000 cfs for the period 1978-2009.

Month	Flow Threshold	
	2,500 cfs	3,000 cfs
July	1 (3.1%)	2 (6.3%)
August	5 (15.6%)	14 (43.8%)
September	6 (18.8%)	13 (40.6%)

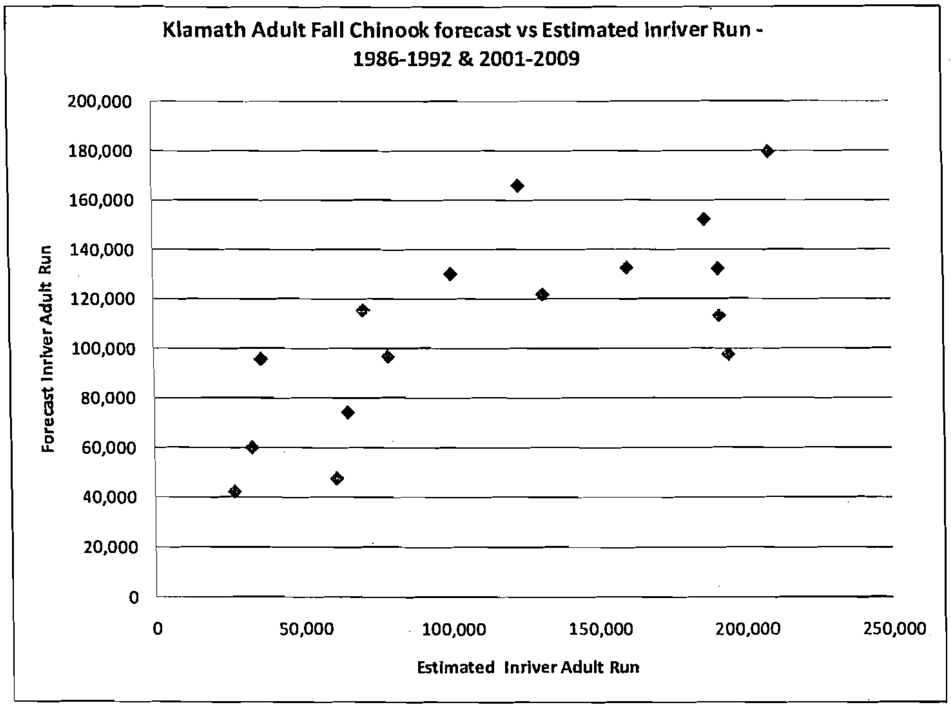

Figure 1. Preseason forecast vs post-season inriver run for Klamath Basin fall Chinook salmon, 1978-1985 and 2001-2009.

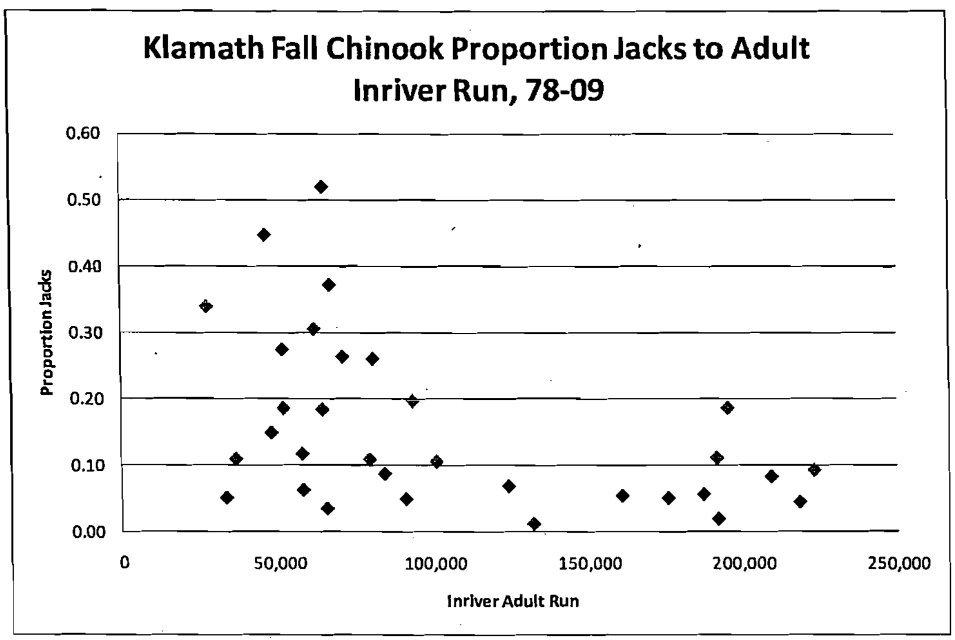

Figure 2. Proportion of jacks vs inriver adult run for Klamath Basin fall Chinook salmon, 1978-1985.

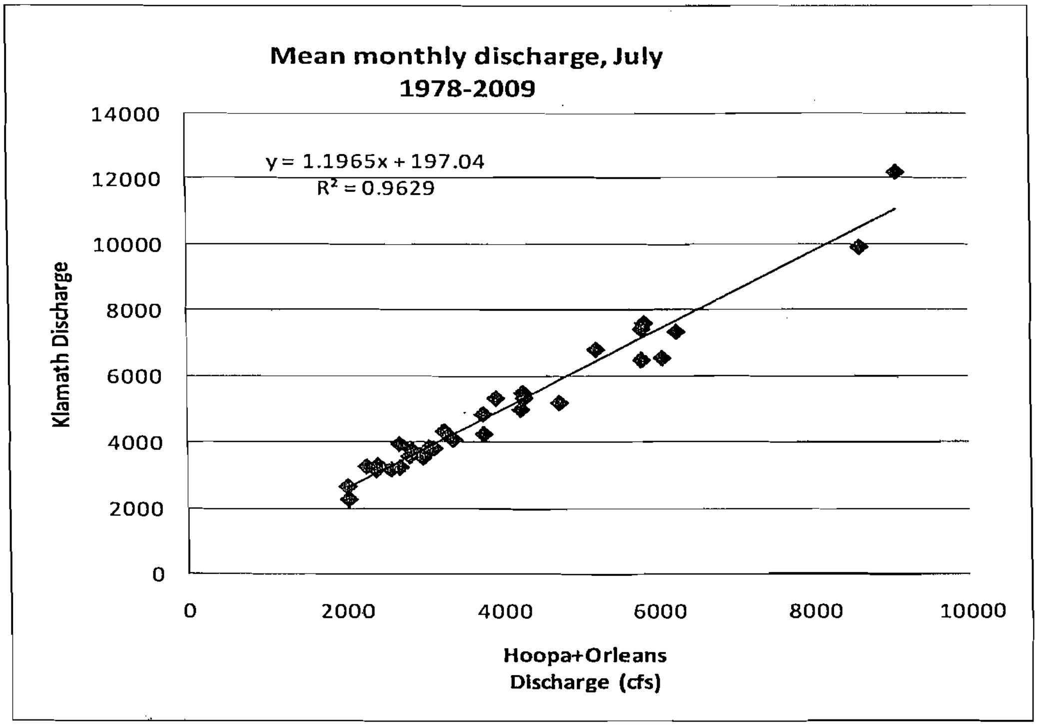

Figure 3. Mean monthly discharge for July in the lower Klamath vs Orleans + Hoopa discharge, 1978-2009, excluding 1996 and 1997.

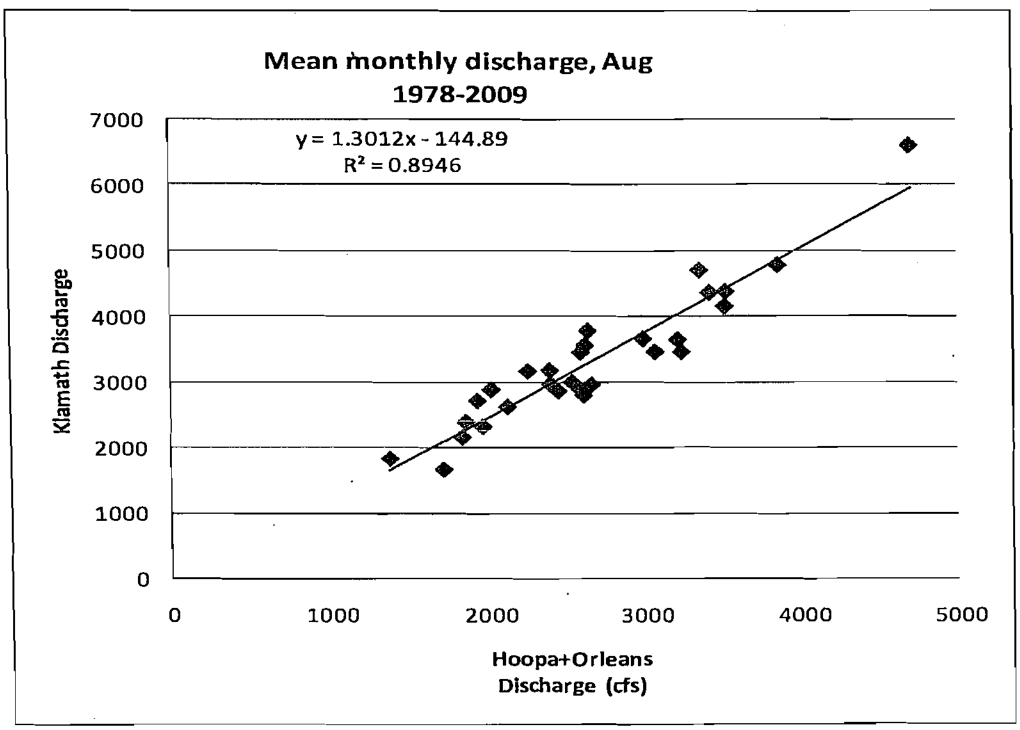

Figure 4. Mean monthly discharge for July in the lower Klamath vs Orleans + Hoopa discharge, 1978-2009, excluding 1996 and 1997.

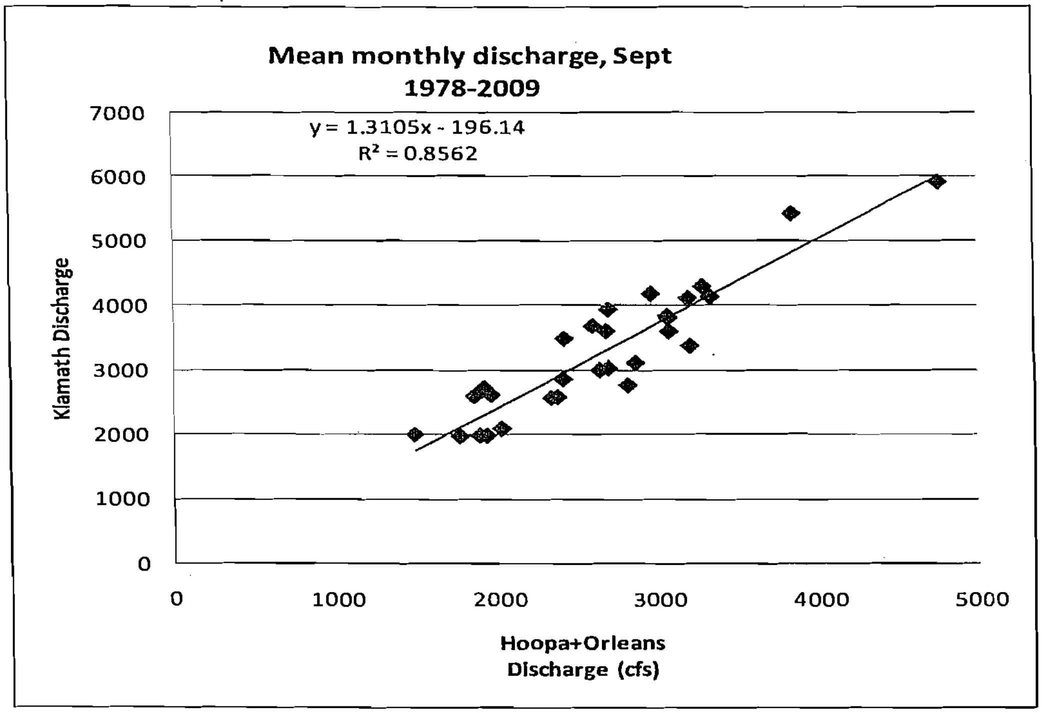

Figure 5. Mean monthly discharge for July in the lower Klamath vs Orleans + Hoopa discharge, 1978-2009, excluding 1996 and 1997.

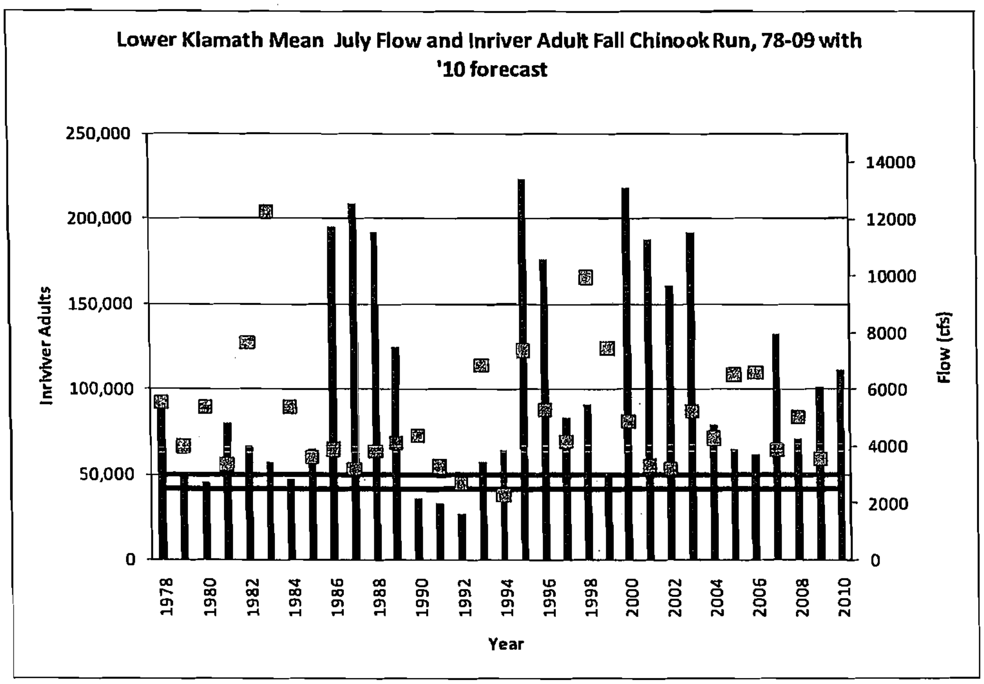

Figure 6. Klamath fall Chinook salmon adult inriver run and mean monthly July flow in the lower Klamath River, 1978-2009. Blue bars are number of fish, yellow squares are flow, horizontal red line is the 2,500 cfs threshold, green line is the 3,000 cfs threshold, and 2010 inriver run is the preseason forecast.

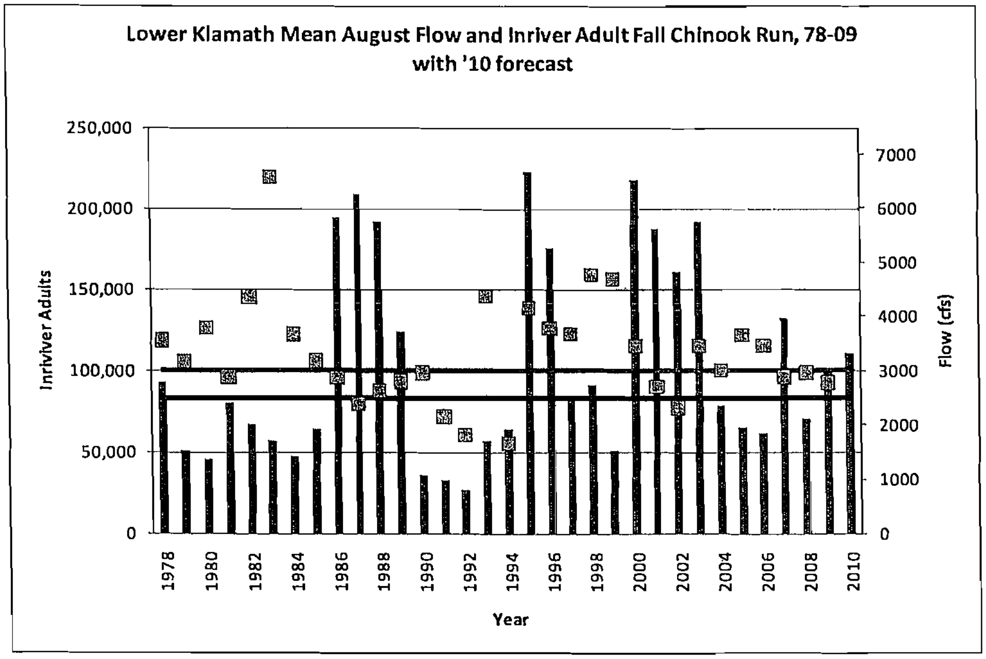

Figure 7. Klamath fall Chinook salmon adult inriver run and mean monthly August flow in the lower Klamath River, 1978-2009. Blue bars are number of fish, yellow squares are flow, horizontal red line is the 2,500 cfs threshold, green line is the 3,000 cfs threshold, and 2010 inriver run is the preseason forecast.

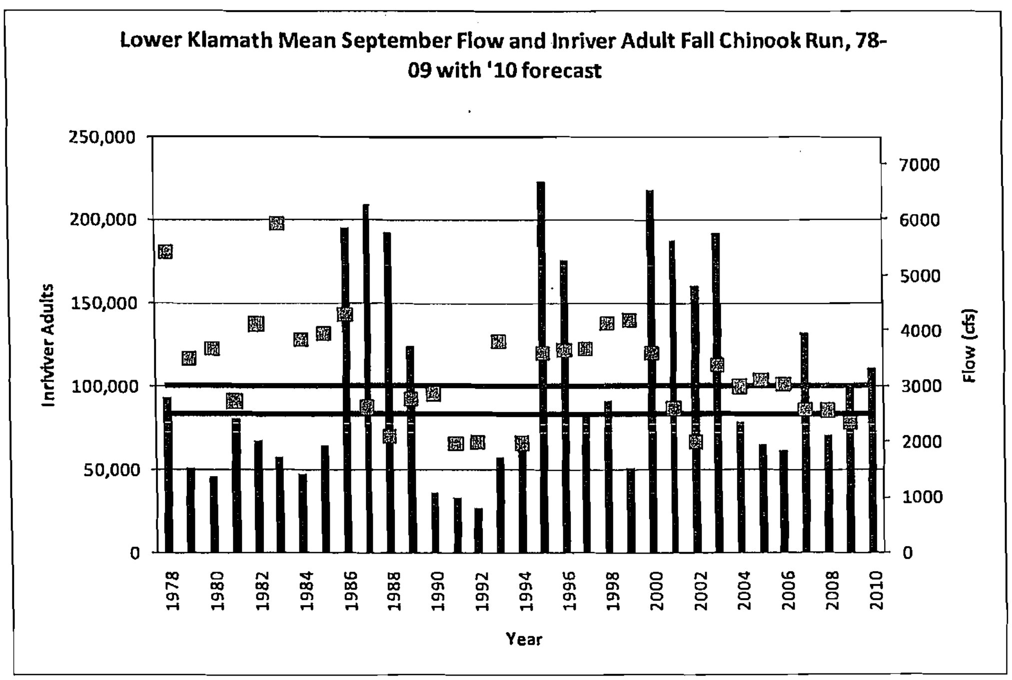

Figure 8. Klamath fall Chinook salmon adult inriver run and mean monthly September flow in the lower Klamath River, 1978-2009. Blue bars are number of fish, yellow squares are flow, horizontal red line is the 2,500 cfs threshold, green line is the 3,000 cfs threshold, and 2010 inriver run is the preseason forecast.

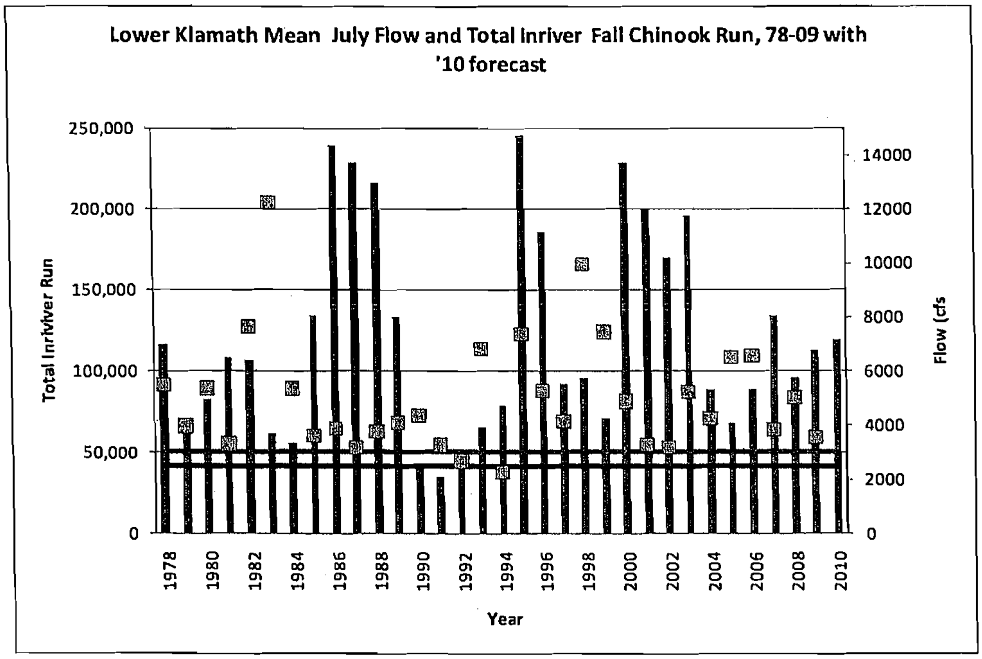

Figure 9. Klamath fall Chinook salmon total inriver run (jacks and adults) and mean monthly July flow in the lower Klamath River, 1978-2009. Blue bars are number of fish, yellow squares are flow, horizontal red line is the 2,500 cfs threshold, green line is the 3,000 cfs threshold, and 2010 inriver run is the preseason forecast.

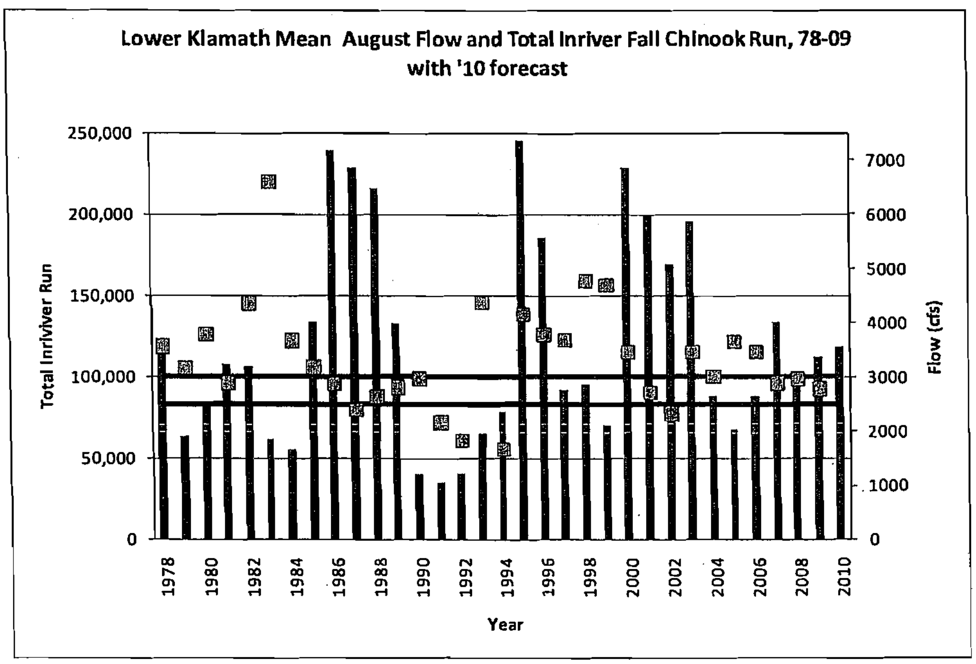

Figure 10. Klamath fall Chinook salmon total inriver run (jacks and adults) and mean monthly August flow in the lower Klamath River, 1978-2009. Blue bars are number of fish, yellow squares are flow, horizontal red line is the 2,500 cfs threshold, green line is the 3,000 cfs threshold, and 2010 inriver run is the preseason forecast.

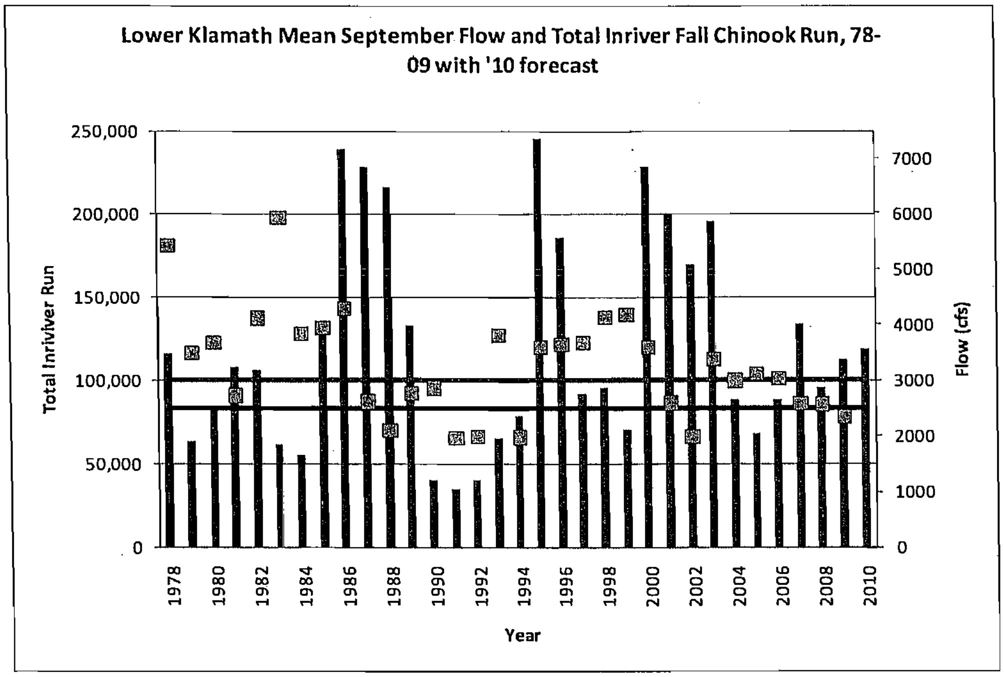

Figure 11. Klamath fall Chinook salmon total inriver run (jacks and adults) and mean monthly September flow in the lower Klamath River, 1978-2009. Blue bars are number of fish, yellow squares are flow, horizontal red line is the 2,500 cfs threshold, green line is the 3,000 cfs threshold, and 2010 inriver run is the preseason forecast.

Attachment 1.

Scatter-plots of Klamath fall Chinook salmon inriver run and mean flows at the lower Klamath River, 1978-2009.

First four graphs (A-D) depict lower Klamath flows vs inriver adult and total inriver fall Chinook salmon run in August and September.

Second four graphs (E-H) depict lower Klamath flows vs inriver adult and total inriver fall Chinook salmon run in August and September limited to years when the flows in the lower Klamath River were below 3,100 cfs. This was done to allow a more focused look at the lower flow years. Data point from 2002 is colored red.

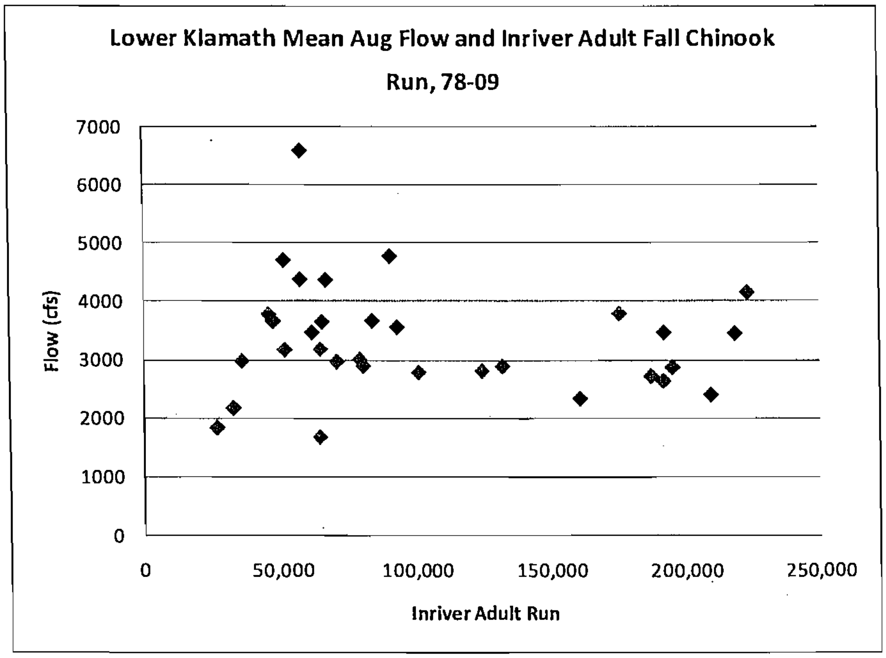

Figure A. Mean monthly August flow in the lower Klamath vs inriver adult fall Chinook salmon run size, 1978-2009.

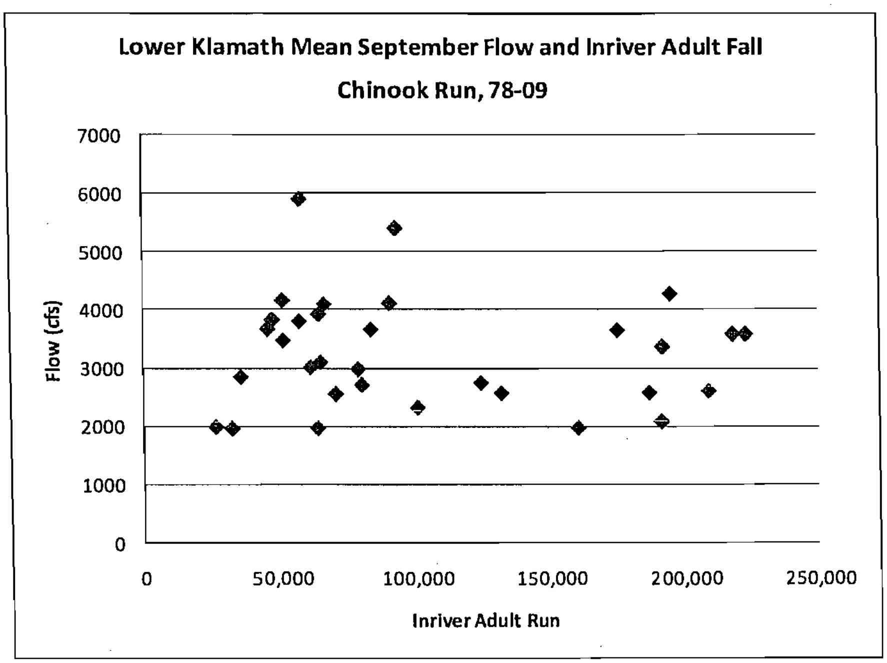

Figure B. Mean monthly September flow in the lower Klamath vs inriver adult fall Chinook salmon run size, 1978-2009.

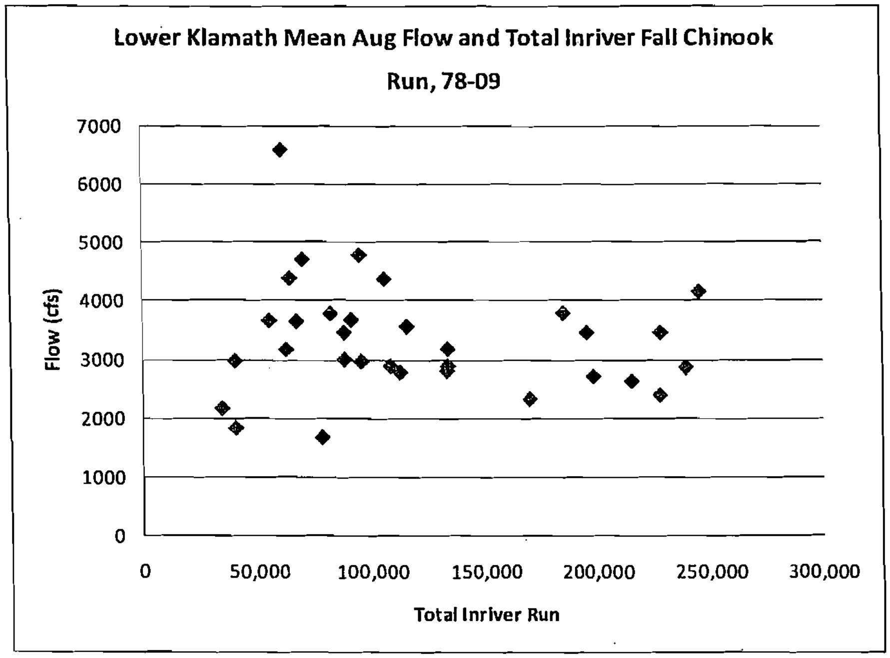

Figure C. Mean monthly August flow in the lower Klamath vs total inriver fall Chinook salmon run size, 1978-2009.

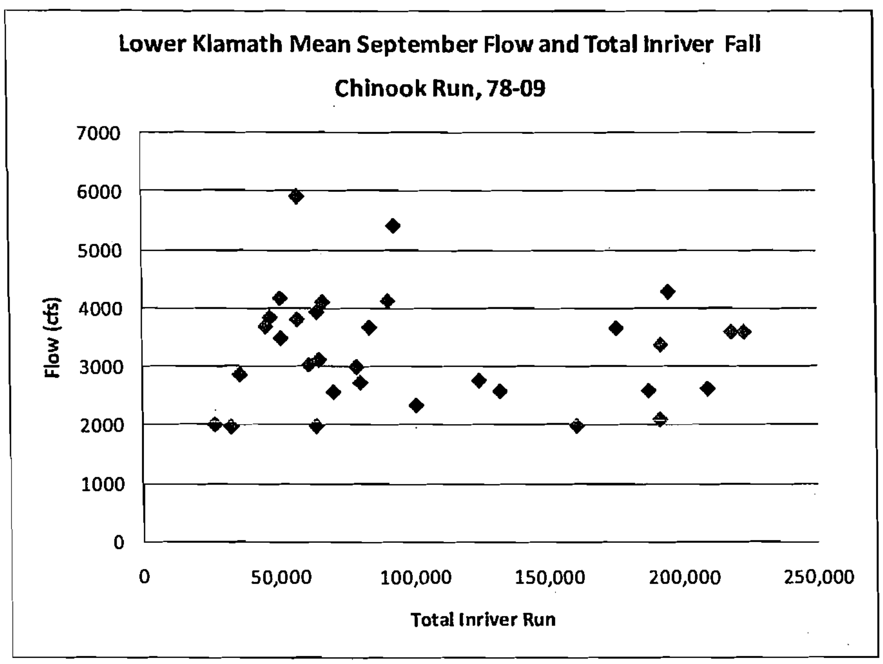

Figure D. Mean monthly September flow in the lower Klamath vs total inriver fall Chinook salmon run size, 1978-2009.

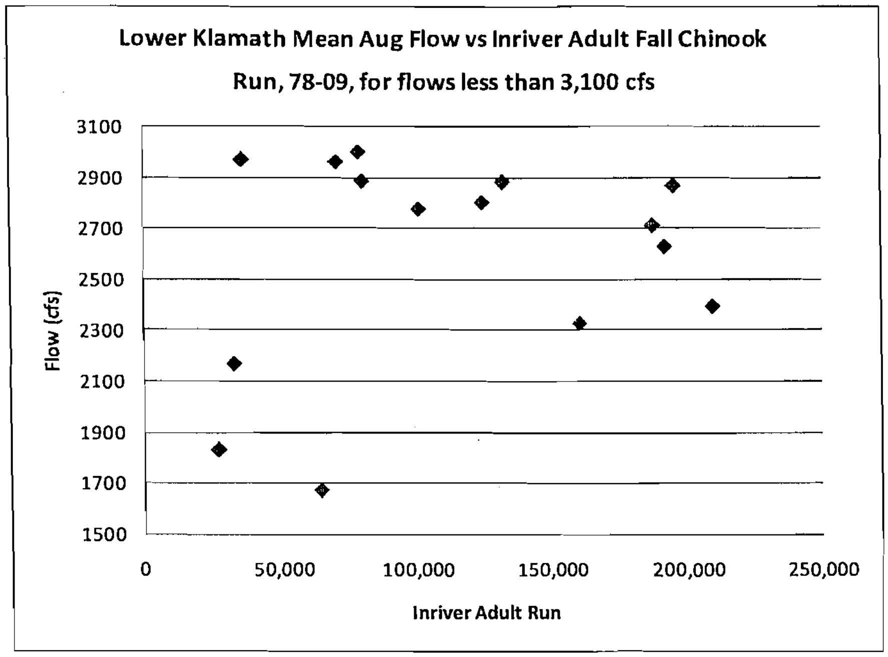

Figure E. Mean monthly August flow in the lower Klamath vs inriver adult fall Chinook salmon run size, 1978-2009, for flows less than 3,100 cfs. Red marker is 2002 data.

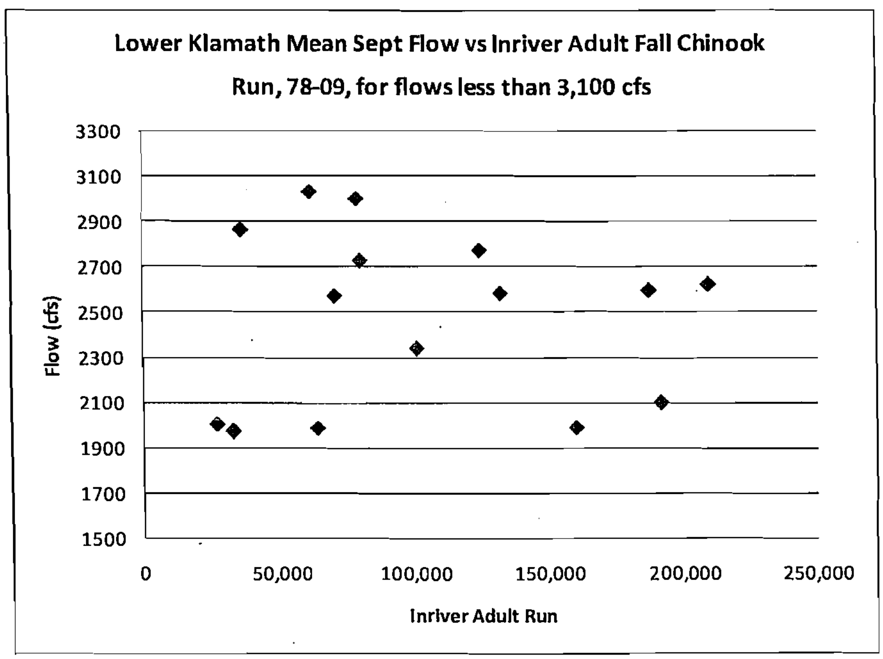

Figure F. Mean monthly September flow in the lower Klamath vs inriver adult fall Chinook salmon run size, 1978-2009, for flows less than 3,100 cfs. Red marker is 2002 data.

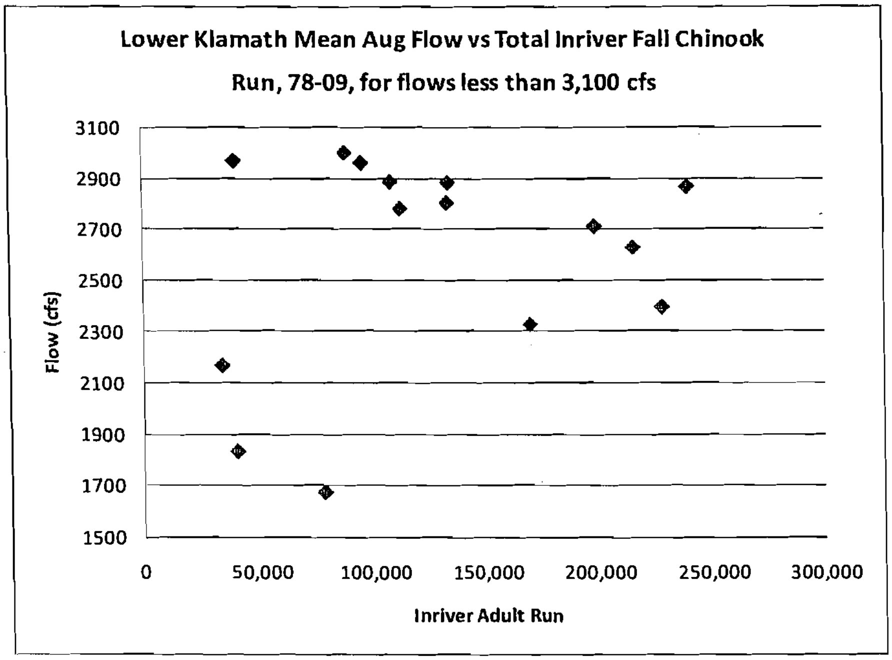

Figure G. Mean monthly August flow in the lower Klamath vs total inriver fall Chinook salmon run size, 1978-2009, for flows less than 3,100 cfs. Red marker is 2002 data.

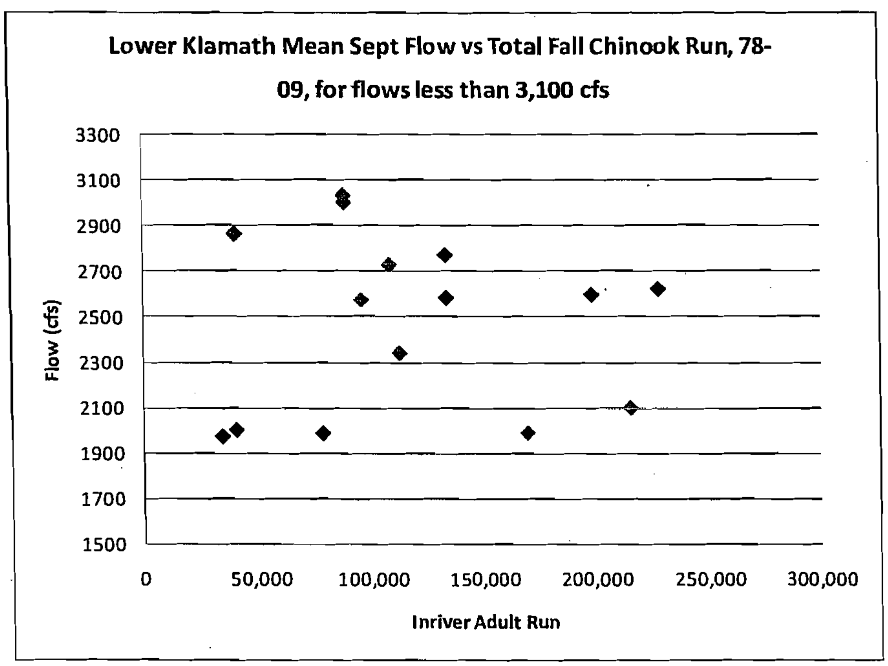

Figure H. Mean monthly September flow in the lower Klamath vs total inriver fall Chinook salmon run size, 1978-2009, for flows less than 3,100 cfs. Red marker is 2002 data.

Attachment E

Eric Peterson's report "Forecasting flows on the lower Klamath River in late summer with empirical models"

Forecasting flows on the lower Klamath River in late summer with empirical models

Technical Brief

Prepared by E. Peterson

Trinity River Restoration Program

August 25, 2010[1]

INTRODUCTION

The flow of the Klamath River in August and September is considered vital to the success of fall-run salmon. In 2002, a disease outbreak severely impacted incoming adults, and it is thought that a combination of very low flows plus a large incoming run were causative factors. To avoid similar fish kills in the future, options are being considered to either maintain flows at some minimum level, or provide a brief, but large, pulse of water.

These management options should involve planning for dam operations. Forecasting minimum flow levels in the lower Klamath prior to exceeding trigger thresholds for the increased flows will be of value to planning efforts. In early spring of 2010, the Trinity River Restoration Program's (TRRP) Weaverville office was asked to estimate flows in the Klamath below the confluence of the Trinity and Klamath Rivers, with the knowledge that the Trinity had been experiencing a normal, to slightly above normal, water year while the Klamath was experiencing an exceptionally dry water year. TRRP provided tables that enabled a 'look-up' of likely flow levels based on water year percentile. The method was simple, but imprecise, and since accretions on the Klamath below Iron Gate dam may not correspond to conditions above, it was difficult to decide what kind of water year was appropriate to apply for the Klamath portion.

Since then, more specific forecasts have been requested. NOAA was requested to provide a forecast through their river flood forecasting program; a forecast for 2010 has now been received which uses a trace analysis tool online at http://www.cnrfc.noaa.gov . Simultaneously, TRRP was requested to provide an improved forecast with more specific values and better use of conditions on the Klamath below Iron Gate dam. In response, TRRP has developed statistical models to forecast minimum late-summer flows utilizing data from spring and early summer. Between the regression based forecast presented here, and the NOAA trace forecast, viewpoints toward future flows can be provided through two methodologies which may provide assurance in the forecasts as long as the forecasts are compatible.

This report addresses the models developed by TRRP. A discussion of the process for developing the models is given (Methods and Discussion sections) and guidance for using the models are provided (Application section). *With this method, the forecast minimum flow at the Klamath River near Klamath gage for August and September, 2010, based on June 2010 flows, was centered at 3293 cfs and had a 90% chance of exceeding 2758 cfs, assuming releases of 1450 cfs combined from Iron Gate and Lewiston dams. Flows are reducing somewhat faster than the June forecast would suggest, and the July forecast is centered at 3061 cfs and has a 90% chance of exceeding 2683 cfs, assuming releases of 1450 cfs combined from Iron Gate and Lewiston dams.*

METHODS

The forecast method chosen for this forecast is a statistical, empirical modeling approach, rather than a mechanistic approach. With a statistical model, data are analyzed for correlative relationships such that the level of one or more variables will indicate the level of the variable to be predicted. Statistical models are easily generated once appropriate datasets are obtained, and provide measures of certainty that allow construction of high and low bounds around an estimate. The accuracy of the model depends on the strength of correlation between input and

[1] An earlier version was circulated for planning purposes, dated July 6 2010. No numeric results have changed except that a forecast utilizing July 2010 flow data, and functions for calculating 90% forecasts are now provided.

response variables and so can be used with rather few input variables if correlations are strong. By contrast, a mechanistic model would require knowledge of all major components of the system in question, and how they come together to produce a response. In the case of flow modeling, a fully mechanistic model would require inputs of water storage and output across the watershed. The model might provide better understanding of how particular watersheds contribute to river flows, or the importance of snow pack versus ground water, but would require much more data than is readily available.

Models are never purely empirical (there must be some mechanistic reason for using a predictor variable) unless to predict flows based on the price of tea in China, nor purely mechanistic (all require quantification of components and approximation of their relationships). Statistical models often balance mechanistic details (more input variables) versus over-use of limited datasets (which allows background noise in variables to produce false results). Building statistical models is generally a process of data exploration and testing of potential models to determine a model of appropriate mechanistic detail for the data that are available.

Developing the statistical forecast models for the Klamath River near Klamath included several phases: data acquisition, data processing, and model building.

Data Acquisition. Flow data for the Klamath River near Klamath and a number of tributary gages (Table 1; Figure 1) were obtained from the USGS National Water Information System (NWIS). Data were obtained for the full period of record through June of 2010. Data for months of interest in 2010 are provisional, that is, they may yet be adjusted during quality control processes.

Snow data were sought to address storage of water in snowpack, which could extend relatively high flows into late summer. Two forms of snow data are readily available:

- Snow course data, collected monthly in late winter and spring, were considered but found to be of poor use due to frequent missing data. Since data are collected manually, sites must be accessed for measurements during seasons that are stormy. If weather conditions are too hostile, the data is not collected. Issues of legality and liability have increased over time to the point that snow course data are now rarely collected within our region; of the 12 sites considered for this project, only 4 had any data in 2010 and then only one in the Shasta River watershed had data for 3 consecutive months.

Table 1: Data Acquisition. Average daily values were obtained for flow (cfs) and Snow Water Content (Revised, inches) from NWIS and CDEC websites.

Data Type	Site Name	Site Code	Period of Record (months Apr - Sept)
Stream Flow	KLAMATH R NR KLAMATH CA	11530500	1911-1926, 1951-1995, 1998-present
Stream Flow	KLAMATH R A ORLEANS	11523000	1928-present
Stream Flow	SALMON R A SOMES BAR CA	11522500	1912-1915,1928-present
Stream Flow	SHASTA R NR YREKA CA	11517500	1934-1941, 1945-present
Stream Flow	KLAMATH R BL IRON GATE DAM CA	11516530	1961-present
Stream Flow	TRINITY R A HOOPA CA	11530000	1912-1913, 1917-1918, 1932-present
Stream Flow	TRINITY R NR BURNT RANCH CA	11527000	1935-1939, 1957-present
Stream Flow	SF TRINITY R BL HYAMPOM CA	11528700	1966-present
Stream Flow	NF TRINITY R A HELENA CA	11526500	1911-1913, 1958-1980, 2005-present
Stream Flow	TRINITY R A LEWISTON CA	11525500	1912-present
Snow Water Content	Red Rock Mountain	RRM	1987-present
Snow Water Content	Sand Flat	SDF	1984-present

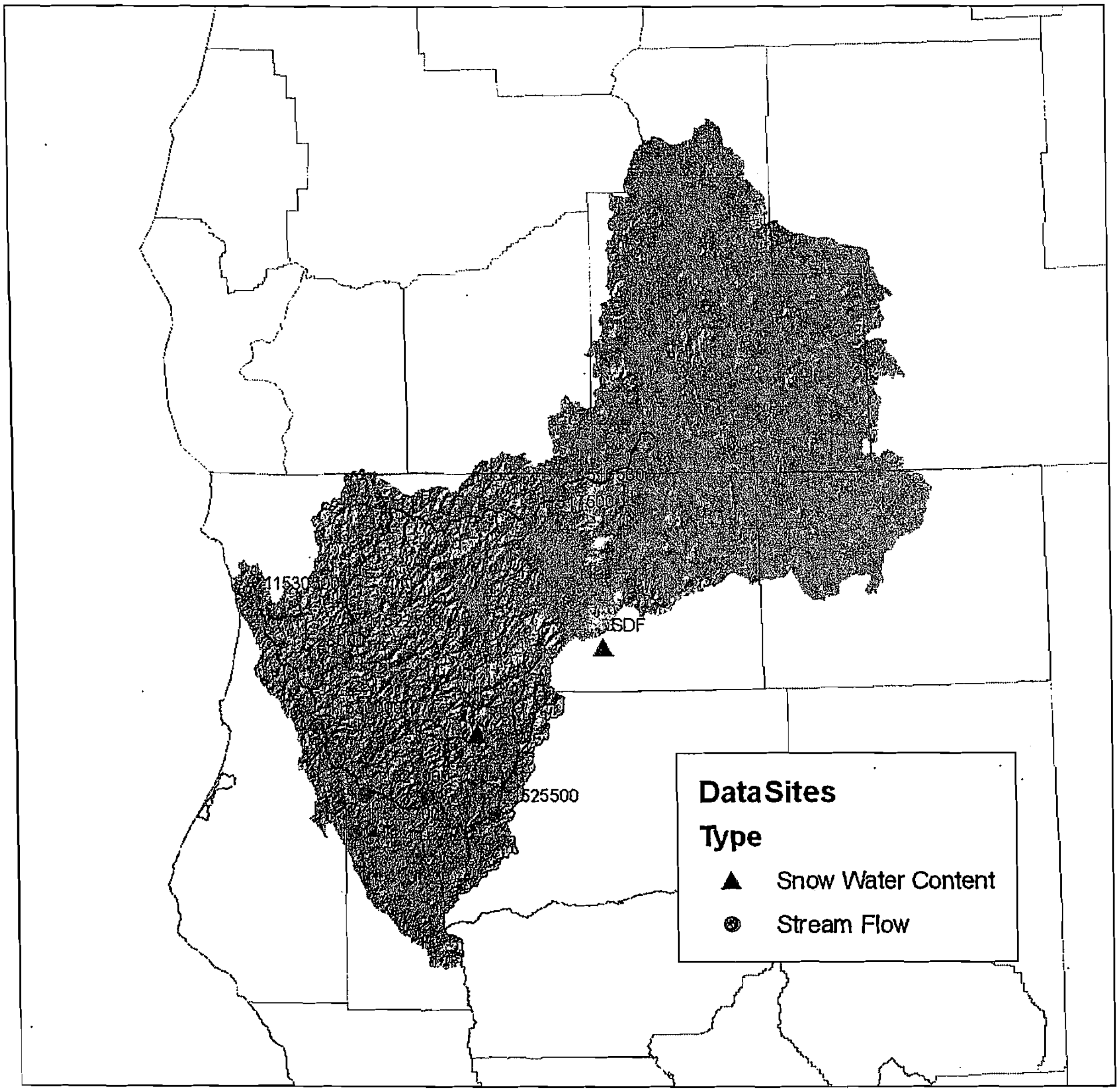

Figure 1: Map of Klamath River watershed showing flow and snow gages used in this analysis.

Therefore, snow course data were determined to be ineffective for flow modeling.

- Snow sensor data are available for several sites in or near the Trinity Alps Wilderness. These data are passively collected and transmitted via satellite so that daily values of snow depth and snow water content are available through the California Department of Water Resources, California Data Exchange Center (CDEC). Two sites (Table 1; Figure 1) were chosen for data based upon (1) duration and continuity of data collection, and (2) geographic representation of watersheds relevant to the model. The sensor at Red Rock Mountain (RRM) is very near the divide between the Salmon and Trinity Rivers and thus should represent the snow accumulation in the Trinity Alps flowing into both Klamath and Trinity Rivers; the sensor at Sand Flat (SDF) represents snow accumulation further inland. No sensors were available for more coastal or southerly geographies (e.g. South Fork Mountain). The Adjusted Snow Water Content values were used.

Data Processing. Building models requires data on past values for both the input variables (predictors) and the response variable (the one to be predicted). The interest here is to build a model for minimum flows in the Klamath for late summer (response variable) as a function of flows and snow conditions in the spring or early summer.

late summer minimum flow = f(late spring or early summer measurements)

Multiple models could be useful, utilizing progressively later spring/summer data, so that a forecast may first be made in, say, May, then again each month afterward presumably becoming more accurate as data become available closer to the late-summer period being forecast.

The modeling interest is specifically in the accretion of flows between the dams and the Klamath River near Klamath gage (USGS gage 11530500). Therefore, data for this gage was corrected for dam releases (see challenges below) and the minimum flow accretion value over the months of August and September across available years were used as the response variable.

Flow and snow data were summarized for each location, for each of the months April, May, June, July, and August, using the minimum values during each of those months. Monthly minimum values were used as a reliable representation of seasonal conditions, as both averages and flows on particular days would be more sensitive to spikes from passing storms.

Assembling data sets for analyses had two primary challenges:

- Data needed to be available simultaneously for all variables used in a particular test model. If a site missed data in, say, 2003, then that year's data could not be used for any sites for that test model.
  Due to this issue, four basic datasets were organized. First, separate datasets were constructed for basing forecasts on 'upper' versus 'lower' watershed components. The 'upper' components included the Salmon River, Shasta River, South Fork of the Trinity River, and mainstem of the Trinity River at Burnt Ranch (use of the North Fork of the Trinity River was prohibited by discontinuities in the dataset, so the mainstem at Burnt Ranch was the best available dataset to represent accretion in the Trinity above the South Fork). The 'lower' components consisted of the Klamath River at Orleans, the Trinity River at Hoopa, and the Klamath River at Klamath.

  Secondly, snow data are available for only a subset of years that flow data are available. Therefore both the 'upper' and 'lower' datasets were split into two copies, one with snow data and thus for a short set of years, and one left without snow data for a longer set of years (Table 2).

- To calculate flow accretions, dam releases needed to be subtracted out from gage data along the Klamath and Trinity River mainstems. However, the travel time of water between the dams and the gages needed to be accounted for. Changes in releases results in the appearance of frequent negative accretions if travel time is not accounted for. Travel time between sites is dependent on flow volumes and can be spread across daily average flow values, so even when the time is accounted for, accretion calculations still

Table 2: Length of Data Sets.

Data Set	Number of years	Total Span of Years*
Upper, no snow	42	1966-1995, 1998-2009
Upper, with snow	15	1987-1989, 1991-1995, 1998-1999, 2003-2004, 2006-2007, 2009
Lower, no snow	47	1961-1995, 1998-2009
Lower, with snow	15	1987-1989, 1991-1995, 1998-1999, 2003-2004, 2006-2007, 2009

sometimes had negative values. These were replaced by values of 10 cfs, a low yet sufficiently realistic value so as to not produce severe statistical-outliers in the analysis even when data were log transformed.

Model Building. An initial data exploration was conducted to evaluate the form of modeling needed. Flow data, once log-transformed, had reasonably even, linear distributions, sufficient for ordinary least squares regression. Snow water content data were sufficient without log-transformation. Model construction was somewhat exploratory (more detail given in results), but generally followed a stepwise backward selection process.

RESULTS

Most analysis was performed in early July, so models using data from June to produce forecasts were focused on, with the expectation that they would (a) provide the best available forecast for the present, and (b) models for forecasting based on other months should use the same input (predictor) variables.

The input variables are highly collinear (correlated amongst each other). This presents problems with linear modeling and clearly identifying predictor variables. The variables overlap; one will account for a similar component of the overall variation as another. Variable selection then, is a poor indicator of causative relationships and can be vulnerable to random variation ('noise'). Consequently, complex models (containing many predictor variables) yielded results with no predictor variables identified as statistically significant, and although modeled values of flows correlated well with actual modeled values ($0.65 < r^2 < 0.85$), confidence intervals for the input variable coefficients were greater than those from simpler models. Backward selection therefore quickly reduced models to single input variables with statistical significance.

Exploration of models also began with the most complex dataset (Upper, with snow). While exploring models using this dataset, it was discovered that the flow data for the Shasta River would dominate any model that included it. This may be because it has the lowest flows of any of the input variables, which should correspond to relatively low variance and thus should have low levels of random noise. Meanwhile other flow data with higher variance could have inherently greater statistical noise. Furthermore, these models dominated by the Shasta River would consistently produce forecasts close to the overall average minimum late-summer flows (ca. 1200 cfs accretion). Since the Shasta River provides a minor portion of the flow accretions to the Klamath and represents a geographically small interior portion of the accretion watershed, it was decided to abandon its use as a predictor variable despite the statistical significance.

Since backward selection tended to reduce models to a single predictor variable, it would be logical to focus on variables that integrate larger portions of the watershed, thus it was decided to switch to the 'Lower' river datasets. Again, backward selection reduced models to a single predictor variable. These were consistently a flow variable rather than a measure of snowpack.

As a final test of including snowpack, a model was built for flows based solely on flows at Terwer using the longer term dataset lacking snow data, then residuals for years where snow data is available were correlated with the snow water content, but r^2 values were too low to warrant including the snow data in the model. This was done for April and May models as well as the June model. The highest r^2 found was 0.09 for Red Rock Mountain snow water content in the May model.

The final model based on June data used only Klamath River near Klamath data for forecasting minimum flows in late summer. This was used to build similar additional models for producing forecasts based on other months. (Table 3). The 47 year dataset (Table 2) was still used for the final model although the full period of record for this gage extends 73 years.

DISCUSSION

It is obvious that the flow of a river is a function of the flows of its tributaries and that flows may be sustained in dry periods proportional to the water storage of watersheds. So why isn't the best model one that incorporates as much tributary and snow pack data as possible? The answer may have several components.

One component is collinearity among the input variables. The watersheds providing flow accretions to the Klamath below the dams are at a geographic scale much smaller than the weather patterns that supply water. Therefore flows and storage in one part of the system are highly correlated with those in another part of the system. Therefore, in building models, a variable for flow in one tributary competes with variables for flow in other tributaries or with snow pack variables to explain roughly the same variation in the overall system (the response variable).

A second component may be random variation (or noise) within variables. Since variables compete to explain variation in the response variable, yet they are highly correlated, random noise may become the greatest distinguishing factor between variables. Therefore, when more than one variable is considered in models, the noise becomes a major factor in the performance of the variables. So while a mechanistic model probably should consider all pieces of the watershed, a statistical model may be confused by them.

APPLICATION

Models are provided to enable forecasting at the end of each month starting after April, through August (Table 3, figures 2-6). Use of these models requires determination of the minimum flow during a particular month – a relatively simple task. Use of a ruler on the graphs provided will give an approximation of the accretions and prediction intervals. Functions provided in Table 3 for calculating the 50% forecast of minimum flows. Functions are also provided to approximate the 90% forecast (within 20cfs) but precise calculation of the 90% forecast or other prediction intervals should be performed within a statistical software package; files for calculation within R are available upon request (created in version 2.9.0).

Models are based on 47 years of data and should be recalculated in the future with accumulating data. However it is probably not necessary to recalculate them every year as a single additional year should have rather minor affects relative to the prior 47.

Models for later in the season generally provide more precise forecasts (smaller prediction intervals), with the exception of the May model being more variable than the April model (Figure 7). This may be due to variation in weather patterns for the month of May, particularly the timing of 'spring weather' transitioning to 'summer weather'. This transition frequently happens sometime within May.

Certainly, it is informative to make forecasts with the April and June models. In years where there is still substantial question if flows will drop below some threshold, forecasts may be made with the July and August models, each becoming more precise than the prior. The big question is if it is worthwhile to make a forecast with the May model. For 2010, the April and May forecasts were both much lower than the June forecast (Table 4), even though there was a general sense among local river scientists before the end of May that the flows should remain strong this year. If a forecast in some future year with the May model indicates substantially different accretions than the April model, then it may have some information value. However, in the case of 2010 it would not have provided any information over the April forecast.

This forecast tool does not indicate when during the months of August and September this low value is likely to occur. If forecasting a date or the minimum flow is considered desirable in the future, then an additional modeling exercise will need to be performed. Such a model would probably have poor accuracy if based on early season data; rather it may need to be performed after the month of July.

Table 3: Statistical Models. "50pct" is the forecast minimum flow at the Klamath River near Klamath gage during the months of August and September; this is a 50% forecast that should be met or exceeded 50% of the time. "MinFlow[*n*]" is the minimum flow at the same location during month *n*. "approx90pct" is an aproximated forecast minimum flow that should be met or exceeded 90% of the time (see Application section for details). "ResSE" is the residual standard error and "r^2" is the proportion of variance explained by the model (for 50% models).

Forecast Basis	Model	ResSE	r^2
April	50pct = exp(0.5156 + 0.6867 * log(MinFlow04))	0.2663	0.604
	approx90pct = exp(-0.667 + 1.044 * log(50pct))		
May	50pct = exp(1.7632 + 0.5729 * log(MinFlow05))	0.3005	0.4954
	approx90pct =exp(-0.681 + 1.038 * log(50pct))		
June	50pct = exp(1.7293 + 0.6310 * log(MinFlow06))	0.2579	0.6371
	approx90pct = exp(-0.361 + 1.001* log(50pct))		
July	50pct = exp(0.7708 + 0.8239 * log(MinFlow07))	0.2014	0.7734
	approx90pct = exp(-0.386 + 1.014 * log(50pct))		
August	50pct = exp(0.2488 + 0.9440 * log(MinFlow08))	0.1112	0.9309
	approx90pct =exp(-0.215 + 1.008 * log(50pct))		

Table 4: Forecast values for 2010 using each model. The April model provides the best forecast available as of the end of the month of April, and so on. As this report is written in August, the 2010 forecast is not available for the August model. Prediction intervals provide the range within which the actual forecast late summer flow value should occur for 80 % of similar years. Since the remaining 20 % is split between the upper and lower tails, 9 out of 10 years should exceed the value for the lower interval. Therefore, for years like 2010 with a minimum flow accretion in June of 9660 cfs , 90 % will have a minimum accretion in August and September of 1309 or greater. The values given in parentheses have 1000 cfs added for Iron Gate releases and 450 cfs for Lewiston releases.

Model	Forecast (50%)	Prediction Interval (0.8)	
		Lower ("90%")	Upper
April	1399 (2849)	985 (2435)	1989 (3439)
May	1407 (2857)	946 (2396)	2094 (3544)
June	1843 (3293)	1309 (2759)	2596 (4046)
July	1611 (3061)	1233 (2683)	2104 (3554)
August	NA	NA	NA

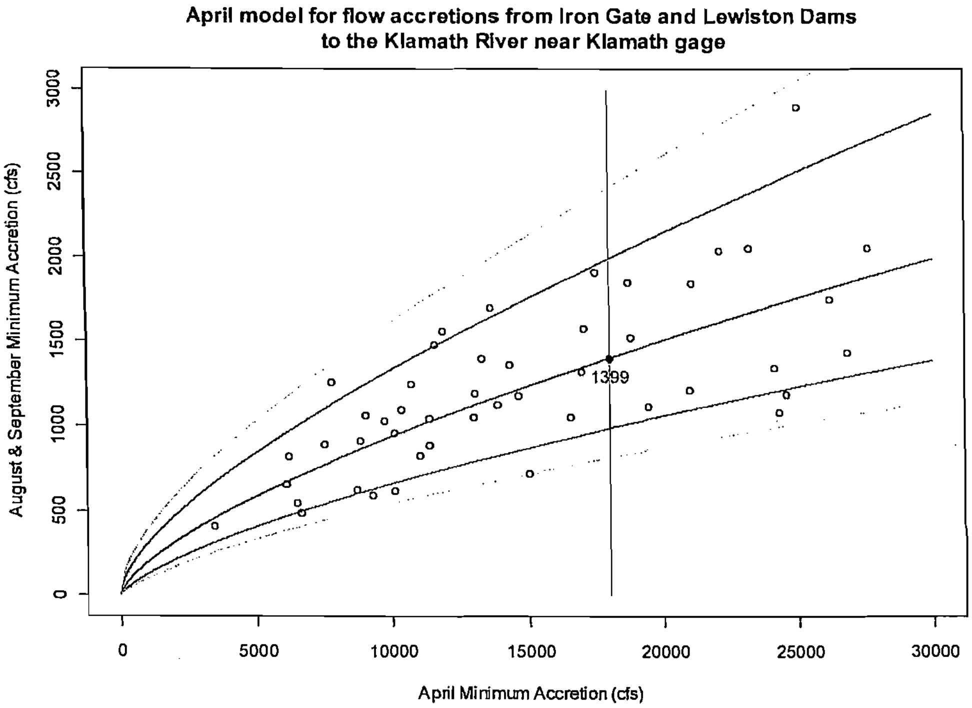

Figure 2: April model showing data from prior years (circles), forecast values (blue line), 80% prediction intervals (red lines; 90% of years should meet or exceed the lower red line), 95% prediction intervals (pink lines), the 2010 minimum accretion during April (gray line), and the forecast value based on April data (purple dot and number provided).

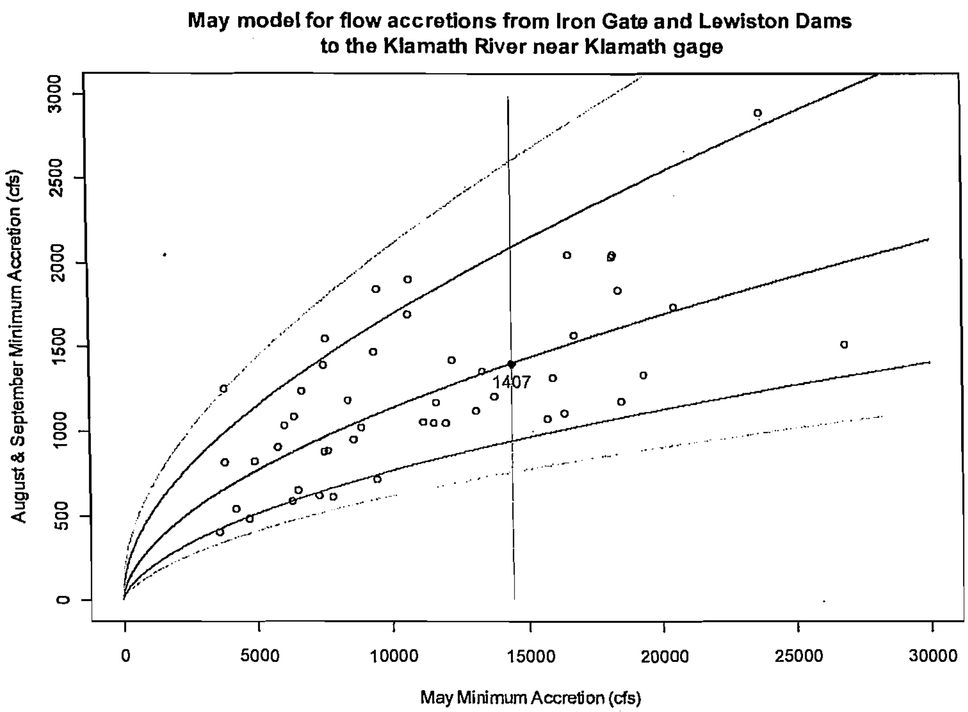

Figure 3: May model showing data from prior years (circles), forecast values (blue line), 80% prediction intervals (red lines; 90% of years should meet or exceed the lower red line), 95% prediction intervals (pink lines), the 2010 minimum accretion during May (gray line), and the forecast value based on May data (purple dot and number provided).

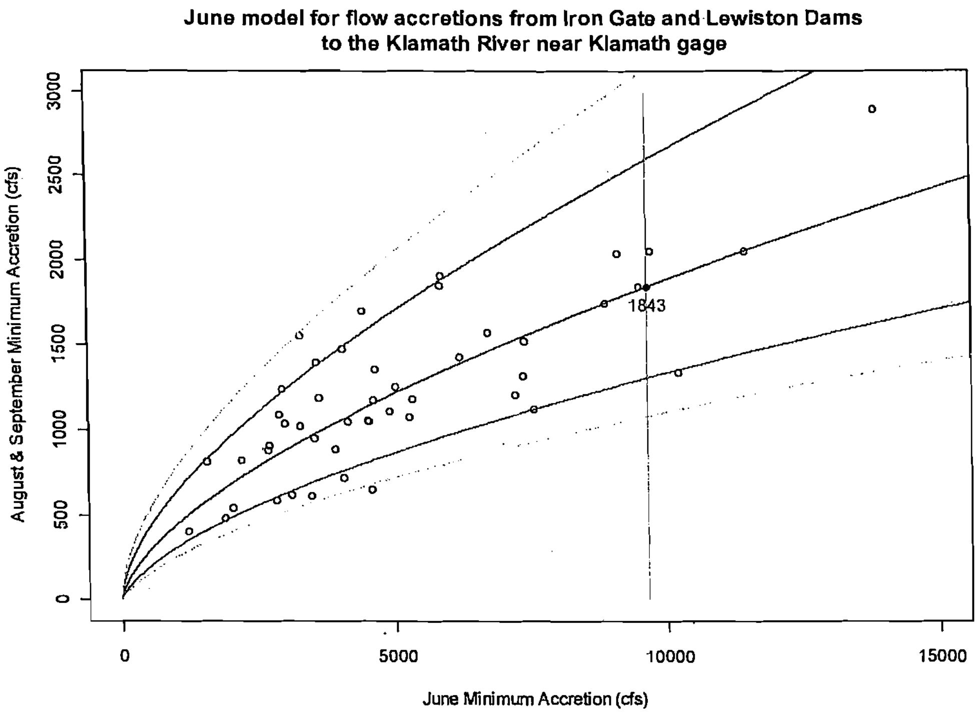

Figure 4: June model showing data from prior years (circles), forecast values (blue line), 80% prediction intervals (red lines; 90% of years should meet or exceed the lower red line), 95% prediction intervals (pink lines), the 2010 minimum accretion during June (gray line), and the forecast value based on June data (purple dot and number provided).

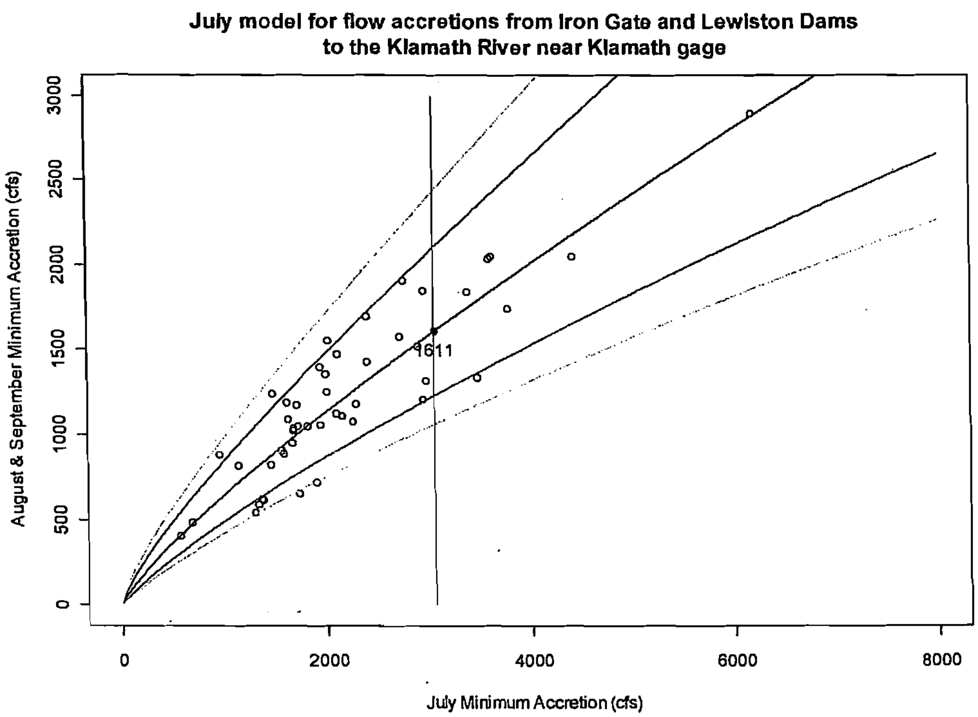

Figure 5: July model showing data from prior years (circles), forecast values (blue line), 80% prediction intervals (red lines; 90% of years should meet or exceed the lower red line), 95% prediction intervals (pink lines), the 2010 minimum accretion during July (gray line), and the forecast value based on July data (purple dot and number provided).

August model for flow accretions from Iron Gate and Lewiston Dams to the Klamath River near Klamath gage

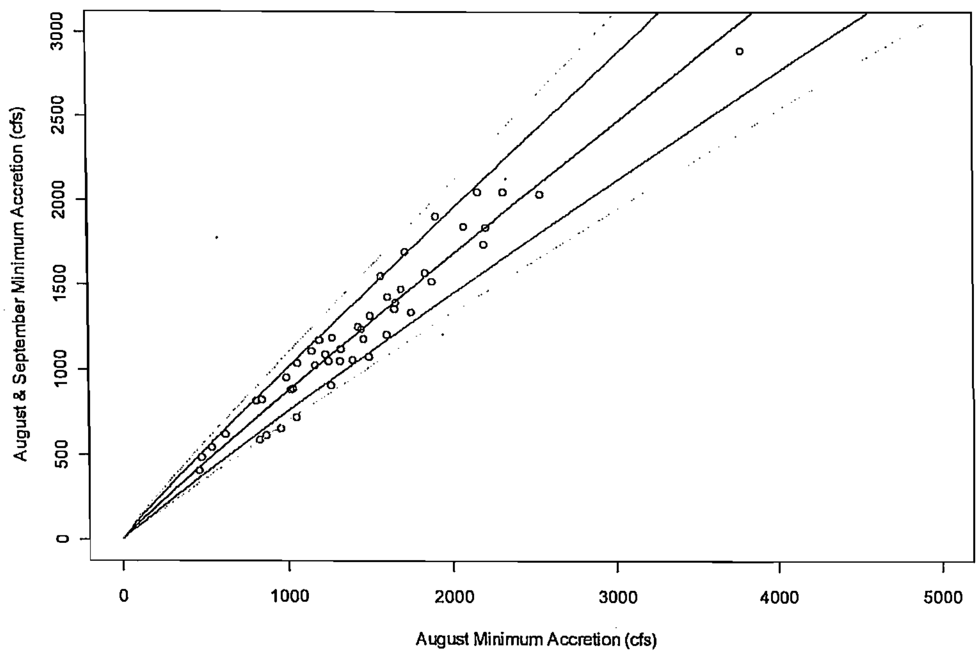

Figure 6: August model showing data from prior years (circles), forecast values (blue line), 80% prediction intervals (red lines; 90% of years should meet or exceed the lower red line), 95% prediction intervals (pink lines).

Changes in Forecasts with Time

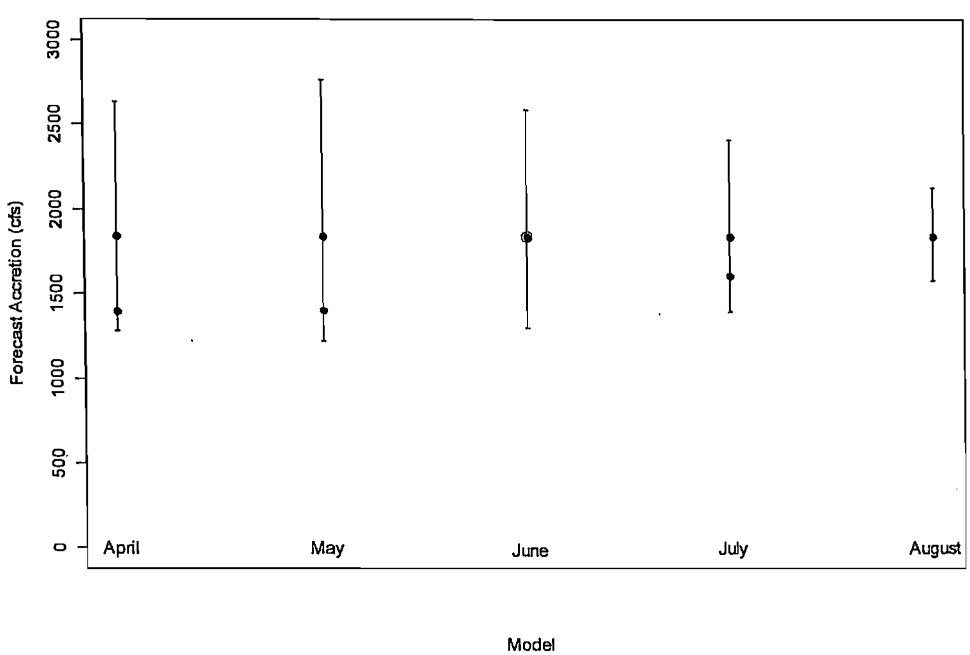

Figure 7: Comparison of forecast precision by models for consecutive months April through August. For illustration purposes, artificial forecast values were held at 1843 cfs (black dots; the forecast accretion from June 2010). Red lines indicate 80 % prediction intervals around those artificial forecasts (9 of 10 years should meet or exceed the lower end). Actual 50% forecast values for 2010 from the April, May, and July models are shown for reference (purple dots).

Attachment F

Instructions for the National Weather Service discharge forecast tool

Seth Naman
<Seth.Naman@noaa.gov>
07/15/2010 10:41 AM

To "'Faler, Jennifer A.'" <JFALER@usbr.gov>, "'Brock, William'" <wbrock@fs.fed.us>, "'Clarke, Ernest'" <ernest_clarke@fws.gov>, 'Dave Hillemeier'

cc

bcc

Subject FW: Late Summer Flow Forecasts for the Klamath River nr Klamath

TMC members,

Below are directions for accessing the forecast tool developed by the California-Nevada River Forecast Center of the National Weather Service. If you need help or clarification on using the tool please let me know. For more detailed questions on data inputs and other specifics of the analysis, contact Robert Hartman: Robert.Hartman@noaa.gov.

Seth

From: Robert Hartman [mailto:Robert.Hartman@noaa.gov]
Sent: Wednesday, July 07, 2010 8:51 AM
To: Seth Naman
Cc: Andy Morin; Alan Haynes; Scott Staggs; Arthur Henkel; Reginald Kennedy; Daniel Kozlowski
Subject: Late Summer Flow Forecasts for the Klamath River nr Klamath

Hi Seth,

We're all set to go. I'll provide you with some instructions on how to retrieve the current forecast and then give you a call and walk you through the process later today or tomorrow. The steps are as follows:

1. Go to the CNRFC website (www.cnrfc.noaa.gov)

2. The main page has a three tab map. Click on the third tab entitled "AHPS/ESP Trace Analsysis (Create Your Own Product)". You're going to be creating your own product from information residing on our site. This way, you'll have the flexibility to look at the forecasts in a variety of ways.

3. The provided map will have little white markers for the gage locations where we provide this service. Click on the marker for the Klamath - Klamath (KLMC1). This is the new USGS gage that replaced the Klamath near Klamath below Turwar Ck a few years ago. The flows are equivalent.

An interface will come up with your location already selected as "KLAMATH RIVER - KLAMATH (KLMC1) * EXCLUDES RESERVOIR RELEASES*". Please note that what you're going to see excludes the release from Trinity Lake and from Iron Gate Dam. You indicated that the USBR will be releasing 1000cfs and 450cfs respectively. If you add the 1450cfs to the results of the forecast you're going to see, then you'll have the total flow. Channel losses will be taken out of the local flow so you don't need to worry about inappropriately adding the releases back in.

You now have a bunch of options. If you want to look at some examples, there is a Help button that will step you through the generation and interpretation of the products. I'll give you the instructions for generating what I believe you'll need and you can take it from there.

4. Section (2) = Mean (default)
   Section (3) = Day (default)
   Section (4) = set date to August 15 2010
   Section (5) = set date to October 1 2010

You can set these dates to whatever you want as long as (4) comes before (5), (4) is in the future and (5) is less than a year ahead.

Section (6a) = click on Probability and then "Generate a Plot"

You'll get a plot that shows the daily flow levels for 5 probability ranges. The most likely (50%) will reside at the intersection of the red and yellow ranges. You'll see that the minimum flows are around October 1 at just under 1500 cfs. Combine that with your 1450 cfs releases and you're at 2950. Note that the 90% probability flow isn't much below the 50%.

You can adjust the dates and aggregate the interval (Day, Week, Month, Entire Period) to generate different plots.

If you select "Minimum" in Section (2) and "Entire Period" in Section (3), (same dates, Probability, and Generate Plot), you'll get a plot that shows the probability of the minimum flow during the period (regardless of when it happens). That's probably what you need to know, but if you needed to know *when* to release more water from the reservoirs, you'd need to look at the daily values.

5. If you prefer to look at numbers rather than a plot. You can select "Forecast Info" and click on "Generate a Table". You'll then get back a table that has all of the data that your saw plotted. This is a bit more accurate if you're just looking for a specific number.

I did look at the current simulations and at the watershed calibrations for the locals below the reservoirs. Currently, the models are tracking pretty well and if anything would tend to under slightly predict the runoff. The same is true for the calibration period where most tended to slightly under simulate the late summer runoff. Both of these would suggest that the forecasts your getting through the interface would have a tendency to be a bit low rather than a bit high. That should give you greater confidence that the river will see more than the 2500 cfs needed at KLMC1.

Information for this site are updated every night (365 days per year), so you can get an updated forecast any day you'd like. You'll notice that there are many other locations where we provide this service. Some may be of interest to you.

Best Regards,
Rob

Attachment G

Meeting summaries (April 19, May 10, June 28, July 12, August 10)

Teleconference Summary

Topic:	Klamath Fall Flow Augmentation Evaluation
Date/Time:	April 19, 2010/10 AM
Attendees:	Charlie Chamberlain (USFWS Arcata), Ernie Clarke (USFWS Weaverville), Robert Franklin (Hoopa Valley Tribe), Scott Foott (USFWS Fish Health Center), Tim Hayden (Yurok Tribe), John Hicks (Reclamation), Eric Wiseman (USFS)
Recorder:	Ernie Clarke

Topics:

1. Objectives of this evaluation from the TMC.
2. Action items from this call.
3. Additional issues to be addressed in the future.
4. Next meeting.

1. Objectives from the TMC:

- Compile available information relevant to augmenting Klamath flows.
- Review triggers established previously and determine if they were beneficial.
- Develop forecast for the Lower Klamath at Turwer to determine if triggers are likely to be tripped.
- If so, what would alleviate the problem? Consider solutions on both sides.
- If so, would it be helpful to release additional Trinity water?
- If so, how?

2. Action items (Due by close of business on April 26):

- **FWS Arcata Staff (individual TBD)** – Summarize available information regarding the 2002 die-off and subsequent management actions.
- **Ernie Clarke** – Provide a projection of August and September flows at Terwer based on Klamath and Trinity operations and tributary accretion.
- **Joe Polos** – Provide fall run predictions.
- **Ernie Clarke** – Collect NEPA documents for 2003/2004 fall flow releases from Buford Holt.
- **Tim Hayden** – Summarize triggers established for 2003/2004 flows. Propose modifications (e.g. per Scott mortality is not a useful trigger).
- **Tim Hayden** – Provide information on potential ceremonial releases.

3. Additional issues to be addressed in the future:

- Combine projected discharges at Terwer with fall run size to determine likelihood of adult fish die-off.
- Determine the volume and timing of a release. Group agrees that the volume needs to be technically supported. Robert suggested that a release should mimic a natural storm to the extent possible.
- Determine if the recommended volume of water is available.

4. Next meeting: Proposed conference call on Monday, May 10th.

Teleconference Summary

Topic:	Klamath Fall Flow Augmentation Evaluation
Date/Time:	May 10, 2010/10 AM
Attendees:	Mike Berry (California DFG), Ernie Clarke (USFWS, Weaverville), Andrea Davis (Hoopa Valley Tribe), Larry Hansen (California DFG), John Hicks (BOR, Klamath Basin Area Office), Buford Holt (BOR, Northern California Area Office), Seth Naman (NOAA Fisheries), Joe Polos (USFWS, Arcata), Josh Strange (Yurok Tribe), Eric Wiseman (USFS)
Recorder:	Ernie Clarke

Topics:

1. Tasks from 4/19/10 meeting
2. Proactive and Emergency Triggers
3. 2010 Projections
4. Recommendations for this year
5. Monitoring
6. New tasks
7. Next meeting

1. Tasks (responsible party) from 4/19/10 meeting:

- Flow projection (Ernie Clarke)
  STATUS - projected flows were shared via email on April 22.
- Run projection (Joe Polos)
  STATUS - run size projection were shared via email on April 30.
- NEPA documents (Ernie Clarke)
  STATUS - Buford provided Ernie with the NEPA documents for 2003/2004 actions.
- Summarize triggers for 2003-2004 flows. Propose modifications (Tim Hayden).
  STATUS - Outstanding.
- Provide info on potential ceremonial releases (Tim Hayden).
  STATUS - Outstanding.

2. Proactive and Emergency Triggers:

- Proactive triggers
  - Used to prompt a proactive or preventative release. The objective of such a release is to reduce the likelihood of a large scale fish die-off by ensuring conditions known to be adequate for adult up migration through the Lower Klamath River.
  - Include (1) projected fall Chinook run sizes in combination with (2) projected flows in the Lower Klamath River.
  - Run size trigger

        - Projected run size ≥ average
    - Flow trigger
        - A minimum discharge of 2200 cfs for Klamath River at Orleans plus Trinity River at Hoopa was recommended by the DFG (July 2004).
        - Ambiguity exists over the flow target for the Klamath River at Turwar. The Yurok Tribe previously recommended a target of 2500 cfs at this location. Other thresholds (3000, 2750) have also been mentioned in previous years.
- Emergency triggers
    - Used to prompt an emergency release. The objective of such a release is to reduce the severity of a fish die-off
    - Triggers related to water temperature, fish behavior, estuary configuration, disease monitoring, incidence of dead fish, and fish density have been proposed in previous years.
    - Josh suggested that the emergency release could be tied primarily to one of these emergency triggers: disease monitoring.
    - In previous years it was uncertain if the response time was rapid enough to allow real-time monitoring to be used to reduce the severity of a fish die-off. There are physical and operational constraints that limit the speed of an emergency release. While the biologists would prefer the use of emergency triggers as a more measured approach, proactive releases have been the preferred response in the past to limit the risk of a major die-off.

3. 2010 Projections:

- Flow projections were made by combining scheduled releases from Iron Gate and Lewiston Dams with cautious tributary accretion forecasts (90% exceedence level). Projections fell short of target flows for both Klamath River at Turwar and Klamath River at Orleans plus Trinity River at Hoopa.
- The projected in-river fall Chinook salmon run is 110,700 adults, slightly above the mean.
- *PROVISIONAL FINDING: Since the estimated pre-season run is average or greater in size and discharges are projected to be low, there is concern for a die-off. Therefore, a release may be warranted this fall.*
- The group intends to revisit the flow projection/finding on June 28.

4. Recommendations for This Year:

- Group recommends that BOR reserve 35,000 acre-feet of water for a possible fall flow.
- The forecast and recommendation will be updated late June. A refined recommendation will be provided at that time.
- Since an emergency release would be preferable if it can be timed to reduce the severity of a die-off, the group will document the necessary sequence and duration of events in June to determine if that approach is viable.
- The group will attempt to develop a standard approach for this issue to be used in future years.

5. Monitoring:

- An August 17 2004 USFWS memo summarized monitoring that was ongoing and needed to support and evaluate fall flow releases.
- Of the emergency triggers, disease and temperature monitoring are ongoing.
- The discussion was tabled for the June 8 meeting.

6. New Tasks:

- **Ernie Clarke** – Document the various flow triggers previously mentioned for the Klamath River at Turwar.
  GOAL – Clarify the flow trigger for this location.
- **Joe Polos** – Provide potential Trinity River pulse flow hydrographs.
  GOAL – Development of a release schedule.
- **Buford Holt** – Chronicle how fast water could be delivered to alleviate a problem identified through monitoring.
  GOAL – Evaluate the utility of an emergency response.
- **Josh Strange** – Document the proposed Ich trigger.
  GOAL – Development of real time monitoring triggers.
- **Josh Strange** – Describe the utility of temperature monitoring as an emergency trigger.
  GOAL – Development of real time monitoring triggers.
- **Seth Naman** – Get forecast from California/Nevada river forecast center.
  GOAL – Integrate best possible information when developing a fall flow recommendation.
- **Ernie Clarke** – Provide Jennifer Faler, Acting Executive Director of the Trinity River Restoration Program, the recommendation that BOR reserve 35,000 acre-feet of water for a possible fall flow. Ask that Jennifer forward the request on to Sue Fry and Brian Perrson, BOR Area Managers for the Klamath Basin and Northern California Area Offices.
  GOAL – Ensure capacity exists to respond to a potential die-off since this is a borderline year.
- **Buford Holt/Ernie Clarke** – Develop a straw man decision tree/timeline.
  GOAL – Develop a standard approach for fall flow augmentations.

7. Next meetings:

- Conference call on 6/8/10 (Tuesday) at 10AM
  TOPICS: Task update, emergency triggers, emergency response timing, monitoring, decision tree.
- Conference call on 6/28/10 (Monday) at 10AM
  TOPICS: Updated flow projection, recommendation.

Meeting Summary

Topic:	Klamath Fall Flow Augmentation Evaluation
Date/Time:	June 28, 2010/10 AM
Location:	Yurok Community Center, Weitchpec, California
Attendees:	Michael Belchik* (Yurok Tribal Fisheries Program (YTFP)), Mike Berry (California DFG), Ernie Clarke (USFWS, Weaverville), Robert Franklin (Hoopa Valley Tribal Fisheries (HVTF)), Tim Hayden (YTFP), Danny Jordan (Hoopa Valley Tribe Self-Governance Coordinator), George Kautsky (HVTF), Seth Naman (NOAA Fisheries), Mike Orcutt (HVTF), Joe Polos (USFWS, Arcata), Josh Strange (YTFP), Eric Wiseman (USFS)
On phone:	Eric Peterson* (Bureau of Reclamation (BOR)), Rod Wittler* (BOR), * indicates participation in a portion of the meeting.
Background:	This was the 3rd in a series of meetings to evaluate the need for a special flow release for late summer/fall 2010.
Goal:	The goal of the meeting was to discuss potential criteria and protocols for a fall flow release based on available information. Josh Strange's June 2010 *Draft Summary of Scientific Evidence to Guide Special Dam Releases to Prevent Adult Fall Chinook Salmon Mass Disease Mortality in the Klamath River* provided a framework for the discussion and included proposals for proactive and emergency releases.
Recorder:	Ernie Clarke

General Comments/Concerns:

- Why did the group ask BOR to reserve an arbitrary volume of 35,000 acre-feet for this autumn when a different volume (50,000 acre-feet) has precedent?
- BOR does not need to purchase water in the Trinity reservoir to protect downstream fishery resources.
- Is the group considering the utility of a release on the Klamath side?
- Is the group focusing on adults? If so, the focus needs to be broadened.
- The group needs to consider impacts to ongoing monitoring and construction activities.
- Is the group considering the monitoring needed to support an emergency release?
- The group needs to develop a specific recommendation as soon as possible.

Flow Forecast/Eric Peterson:

Eric briefly described the refinements he is making in flow forecasting, which is a work in progress. Eric focuses on improvements in the tributary accretion forecast between Iron Gate Dam and Orleans on the Klamath River. Comments/discussion on the flow forecast:

- Trinity accretions should also be refined.
- Need to account for accretion between Orleans/Hoopa and Terwer.

- Need to verify Iron Gate Dam releases for August.
- The forecast will be helpful early in the year but needs to get more accurate as the year progresses. A key prediction is of September 1 flow made on August 1.
- USFS may have tributary data records to share and may collect data this year to support forecast.
- National Oceanic and Atmospheric Administration, National Weather Service, California-Nevada River Forecast Center may provide a forecast.
- Need to consider ceremonial releases from Iron Gate Dam.
- Group recommends that Eric model both average and minimum flows.

Summary of Scientific Evidence to Guide Special Dam Releases/Proposed Release/Josh Strange:
Josh summarized his paper and then discussed his proposed criteria and protocols for a proactive release. Comments/discussion on the elements of a proactive release:

- Need to maintain a high standard for protection of a trust resource.
- People agree with the proactive release concept. Individuals want the opportunity to consider the (1) minimum flow threshold and (2) window of concern.
- General agreement that the minimum flow threshold ≥ 2500 cfs and ≤ 3100 cfs.
- Consideration given to a minimum flow threshold moderated by run size.
- Consideration given to extending the widow of concern through the end of Sept.
- Collateral damage not evident from past releases.
- Need to document process/results each year.

LUNCH BREAK

Summary of Scientific Evidence Continued/Josh Strange:
Josh summarized his paper and then discussed his proposed criteria and protocols for an emergency release. Comments/discussion on the elements of the emergency release:

- People agree with the emergency release concept. Individuals want the opportunity to consider the (1) magnitude and (2) duration of the pulsed spike.
- Response if a single diseased fish is found needs to be elaborated.
- Monitoring is in place to support the emergency release triggers. Might be beneficial to use telemetry if we have a high release.

TASK SUMMARY

INPUT REQUESTED FROM ALL
Input is requested by July 8th on four specific elements of the Proactive and Emergency releases. In each case, please provide justification for the option your organization supports.

Proactive release

1. FLOW TRIGGER for rkm 13

   Options:

   1. IF flows were above 2,500 cfs THEN no special flow release (Source: Josh Strange's paper)
   2. IF flows were above 3,000 cfs THEN no special flow release (Source: 2003/2004 actions)
   3. IF flows were above 3,100 cfs THEN no special flow release (Source: discussion at 6/28 meeting; 3,100 cfs is the long-term average September flow)
   4. Moderated flow threshold - threshold would be a function of run-size. (Source: discussion at 6/28 meeting; under development by Josh Strange)
   5. Other?

2. WINDOW OF CONCERN

   Options:

   1. Last week in August through third week in September (Source: Josh Strange's paper)
   2. Last week in August though end of September (Source: discussion at 6/28 meeting; window should be flexible to allow for deviations in run timing)
   3. Other?

Emergency release

3. MAGNITUDE OF PULSED SPIKE

   Options:

   1. Double flows (Source: discussion at 6/28 meeting)
   2. Increase flows to 4500 cfs (Source: discussion at 6/28 meeting; 4,500 cfs exceeds almost all August/September flows from 1978 to 1990)

4. DURATION OF PULSED SPIKE

   Options:

   1. Three days (Source: Josh Strange's paper)
   2. Other?

Other tasks:

1. Eric Wiseman – provide available USFS tributary flow records. Describe monitoring that will be conducted this year to support Eric Peterson's forecast.
2. Ernie Clarke – Calculate water volume needed for proactive releases of 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 cfs between the last week of August and end of September.
3. Ernie Clarke – Calculate water volume needed for an emergency release. Assume flows before the release are 2,500 cfs. Consider spikes of 4,500 cfs and 5,000 cfs.
4. Eric Peterson – Complete forecast tool. Revise flow forecast.
5. Seth Naman – Pursue forecast from California/Nevada River Forecast Center.
6. Josh Strange – revise the paper to include
   a. Provision for extending window of concern through October 1 depending on run timing.

b. Moderated flow threshold based on run-size.
c. Description of response is 1 diseased fish is encountered (i.e. notify Scott Foott, increase sampling)
d. Statement that Klamath or Trinity water could be used for the emergency release.

7. Ernie Clarke – Advise individuals involved in construction/monitoring activities of the provisional plan for 2010 releases.
8. Ernie Clarke – Provide June 28th meeting summary
9. Ernie Clarke – Provide agenda/call-in number for July 12th meeting in Hoopa.
10. ALL – provide comments on draft paper to Josh Strange
11. Ernie Clarke – provide draft rules for the proactive/emergency releases
12. Ernie Clarke – seek Reclamation input on emergency release (see June 25 email from Seth Nanam)

Next meetings:

- 7/12/10 at 1PM in Hoopa, California

Meeting Summary

Topic:	Klamath Fall Flow Augmentation Evaluation
Date/Time:	July 12, 2010/1 PM
Location:	Hoopa Valley Tribal Fisheries, Hoopa, California
Attendees:	Ernie Clarke (USFWS, Weaverville), Robert Franklin (Hoopa Valley Tribal Fisheries (HVTF)), Tim Hayden* (Yurok Tribal Fisheries Program (YTFP), Danny Jordan (Hoopa Valley Tribe Self-Governance Coordinator), Seth Naman (NOAA Fisheries), Mike Orcutt* (HVTF), Josh Strange* (YTFP)
On phone:	Mike Berry (California DFG), Larry Hanson (California DFG), Buford Holt (Bureau of Reclamation (BOR), NCAO), Eric Peterson* (BOR, Weaverville), Rod Wittler* (BOR, Weaverville), Thomas Weseloh (Trinity River Adaptive Management Working Group, California Trout, Inc.) * indicates participation in a portion of the meeting.
Background:	This was the 4th in a series of meetings to evaluate the need for a special flow release for late summer/fall 2010.
Goal:	Develop a recommendation for 2010 proactive and emergency releases.
Recorder:	Ernie Clarke

Opening Comments (Ernie Clarke):

- Group charged with answering the 6 objectives that arose at the March 31/April 1 Trinity Management Council meeting in Hoopa, California.
- Summary of key events:
  - April 19 and May 10 - Met by telephone.
  - May 11 – Provisional recommendation that BOR reserve water.
  - June 24 – Strange's draft whitepaper with proposed special flow releases.
  - June 28 – Met in person in Weithcpec.
  - July 7 – National Weather Service flow forecast tool available.
  - July 7 –Peterson's draft report on a different Terwer flow forecast tool.
  - July 9 – Shared input provided by each organization on special flow releases.
- Review today's goal/agenda

Report on Outstanding Tasks:

- Wiseman – provide available USFS tributary flow records. Describe monitoring that will be conducted this year to support Eric Peterson's forecast.
  Report: no data were provided thus far; no tributary flow surveys will be conducted.
- Clarke – Calculate water volume needed for proactive release.
  Report: Water volume needed to increase dam releases by 100 to 1000 cubic feet per second (cfs) between the last week of August through the end of September shared with team on July 7; ranges from approximately 7,000 to 70,000 acre-feet.
- Clarke – Calculate water volume needed for emergency release.
  Report: Water volume needed for 3 emergency release options shared with team on July 7; ranges from approximately 17,000 to 21,000 acre-feet.
- Peterson – Complete forecast tool. Revise flow forecast.

Report: draft description provided to team on July 7; indicates that there is a 90% chance of exceeding flows of 2759 cfs in August and September 2010.

- Naman – Pursue forecast from California/Nevada River Forecast Center.
  Report: National Weather Service flow forecast tool provided to team on July 7; indicates Terwer flows will likely exceed 3000 cfs in August and September 2010.
- Strange – revise the whitepaper.
  Report: 2nd draft provided on July 7.
- Clarke – coordinate with construction/monitoring activities.
  Report: RIG has indicated the impact of even special releases of 100 cfs. Still needs to coordinate with weir/IHAP monitoring teams.
- ALL – provide comments on draft paper to Josh Strange
  Report: USFWS provided comments.
- Clarke – provide draft rules for the proactive/emergency releases
  Report: release instruction template was provided by Rod Wittler on July 7.
- Clarke – seek Reclamation input on emergency release
  Report: Reclamation is awaiting a recommendation from this group in order to provide input.

ELEMENTS OF THE SPECIAL FLOW RELEASES

Input was provided by several organizations on four specific elements of the special flow releases (see table).

Release	Element	Organization						
		CDFG	Hoopa	NOAA	Reclamation	USFS	USFWS	Yurok
Proactive	FLOW TRIGGER for rkm 13							
	Option 1. IF flow > 2,500 cfs THEN no special flow release	X		X	X		X	X
	Option 2. IF flow > 3,000 cfs THEN no special flow release							
	Option 3. IF flow > 3,100 cfs THEN no special flow release							
	Option 4. Moderated flow threshold.		X			X		
	Option 5. Other?							
	WINDOW OF CONCERN							
	Option 1. Last week in August through third week in September	X		X	X		X	X
	Option 2. Last week in August though end of September		X			X		
	Option 3. Other?							
Emergen.	MAGNITUDE OF PULSED SPIKE							
	Option 1. Double flows			X	X	X	X	
	Option 2. Increase flows to 4500 cfs	X						
	Option 3. Other?							
	DURATION OF PULSED SPIKE							
	Option 1. Three days	X		X	X	X	X	
	Option 2. Other?							

Each element was discussed relative to a 2010 recommendation.

Proactive release

FLOW TRIGGER for rkm 13

Discussion: The group wants to consider a flow trigger that is moderated by run size in future years. It needs to be clear to Reclamation that 2,500 cfs is the floor.

If an emergency release can't be implemented immediately, the group will revise the proactive release to be more protective.

Water from Trinity or Iron Gate Reservoirs can be used to for the proactive release.

Decision: Unless it is learned that an emergency release can't be implemented immediately, a lower Klamath discharge of 2,500 cfs will trigger a proactive release.

WINDOW OF CONCERN

Discussion: The group wants to have flexibility to act if unexpected conditions arise (e.g. late run).

Decision: Last week in August through third week in September. Language will be added to the recommendation to allow flexibility in this period if conditions differ from what is typical.

Emergency release

MAGNITUDE OF PULSED SPIKE

Discussion: Group relying on judgment of Josh Strange and Dr. Scott Foott.

If an emergency release can't be implemented immediately, the group will rely more heavily or entirely on proactive releases.

Water from Trinity or Iron Gate Reservoirs can be used to for the emergency release.

Decision: Tentatively to double flows in the lower Klamath. Dr Foott's input is critical.

DURATION OF PULSED SPIKE

Discussion: Group relying on judgment of Josh Strange and Dr. Scott Foott.

Decision: Between 3 – 7 days. Dr Foott's input is critical.

New tasks:

1. Clarke – Advise individuals involved in construction/monitoring activities of the provisional plan for 2010 releases.
2. Clarke – Replace 2005 ceremonial release with the more recent 2009 release.
3. Clarke – Provide July 12th meeting summary.
4. Clarke – seek Reclamation input on emergency release; if an emergency release can't occur immediately then the group needs to rely more heavily on preventative measures. Therefore the proactive release would be adjusted.
5. ALL – Provide input on FUTURE special flow releases. Specifically need input on 2-step proactive threshold.
6. ALL – Provide specific policy issues that impact the special flow releases
7. Strange – Coordinate with Dr. Scott Foott regarding the emergency release. Revise emergency release criteria accordingly.
8. Strange – Revise paper to state that Iron Gate or Trinity water can be used for both special release types.
9. Strange – Add flexibility to the window of concern for the proactive release.
10. ALL – Provide list of individuals/organizations that need to participate in future years.

Next meetings:

- No future meeting was scheduled.

Meeting Summary

Topic:	Klamath Fall Flow Augmentation Evaluation
Date/Time:	August 10, 2010/10 AM
Location:	Yurok Community Center, Weitchpec, California
Attendees:	Michael Belchik (Yurok Tribal Fisheries Program (YTFP)), Ernie Clarke (USFWS, Weaverville), Tim Hayden (YTFP), Mike Orcutt (Hoopa Valley Tribe Fisheries), Joe Polos (USFWS, Arcata), Don Reck (Bureau of Reclamation (BOR), NCAO), Keith Schultz (BOR, KBAO), Josh Strange (YTFP)
On phone:	No one; while a call-in number was available, phone service from Weitchpec was interrupted.
Background:	This was the 5th in a series of meetings to evaluate the need for a special flow release for late summer/fall 2010.
Goals:	Receive Input From Bureau of Reclamation Klamath Basin Area Office (KBAO). Review recommendation for 2010 proactive and emergency releases.
Recorder:	Ernie Clarke

Opening Comments (Ernie Clarke):

- Group charged with answering the 6 objectives that arose at the March 31/April 1 Trinity Management Council meeting in Hoopa, California.
- History:
  - There was a significant fish die-off occurred in the lower Klamath River in 2002.
  - The die-off was attributed to the pathogens Ich and Columnaris, though several other contributing factors were cited, including an above-above average run size, low flow rates, and correspondingly high river temperatures.
  - Water was released from Trinity Reservoir in 2003 and 2004 in an attempt to prevent a similar episode. A flow trigger of 3,000 cfs was used in each case.
  - From 2005 onward two triggers were considered: above average run-size and flows below 2,500 cfs.
- Review today's agenda:
  - KBAO General Concerns, Specific Comments, Additional Information
  - Discussion of KBAO Input
  - Review of 2010 Recommendation
  - Review of Summary Memo
  - Review of Outstanding Tasks
  - New Actions/Next Steps

KBAO General Concerns, Specific Comments, Additional Information:

- Keith Schultz shared comments and concerns with the group through review of 3 documents:

- MS Word file "KS edited version of July_15_2010 document"; includes Keith's highlighted concerns with the July 15 version of "Summary of Scientific Evidence to Guide Special Flow Releases to Prevent Adult Fall Chinook Salmon Mass Disease Mortality in the Lower Klamath River".
- PDF file "July 30 2010 Attachments"; includes pages 209, 213 and 215 from Bodensteiner et al. (2000) and pages 66 and 159 from Turek et al. (2004).
- PDF file "August 6 2010 Attachment"; includes pages 856, 866 and 869 from Bartholow et al. (2005).

- Keith's overall concerns were that the group better describe the limitations of the evidence and uncertainty associated with the suggested management action.

Discussion of KBAO Input:

- The group reviewed many of Keith's concerns and discussed how to add clarification or supporting evidence.
- Josh will revise the paper to reflect Keith's input plus the group's discussion.

Review of 2010 Recommendation

- Previously agreed upon criteria and protocols were not revised based on this meeting.

Review of Summary Memo

- Ernie shared a summary memo with the group on July 23, 2010
- The intent of the memo is to convey the group's findings to the Trinity Management Council and document the process/tools utilized.
- The memo could use a critical review to ensure it highlight salient information and provides appropriate context.
- Contributor's policy concerns also need to be submitted for inclusion.

Review of Outstanding Tasks

- Not addressed.

New tasks:

- ALL – provide Ernie Clarke with comments on summary memo by August 13. Critical items are: suggested revisions, policy concerns, salient information from attachments.
- Josh – revise the paper to reflect Keith's input plus the group's discussion by August 13.

Next meetings:

- No future meeting was scheduled.