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IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF CALIFORNIA

SAN LUIS & DELTA-MENDOTA WATER AUTHORITY and WESTLANDS WATER DISTRICT, Plaintiffs, v. SALLY JEWELL, as Secretary of the U.S. Department of the Interior; U.S. DEPARTMENT OF THE INTERIOR; U.S. BUREAU OF RECLAMATION; ESTEVAN LOPEZ, as Commissioner, Bureau of Reclamation, U.S. Department of the Interior; and DAVID MURILLO, as Regional Director, Mid-Pacific Region, Bureau of Reclamation, U.S. Department of the Interior, Defendants.	Case No. 15-cv-1290 **DECLARATION OF JOSHUA STRANGE** Courtroom 4, 7th Floor Judge: Honorable Lawrence J. O'Neill Hearing Date: TBD Action Filed: August 21, 2015

I, JOSHUA S. STRANGE, Ph.D., declare as follows:

I. Qualifications

1. I am employed by Stillwater Sciences as a Senior Fisheries Biologist wherein I perform a wide-range of duties as part of a multidisciplinary team of environmental resource professionals. We serve a full spectrum of clientele, including a variety of governmental agencies, NGOs, tribes, hydropower companies, construction firms, and irrigation and water districts. My overall training is in aquatic ecology, which is widely inclusive, and I have specific expertise in fish biology, fish physiology and bioenergetics, fish migration and behavior, fish disease ecology, fish population dynamics, plus instream flows, habitat use, and restoration. My academic degrees include a Bachelor of Science in Fisheries Biology from Humboldt State University, and a Ph.D. in Fisheries Biology from the School of Aquatic and Fisheries Sciences at the University of Washington. I have completed graduate level courses in hydrology and statistics, and taught a comprehensive fish ecology course at Humboldt State University. I have conducted extensive applied research in the Klamath–Trinity basin and have first-hand knowledge of its rivers and fishes, in particular the migration behavior, run-timing, and fish health dynamics of all races of Chinook and coho salmon. I previously worked both part and full time for the Yurok Tribe as a research biologist for ten years, and my Ph.D. dissertation research was funded in part by the National Science Foundation.

2. My dissertation research focused on adult Chinook salmon migration in the Klamath-Trinity basin and was initiated in 2002 prior to the Klamath River fish kill in September of that year. I was on the lower Klamath and Trinity rivers daily tracking adult Chinook salmon by boat, airplane, and road during the summer and fall of 2002 and was one of the initial responders on September 19th 2002 to the first reports of salmon mortality from the day before. I have personal, first-hand knowledge of the river conditions, monitoring data, and salmon behavior leading up the 2002 fish kill and in subsequent years thereafter including 2014 and thus far in 2015. The peer-reviewed publications resulting from my dissertation research established

the upper thermal limits to upstream migration in adult Chinook salmon, comprised the first large-scale published study of estuarine behavior of adult Chinook salmon, and revealed the migration patterns and migration timing of all major runs of adult Chinook salmon in the Klamath River basin starting from estuary entry until arrival to spawning grounds or hatcheries.

3. I have designed, led, and assisted with numerous studies of fish health and disease ecology for juvenile and adult salmonids in the Klamath-Trinity basin, including but not limited to annual monitoring of pathogen levels in adult fall run Chinook salmon in subsequent years after the 2002 Klamath River fish kill. As part of these studies I have conducted extensive work in the field and laboratory and have collaborated with fish pathogen experts and researchers at the U.S. Fish and Wildlife Service (USFWS) CA-NV Fish Health Center and the Department of Microbiology at Oregon State University (OSU) among others. I have participated in the Klamath Fish Health Assessment Team (KFHAT) and have helped provide leadership for the core group of fish disease researchers in the Klamath-Trinity basin that organizes the annual Klamath Fish Health Conference. I have thoroughly researched the various scientific explanations for why and how the 2002 fish kill happened, and for why and how Ich outbreaks occur, including interviewing authors of relevant papers from other Ich fish kills of adult salmonids and controlled experimental studies on Ich. I was the author of the technical memorandum (Strange 2010a) that formed the basis of the original fall flow fish health release recommendations to the Trinity River Restoration Program (TRRP) and I have continued to provide updates to disease outbreak risk in subsequent years. The TRRP fall flows subgroup used this report to develop the first comprehensive fall flow release criteria to protect mixed-stock fall run Chinook salmon, and coho, in the lower Klamath River, which was issued in 2010. I have been an active participant in the TRRP's fall flows subgroup and associated coordination and management meetings, including technical discussions with the USBR. In light of my expertise on fish disease ecology and migration behavior, I have provided technical assistance and input on ESA consultations regarding listed Southern Oregon/Northern California coho ESU (includes Klamath and Trinity coho), Klamath hydro-relicensing, the Trinity Management Council, and the Secretarial Determination process for the Klamath River settlements. I have

assisted collaborators at the USFWS, USGS, and OSU in developing fish disease modules and epidemiological models that interface with larger population models.

4. I have experience reviewing, developing, and conducting limiting factors analysis for salmonids using a variety of quantitative life-cycle models in the California Central Valley, California coast, Alaska, and the Klamath-Trinity basin for coho, Chinook salmon, and steelhead/rainbow trout to assess population level effects. These modeling efforts have often included instream flow analysis and water temperature models with a variety of management scenarios including climate change. I have monitored and analyzed water temperature data throughout the Klamath-Trinity basin.

5. I am actively involved in environmental review and research in the Sacramento-San Joaquin basin for a variety of fish species with an emphasis on the Sacramento-San Joaquin Delta and listed species such as Delta smelt and winter and spring run Chinook salmon. I previously completed comprehensive environmental review of available information, study results, and management actions pertaining to the Delta as the lead author on fisheries resources of the Delta as part of the development of the CVP/SWP OCAP Remand EIS.

6. I am an active member of the American Fisheries Society and have organized conference sessions and been invited as a plenary speaker at other professional conferences. I provide peer-review for submitted manuscript for a variety of fisheries journals. I have published multiple articles in peer-reviewed fisheries journal and authored numerous technical reports and conference presentations. A partial statement of my qualifications is provided as Exhibit 1.

II. <u>Scope of declaration</u>

I intend to discuss the following in my updated declaration and testimony as needed: 1) The causative and contributing factors in the 2002 Klamath River fish kill including leading explanations and hypotheses, the role of river flows, origin of water, water velocities, turn-over rates, water temperature, fish densities, fish size, run size, fish migration behavior, pathogen behavior, and timing and trajectory of lethal infections. 2) The scientific rationale and evidence supporting the protective fall flow recommendations to reduce the likelihood of future Ich outbreaks, including the biology and pathology of Ich. The process of development of protective flow release recommendation by the TRRP fall flows subgroup from 2010 to 2015 and the impacts of past special and protective flow releases including 2013 and 2014. 3) The protective flow augmentation releases (FARs) for 2015, including the risk factors and the level of risk with and without the 2015 FARs, and the level of uncertainty versus confidence in this assessment and effectiveness of such protective flows. 5) A review of the low likelihood of significant non-target negative biological impacts as identified previously by the TRRP fall flows subgroup.

III. The best available science on the 2002 Klamath River Fish Kill

1. I previously conducted a comprehensive and independent review and analysis of the 2002 Klamath River fish kill and of the primary pathogen responsible, a motile protozoan parasite commonly called Ich (*Ichthyophthirius multifiliis*). The results are represented in precise, technical detail in Strange (2010a) but are summarized below in less technical language[1].

2. The key to understanding the 2002 fish kill in the lower Klamath River lies primarily in the biology of Ich, which has three primary life-stages: 1) the free-swimming infectious theront; 2) the parasitic and pathogenic trophont; and, 3) the reproductive tomont (Figure 1). The free-swimming theront is the most vulnerable life-stage because it is not embedded in a host fish like trophonts, nor eventually encysted and attached to substrates like tomonts, and it also must find a suitable host within 22.5 hours at 20°C or it will perish from starvation (McCallum 1982). While low level Ich infections can be tolerated well, Ich typically kills when trophonts reach an excessive level of abundance on the gills in too short of a time leading to a diseased state (hyperplasia) with loss of gill function and asphyxiation (Dickerson 2006).

3. The biology of Ich is very well established because it is one of the paramount diseases of concern in the aquarium trade and in freshwater fish farming (typically called white spot disease), and as such is the subject of a very large body of studies and published literature, and this research spans a century (Fish 1935; Hines and Spira 1974; Dickerson 2006). In recirculating water systems, such as used in the aquarium trade, aside from toxic chemicals the primary treatment is to regularly replace the tank water with clean water absent of Ich, which reduces the number of parasites that can eventually attack and infect skin tissues of fish in the

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[1] A secondary parasite, the bacterium *Flavobacterium columnare* (columnaris), often goes hand in hand with Ich, but in combination, Ich comes first because it provides an opening in the skin for the bacteria to enter, either on its own or attached to the cilia of Ich. Further, columnaris can infect fish without Ich being present from minor scratches and cuts that fish get during the course of their migration and surviving predators and fisheries. For these reasons and others I will focus on Ich.

system. In flow-through water systems such as often used in hatcheries and in freshwater fish farms, the primary treatment is to increase the amount of water flowing through the system. In addition to dilution of parasites, increasing the flow and turn-over rates in a flow-through system can remove parasites by flushing them out of the system. Also, the high velocities can help disrupt Ich's ability to encounter and attach to the skin or gills of host fish. In sum, such treatments address Ich infections by diluting, disrupting, or removing the infectious Ich theronts. This free-swimming theront is the key, and most vulnerable, life-stage to disrupt in order to reduce the risk of an Ich outbreak. The tiny hairs (cilia) that allows theronts to swim provide weak mobility in relation to swift currents and the swimming ability of fish. According to noted microbiologist, fish immunologist, and Ich expert Dr. Harry Dickerson, the simplest treatment for Ich infections is to break the infectious cycle by "reduction or removal of theronts" (Dickerson 2006; pg. 142), consistent with the positive linear relationship between theront abundance and resulting parasitic trophont infection level found my McCallum (1982) absent disruption from swiftly flowing water.

4. Multiple studies and reports describe and recommend the use of increased flows, reservoir releases, or flow rates as a treatment for Ich in rivers and fish culture settings (Butcher 1947; Reshetnikova 1962 as cited by Hines and Spira 1974; MELP 1993; Hop Wo et al. 2005; Bodensteiner et al. 2002; Dickerson 2006). One notable study conducted in a controlled hatchery setting, found that increase water flow, and specifically water velocities and turnover rates, was the most effective means to prevent Ich outbreak and reduce mortality rates (Bodensteiner et al. 2002). Importantly this occurred at all fish densities tested suggesting that fish densities are not a controlling factor in Ich outbreaks but rather a contributing factor, similar to host fish density findings by McCallum (1982). It's also important to note that while this study clearly demonstrated the paramount importance of flow for Ich outbreaks by controlling other variables, and specifically water velocities and turnover rates, it would be scientifically invalid to transfer the specific quantitative values measured in this controlled hatchery study to a river setting for another fish species. Rather measurements would have to be taken at variety of river flow conditions with and without outbreaks in addition to data on the levels of Ich in the river and on

fish. Accounting for confounding or contributing variables would require direct measurement of such variables or a long-term data set using consistent methods. In the case of the Klamath River, repeating such a study is neither readily possible nor desirable, but we do know with certainty that the low flows in 2002 resulted in water velocities and turnover rates that were sufficiently low to allow for an explosive and lethal Ich outbreak under the circumstances and conditions in that year, which included a large run of salmon. The need for Ich parasites to be mobile, but their limited ability to move in currents, helps explain why the unusually lows flows of 2002 caused conditions that allowed the rapid spread of Ich leading to mass mortality of infected salmon. The large salmon run of 2002 given the low flows helps explain why infection severity, while unquantified, reached lethal levels. This is also consistent with the observation that no Ich outbreaks have occurred in years with sufficient protective flows. Based on the literature and observations from the Klamath River, it can be concluded that Ich outbreaks can reliably be prevented with sufficient flows (magnitude, duration, timing) even with large runs of salmon or large numbers of fish, even with less than ideal water quality or temperatures (e.g., 2012 and 2013). The only uncertainty in this is what constitutes sufficient flows for a given setting. I discuss the topic of flows sufficient to prevent outbreaks in the lower Klamath River and the explanations for occurrence of the non-lethal Ich outbreak in 2014, and the lack of fish kills in other years outside of 2002, in subsequent sections of this declaration.

5. Furthermore, the biology of Ich and the controlling versus contributing factors for outbreaks and the importance of flows can be understood further by examining evidence and circumstances from all known Ich outbreaks that have occurred in wild salmonids. Such outbreaks have occurred, typically with high rates of mortality, in four locations: in tributaries to Babine Lake British Columbia (over a cluster of several years; Traxler et al. 1999), in the Nanaimo River on Vancouver Island British Columbia (MELP 1995; Wo et al. 2005), in a tributary to the Sacramento River (Butte Creek over two consecutive years; CDFG 2004), and in the lower Klamath River in 2002 (Foott 2002; Guillen 2003; Belchik et al. 2004; Turek et al. 2004) and 2014 (Belchik 2015). Several important lines of evidence and conclusions emerge from these fish kills: 1) the outbreaks in Babine, BC occurred at cold water temperatures that are

ideal for salmon and less than optimal for Ich (13-15ºC), which proves that warm or stressful water temperatures are not required for lethal Ich outbreaks in wild salmon; 2) all of these outbreaks occurred in rivers or reaches in drier years that also had artificially reduced flows or severely degraded water quality; 3) increases in flows and special flow releases were instituted with apparent success at preventing Ich outbreaks and mortality in all locations; and 4) all of these outbreaks occurred with adult salmon that were holding prior to spawning or unable to migrate (i.e., not migrating) with the exception of salmon in the Klamath River, which were just beginning their upstream migration with no migration barriers present.

6. In all of these locations increased flows and augmented flow releases were subsequently used with apparent success at preventing Ich outbreaks, including the Klamath River. For example, Butte Creek experienced drought conditions in 2012, 2013, and 2014 and generally large returns of Chinook salmon (i.e., ≥15,000 spring run fish), similar to the Klamath River. In these recent years on Butte Creek, no Ich outbreaks (Garman 2014) and elevated mortality occurred such as was documented in 2002, and especially 2003, with the overlap of large returns and drought conditions with diversions (CDFG 2004). The notable difference was changes in hydropower diversions led to flows in Butte Creek being approximately doubled in recent years relative to the Ich outbreak years as part of real-time adaptive management flow releases in a collaborative effort between agencies and PG&E to improve creek conditions and protect fish health (Garman 2014). As another example, in the Nanaimo River BC, recurrent Ich outbreaks and mortality associated with elevated water temperatures and artificially reduced flows led to the adoption of the multi-objective Nanaimo River Water Management Plan (MELP 1995), which includes minimum flow requirements encompassing fall run Chinook salmon migration timing, much like the Klamath. Flows below these minimum requirements trigger reservoir releases to improve river and migratory conditions to prevent Ich outbreaks and mortality. In the years after implementation of this water management plan, which includes reservoir management rules to ensure sufficient storage for fish releases, Ich outbreaks have not been occurring among Nanaimo River Chinook salmon (Hop Wo et al. 2005; Lam and Carter 2010).

7. The fact that all of these Ich outbreaks in other locations occurred with adult salmon that were not migrating with the exception of salmon in the Klamath River is notable for several reasons. Actively migrating salmon would be unlikely to suffer a serious Ich outbreak compared to fish that were holding in one location because migrating adult salmon are actively swimming upstream thereby making it difficult for a free swimming Ich to encounter and attach to such a fish. If there was localized hot spot of a highly concentrated of Ich theronts, then migrating fish would move through and beyond such an area relatively quickly and their exposure dose would be comparatively low. This leads to the question of why Ich outbreaks have occurred among migrating salmon in the Klamath River in exception to the dynamic described above.

8. My dissertation research provided the answer to the mystery of why an Ich outbreak occurred in migrating fish: fall run Chinook salmon in the Klamath River have a very unusual behavior of migrating rapidly out of the estuary and upstream for a relatively short distance and then essentially suspending their migration for 7 to 10 days to mill around in deep pools and slowly move from the vicinity of Blue Creek (river kilometer 26) to the confluence of Trinity River (river kilometer 70), after which point they resume steady and comparatively rapid upstream migration to spawning grounds or hatcheries (Strange 2012). I found this to be especially true for Klamath stocks, which mill around more than Trinity stocks, and also enter the river largely before Trinity stocks. This pattern of suspended and slowed migration occurred for fish at the head of the run, in the middle, and at the tail and under a wide range of flow and water temperature conditions, in all years, and with or without augmented baseflows or pulsed flow releases and was not associated with the use of thermal refuges (Strange 2012) or river temperatures in excess of their upper thermal limits to migration (Strange 2010b). In other words, the salmon involved in the 2002 Klamath River lethal Ich outbreak and the 2014 non-lethal Ich outbreak were essentially behaving more like salmon holding in one location, such as occurs on spawning grounds or with migration barriers, which will increase the risk of Ich outbreaks for these fish in any year when flows are low enough to allow or favor Ich infections.

9. I have hypothesized that this atypical suspended and slowed migration is most likely due to the thermal lag in autumn cooling creating by the hydroelectric reservoirs on the upper Klamath River creating an increasing thermal profile as salmon migrate upstream (Strange 2012). I predict that this unusual behavior will mostly dissipate after the planned removal of these dams with implementation the Klamath Hydroelectric Settlement Agreement. If this suspended and slowed migration behavior does indeed dissipate with dam removal, then the risk of an Ich outbreak at given flow will be reduced greatly because the residence time of salmon in the area of concern will decrease significantly along with their exposure dose to theronts. Exposure dose is primarily a function of fish residence time, theronts density, and theront attachment probability. In my opinion, this predicted outcome of dam removal would be the primary non-flow alternative to protecting fish health of all species and life-stages in the Klamath River, including specifically for adults in the lower Klamath River from Ich outbreaks. Based on extensive study and field research, I predict that removal of these dams and their reservoirs will also largely dissipate the problems with toxic *Microcystis aeruginosa* blue-green algae and greatly reduce the abundance of myxospordian pathogens, which are likely important secondary stressors on the health of adult salmon migrating in the lower Klamath River. Unfortunately, until the experiment of dam removal occurs to test these predictions and such benefits of dam removal are realized, FARs are the only effective management tool available to prevent Ich outbreaks and mass mortality in the Klamath River.

10. Finally, while host fish density is not considered a constraint on the establishment of infections (McCallum 1982), the more fish that are present and the larger their body size, the more total Ich parasites that can be shed from infected fish to infect more fish (i.e. average fish body size multiplied by their abundance equals total surface area of fish available to be infected). One outcome of this dynamics is that once an outbreak occurs with high host fish abundance and density (total surface area of the host fish population or run), the mathematics of an outbreak under such host abundance can produce relatively greater numbers of theronts in shorter time, increasing the severity of infections and the likelihood of mortality. Further, while warm water temperatures are not necessary for an Ich outbreak, it does speed up the rate at which Ich can

complete its life cycle and spread from one fish to another (e.g., ~ 5-9 days at temperatures typically occurring in September in the lower Klamath River) and can increases its replicative potential (Nigrelli et al. 1976; Dickerson 2006; Forwood et al. 2015). These factors result in the potential for rapid, explosive spread of Ich during outbreaks (exponential growth rate curve) wherein a small initial number of infected fish can lead to the rapid infection of very large numbers of fish.

11. For example, assuming a value of 512 theronts produced from every trophont (Dickerson 2006), I calculated one adult Chinook salmon with an average of 500 Ich trophonts per gill arch would produce over 3.5 million theronts from such a level of infection. That level of infection in only 1,000 salmon would produce a swarm of over 3.5 billion theronts, while such an infection in 100,000 salmon would produce over 350 billion theronts! This illustrated how the second generation of theronts from an initial group of infected salmon can then infect a much larger number of salmon that will produce even more theronts, with potential result of hyper-levels of Ich. Such as super-infection appeared to be what happened in September of 2002 in particular. Based on the actual water temperatures recorded in the lower Klamath River in September of 2002, I back-calculated September 7th to the 9th as the approximate date when the infection reached a critical mass in 2002. That was when the lethal Ich outbreak initiated its exponential growth phase as allowed by the conditions at that time. Even though the first dead fish were not observed until September 18th, by September 20th, thousands of dead salmon where washing up for miles and then just a few days after that all the fish that were going to die had died. In 2014, direct sampling of fish to count Ich trophont numbers on gills, and analysis of such data, determined that the initiation of the Ich outbreak also occurred during the second week of September (Figures 2 and 3; Belchik 2015).

12. Again, this dynamic of delay between the window of infectivity and actual death, and the rapidity of the exponential spread of infection during favorable conditions, illustrates why it is problematic to simply monitor for signs of Ich infections and then have an emergency release of high flows that would reliably prevent substantial mortality from occurring. In addition, there is time needed to verify that Ich infections are actually at a level that warrants

release of water, then time to get official approval to release the water, and then the two day travel time for the water to reach the lower Klamath River from either Lewiston Dam or Iron Gate Dam. At best it would likely take four days from the first observations of Ich infections by field biologists before the protective flows would arrive to the lower Klamath River. Four days would be more than enough time for the exponential spread of Ich to result in a lethal dose of Ich parasites, depending on severity levels, to tens of thousands of adult salmon. In 2014, it took 6 days from the first detection of severe Ich infections, to verification, to release and arrival of emergency flows to the area of the outbreak in the lower Klamath River. During this delay period, the probability of infection for the run increased to over 50% (Figure 2; Belchik 2015) but fortunately the severity lagged behind prevalence and the emergency doubling of flows retarded the severity of infections (Figure 3; Belchik 2015) and had the apparent effect of preventing mass mortality as intended.

13. Further, lower minimum baseflows or the lack of FARs leading up an outbreak and in the portion of the outbreak prior to the arrival of any emergency flows could contribute to a higher abundance of Ich parasites leading to steeper growth curves for the outbreak, increased severity of infections, and poorer prognosis for survival and greater risk of mass mortality. In 2014, I contend that the augmented baseflow of 2,500 cfs, while not enough to prevent an outbreak given the extreme drought conditions and poor water quality during July to through September combined with a large-run, helped delay the onset and mitigate the severity of the initial outbreak and assisted the emergency flows in having the intended effect of preventing mass mortality of infected salmon. Of course, sufficiently effective preventive FARs would prevent outbreaks and the need for emergency releases.

14. Monitoring of the fall Chinook salmon run for general fish health to determine the level of Ich infections in adult fall run Chinook salmon, and to a lesser extent steelhead and coho, year in and year out was initiated starting in 2003 with sampling every year since including 2014 as part of a long-term monitoring program (Foott 2003; McCovey and Strange 2011; Belchik 2015). If moderate levels of Ich infections are observed but no outbreaks or mass mortality in a given year, it would indicate a lower threshold for infectivity and higher threshold

for mortality that could be monitored and interrupted. However, the opposite has been found with only few fish infected (as in 2 or 3) with Ich and at low infection severity (i.e., only a few parasitic trophonts) from 2003 through 2013 (Foott 2003; McCovey and Strange 2011; McCovey 2014). Consistent with the fact that Ich is an obligate parasite that always requires fish hosts and with the episodic nature of Ich outbreaks described in the literature (Dickerson 2006), this monitoring data from the lower Klamath River strongly suggests an “on-or-off” threshold relationship wherein hard-to-detect low background levels of Ich are always present in the Klamath River, most likely from resident fish species (e.g., suckers, speckled dace, sculpins, introduced brown bullhead catfish). When conditions are not favorable for the spread of Ich, the threshold is “off” and Ich is at non-detectable levels among adult salmon with no outbreaks. Then as soon as conditions are favorable for the spread of Ich, the threshold turns “on” that can quickly lead to an explosive outbreak with high risk of mass mortality. This dynamic was observed in 2014 when Ich counts went from 1 out of 15 salmon (7%) with low-level Ich infections on 9/10/2014, to 7 out of 9 salmon (78%) with low-level to “severe” Ich infections on 9/13/2014, with the outbreak proceeding from then (Figures 2 and 3; Belchik 2015).

15. This is partly why it is so important to prevent an outbreak of Ich before it gets started with proactive FARs. As stated by Dickerson (2006; pg. 142), “prevention of disease is always more cost-effective than treatment”. Even so protocols were developed, by myself and other in the TRRP fall flows sub-group, for triggering an emergency release of a larger magnitude pulsed flow in order to quickly respond if an Ich outbreak was detected and with the goal of sparing as large of a percentage of fish that otherwise would have died if possible. The outbreak of 2014 demonstrated both the importance of preventing outbreaks and also the apparent success of such emergency releases, at least in 2014, in reducing infection severity and subsequent disease progression and mortality.

16. In summary, while there is still always some residual uncertainty involved fish disease ecology involving migrating salmon in a large rugged river, the biology of Ich is very well established as is the importance of flows in controlling Ich outbreaks. Using flows in the form of augmented baseflows and pulsed flow releases from reservoirs is also the only

management tool available in the near-term to prevent outbreaks and mass mortality in the lower Klamath River, and similar flow release strategies have been used in other locations as the primary management action to prevent Ich outbreaks among salmon in regulated river. Even without knowing the exact relative importance of the causative mechanisms whereby flows allow or prevent and control Ich outbreaks in the lower Klamath River among fall run Chinook salmon, or the relative importance of the known contributing factors, FARs from Trinity Reservoir provide benefits to all of the known causative mechanisms controlling theront abundance and Ich related infection probabilities – dilution, disruption, and removal by flushing – in addition to providing benefits to key contributing factors – water temperatures, water quality, and secondary fish stressors.

IV. Protective Flow Recommendations Explained

1. Given the importance of flow in controlling Ich and my documentation of consistently suspended and slowed migration among fall run Chinook salmon in the lower Klamath River, I originally conducted an analysis of summer and fall minimum flows in the lower Klamath River basin in 2010 (Strange 2010a), which showed that flows below 2,500 cfs occur infrequently, and flows near or below the critically low 2002 fish kill flows of 2,000 cfs occur rarely, with only five occurrence since 1978, the starting point for when flow and run size data is available (Figure 4). Further, only two out of the five years with flows on average around 2,000 cfs or lower during the primary fall Chinook migration season (Aug 25 to Sep 21) also had above average run sizes (1988 and 2002), otherwise the other three years occurred in the early 1990s with some of the smallest run sizes on record. Conversely, flows of approximately 2,500 cfs to 4,500 cfs had occurred frequently since 1978 (Figure 4) without any lethal Ich outbreaks such as occurred in 2002. An absence of flows from 2,100 to 2,500 cfs occurred during this period of record.

2. Based on this analysis, I concluded 2,500 cfs to be the absolute minimum required for a reasonable level of confidence that an Ich outbreak and fish kill would be unlikely to occur among fall run Chinook salmon in the lower Klamath River, with disease risk decreasing as

flows increased beyond this minimum threshold. It’s worth noting that using a completely different technique, CDFW staff identified the same flow level as the threshold for substantial fish kill risk and a target for fish kill prevention flows (Turek et al. 2004).

3. To account for the increased Ich outbreak risk and severity potential associated with large runs such as in 2002, I recommend an additional 300 cfs at <u>minimum</u> to provide an adequate level of protection during years with larger run sizes. Thus I recommended a target for augmented baseflows during the primary fall Chinook salmon migration season of 2,800 cfs during years with a forecasted run of ≥ 170,000 fall Chinook salmon, which was the official in-river run size estimate for 2002. One component of my reasoning was that risk of Ich outbreaks should not be considered static over time but rather reasoned that it would be elevated over time in correlation with increasing ecological degradation of the river, especially decreased water quality and increased secondary pathogens, which provided one potential explanation for why a lethal outbreak occurred in 2002 and not in 1988 (I discussed this outlier year further in my 2014 declaration to the court). While there was and is some uncertainty is terms of the degree of importance of run-size for Ich outbreak risk, and whether a run-size threshold exists, smaller run sizes were not considered to adequately compensate for low flows in terms of risk of an Ich outbreak. Risk adverse decision making was recommended, especially given on-going cumulative ecological degradation and residual uncertainties.

V. <u>The non-lethal outbreak of 2014 and further analysis</u>

1. In terms of recent events, a primary question is why did a widespread and serious Ich outbreak occur in 2014 among fall Chinook salmon in the lower Klamath River even with FARs? And secondarily, why didn’t the outbreak result in disease progression and mass mortality as occurred in 2002? I have touched upon the second question to some extent already and discuss the first question in more detail below.

2. As part of evaluating Ich outbreak risk and developing specific FAR recommendations to protect the fall Chinook salmon run in 2014, I evaluated river conditions, projected flows, and likely run size (Strange 2014). For river conditions and flows, 2014 was

worse than 2002 based on flows, water quality, and observations of fish in thermal refuges during July and August. Stressful summer conditions and larger amounts of spring-summer run Chinook salmon using cold water thermal refuges in the lower Klamath River was also observed in 2002 and hypothesize to increase background levels of Ich prior to arrival on the fall Chinook salmon run in late August.

3. In terms of run-size, the preseason forecast was for 92,800 adults fall run Chinook salmon to return to the Klamath River. Based on a conditional correlation with Columbia River fall Chinook salmon run size, I accurately assessed that the preseason forecast was a significant under prediction of the true run size for Klamath River fall Chinook salmon, would I predicted would be at least 150,000 adults. The post-season 2014 in-river run size was 160,444 adults. Given the extreme drought conditions in the summer of 2014 and the likely similarity in run size between 2002 and 2014, I reasoned that the higher minimum protective baseflow for the lower Klamath River of 2,800 cfs (Strange 2010a) should be the target for FARs in 2014 during the primary fall run Chinook salmon migration season. In addition a pulsed flow at the beginning of this period was considered to provide additional protection by allowing any residual spring-summer run Chinook salmon to migrate upstream out of the lower Klamath River and have some flushing effect on any theronts. The final FARs chosen by Reclamation, included a smaller magnitude pulsed flow with a slightly later start date and augmented baseflows on 2,500 cfs. While it impossible to know with certainty, or redo the events of 2014, the answer to the first questions regarding why an Ich outbreak occurred in 2014 is that there the FARs were insufficient. Had 2,800 cfs been the target augmented baseflow then the outbreak would have likely not occurred, consistent with my original recommendations developed in 2010 and my adjusted forecast of run size. This claim is substantiated by the lack of an Ich outbreak in 2013 (McCovey 2014) with an equivalent run size (179,381 total fall run Chinook salmon, albeit significantly lower than preseason forecasts), but with FAR augmented baseflows of 2,800 cfs and a slightly larger magnitude initial pulsed flow (FAR plus Hoopa ceremonial flow)(Hetrick and Polos 2015), even with summer flow conditions being equivalent to 2002 and only somewhat better than 2014 (Figure 5). Again, the official run-size in 2002 was 170,014 total fall

run Chinook salmon, including the fish killed in the lethal Ich outbreak as initially reported by Guillen (2003).

4. In addition, recent analysis that I conducted revels that 2002 and 2014 had a worse combination of flows and run-size than previously realized. I ranked of all 35 years with records of fall Chinook salmon run size and flow data. This ranking is based on a rank summing procedure that sums the rank of average summer and fall flows leading up to and through the primary fall Chinook salmon migration season in the lower Klamath River (July 1st to September 21st) with the rank of fall Chinook salmon in-river size with estuarine sport and tribal harvest removed to produce a combined ranking. A ranking of 1 represents the worst combination of low flows and run-size for Ich outbreak risk, and a rank of 35 represents the best. This analysis revealed that 2002 had the worst combination of low flows and large run size of all 35 years, and 2013 was ranked as the 3rd worst (Table 1), even with the FARs leading up to but excluding the emergency doubling once the Ich outbreak was detected. This provides further supporting evidence of the role of low flows and large run size in the 2002 lethal Ich outbreak, and suggests that the magnitude of the FARs in 2014 were too low for the size of the run to prevent an outbreak, thereby leading to the larger magnitude 7 day emergency releases of flows (5 days doubling with 2 days of ramping down)(Figure 5). These emergency flows most likely prevented mass mortality by retarding the rate of increase of severity (Figure 3) long enough for the majority of the fall run to leave the infectious zone of the lower Klamath River with lower and survivable total parasite loads and disperse to points upstream in the Trinity and Klamath rivers. Notably, once migrating beyond the Ich infectious zone in the lower Klamath River, adult Chinook salmon were able to largely clear their parasite loads (as explained by shedding maturing trophonts without replacement by more theronts) by the time they arrived to basin hatcheries as evidence by the observation of only light, non-serve infections and lowered infection prevalence (Belchik 2015). According to Dickerson (2006), in large fish culture operations when an Ich outbreak occurs "a rapid flow of water is maintained for a week to reduce the number of theronts" as a treatment.

5. Of the known mechanisms that can impact the probability and outcome of Ich infections, the Bodensteiner et al. (2000) study showed that when water velocities and turnover rates are increased enough, it can provide a sufficiently strong disruption effect to stop Ich outbreaks and reduce mortality. These absolutes values, as previously discussed, are not applicable to other settings but the fundamental finding that sufficiently high flows can result in sufficient disruption of Ich to stop outbreak and reduce mortality. This fundamental relationship underpins the emergency release provision with the detection of the early stages of an Ich outbreak in the lower Klamath River, and help explains why no widespread mortality occurred with the emergency release in 2014, i.e., a partial mechanistic cause-and-effect explanation of the why the emergency release was so successful at having the intended outcome. It’s important to understand the increased flows in the form of FARs from Trinity Reservoir, will have positive benefits to ALL of the known mechanistic factors, aside from salmon run size, that dictate the probability and severity of Ich outbreaks with larger flows producing large benefits. The benefits include the following controlling and contributing factors: 1) increased flushing of Ich’s infectious free-swimming life stages, especially theronts, out to the ocean where they will perish in salt water; 2) increased disruption of theronts ability to find and successfully attach to a fish host within their brief life-span, and potential disruption of the encystment process of tomonts preventing replication (Butcher 1947); 3) dilution of theronts, which reduces their density and the probabilities of encounter with fish in flowing water; 4) reduced water temperatures, which reduces fish stress and slows the development rate of Ich (Dickerson 2006) and its replication potential (Nigrelli et al. 1976; Dickerson 2006; Forwood et al. 2015) thereby reducing the rate of increase of theront abundance during an outbreak and the likelihood of infection for any given individual salmon (McCallum 1982); and 5) improves water quality and reduces fish stress by diluting stressors such as toxic mycrocystins, myxosporidians pathogens, and free ammonia.

VI. Risk factors and protective flow recommendations for 2015

1. I have previously evaluated river conditions, projected flows, and likely run size for 2015 as part of evaluating Ich outbreak risk and developing specific FAR recommendations to protect the fall Chinook salmon run in 2015 (Strange 2015). In summary, 2015 is experiencing almost the exact same summer conditions and flows as the extreme year of 2014, with 1977 being the only year with worse flow conditions. While the preseason run size forecast is 119,000 adults (plus an unpredicted number of jacks), these forecasts should be considered too unreliable to be useful in fine tuning FARs. Thus the risk of an outbreak based on flows alone is considered equivalent to 2014 and more likely to occur than not without the FARs; however, I predict with a high level of confidence that background levels of Ich are significantly elevated relative to 2014, which adds a significant amount of risk for an outbreak in 2015 relative to 2014. The 2015 FARs have been developed with this increased risk in mind in order to reduce the risk of an Ich outbreak and mortality, and the probability of needing emergency flow releases.

2. There are multiple potential mechanisms that could elevate background levels of infectious theronts in a given year depending on circumstances. For the lower Klamath River, these mechanisms can be separated into two primary categories: 1) increased stress and infections, including Ich and secondary pathogens, due to drought exacerbated conditions among adult Chinook salmon migrating during July and August (as identified above for 2014); and, 2) a "hangover effect" from any Ich outbreaks the previous year. I contend that it is more likely than not that both of these mechanisms are occurring in 2015 leading to elevated background levels of Ich and increasing the risk and potential severity of an Ich outbreak among fall run Chinook salmon in the lower Klamath River this September.

3. Controlled laboratory studies have observed a positive linear relationship between the number of theronts a host fish is exposed to and the resulting level of infection by parasitic trophonts (McCallum 1982) absent disruption by sufficiently high flows for a given setting such

as documented by Bodensteiner et al. (2000). Simply put, the more infectious theronts that are present in a given habitat, the greater the resulting probability of infection and resulting severity for a given host fish in that habitat. The starting level of abundance of infectious theronts present upon arrival on new group of naïve host fish, in this case entry of the fall Chinook salmon run into the lower Klamath River, will therefor influence the risk of an outbreak and the resulting growth curve of the outbreak and its severity.

4. One primary mechanism I have postulated for elevating the background levels of Ich in the lower Klamath River is unusually stressful migratory conditions during droughts leading to poor fish health and increased numbers of infected fish during the summer months. Adult Chinook salmon enter and migrate through the lower Klamath River during the spring, summer and fall months (Strange 2012), and fish that migrate through during the summer months are subject to thermal stress and periods when water temperatures exceed their thermal limits to migration (~23°C; Strange 2010b). During such periods, migrating fish will seek refuge in the cool water associated with cool water tributary confluences, such as Blue Creek, and then will continue migrating upstream as soon as water temperatures drop enough to allow migration (Strange 2010b). This can be a risky migration strategy and some of these fish perish en route due to stress and infections with columnaris bacteria; however, this could also include Ich infections. In drought years the number of fish that are observed using thermal refuges during increases with such periods of excessively high temperature being larger in magnitude and longer in duration resulting greater stress and reduced fish health. This was observed in 2014 and was noted as an increased risk factor for an Ich outbreak in 2014 (Strange 2014; Belchik 2015; Hetrick and Polos 2015). Further, 2014 and 2015 have exceptionally low accretion levels, with accretions typically being much cleaner and colder, resulting in poorer water quality in the lower

Klamath River and smaller thermal refuges (Hetrick and Polos 2015) compared to dry years with higher accretions, which can further increase stress and concentrate any fish pathogens present.

5. Yurok Tribal Fisheries Program (YTFP) staff monitoring fish health in 2014 first sampled adult Chinook salmon on 7/17/2014 with first confirmed detection of a non-severe Ich on 8/21/2014 with an infection prevalence that week of 10% (Belchik 2015). The detection of Ich in 2014 prior to the arrival of the head of the fall run is believed to have contributed to the occurrence of the Ich outbreak that was detected on 9/13/2014 (Belchik 2015). I have likened these initial non-lethal Ich infections of Chinook migrating during July and August to “priming the pump” for an Ich outbreak when the fall Chinook salmon run subsequently enters the lower Klamath River in late August and early September. In 2015, the first sampling of adult Chinook salmon occurred on 7/8/2015 with first confirmed detection of an Ich infection on 7/22/2015, which is a month prior to detection in 2014 and included 88% infection prevalence during that week with one fish having a more severe infection (YTFP 2015). More recently two fish with severe infections approaching the parasite loads seen in the 2014 Ich outbreak were seen on 8/18 and 8/19/2015 (YTFP 2015). Based on river temperatures and the thermal limits to migration (Strange 2010b), I estimated that these fish had been holding in the lower Klamath River for about one week with flows of ~ 2,100 cfs.

6. With consistent sampling methods and sampling periods between 2014 and 2015, these results strongly indicate that Ich infections are already greater in 2015 than 2014, which also suggests that theront abundance is increased in the summer of 2015 relative to the summer of 2014 based on the linear relationship between theront abundance and resulting trophonts (McCallum 1982). Using the “priming the pump” analogy, the pump is primed to greater extent in 2015 compared to 2014, and obviously an Ich outbreak occurred with baseflows of 2,500 cfs in September of 2014. However, given the remarkably comparable flow, water temperature, and

poor water quality conditions during the summer of 2014 and 2015 (Figure 5)(Strange 2015), this earlier onset of Ich infections with greater prevalence and severity observed already in 2015 compared to 2014 is not readily explained by environmental conditions. This provides supporting evidence to the hypothesized “hangover effect” that is predicted to occur in the year after a significant Ich outbreak, as discuss below, which is the second major mechanisms postulated for elevating background levels of Ich in 2015 relative to other years, including 2014.

7. In the year following an Ich outbreak, there is a hypothesized “hangover effect” wherein the background levels of Ich are elevated leading to greater probability of another outbreak occurring and increased likelihood for greater severity and fish kill risk. The documented non-lethal outbreak of Ich in September of 2014 among adult fall run Chinook salmon in the lower Klamath River produced a large amount of infectious theronts. Given the linear relationship between infectious theront abundance and resulting parasitic trophonts (McCallum 1982), the hyper abundance of theronts produced during the 2014 outbreak is predicted, with a high level of confidence, to have resulted in higher trophont loads in resident fish in the lower Klamath River. These resident fish species, such suckers and speckled dace, are considered to be the reservoir host fish species that allow Ich to persist in the lower Klamath River in years when no outbreak occurs among salmonids and allows the parasite to bridge the years between outbreaks (i.e., 2002 to 2014). Speckled dace with non-severe Ich infections have been observed in August of 2015 in the lower Klamath River (Nick Hetrick, FWS, personal communication, 2015) and suckers have not been sampled sufficiently yet. The dynamic of resident fish species being the reservoir host and source of Ich theronts to initiate Ich outbreaks in salmon has also been documented in British Columbia (Traxler et al. 1998) and Ich is an obligate parasite that cannot survive without a year round host, whereas salmon die after they spawn and are migratory (thus meaning the will generally be naïve to Ich when they return from

the ocean as adults to migrate and spawn). In summary, there is a high level of scientific confidence that these resident fish species are the reservoir host for Ich in the Klamath River and the source for infective theronts as naïve salmon begin their spawning migrations.

8. Under the hangover effect hypothesis, the higher parasite loads in resident fish resulting from the 2014 outbreak in the autumn would carry-over through the winter by cycling through the resident fish populations to produce elevated levels of infectious theronts in the spring and early summer when temperatures and flows would again be favorable to their life-cycle dynamics and adult salmon would be again be migrating through the lower Klamath River, as discussed above under mechanism #1. It should be noted that at 9°C, trophonts can reside attached to their host fish for approximately 20 days (Noe and Dickerson 1995), which means that under winter temperatures, the Ich life-cycle would be completed in about a month at which point infectious theronts would re-infect resident fish serving as the reservoir host. During the winter months, Ich would be generally sheltered from high flow conditions by being attached in host fish as trophonts, and theronts would be protected to some degree by the sheltered habitat that such fish seek during periods of high flows. The parasite loads in the resident fish, even if still at low-levels and low prevalence as is typical between outbreaks even with some level of acquired resistance (McCallum 1986), would still be elevated compared to no outbreak, thus leading to elevated parasite loads in Chinook salmon during the summer resulting from elevated levels in resident fish, which in turn would create elevated background levels on infectious theronts upon entry of fall run Chinook salmon in the lower Klamath River in late August and September.

9. The observation of elevated Ich levels among Chinook during the summer of 2015 as discussed previously provides supporting evidence for this hypothesis and is consistent with predictions resulting from this hypothesis. This hypothesis is also consistent with the

observation of Ich outbreaks in wild adult salmon occurring in clusters; in the 1990s in British Columbia, in 2002 and 2003 in Butte Creek, and to a lesser extend in the Klamath River in 2002 and with low infection levels but notable prevalence in adult Chinook salmon in 2003 (Foott 2003) albeit with significant flow augmentation (Figure 5). Otherwise Ich levels have been non-detectable in sampled adult Chinook salmon until 2014 and 2015 (McCovey 2014; Belchik 2015; YTFP 2015), albeit with varying levels of sampling in 2003 through the present date. Because fall run Chinook salmon, in particular Klamath stocks, tend to delay or slow their migration in the lower Klamath River for one to two weeks every year regardless of environmental conditions (Strange 2012), this consistently slowed migration provides ample opportunity for any elevated numbers of infectious theronts infect fall run Chinook salmon. Once the lifecycle of the first wave of trophonts on fall run Chinook salmon is completed, an enormous amount of theronts can be generated and the pump will be fully primed for another major outbreak of Ich. The only significant management action that can be taken to interrupt this dynamic is sufficiently effective preventative flow releases that increase flow to disrupt and dilute theronts, decrease water temperature to slow the Ich life-cycle and decrease fish stress, and improve water quality through dilution of water originating from the upper Klamath River to further decrease fish stress.

10. While the occurrence of a hangover effect from the outbreak in 2014 as postulated herein is a logical conclusion based on the well-understood life-cycle dynamics of Ich and salmon, I did seek scientific counsel and discussed this hypothesis with an independent Ich expert, Dr. Dickerson of the University of Georgia's Department of Infectious Diseases, who literally wrote the textbook chapter on Ich (Dickerson 2006). In discussing the topic of Ich outbreaks in the Klamath River and the likelihood of elevated background levels in 2015, Dr. Dickerson agreed that the hangover effect "is a very reasonable hypothesis and it makes a lot of sense that it would be occurring" (Harry Dickerson, UG, personal communication, 2015). He

also agreed that it was not surprising that the outbreaks in 2002, 2003 (minor), and 2014 had initiated with consistent timing (i.e., the 2nd week of September) due to the synchronized nature of Ich outbreaks and that additional preventative measures targeting this window of time would make sense, including the proposed concept of a larger pulse flow during this window of peak salmon abundance and Ich outbreak risk.

11. Due to the concern over the projected low flows in 2015 and an associated increase in stressors and secondary pathogens and elevated background levels of Ich, I circulated a technical memorandum to relevant parties (e.g., KFHAT and the Bureau) on July 17th 2015 updating the projected flow conditions and fish kill risk for 2014 (Strange 2015). In order to reduce the significant risk of another Ich outbreak and associated serious mortality levels to the incoming run of fall Chinook salmon in 2015, I reemphasized the recommendation that protective flows of no lower than 2,800 cfs be maintained in the lower Klamath River during the peak of fall Chinook salmon migration season (with flows measured at the USGS gauge KNK at river kilometer 13). The higher baseflow of 2,800 cfs was recommended due to run size uncertainty and the elevated background levels I was predicting for the 2015 fall Chinook salmon run. <u>I concluded that a fish kill via an Ich outbreak was more likely than not for the 2015 fall Chinook salmon run without the FARs</u>.

12. The resulting flows schedule set by the Bureau is deemed to provide a sufficient but minimum level of protection of migrating adult salmon from the risk on an Ich outbreak given current and expected conditions. This recommendation will require the least volume of water possible to provide reasonable protection. The Hoopa ceremonial boat dance flow that occurred should help to flush out any Ich infective life-stages to provide a less infectious environment for the head of the fall run and clear the river of any residual spring-summer run Chinook salmon. The protective increased baseflows of 2,800 cfs that is occurring will then be

extended through September 20th to help prevent any residual Ich from being able to initiate an outbreak and thereafter ramped down appropriately to un-augmented baseflows. The volume of water required to meet this recommendation will depend on the level of tributary inflows and accretions to the lower Klamath River during this time, but current projections indicate that it will most likely be 51,000 AF, which includes the potential use of approximately 10,000 AF for the mid-September pulse. The mid-September pulse is intended to encompass the lifespan of any existing theronts at the most critical time for Ich outbreaks as evidenced by the consistent timing of initiation of Ich infections in 2002, 2003, and 2014 (i.e., the second week of September, which is when fish densities are almost always at a maximum in the lower Klamath River based on run-timing; Strange 2012).

13. If the full protective FARS as planned by the BOR are implemented, I anticipate, with a moderate to high level of confidence, that an Ich outbreak will be unlikely initiate and thus no additional emergency flow release will be needed either. Ich an outbreak does occur I anticipate with a high level of confidence that the emergency release, on top of any previously released FARs, will prevent mass mortality. <u>Failure to provide supplemental flows with the FARs will make it more probable than not that an adult fish kill will occur this year. If the FARs were to be halted and not allowed, I would anticipate with very high level of confidence that an Ich outbreak and fish kill would occur.</u> I advise against underestimating the risk associated with the hypothesized hangover effect from 2014 outbreak and the levels of already observed in 2015. One of the lessons from 2014, given the apparent occurrence of the hangover effect, is that preventing outbreaks is not only more economical (Dickerson 2006) but can help reduce risk if the following year is also dry.

14. This recommendation represents the best compromise available at this time given the current drought conditions, constraints on available water volumes and competing demands,

and is likely to provide adequate protection from a lethal Ich outbreak such as occurred in 2002 and an outbreak in 2014 that would have most likely been lethal without supplementation and emergency releases. Stopping these protective FARs now that they have started with the fall run poised to enter the lower Klamath River en masse would be excessively risky. This determination is based on my professional opinion with consideration for conditions in 2015 and the best available scientific information.

VI. Evaluation of potential negative biological consequences

1. The likelihood and consequences of potential negative biological consequences being realized from a protective fall flow release such as underway in 2015 or that have occurred in previous years, has been greatly exaggerated and erroneously evaluated based on the court documents and proceedings. I will briefly describe the likelihood and consequences and the supporting logic and evidence therein below for fish species and can expound further if so desired by the court. First and foremost, the past outcomes of past FARs has not brought about the stated negative biological consequence.

2. Potential impacts resulting from, and the degree, of variation from the natural flow regime: 1) Flows of 2,800 cfs are below the median flow value for the lower Klamath River and within the natural flow regime for that reach. Flows of ≥ 4,000 cfs occur regularly over the period of record for the lower Klamath River as well as do sudden increases and slower decreases associated with natural precipitation based freshets (Figure 4 bottom graph). The magnitude of protective flow releases during the summer and fall in the upper Trinity River are rarer but do have historic precedent as shorter duration flash floods and fall freshets. Thus the protective flow releases can be considered unusual but natural in the upper Trinity River depending on their duration and magnitude as they are within the environmental variability experienced over the evolutionary history of the species involved. Also, the likelihood and consequences of any potential negative impacts should be evaluated on their specific information and logic as opposed to over-generalized assumptions. On the lower Trinity River, where I have

direct observational experience for the 2003 and 2004 pulsed flows, ceremonial flows, and the 2012, 2013, and 2014 protective flow releases, such higher flows have benefits to water quality and temperature, a reduced nuisance algae (very notable in 2012, 2013, and 2014), improve rearing conditions and habitat area for juvenile salmonids including coho if present, and better migratory conditions for adults. A full accounting of the impacts of the increased fall flows would likely show a net benefit and unanticipated positive consequences to a variety of fish species and life-stages in the Trinity and Klamath rivers. I would hypothesize that this would apply to increased summer base flows as well, partly demonstrated by the enhanced productivity and survival for salmonids in spring fed river systems that maintain higher flows and colder water temperatures during the summer compared to non-spring fed rivers in the same region. Simply put, based on an extensive body of information and published literature, increased releases of cold, clean reservoir water will generally benefit cold-water species in the arid west wherein where natural poor and limiting summer water quality and habitat conditions have been exacerbated by human activities such as dam construction and water diversion. Several authors studying climate change and the resiliency and management of salmon populations (e.g., Thompson et al. 2012) concluded that proactively using increased flow releases from large, cold water storage reservoirs during the warm season could greatly benefit salmon populations and are even predicted to be a necessity in some cases to prevent the extinction of species (ESUs) dependent on cold over-summering habitat such as spring run Chinook salmon and inland populations of coho salmon. This dynamic will certainly apply to the Trinity River given the most recent global warming projections and timelines, especially when combined with the serious disease risk for adult salmon and the annual disease mortality for juvenile salmon in the lower Klamath River with both diseases (from Ich for adults and malaria-like myxosporidians for juveniles) showing strong evidence for being less likely or less lethal at higher flows (i.e., fish health and survival positively correlated with flows). At the time of Trinity River flow study and ROD, predictions of global warming magnitudes and rate of change were not as fully formed and relatively understated compared to now, and the serious disease risk and problems of the lower Klamath River were not yet known.

3. Spring and fall Chinook salmon hybridization and redd dewatering: highly unlikely and of minimal consequence because 1) the protective flow release dates through the 2nd (or even 3rd) week of September were designed to cover the peak migration season for Klamath and Trinity fall Chinook salmon in the lower Klamath River but also exclude the spawning season for spring Chinook salmon that begins the last week of September (fall Chinook generally spawn even later) based on extensive data of redd counts and dates, which means redd dewatering and egg incubation impacts from water temperature changes are also not a realistic concern. This was evaluated in relation to 2013 protective release by both the USFWS and by North State Resources (as hired by Westlands) (note: the “up to 20% of spring Chinook salmon redds that could be dewatered” as quoted by Mr. Hanson in his 2013 declaration refers to the maximum possible for the very few spring Chinook salmon that spawn prior to the third week of September based on the maximum count for all years during that period, not the average and not for the entire population of spring Chinook, thus the “up to” qualifier); 2) hybridization is already occurring due to spring Chinook salmon being forced to spawn in fall Chinook salmon spawning reaches due to blocked access of their historic habitat by the Trinity dams (spatial overlap), thus any potential additional hybridization (highly unlikely) due to protective flow releases would have minimal consequence; 4) six years of extensive migration behavior data that I collected showed that fish did not migrate faster (or slower) as a result of pulsed flows and demonstrated run-specific migration behaviors that were consistent regardless of flow conditions and with and without fall pulsed flows such as occurred in 2003 and 2004, which is consistent with findings in other larger rivers as opposed to smaller river where flows become more important for allowing migration to be possible (Strange 2012); this data also showed that fish counting weirs on the Trinity River can extensively delay migrating adult salmon, and during some of these pulsed flows these weir had to be partially dismantled thereby decreasing fish delays at the weir and giving the erroneous perception of earlier arrival to spawning grounds due to pulsed flows (Note: arrival to spawning grounds and actual spawn timing are not directly related). This data and my personal observations also show that sand bar closures at the mouth of the Klamath River are very rare and do not influence the run-timing of spring versus fall

Chinook salmon or contribute to their spawning segregation (run-timing and spawn timing are largely under genetic control, and the Klamath River is too large to have estuarine sand bar closures like many smaller California rivers such as the Russian River).

4. Potential Pacific lamprey impacts: 1) the non-adult life-stages of Pacific lamprey, which rear in sandy and soft sediments, are highly mobile and when disturbed simply swim away to a new location. The observation by Stutsman 2005 of increased larval lamprey catches in rotary screw trap(s) shows increased mobility as a result of the pulsed flows but this report did not contain evidence that this was harmful or that it constituted migration as opposed to relocation. One notable, exception is if they are lured into an area that they can’t swim away (i.e., an channel bank depression) from that would later be dewatered causing stranding mortality; however, as long as ramping rates are appropriate during decreasing flows then stranding should not be an issue, and fall flows ramping rates will not be any different than are used for other parts of the ROD hydrograph during more critical windows of time such as the spring when young-of-the-year lamprey are newly emergent.

5. Potential impacts to Trinity River coho salmon: higher flows would likely increase the inundation of channel margins (depending on the actual water surface elevations involved), which increases the availability of the type of sheltered habitats of inundated vegetation and woody debris with cover from predators, excellent feeding stations, and refuge for any non-preferred higher velocities that juvenile coho salmon are especially noted for seeking out and using. This habitat/flow relationship would be expected to be similar to those for spring flows, for which rearing habitat is maximized at flows well above summer and fall baseflow levels. This dynamic of inundation of channel margins is common and widely known in-stream flow methodologies and habitat use studies, such as for coho in larger rivers (i.e., Beechie et al. 2005). Given extensive floodplain improvement as part of the Trinity River Restoration Program, the abilities of fishes to utilize lateral habitats intermittently, and the conferred benefits of utilization of these types of habitat for improved growth and survival, the proposed flows will present a negligible risk of stranding while providing a net benefit to rearing coho salmon. The extension of suitable temperatures downstream from higher flows provides further benefits

through an expansion in the amount and quality of available rearing habitat currently limited by high water temperatures. The negative consequences of adults being infected with Ich due to an outbreak among fall Chinook in the lower Klamath River, which may have been the cause of abnormally high pre-spawn mortality among coho salmon in 2014 in the Trinity River (Belchik 2015), outweighs any risk associated with exposure to warmer but still relatively cold thermal conditions in the upper Trinity River such as occurred in 2014. Further, the FARs can decrease temperature for the head of coho run, which enters the lower Klamath River in the second half of September. Based on a study I conducted adult coho migration in the lower Klamath River, the exposure to truly warm temperatures beginning of their migration in the lower Kamath River greatly exceeds the exposure to any temperatures associated with cold pool impacts in Trinity Reservoir.

6. Potential impacts to Sacramento and Delta fishes and cold-pool management: these potential impacts are primarily based on the temperature of releases from the Spring Creek inflow to Keswick from the Trinity diversion and reservoir refill probabilities and the extent of refill for 2016. The fact that only 51,000 AF will be used will reduce the risk of speculative harm especially in relation Shasta reservoir levels. The increased flows will not appreciably change water temperatures in the Sacramento River and associated temperature related effects to egg incubation, rearing, or spawning fishes. The Trinity River will continue to contribute warmer water to the Sacramento than releases from Keswick, demonstrating that this inter-basin transfer is not an important contributor to improved water temperatures regardless of this action.

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VIII. Tables and Figures

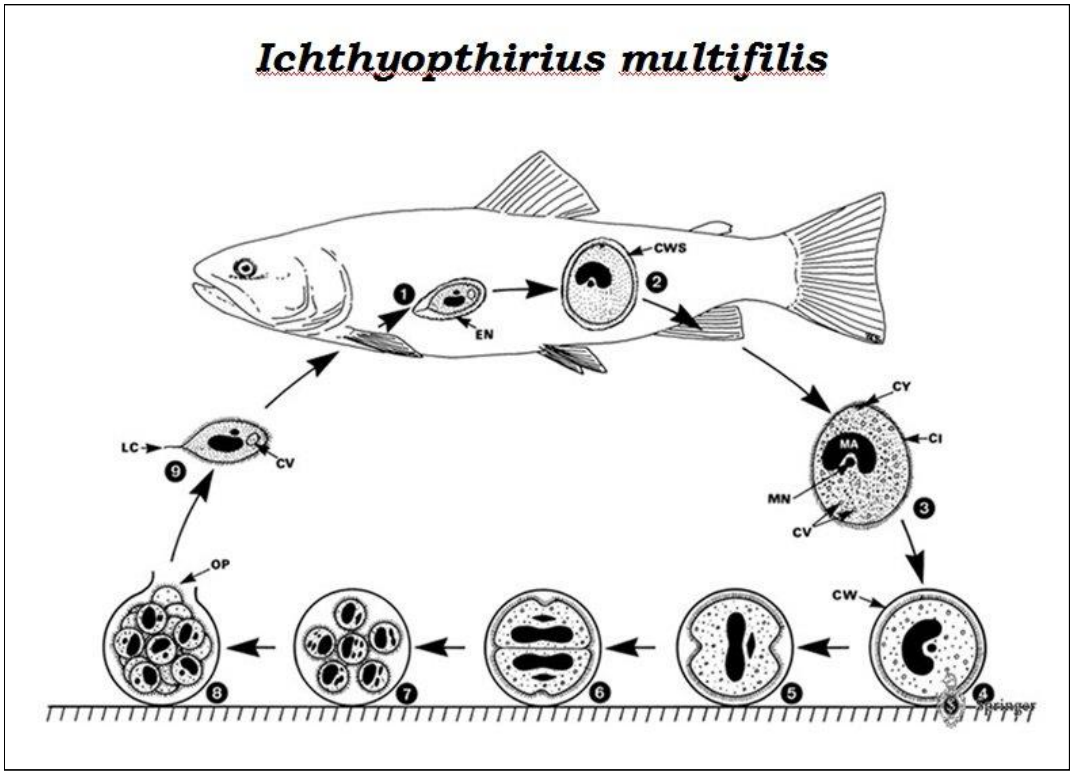

Figure 1. Life cycle of Ich showing the parasitic trophont stage (#1 and 2), the reproductive tomont stage (#3 to 5) that attaches to benthic substrates, encysts, and divides into tomites (#7 and 8), which are then released as the free-swimming infectious theront stage (#9) that must find and successfully attach to fish host within approximately 24 hours at 20°C. Ich cannot tolerant salt or brackish water.

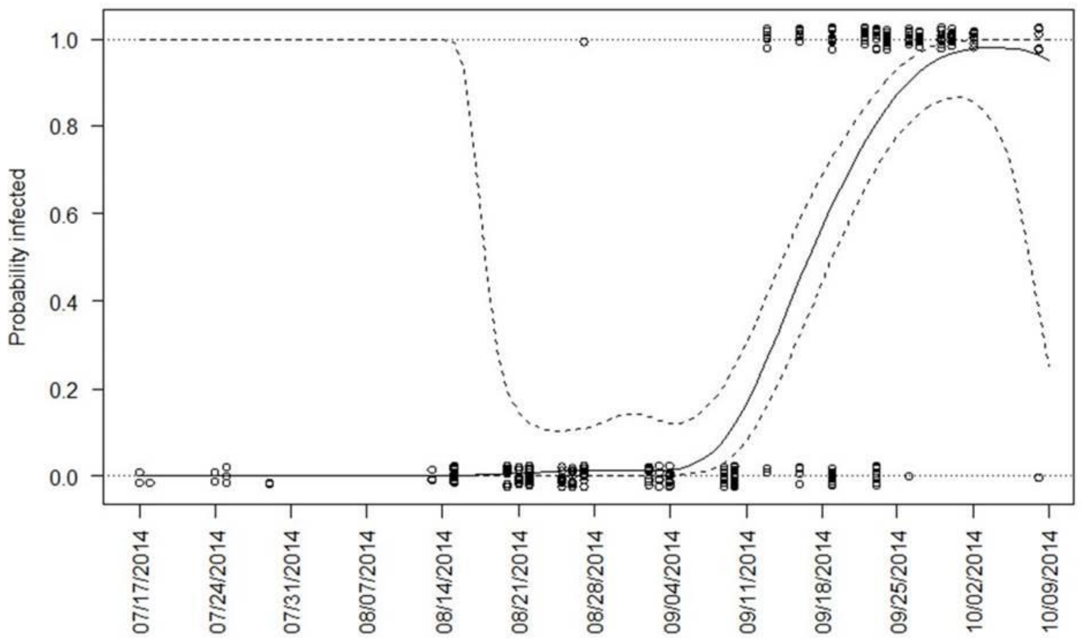

Figure 2. The probability that an individual Chinook salmon would be infected with Ich as a function of time, fitted in R with the routine sm.binomial from the kernel smoothing library (h=7)(Bowman 1997). The dotted lines are two standard deviations from the modeled value. This Ich severity curve indicates that the Ich outbreak of 2014 initiated its exponential growth phase in early in the second week of September. In addition, an analysis of water temperatures, Ich life-cycle development rate as a function of temperature, and the onset of observed fish mortalities in 2002 suggested that the Ich outbreak initiated its exponential growth phase during the second week of September as well (Sept 7-9, 2002; Dr. Joshua Strange, unpublished data). This evidence provides the rationale for the timing of mid-September pulse to flush and further disrupt any infectious theronts existing during this critical window for Ich outbreaks in the lower Klamath River, which is also when Klamath stock fall run Chinook have been residing in the lower Klamath River for enough time to allow an infection to initiate while Trinity stocks are just starting to enter.

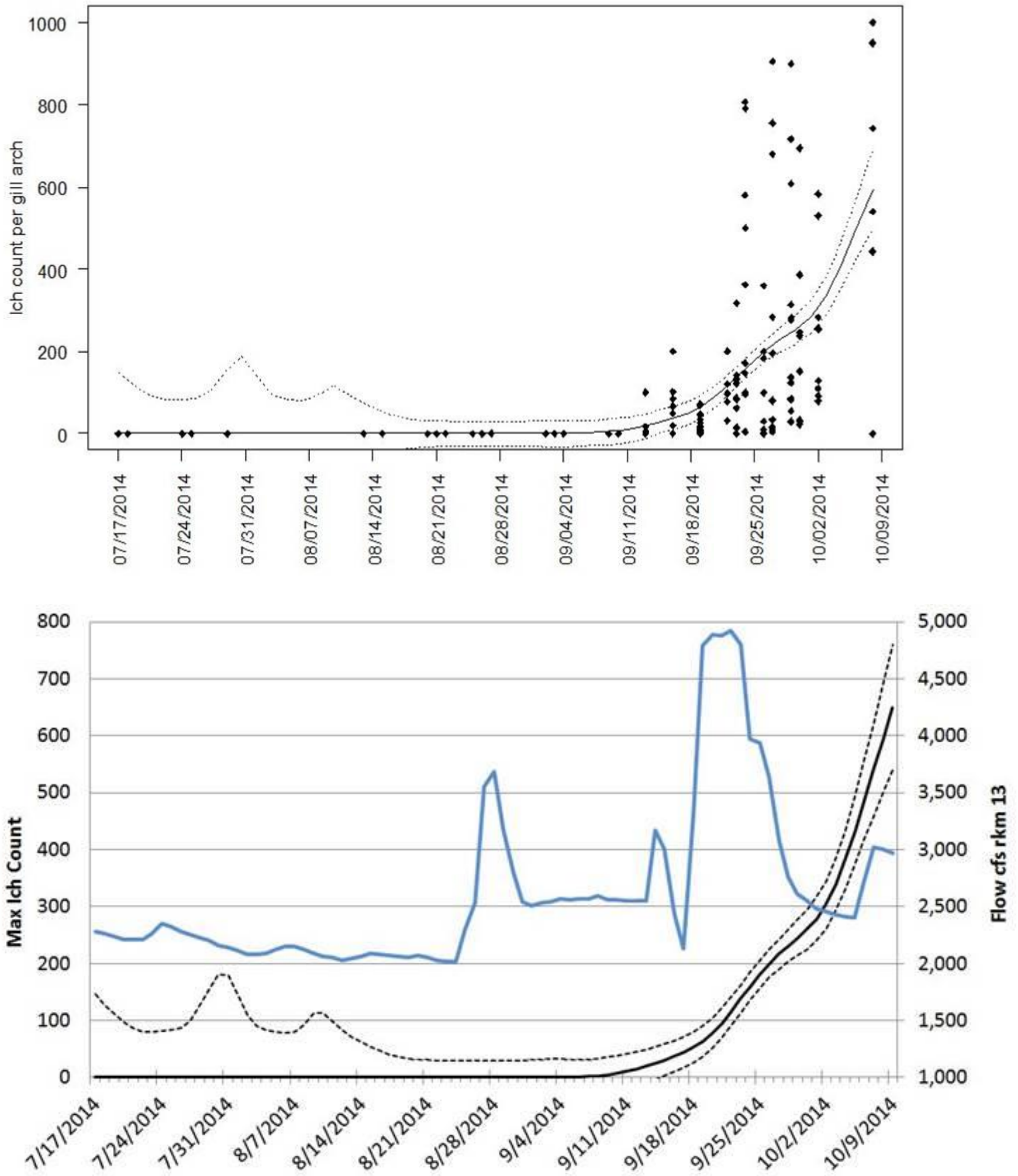

Figure 3. Maximum Ich count between left and right gill arch during the 2014 Ich sampling period (top graph, a surrogate for infection severity) fit with a non-parametric model curve using local linear smoothing (Belchik 2015). Each data point represents at least one individual fish (some data points overlap each other). The bottom graph overlays flows in the lower Klamath River (USGS KNK gauge). The dotted line is a visual representation of the amount of variation.

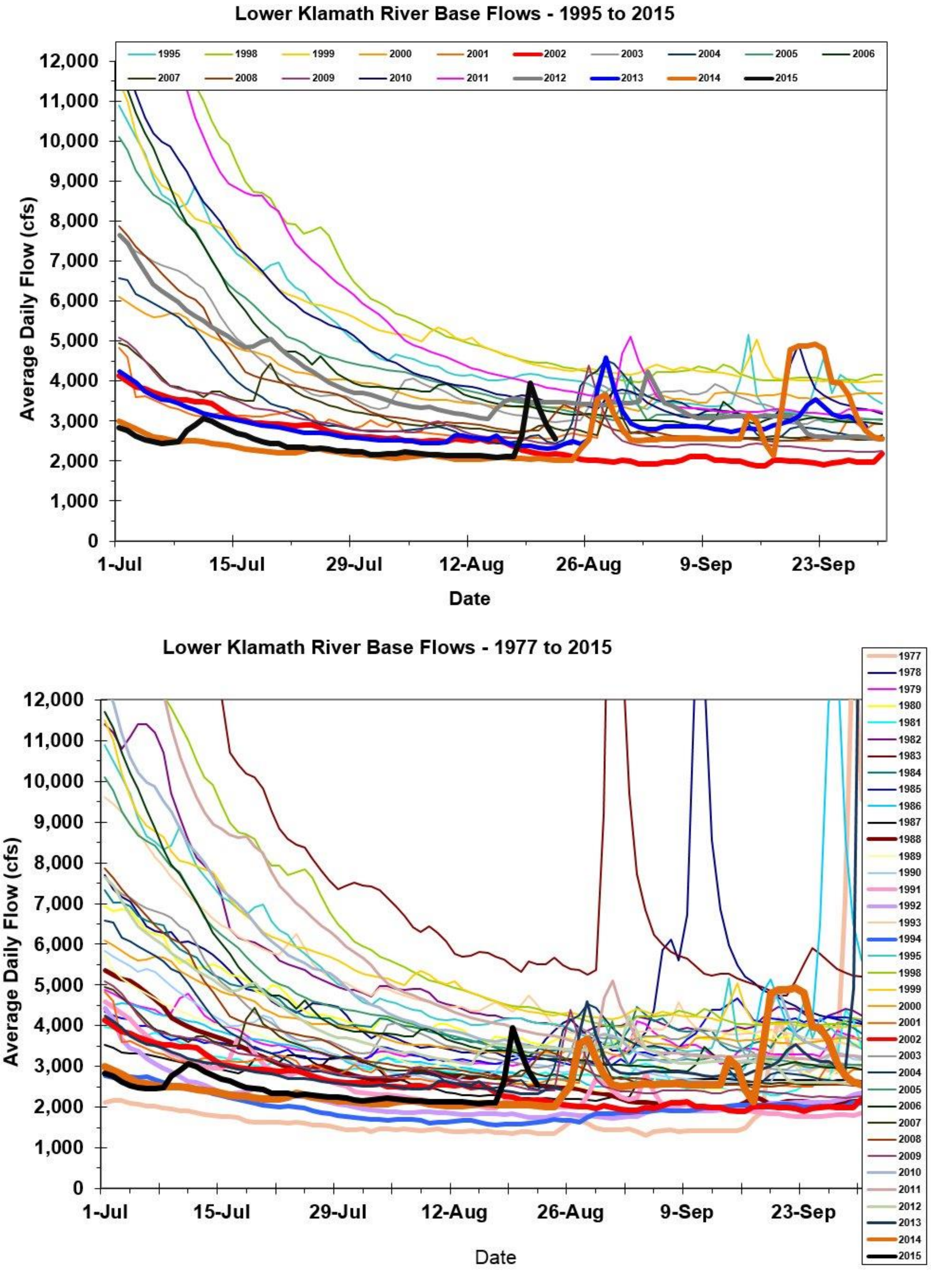

Figure 4. Available flow data for the lower Klamath River (USGS Gauge #11530500 KNK) from and from 1995 to 2015 (top graph) and 1977 to 2015 (bottom graph). Mean monthly flows for August and September during the period of record are approximately 3,100 cfs.

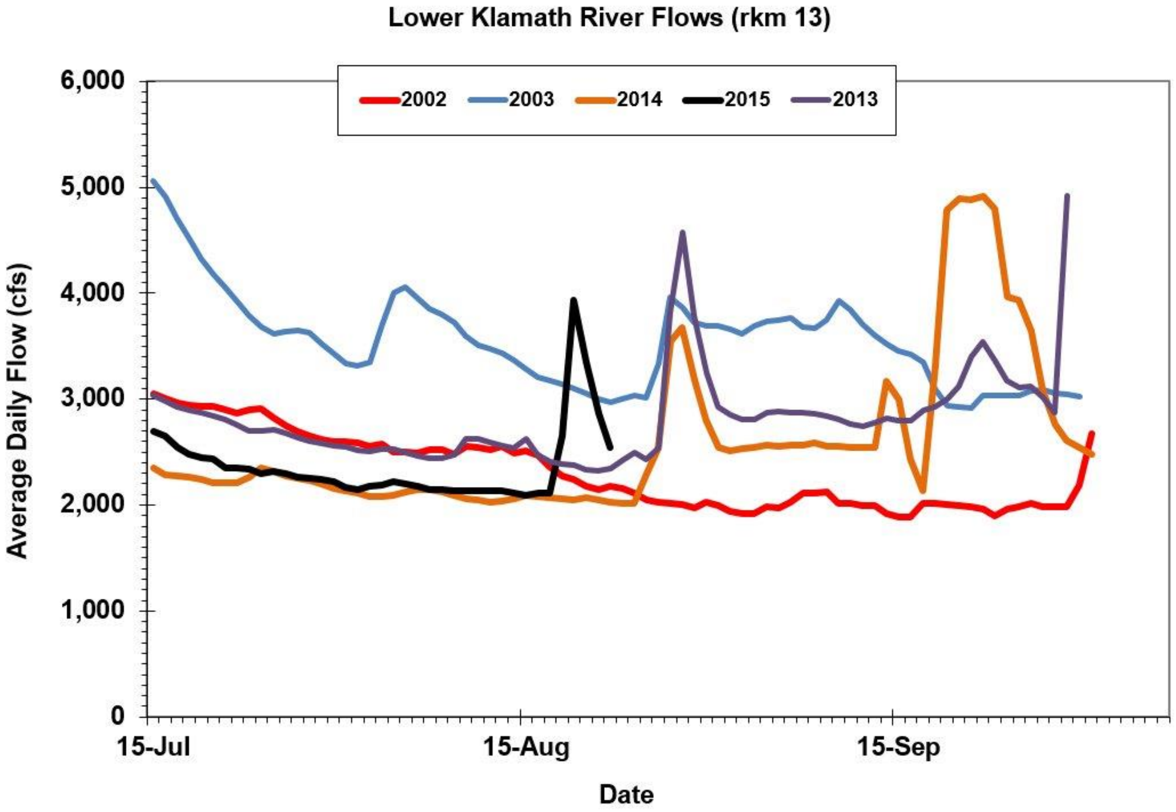

Figure 5. Flows in the lower Klamath River during the period of concern for 2002, 2003, 2013, 2014, and thus far for 2015. With the exception of 2013, these are only years when Ich has been detected among adult fall run Chinook salmon sampled in the lower Klamath River. The outbreaks in 2002 (lethal, no FARs) and 2014 (non-lethal, FARs) were the only years with wide-spread serious outbreaks.

Table 1. Ranking of all years with records of fall Chinook salmon run size and flow data. This ranking is based on a rank summing procedure that sums the rank of average summer and fall flows (source: USGS at KNK) leading up to and through the primary fall Chinook salmon migration season in the lower Klamath River (July 1st to September 21st) with the rank of fall Chinook salmon in-river size with estuarine sport and tribal harvest removed (source: CDFW Mega-Table) to produce a combined ranking. A ranking of 1 represents the worst combination of flows and run-size for Ich outbreak risk, and a rank of 35 represents the best. There is no flow data for 1996 and 1997 due to flood damage at the gauge, but these were generally wet years. The driest year on record, 1977, isn't included because no run-size data exists but it was most likely well below average. The flows for 2014 were adjusted to remove the emergency flows resulting from detection of the Ich outbreak, the run-size for 2002 was adjusted to account for the revised estimated of fish kill mortality (George Guillen, formerly of FWS, personal communication 2004). Flows in 1986 and 1987 were over 2,500 cfs during the primary fall Chinook salmon migration season, but 1988 appears to be an outlier with flows during this period 2,167 cfs. This apparent outlier relative to 2002 could be due a variety of mechanisms included considerable cumulative ecological degradation since 1988 to 2002, including differences in river temperatures and higher flows in July and August in 1988 relative to 2002.

Year	Run Size and Summer-Fall Flow Rank	Year	Run Size and Summer-Fall Flow Rank
2002	1	2011	19
1987	2	1991	20
2014	3	2008	21
1988	4	2006	22
1986	5	1978	23
2001	6	2004	24
2012	7	1982	25
2013	8	2010	26
2000	9	1979	27
1994	10	1980	28
2007	11	1990	29
2009	12	1998	30
1989	13	2005	31
1995	14	1984	32
2003	15	1993	33
1985	16	1999	34
1981	17	1983	35
1992	18		

I declare under penalty of perjury under the laws of the State of California and the United States that the foregoing is true and correct.

Executed this 24th day of August 2015, at Arcata, California.

/s/ Joshua Strange, Ph.D. (as authorized 8/24/2015)
Joshua Strange, Ph.D.