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TECHNICAL MEMORANDUM

Date:	June 17, 2015
Prepared for:	Robert Seyfried
Prepared by:	Michael Bryan, Ph.D.
Subject:	Operating the SRWTP Under the Currently Granted Thermal Plan Exceptions: Thermal Studies

Introduction

The Sacramento Regional Wastewater Treatment Plant (SRWTP), owned and operated by the Sacramento Regional County Sanitation District (Regional San), provides wastewater treatment for unincorporated Sacramento County; the cities of Citrus Heights, Elk Grove, Folsom, Rancho Cordova, Sacramento and West Sacramento; and the communities of Courtland and Walnut Grove. Treated effluent from the SRWTP is discharged into the lower Sacramento River near the town of Freeport, within the legal boundary of the Sacramento-San Joaquin Delta (Delta).

The SRWTP discharge to the lower Sacramento River is permitted by the Central Valley Regional Water Quality Control Board (Central Valley Water Board) for a design average dry weather flow (ADWF) of 181 million gallons per day (mgd) under NPDES Permit No. CA0077682 (Order No. R5-2010-0114-03). The NPDES permit includes waste discharge requirements that must be met to discharge to the lower Sacramento River, including effluent and receiving water limitations for temperature.

As required by Special Provision VI.C.2.d (Temperature Study) of the NPDES permit when it was initially renewed and adopted in 2010, Regional San conducted a detailed study of the effects of the SRWTP's thermal discharge on the aquatic life resources of the lower Sacramento River and Delta. The Temperature Study evaluated whether operating the SRWTP to the currently permitted effluent and receiving water temperature limitations, which tier directly from objectives in the Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Water and Enclosed Bays and Estuaries of California (Thermal Plan), as well as exceptions to the Thermal Plan objective 5.A.(1)a and objective 5.A.(1)b, is protective of the aquatic life beneficial uses of the lower Sacramento River and Delta. No exception has been granted for Thermal Plan objective 5.A.(1)c. The objectives, as identified in Section 5.A of the Thermal Plan, are as follows.

"(1) Elevated temperature waste discharges shall comply with the following:

a. The maximum temperature shall not exceed the natural receiving water temperature by more than 20°F.

b. Elevated temperature waste discharges either individually or combined with other discharges shall not create a zone, defined by water temperatures of more than 1°F above natural receiving water temperature, which exceeds 25 percent of the cross-sectional area of a main river channel at any point.

c. No discharge shall cause a surface water temperature rise greater than 4°F above the natural temperature of the receiving waters at any time or place.

d. Additional limitations shall be imposed when necessary to assure protection of beneficial uses."

The corresponding Thermal Plan exceptions and resulting alternative effluent and receiving water limitations contained in the current NPDES permit are listed below. The two alternative limitations based specifically upon the two exceptions to the Thermal Plan objectives that have been granted are identified in bold text.

Effluent Limitation

"1.e. The maximum temperature of the discharge shall not exceed the natural receiving water temperature at RSWU-001 by more than 20°F from 1 May through 30 September and more than **25°F from 1 October through 30 April**."

Receiving Water Limitations

"a. If the natural receiving water temperature is less than 65°F, the discharge shall not create a zone, defined by water temperature of **more than 2°F above natural temperature**, which exceeds 25 percent of the cross sectional area of the River at any point outside the zone of initial dilution."

"b. If the natural receiving water temperature is 65°F or greater, the discharge shall not create a zone, defined by a water temperature of 1°F or more above natural receiving water temperature which exceeds 25 percent of the cross sectional area of the River at any point outside the zone of initial dilution for more than one hour per day as an average in any month."

"c. The discharge shall not cause the receiving water surface temperature to increase more than 4°F above the ambient temperature of the receiving water at any time or place."

The final report for the Temperature Study, titled: *Temperature Study to Assess the Thermal Impacts of the Sacramento Regional Wastewater Treatment Plant Discharge on Aquatic Life of the Lower Sacramento River* (RBI 2013), was submitted to the Central Valley Water Board in March 2013. Also, to address the U.S. Fish and Wildlife Service's (USFWS) December 2013 comment letter on this Temperature Study report, a draft addendum to the above-cited report titled: *Temperature Study to Assess the Thermal Impacts of the Sacramento Regional Wastewater Treatment Plant Discharge on Aquatic Life of the Lower Sacramento River: Delta Smelt Addendum* was submitted to both the USFWS and the Central Valley Water Board in March 2015. Comments provided by the USFWS on this draft delta smelt addendum were addressed, thereby producing a final delta smelt addendum dated May 2015 (Attached). The addendum provides a complete analysis of the potential impacts to delta smelt from operating the SRWTP under the Thermal Plan exceptions and alternative effluent and receiving water limitations contained in the current NPDES permit.

The analyses completed by RBI support the conclusion that the effluent and receiving water limitations under the exceptions meet the criteria in 40 CFR Section 125.73(a). That is, they are sufficient, considering the cumulative impact of the thermal discharges together with all other significant impacts on aquatic species, to assure the protection and propagation of a balanced, indigenous community of shellfish, fish and wildlife in and on the lower Sacramento River and Delta (RBI 2013, Chapter 5, p. 248).

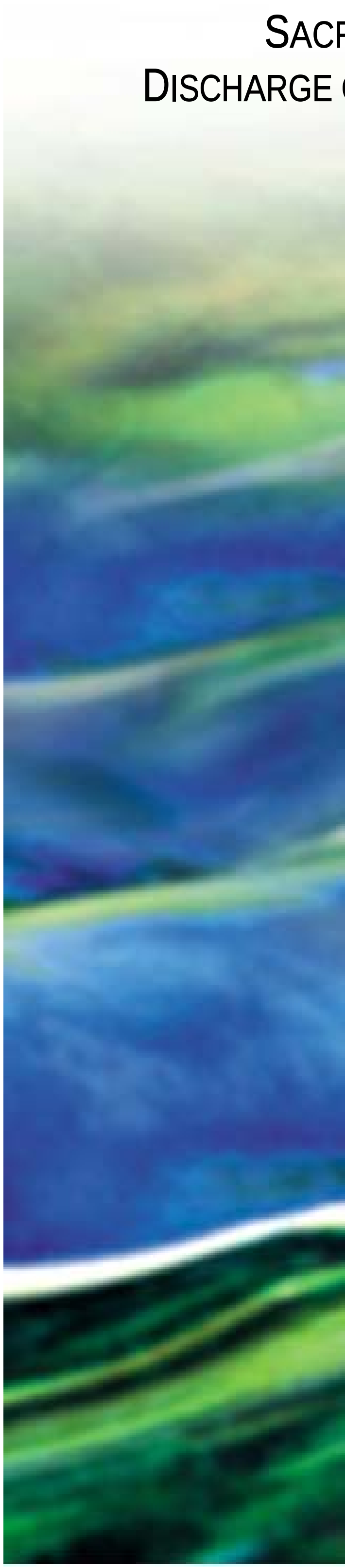
Consideration of cumulative effects of all stressors presently acting upon the aquatic species assessed is inherent in the existing studies and reports prepared by RBI (RBI 2013, 2015). The RBI analyses are based on the environment in which the species assessed exist, including actual river and Delta temperatures resulting from all actions that affect temperature. In addition, the assessments and findings presented in the RBI reports have taken into account all other environmental stressors acting upon the populations of aquatic organisms within the lower Sacramento River and Delta system, into which the SRWTP discharges. It is also to be noted that, as explained, in RBI's Temperature Study report (RBI 2013) and delta smelt addendum (RBI 2015), aquatic organisms passing through the near-field thermal plume area would not experience any chronic, adverse thermal effects when the SRWTP is operating under the current Thermal Plan exceptions and alternate effluent and receiving water limitations contained in the NPDES permit. Because no adverse thermal effects to any of the species assessed would occur when passing through the near-field plume area, there are no effects to cumulate with other adverse effects or stressors to the aquatic organisms. Similarly, in the far-field area, at and downstream of where the SRWTP effluent discharge initially becomes fully mixed with lower Sacramento River flow, there are not significant thermal effects on aquatic organisms to cumulate and the negligible thermal changes in the river from operating under the alternative limitations would not exacerbate or cumulate with other stressors to aquatic life, and thus would not make other stressors (e.g., water quality stressors, toxic algal blooms, predation, food web dynamics) worse.

References

RBI (Robertson-Bryan, Inc.). 2015. Temperature Study to Assess the Thermal Impacts of the Sacramento Regional Wastewater Treatment Plant Discharge on Aquatic Life of the Lower Sacramento River: Delta Smelt Addendum. May 2015. 72 pp. plus appendices.

RBI (Robertson-Bryan, Inc.). 2013. Temperature Study to Assess the Thermal Impacts of the Sacramento Regional Wastewater Treatment Plant Discharge on Aquatic Life of the Lower Sacramento River. March 2013. 259 pp. plus appendices.

TEMPERATURE STUDY TO ASSESS THE THERMAL IMPACTS OF THE SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT DISCHARGE ON AQUATIC LIFE OF THE LOWER SACRAMENTO RIVER: DELTA SMELT ADDENDUM



Prepared for:

U.S. FISH AND WILDLIFE SERVICE

AND

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

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Solutions for Progress

On behalf of:

SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT

May 2015

Temperature Study to Assess the Thermal Impacts of the Sacramento Regional Wastewater Treatment Plant Discharge on Aquatic Life of the Lower Sacramento River: Delta Smelt Addendum

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1.1 BACKGROUND

The Sacramento Regional Wastewater Treatment Plant (SRWTP), owned and operated by the Sacramento Regional County Sanitation District (Regional San), provides wastewater treatment for unincorporated Sacramento County; the cities of Citrus Heights, Elk Grove, Folsom, Rancho Cordova, Sacramento and West Sacramento; and the communities of Courtland and Walnut Grove. Treated effluent from the SRWTP is discharged into the Sacramento River near the town of Freeport (**Figure 1**), within the legal boundary of the Sacramento-San Joaquin Delta (Delta).

The SRWTP discharge to the Sacramento River is permitted by the Central Valley Regional Water Quality Control Board (Regional Water Board) for a design average dry weather flow (ADWF) of 181 million gallons per day (mgd). On December 9, 2010, the CVRWQCB issued a new NPDES permit (Order No. R5-2010-0114). This permit was amended by CVRWQCB Order No. R5-2011-0083 on 1 December 2011. The State Water Resources Control Board (SWRCB) issued Order No. WQ 2012-0013, which provided direction to the CVRWQCB for further refinements to the NPDES permit. Subsequently, the CVRWQCB amended the NPDES permit through Order No. R5-2013-0124 on October 4, 2013; Order Nos. R5-2014-0102 and 0103 on August 8, 2014, and Order No. R5-2014-0122 on October 9, 2014. These CVRWQCB and SWRCB Orders did not alter the NPDES permit effluent and receiving water limitations for temperature including, Special Provision VI.C.2.d (Temperature Study) that requires Regional San to:

> "…submit a workplan and time schedule for Executive Officer approval for determining whether permitted conditions are protective of aquatic life beneficial uses in the Sacramento River. The work plan shall be implemented upon approval by the Executive Officer. The study will include an evaluation of: (1) the existing Thermal Plan Exception and its effects on aquatic life, and (2) any proposed request for new Thermal Plan Exception(s). The Discharger must consult with the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the California Department of Fish and Game, to consider additional issues (such as fish attractively [sic] to mixing zone areas) in development of the workplan for the Study."

The "*Work Plan - Temperature Study to Assess the Thermal Impacts of the Sacramento Regional Wastewater Treatment Plant*" (Work Plan; RBI 2011) was developed in coordination with representatives from several State and federal agencies, which were initially convened in January 2011 to provide technical input on the study's goal, study questions, objectives, and study elements. A draft version of the Work Plan (Agency Draft Work Plan), prepared by Robertson-Bryan, Inc. (RBI), Flow Science, Inc., and Hydroacoustic Technology, Inc. (HTI) on behalf of Regional San, was submitted to the participating agencies in May 2011. Comments received from the agencies on the Agency Draft Work Plan were incorporated into the final Work Plan, which was submitted by Regional San to the Regional Water Board on June 7, 2011 and subsequently approved on July 6, 2011.

The NPDES permit contains a Reopener Provision (VII.B.1.a), which states:

> "There are uncertainties that the discharge may impact aquatic life in the vicinity of the discharge as regulated under the existing thermal exemption conditions. This Order

requires the Discharger to complete a study of temperature's potential effect in the receiving water. This reopener provision allows the Central Valley Water Board to reopen this Order for modification of effluent limitations and receiving water limitations and requirements for temperature if after review of the study results it is determined that the discharge impacts beneficial uses."

Figure 1. Location of the SRWTP and discharge location within the lower Sacramento River.

The Work Plan was implemented during the period October 2011-May 2012 and a report titled "*Temperature Study to Assess the Thermal Impacts of the Sacramento Regional Wastewater Treatment Plant Discharge on Aquatic Life of the Lower Sacramento River*" (Temperature Study Report; RBI 2013) was prepared and submitted to the Regional Water Board in March 2013. In December 2013, the United States Fish and Wildlife Service (Service) submitted a letter to the Regional Water Board in which it provided comments on the Thermal Study (**Appendix A**). The comment letter concluded that:

> "The final report of the temperature study is generally complete and is mostly consistent with the Work Plan developed with stakeholders that was completed in June 2011. There are, however, a few omissions in the study which prevents the Service from fully evaluating the thermal effects of the facility on delta smelt."

The comment letter provided recommendations that would allow the Service to fully evaluate the thermal effects of the SRWTP effluent discharge on delta smelt. In July 2014, RBI biologists met with Leanna Zweig of the Service to review the comment letter and determine the best approach for addressing the Service's comments and recommendations. In that meeting, it was decided that Regional San would prepare an addendum to the Thermal Study report that specifically addressed the Service's concerns by providing specific analyses on delta smelt, including all potential life stages and critical habitat primary constituent elements, that evaluate the potential for the SRWTP thermal discharge to adversely impact delta smelt and their designated critical habitat.

1.2 Thermal Plan Exceptions

The Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California (Thermal Plan) contains temperature objectives for these waters and specifically includes the Delta in its definition of an estuary. The Thermal Plan's objectives for "elevated temperature waste" to estuaries have been applied by the Central Valley Water Board to the lower Sacramento River and the SRWTP because the outfall is located within the legal boundary of the Delta. These objectives, identified in Section 5.A of the Thermal Plan, are as follows.

> "(1) Elevated temperature waste discharges shall comply with the following:
>
> a. The maximum temperature shall not exceed the natural receiving water temperature by more than 20°F.
>
> b. Elevated temperature waste discharges either individually or combined with other discharges shall not create a zone, defined by water temperatures of more than 1°F above natural receiving water temperature, which exceeds 25 percent of the cross-sectional area of a main river channel at any point.
>
> c. No discharge shall cause a surface water temperature rise greater than 4°F above the natural temperature of the receiving waters at any time or place.
>
> d. Additional limitations shall be imposed when necessary to assure protection of beneficial uses."

Item #4 of the General Water Quality Provisions of the Thermal Plan authorizes exceptions to the Thermal Plan, stating the following:

> "Regional Boards may, in accordance with Section 316(a) of the Federal Water Pollution Control Act of 1972 and subsequent federal regulations [collectively termed the Clean Water Act] including 40 CFR 122, grant an exception to Specific Water Quality Objectives in this Plan."

Clean Water Act Section 316(a) requirements are detailed in 40 CFR 125 Subpart H (Criteria for Determining Alternative Effluent Limitations under Section 316(a) of the Act). Section 316(a) of the Act provides that:

> "With respect to any point source otherwise subject to the provisions of section 301 or section 306 of this Act, whenever the owner or operator of any such source, after opportunity for public hearing, can demonstrate to the satisfaction of the Administrator (or, if appropriate, the State) that any effluent limitation proposed for the control of the thermal component of any discharge from

such source will require effluent limitations more stringent than necessary to assure the projection [sic] and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on the body of water into which the discharge is to be made, the Administrator (or, if appropriate, the State) may impose an effluent limitation under such sections on such plant, with respect to the thermal component of such discharge (taking into account the interaction of such thermal component with other pollutants), that will assure the protection and propagation of a balanced indigenous population of shellfish, fish and wildlife in and on that body of water." [40 CFR 125.70]

Thus, a Section 316(a) exception allows for the development and application of alternative thermal effluent limitations when the existing effluent limitations are more stringent than necessary for the protection and propagation of a balanced, indigenous aquatic community in the receiving water body.

As stated above, the Central Valley Water Board has granted the SRWTP exceptions to meeting certain Thermal Plan objectives, and thus has included alternative thermal limitations in SRWTP's current NPDES permit. The current permit contains the following effluent and receiving water limitations based on the most recently granted Thermal Plan exceptions.

Effluent Limitation

"1.e. The maximum temperature of the discharge shall not exceed the natural receiving water temperature at RSWU-001 by more than 20°F from 1 May through 30 September and more than 25°F from 1 October through 30 April."

Receiving Water Limitations (V.A.15.)

"a. If the natural receiving water temperature is less than 65°F, the discharge shall not create a zone, defined by water temperature of more than 2°F above natural temperature, which exceeds 25 percent of the cross sectional area of the River at any point outside the zone of initial dilution."

"b. If the natural receiving water temperature is 65°F or greater, the discharge shall not create a zone, defined by a water temperature of 1°F or more above natural receiving water temperature which exceeds 25 percent of the cross sectional area of the River at any point outside the zone of initial dilution for more than one hour per day as an average in any month."

"c. The discharge shall not cause the receiving water surface temperature to increase more than 4°F above the ambient temperature of the receiving water at any time or place."

1.3 PURPOSE OF THIS ADDENDUM

This addendum has been prepared to address the Service's December 2013 comment letter on the Temperature Study report. Specifically, this addendum is intended to provide the Service with all necessary information and analyses in a format that will allow for a complete evaluation of the potential impacts on delta smelt from operating the SRWTP under the Thermal Plan exceptions and alternative effluent and receiving water limitations contained in the current NPDES permit. The information contained in this addendum will allow for a determination as to whether the Thermal Plan exceptions are protective of delta smelt.

2 DELTA SMELT

2.1 ESA STATUS AND CRITICAL HABITAT DESIGNATION

The delta smelt populations in the Sacramento-San Joaquin River Delta (Delta) has been in decline since the 1970s and, as such, delta smelt are considered an imperiled species that is listed under both the federal Endangered Species Act (ESA) and California Endangered Species Act (CESA). The Service listed delta smelt as a threatened species under the ESA in March 1993 (58 FR 12854). In early 2005, the Service reviewed the population status of this species and, based on 37 years of data, recommended that no change in its threatened status was warranted. In April 2010, upon completion of a 12-month finding on a petition to reclassify delta smelt as endangered under the ESA, the Service announced that reclassifying the status of the species from threatened to endangered was warranted, but precluded by other higher priority listing actions (75 FR 17667). Delta smelt was also listed as threatened under the CESA in 1993 and re-designated by the State as endangered in 2008.

The Service designated critical habitat for delta smelt on December 19, 1994 (59 FR 65256). Critical habitat for delta smelt includes Suisun Bay, including the contiguous Grizzly and Honker bays; the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous water contained within the legal boundaries of the Delta, as defined in Section 12220 of the California Water Code. In the Sacramento River, critical habitat for delta smelt extends upstream to the I Street Bridge at river mile (RM) 59. As such, the SRWTP diffuser and thermal effects of the discharge lie within the designated critical habitat for delta smelt.

Under the ESA, critical habitat for listed species must include the necessary Primary Constituent Elements (PCEs). PCEs are essential to conservation and recovery of ESA-listed species and are defined as those physical and biological features of a landscape that a species needs to survive and reproduce. The Service has identified four primary constituent PCEs essential to the conservation of delta smelt:

1. Physical habitat – structural components of habitat, including spawning substrate and, possibly, water depth for delta smelt;

2. Water – suitable water quality conditions (e.g., temperature, turbidity, food availability, entrainment risk, contaminants) to support the various delta smelt life stages;

3. River flow – transport flows to facilitate migrations to and from spawning habitats; and,

4. Salinity – low-salinity zone (freshwater-brackish interface) used as nursery habitat.

2.2 DISTRIBUTION AND LIFE HISTORY

Delta smelt are a moderately euryhaline (i.e., tolerant of a wide range of salinities) and pelagic (live in open waters near the surface) fish species that is endemic to the Delta. Delta smelt reside in areas with low salinity (as opposed to high salinity or freshwater) for most of the year, which in most years includes the western Delta and Suisun Bay, not in the vicinity of the SRWTP diffuser. However, in the early winter, delta smelt begin their migration into freshwater to spawn.

Based on their life history, adult delta smelt may occur in the vicinity of the SRWTP diffuser during their January-July adult immigration, spawning and emigration periods. Eggs may be present in the lower Sacramento River from late January to early July (peaking during the March through May period). Larvae may occur from March through July (peaking from mid-April through May). Post-spawning adults may occur from March through July. Each of these life stages is discussed below. Juvenile rearing primarily occurs where freshwater and brackish water mix and where the complex hydrodynamics are created as tidal and riverine waters meet (Moyle 2002; Bennett 2005). These juvenile delta smelt rearing habitats are located far downstream of the measurable thermal influence of the SRWTP discharge, which occur in the Freeport area, near the SRWTP diffuser.

2.2.1 Adult Immigration

The majority of spawning is thought to occur in Suisun Marsh, the Cache Slough region, and the lower portion of the lower Sacramento River downstream of the SRWTP outfall (Merz et al. 2011). Upstream spawning migration to these sites usually occurs between late December and late February, typically during first flush periods when inflow and turbidity are increased as a result of storm run-off (Grimaldo et al 2009).

Although most adult delta smelt in the Sacramento River spawn downstream of Freeport (Merz et al. 2011), a small proportion of the adult population immigrates past the SRWTP diffuser in some years and, therefore, small numbers of adult delta smelt could immigrate past the SRWTP diffuser during their spawning migrations. For more information on the frequency with which delta smelt have been captured in agency trawl surveys historically, see Section 3.1.2.4 of the Temperature Study Report (RBI 2013).

Adult delta smelt fish utilize a "stroke-and-glide" swimming technique, moving in short bursts or strokes, followed by a period of rests or glides (Moyle 2002) and can use tidal currents to effectively migrate even during high spring outflows (Sommer et al. 2011). Using this swimming behavior, delta smelt achieve a maximum swimming velocity of 28 cm/sec (11 inches/sec; Moyle 2002) or 1-2 body lengths per second, which is considered an average swimming capability for fish (Swanson et al. 1998). In order to maximize the bioenergetic efficiency of their migrations, they tend to favor portions of the water column with low velocities (e.g., shallow river margins). As such, they are unlikely to swim upstream through the center of the channel at the river bottom (i.e., where the SRWTP diffuser is located) when passing through the Freeport area during average or high flows but may be found in those locations during low or reverse flow events.

2.2.2 Spawning and Egg Incubation

The spawning period is highly variable from year to year, and may occur from February to early July (Moyle 2002), with peak spawning activity typically occurring in April and May (USFWS 2008, Moyle 2002). It is thought that delta smelt spawn over sandy substrates in shallow areas (Bennett 2005). Delta smelt spawning has not been observed in the wild. However, based on laboratory studies, spawning typically occurs at night, under a new moon or full moon, and under low tide conditions (Moyle 2002; Lindberg et al. 1997). Bennett (2005) states that spawning success for delta smelt is believed to be associated with lunar periods and occurs within the temperature range of approximately 59-68°F. Spawning occurs near the channel bottom. The female broadcasts between 1,200 and 2,600 eggs into the water column, which are fertilized by a dominant male that swims alongside the female releasing milt.

Eggs sink to the bottom and adhere to the substrate. Delta smelt eggs incubate for 9-13 days at temperatures of approximately 59-62°F (Moyle 2002).

2.2.3 Post-spawn Adults

The majority of delta smelt complete their entire life cycle in one year and the adults die after spawning. However, observations from laboratory studies indicate that, in aquaculture settings, a small proportion (<10 percent) of adults do not spawn until age-two and another small portion of adults survive spawning after age-one and live to spawn as age-two adults (Moyle 2002; Brown and Kimmerer 2001). Second-year spawners are larger than first-year spawners and thus second-year females may have a much higher fecundity and contribute a higher number of eggs per female relative to first-year spawners (Moyle 2002). Delta smelt that spawn upstream of the SRWTP outfall may survive after spawning and move back downstream past the SRWTP outfall as post-spawn adults during their March-July emigration.

2.2.4 Larval Transport and Emigration

Upon hatching, larval delta smelt have a large oil globule, which is semi-buoyant and allows them to stay suspended in the water column just above the river bottom. Delta smelt larvae begin feeding 4-5 days after hatching. Because they maintain a position near the channel bottom, they are usually not swept downstream by high flows until they are several weeks old and their swim bladder has developed (Moyle 2002). At this stage, the larvae are able to fill the swim bladder with gas, which makes them more buoyant and allows them to move higher in the water column, where higher velocities carry them downstream to the low salinity mixing zone in the Delta (Moyle 2002). Delta smelt larvae are transported downstream by river currents to zones of freshwater/saltwater mixing from late March through July (Wang 1986, California Department of Water Resources [DWR] and U.S. Bureau of Reclamation 1994). It is during this period that larval delta smelt spawned upstream of the SRWTP outfall would be carried downstream to the low salinity zone within the Delta, and potentially exposed to elevated temperatures within the SRWTP thermal plume along the way.

2.2.5 Juvenile Rearing

Based on their life history, larval delta smelt are transported downstream by river flows to the tidal low salinity zone of the Delta, where they rear as juveniles (Bennett 2005; Moyle 2002). Consequently, juvenile delta smelt would not be expected to occur in the Freeport area because it is outside the historic range of the low salinity zone (i.e., it is a freshwater reach of the river) (Department of Water Resources 1995). . There are no available records of juvenile delta smelt occurring in the lower Sacramento River near Freeport but current fish monitoring programs do not target delta smelt during the juvenile stage from May to November. The USFWS has conducted monthly beach seine surveys since 1994 at the Sherwood Harbor monitoring location (Station ID SR055M), located at river mile (RM) 56 approximately nine miles upstream of the SRWTP diffuser. These surveys have collected only one delta smelt in over 21 years of sampling. In November 2012, a single delta smelt measuring 62-mm in length was collected at the Sherwood Harbor beach seine location. According to Bennett (2005), juvenile fish range from 20 to 40 mm in length, while adult fish range from 50 to 80 mm. Moyle (2002) states that adult delta smelt range from 55 to 70 mm in length. Based on its size and the time of year in which it was collected (i.e., November), this 67-mm delta smelt was an adult or pre-adult life stage.

The CDFW has also conducted the Fall Midwater Trawl (FMWT) survey at 122 stations throughout the Delta annually from September to December. While the primary purpose of the FMWT is to determine the relative abundance and distribution of age-0 striped bass, it is used to monitor trends in abundance of other pelagic species of the Delta, including juvenile delta smelt. FMWT surveys have been conducted in the lower Sacramento River at two stations downstream of the SRCSD outfall (i.e., stations 735 and 736) since 1992. Station 735 is located near Courtland, approximately 11.5 miles downstream of the SRCSD outfall, while Station 736 is located near Clarksburg, approximately 3.8 miles downstream of the SRCSD outfall. No delta smelt have been collected in over 21 years of FMWT surveys conducted at these two locations.

Based on delta smelt life history requirements and associated lifestage-specific habitat usage and findings from USFWS beach seine and CDFW FMWT surveys, the likelihood that juvenile delta smelt would occur in the Freeport area of the lower Sacramento River is negligible.

2.3 Thermal Requirements and Tolerance

Delta smelt are a thermally sensitive species requiring relatively cold water for survival and reproduction. While their temperature tolerances in the wild are not well understood, Bennett (2005) reports that, based on monitoring studies conducted in the wild, delta smelt are most abundant when temperatures are less than 72°F, with greater than 90% of delta smelt catches occurring at temperatures less than 68°F. Spawning success is limited to temperatures between 59 and 68°F in laboratory studies (Bennett 2005).

Swanson and Cech (1995) exposed adult, subadult, and juvenile delta smelt acclimated to temperatures of 53.6, 62.6, and 69.8°F to temperature increases of 10.8°F/hour and reported critical thermal maxima (CTM), of 69.8, 77.0, and 82.4°F, respectively, over exposure durations ranging from 70 to 90 minutes (**Table 1**). The endpoint temperatures (i.e., the temperature at which loss of equilibrium occurred) in this study increased with increasing acclimation temperature. In a similar study, Swanson et al. (2000) exposed wild-caught, adult delta smelt acclimated at 62.6°F to temperature increases of 10.8°F/hour, and reported the same CTM (i.e., 77.0°F) after 80 minutes of exposure.

More recently, Komoroske et al. (2014) conducted thermal tolerance experiments to determine the CTM thresholds for hatchery-reared delta smelt larval, late-larval, juvenile, adult, and post-spawn adult life stages, and to determine the chronic lethal thermal maximum (CLT_{max}) thresholds for juvenile, adult, and post-spawn adult life stages. The CTM experiments grouped life stages into low (53.4-54.3°F), moderate (59.5-61.9°F), and high (65.7-67.5°F) acclimation temperature groups approximating the range of temperatures that they would be exposed to in the wild. These researchers made three notable observations regarding delta smelt thermal tolerance. First, the results of the CTM experiments indicated that, in all three acclimation groups, thermal tolerance decreased with each successive life stage. For example, in the moderate acclimation group, larval fish had the highest CTM value (85.8°F) and these values decreased consistently with age, with post-spawn adults having the lowest CTM (79.3°F; Table 1). In addition, the time taken to reach the CTM endpoint (i.e., loss of equilibrium) decreased consistently with increasing age in the low and moderate acclimation temperature groups, but not in the high acclimation temperature group. Second, the results of the CTM experiments indicated that, for each of the three life stages examined in all three acclimation groups (i.e., juvenile, adult, post-spawn adult), the CTM value increased with increasing acclimation temperature. Like the CTM results, the CLT_{max} studies indicated that delta smelt's tolerance to lethal temperatures decreased with age, where juveniles had the highest CLT_{50} (highest temperature at which 50% lethality was observed) and CLT_{95} (highest temperature at which 95% lethality was observed) thresholds, followed by adults, and post-spawn adults. Finally, the time to reach the CLT_{50} and CLT_{95} thresholds decreased with age of the fish (Table 1).

Table 1. Thermal tolerance thresholds for larval, juvenile, subadult, adult, and post-spawn adult delta smelt.

Author	Type of Study	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Endpoint Reported	Lifestage
Swanson and Cech 1995	CTM [1]	53.6 62.6 69.8	69.8 77.0 82.4	90 min 80 min 70 min	LOE [4]	Subadult (SA) and adult Juvenile, SA, and adult Juvenile and SA
Swanson et al. 2000	CTM [1]	62.6	77.0	80 min	LOE [4]	40-70 mm SA and adults
Komoroske et al. 2014	CTM [2]	53.4 ± 0.2 53.6 ± 0.4 54.3 ± 0.2	80.8 80.8 75.4	50.7 min 50.3 min 39.0 min	LOE [4]	Juvenile (140-164 dph [7]) Adult (200-250 dph) Post-spawn adults (>300 dph)
		61.5 ± 0.5 61.5 ± 0.5 60.3 ± 0.2 61.9 ± 0.2 59.5 ± 0.2	85.8 84.4 82.8 83.1 79.3	45.0 min 42.3 min 41.7 min 39.3 min 36.7 min	LOE [4]	Larvae (30-32 dph) Late-larvae (60-64 dph) Juvenile (140-164 dph) Adult (200-250 dph) Post-spawn adults (>300 dph)
		67.5 ± 0.4 65.7 ± 0.4 65.7 ± 0.4	84.0 82.9 80.8	30.7 min 32.0 min 28.0 min	LOE [4]	Juvenile (140-164 dph) Adult (200-250 dph) Post-spawn adults (>300 dph)
	CLT_{max} [3]	65.7	81.3 79.7 77.2	8.7 days 7.8 days 6.4 days	CLT_{50} [5]	Juvenile (140-164 dph) Adult (200-250 dph) Post-spawn adults (>300 dph)
			82.6 81.3 79.9	9.4 days 8.7 days 7.9 days	CLT_{95} [6]	Juvenile (140-164 dph) Adult (200-250 dph) Post-spawn adults (>300 dph)

[1] CTM (critical thermal maximum); temperatures were increased by 6ºC (10.8ºF) per hour until loss of equilibrium (LOE) was observed.
[2] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[3] CLT_{max} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until lethality occurred.
[4] LOE: loss of equilibrium.
[5] CLT_{50}: temperature at which 50% lethality was observed.
[6] CLT_{95}: temperature at which 95% lethality was observed.
[7] dph: days post-hatch.

Adult delta smelt immigrating to upstream spawning habitats would temporarily encounter increasing river temperatures if they were to pass through the SRWTP plume as they immigrated upstream. Conversely, the nature of exposure to elevated temperatures that emigrating larval and post-spawn adult delta smelt would encounter when moving downstream through the SRWTP plume is one of abrupt temperature increase upon entering the plume just downstream of the diffuser, with temperatures then decreasing steadily as they move further downstream of the diffuser. Studies of fish tolerance to rapid temperature change are relatively rare in the scientific literature and there are no known temperature studies of this nature for delta smelt that would exactly mimic, for example, the thermal exposures delta smelt would experience when emigrating downstream past the SRWTP diffuser. As such, the scientific thermal tolerance literature summarized in Table 1 will be used for this assessment.

3 ENVIRONMENTAL CONDITIONS IN THE SACRAMENTO RIVER

The SRWTP discharges treated effluent into the lower Sacramento River at the town of Freeport (RM 46), approximately 600 feet downstream of the Freeport Bridge. The sections below describe the background (i.e., unaffected by the SRWTP discharge) environmental conditions and delta smelt habitat in the lower Sacramento River near the SRWTP diffuser, both historically and during the time period when the Temperature Study was occurring. The discussions of temperature and flow conditions are presented with an emphasis on the months of January through July, the period in which delta smelt may occur in the lower Sacramento River in the vicinity of the SRWTP outfall. The monthly flow and temperature statistics are provided in the Temperature Study Report (RBI 2013) for the remaining (i.e., August-December) months.

3.1 River Flow

The Sacramento River near the diffuser location (Freeport) drains a 26,146-square-mile basin that spans the entire northern Central Valley of California from the crest of the Coast Range to the crest of the Sierra Nevada. Runoff within this major drainage basin has source areas that include alpine wilderness and parkland, forested watersheds, agricultural lands, and urbanized zones.

Flows in the Sacramento River are influenced by precipitation (rainfall and snowpack/snowmelt), but are also influenced by several reservoirs on the tributaries and main stem, which are managed for flood control, water supply, and hydroelectric power generation. Irrigation diversions and agricultural return flows also affect the river's flow regime. The flows in the Sacramento River are highest in the winter and spring and lowest in the summer. Daily flow probabilities for the Sacramento River at Freeport, based on U.S. Geological Survey (USGS) gauged flow data from water years 1949-2011 indicate that there is only a 10 percent probability of flows less than or equal to 9,160 cfs, and a 10 percent probability of flows greater than 53,800 cfs. The annual average flow at Freeport is 23,560 cfs with monthly average flow ranging from approximately 12,000 to 40,000 cfs (USGS 2013).

The Temperature Study was initiated at the beginning of the 2012 water year, 1 October 2011, and ended on 30 June 2013. Water Year 2012 was classified as a "below normal" year, based on the Sacramento River index. **Figure 2** shows Sacramento River flows at Freeport in terms of daily range, average, and median for both WY 2012, as well as for the entire historical dataset for January 1985 through September 2012. During the January-July period in which delta smelt may occur in the lower Sacramento River near Freeport, the long-term average flows increase from approximately 30,000 cfs in January to a peak of over 40,000 cfs in early March, and decline steadily over subsequent months with average flows below 20,000 cfs in June and July (Figure 2). Historic river flows tend to peak at the beginning of March, and taper off as precipitation decreases through early June. During the study period, precipitation caused river flows at Freeport to rise in late January, but overall, the winter of WY 2012 had lower river flows than the historical median flow by 5,000 to 20,000 cfs from December 2011through mid-March 2012. Furthermore, daily average river flows during the second week of March 2012 were the lowest observed for that particular calendar week throughout the 1985-2012 historical period of record.

Although the winter months of WY 2012 were characterized by rather low flow conditions, they led to a spring period where runoff-induced river flows fluctuated at about the historical average (Figure 2).

Nonetheless, the maximum hourly river flow observed in April 2012 (47,000 cfs) is more typical of the maximum river flows observed in critical and dry water year types during April. Late spring river flows were impacted by the lack of precipitation and low snowfall accumulation during WY 2012. River flows during late May and early June 2012 were up to 5,000 cfs lower than the historic median for these months.

Under normal river flow conditions, treated effluent moves in a downstream direction upon being discharged from the SRWTP diffuser as it mixes with lower Sacramento River flows. However, flow in the lower Sacramento River at Freeport is affected by tidal currents and, as a result, river flow can occasionally reverse (i.e., water can flow in the upstream direction) when high tides are coupled with low river flows. In accordance with the NPDES permit, the SRWTP ceases discharging to the river before the river:effluent flow ratio reaches 14:1 and is not allowed to discharge until flow ratios return to 14:1 or greater. As such, the NPDES permit does not allow the SRWTP to discharge effluent to the Sacramento River when the river:effluent flow ratio is less than 14:1, including during reverse flow events. However, under reverse-flow conditions, diluted effluent that was previously discharged from the SRWTP, before it ceased discharging (i.e., while the river:effluent ratio was 14:1 or greater) may be transported upstream past the SRWTP diffuser and Freeport Bridge by the tidally influenced reverse river flow.

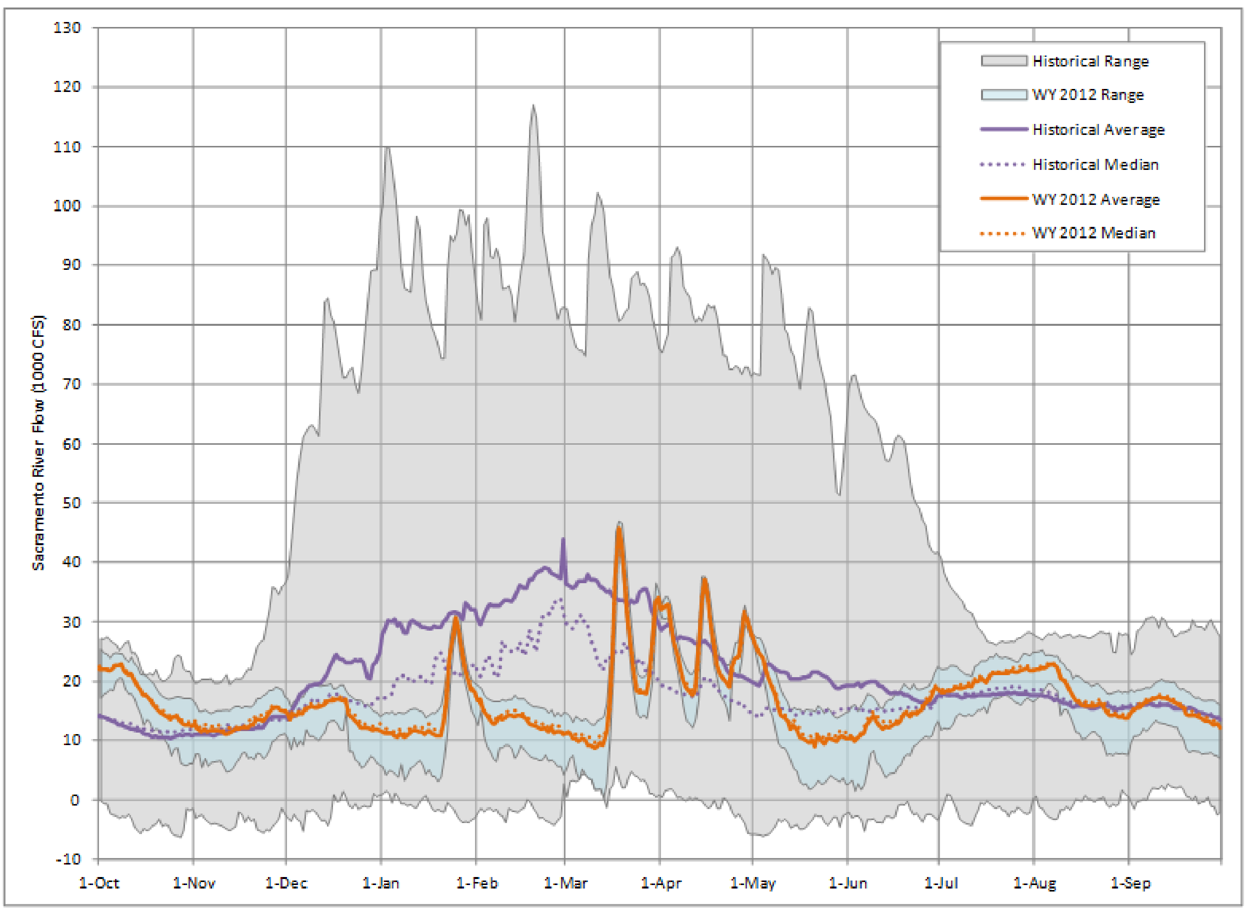


Figure 2. Average, median and range of Sacramento River flows at Freeport Bridge during water year 2012 and during the historical period of record (January 1985 through September 2012).

Based on the January 1, 1985 through September 30, 2012 period of record, reverse-flow events have occurred at the Freeport Bridge in dry and critical water year types during the months of January-July, but have not occurred at all in below normal, above normal, or wet water year types (**Table 2**). Reverse flow events have occurred in all months of the January through July period during critical water year types, but have only occurred in the months of January, February, May, and June during dry water year types. Over all water year types, reverse flow events occurred least frequently during March (0.1% of March days) and most frequently during October and May (12.4% of May days) and June (9.2% of June days). Reverse-flow events occurred in less than 5% of the days during the months of January through April and July.

Table 2. Percentage of days in which reverse flows occurred in the lower Sacramento River at Freeport Bridge during the months of January through July between January 1, 1985 and September 30, 2012.

Water Year Type	Value	Jan	Feb	Mar	Apr	May	Jun	Jul
Critical	Total # Days	186	171	186	180	186	180	186
	# Days with Reverse-Flow Events	23	30	1	29	100	74	38
	% of Days with Reverse Flows	12.4	17.5	0.5	16.1	53.8	41.1	20.4
Dry	Total # Days	217	196	217	210	217	210	217
	# Days with Reverse-Flow Events	15	7	0	0	8	3	0
	% of Days with Reverse Flows	6.9	3.6	0.0	0.0	3.7	1.4	0.0
Below Normal	Total # Days	93	86	93	90	93	90	93
	# Days with Reverse-Flow Events	0	0	0	0	0	0	0
	% of Days with Reverse Flows	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	Total # Days	98	113	124	120	124	120	124
	# Days with Reverse-Flow Events	0	0	0	0	0	0	0
	% of Days with Reverse Flows	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	Total # Days	222	225	248	240	248	240	248
	# Days with Reverse-Flow Events	0	0	0	0	0	0	0
	% of Days with Reverse Flows	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All	Total # Days	816	791	868	840	868	840	868
	# Days with Reverse-Flow Events	38	37	1	29	108	77	38
	% of Days with Reverse Flows	4.7	4.7	0.1	3.5	12.4	9.2	4.4

3.2 RIVER TEMPERATURE

Temperature of the Sacramento River at Freeport Bridge varies in a seasonal manner as influenced primarily by ambient air temperatures (**Figure 3**). River temperatures are generally at the lowest during late December and January, the period at which delta smelt initiate their spawning immigration. Temperatures gradually rise through late-winter and spring months and typically begin to reach average temperatures of approximately 68°F by mid- to late June. Delta smelt spawning is believed to be associated with lunar periods within the temperature range of approximately 59-68°F (Bennett 2005). Therefore, based on this thermal regime, delta smelt are likely to have completed their adult migration and spawning periods by mid to late June during most years. Average river temperatures at Freeport are greatest during the summer months of July and August, which average approximately 70°F (**Table 3**). As such, the delta smelt immigration and spawning period is most likely to extend into the month of July only during years that are colder than average and, specifically, below an average temperature of approximately 68°F. Exceedance probabilities based on hourly temperatures recorded during the period February 1992 through September 2012 indicate that median (i.e., 50th percentile) Sacramento River temperatures ranged from approximately 48°F in January to 70°F in July, while the 100th percentile temperatures ranged from approximately 54°F in January to approximately 76°F in the months of June and July (**Table 4**).

During the Temperature Study period, the coldest days occurred in late December 2011 and late January 2012, when river temperatures were at or near 45°F (Figure 3). Temperatures during February 2012 were generally a few degrees warmer than the historical average. Because cold winter storms moved through northern California in late March 2012 and early April 2012, river temperatures were slightly lower than the historical average (i.e., by about 2º F) during these months. June 2012 river temperatures were the warmest of WY 2012. High variation in river temperature was probably magnified by the relatively low river flow during this period (as discussed above), because the capacity with which a body of water can buffer ambient air temperature decreases as flow decreases.

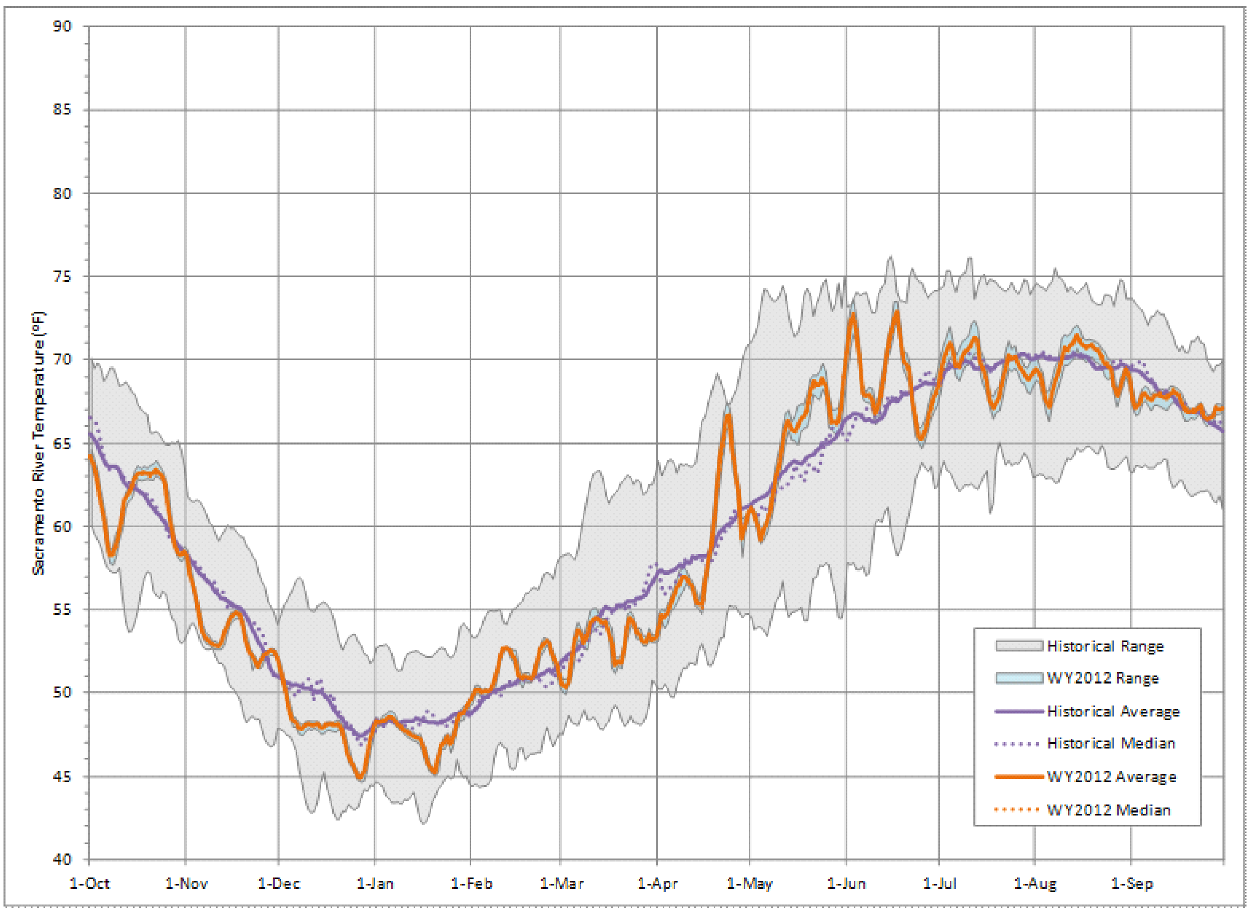


Figure 3. Daily average, median and range of Sacramento River temperatures at Freeport Bridge during water year 2012 and during the historical period of record (February 1992 through September 2012).

Table 3. Monthly mean, median, maximum, and minimum of January-July Sacramento River temperatures at Freeport Bridge, recorded hourly during the period February 1992 through July 2012.

	Jan	Feb	Mar	Apr	May	Jun	Jul
Mean	48.4	50.5	54.5	58.7	63.7	67.4	69.7
Median	48.3	50.3	54.0	58.7	62.7	67.7	70.0

Min	42.2	44.4	47.6	49.8	53.5	57.1	60.8
Max	54.2	58.1	63.4	71.0	75.1	76.3	76.2

Table 4. Exceedance probabilities for January-July Sacramento River temperatures at Freeport Bridge based on hourly data for the period February 1992 through July 2012.

Percentile	Jan	Feb	Mar	Apr	May	Jun	Jul
100	54.23	58.14	63.40	70.97	75.08	76.27	76.15
99.9	54.03	57.71	63.15	70.35	74.48	75.93	75.84
99.8	53.99	57.46	63.09	69.93	74.26	75.41	75.25
99.7	53.89	57.29	62.97	69.69	74.12	75.04	75.10
99.6	53.64	57.18	62.88	69.23	74.04	74.83	74.92
99.5	53.35	57.14	62.85	69.04	73.90	74.71	74.76
99.4	53.25	56.98	62.73	68.84	73.82	74.55	74.68
99.3	53.09	56.88	62.70	68.67	73.73	74.30	74.60
99.2	52.97	56.75	62.65	68.57	73.66	74.18	74.53
99.1	52.89	56.63	62.58	68.54	73.59	74.11	74.47
99	52.87	56.57	62.55	68.46	73.51	74.04	74.42
98	52.49	55.79	62.20	67.61	72.96	73.66	74.11
97	52.31	55.37	61.86	66.70	72.43	73.36	73.84
96	52.15	54.99	61.50	65.90	72.05	73.15	73.67
95	52.02	54.83	60.97	65.01	71.76	72.98	73.50
75	49.99	51.84	57.28	61.27	68.12	70.65	71.45
50	48.30	50.33	53.98	58.71	62.73	67.70	69.98
25	46.80	48.90	51.81	55.80	60.08	64.39	68.58
5	44.84	46.95	49.13	53.26	55.88	61.15	64.63
1	43.57	44.94	48.23	50.66	54.53	57.99	62.80

3.3 HABITAT

The reach of the lower Sacramento River near Freeport that is most thermally influenced by the SRWTP discharge is predominantly channelized, reinforced with levees, and bordered by agricultural lands. The Sacramento River is approximately 600 feet wide at the diffuser location, which is representative of the lower Sacramento River. Aquatic habitat in the lower Sacramento River is characterized primarily by deep, uniform runs and glides, is depositional in nature, and has reduced water clarity and habitat diversity, as compared to the upper portions of the river.

The Sacramento River near the SRWTP diffuser has a thalweg depth of 20-25 ft under typical summer base flow conditions and has a relatively uniform U-shaped channel with shallow near-shore margins extending approximately 25-50 ft from each shore. Velocities are highest in the deepest center portion that occupies 500-550 ft of the overall channel width. Lower velocities are found in the shallower near-shore margins of the river, particularly near the east bank. Substrates in this reach are dominated by fine, unstable sediments (i.e., sand, silt) in the river channel with riprap occurring on the banks. In-channel structure and cover is limited to near-shore overhanging vegetation, fallen trees, and sparse deposits of woody debris at or near the shoreline. Shade-providing overhead canopy cover does occur but is limited due to the width of the river and lack of trees adjacent to the river.

As discussed in Section 2.1, the Service has identified four critical habitat PCEs, physical habitat, water, river flow, and salinity, which are essential to the conservation of delta smelt. The purpose of this addendum is to assess the potential thermal effects of the SRWTP discharge on delta smelt and their critical habitat, and thus a determination of which PCE's are potentially affected by the SRWTP thermal discharge is required.

The physical habitat PCE includes the structural components of delta smelt habitat, such as substrate. The SRWTP thermal discharge does not affect the structural habitat in the lower Sacramento River or Delta and, therefore, the physical habitat PCE is not affected by the SRWTP thermal load to the river (**Table 5**).

The river flow PCE includes transport flows required to facilitate spawning migration, juvenile emigration, and minimize vulnerability to entrainment. The SRWTP's current average dry weather flow discharge rate to the Sacramento River is 141 mgd (218 cfs). Permitted capacity of the SRWTP is 181 mgd (280 cfs). Relative to January through July monthly average Sacramento River flows, the SRWTP current average dry weather flow and permitted capacity discharge rates represents 0.6 – 1.2 and 0.8 - 1.6% of total river flow, respectively. The SRWTP currently has the ability to discharge effluent at instantaneous rates ranging from 0-410 mgd (0 to 634 cfs). Relative to January through July monthly average Sacramento River flows, these discharge rates represents 0 - 3.5% percent of total river flow. Increases in flow that average approximately 1% up to a maximum of 3.5% are of an order of magnitude that would not adversely affect spawning migration, juvenile emigration, or entrainment rates (Table 5). Moreover, it should be noted that the U.S. Bureau of Reclamation accounts for SRWTP discharges to the lower Sacramento River as part of its operations to meet Delta flow and water quality standards.

The salinity PCE includes the location of the low salinity zone (LSZ) and nursery habitat quality and quantity. The SRWTP thermal discharge does not affect salinity concentrations and, therefore, does not alter the location of the LSZ or the quantity and quality of nursery habitat for delta smelt located in the LSZ (Table 5).

The water PCE includes water quality constituents, including temperature. The SRWTP thermal discharge does have the potential to affect lower Sacramento River water temperature, which has the potential to affect all delta smelt life stages that may be present near the SRWTP diffuser. However, as discussed in Section 2, juvenile delta smelt are not present in the lower Sacramento River. Therefore, the life stages that could be affected by impacts to the water PCE are adults, larva, and post-spawning adults (Table 5). Specifically, the discharge of treated effluent to the lower Sacramento River may have thermal effects on spawning habitat, larval transport, and adult migration (upstream and downstream for post-spawn adults).

Table 5. The effect of the SRWTP thermal load to the Sacramento River on the critical habitat PCEs for delta smelt.

Primary Constituent Element (PCE)	Description	Adult [1]	Larvae [1]	Juvenile [2]	Post-spawn Adult [1]
Physical Habitat	Structural components (e.g., substrate).	No Effect	No Effect	N/P	No Effect

Water	Suitable quality (e.g., temperature, turbidity, food availability, entrainment risk, contaminants).	***Potential Effect***	***Potential Effect***	N/P	***Potential Effect***
River Flow	Transport (i.e., facilitate spawning, migration and juvenile emigration, and minimize vulnerability to entrainment).	No Effect	No Effect	N/P	No Effect
Salinity Concentrations	Location of low salinity zone (LSZ; 0.5 - 6.0 psu) nursery habitat quality and quantity.	No Effect	No Effect	N/P	No Effect

[1] No Effect: the SRWTP thermal discharge does not affect the PCE for this delta smelt life stage and is not assessed in this document.
Potential: the SRWTP discharge may affect the PCE for the larval delta smelt life stage and is assessed in this document.
[2] N/P (not present): juvenile delta smelt are not present in the vicinity of the SRWTP outfall and rearing habitat is located in the LSZ of the Delta, where PCEs are not affected by the SRWTP discharge.

4 CHARACTERIZATION OF THE SRWTP EFFLUENT TEMPERATURE AND THERMAL PLUME

In order to determine if the in-river thermal conditions resulting from the current Thermal Plan exceptions are protective of delta smelt, a thorough understanding of the seasonal SRWTP effluent temperatures and associated thermal plume, located in the lower Sacramento River immediately downstream of the SRWTP diffuser, is necessary. This section provides a characterization of the SRWTP effluent temperatures, instantaneous effluent-river temperature differences, effluent discharge rates and flow ratios, near-field temperatures conditions within the SRWTP thermal plume, far-field fully mixed thermal conditions downstream of the SRWTP outfall, and thermal conditions associated with reverse-flow events. The discussions of the effect of the SRWTP discharge on temperatures in the lower Sacramento River are presented here with an emphasis on the months of January through July, the period in which delta smelt may occur in the lower Sacramento River in the vicinity of the SRWTP outfall.

4.1 SRWTP DIFFUSER

The Sacramento River is approximately 600 feet wide at the SRWTP diffuser location. The SRWTP outfall consists of a 120-inch diameter multi-port diffuser pipe located on the bottom of the Sacramento River (**Figure 4**). The diffuser extends approximately 500 ft from the east bank of the Sacramento River perpendicular to river flow. Effluent is discharged via 74 ports in the diffuser pipe. The first 100 ft of the diffuser is primarily buried in the river bottom and has no discharge ports. The next 100 ft. of the diffuser is not buried and has discharge ports that have been capped. The final three hundred feet of the diffuser pipe contains the 74 discharge ports. As a result, the plume width at the point of discharge, indicated by the white line segment in Figure 4, is 300 feet. As such, the SRWTP effluent plume occupies the 300-ft wide area of the Sacramento River downstream of the diffuser that is approximately 200 ft from the east bank and approximately 100 ft from the west bank.

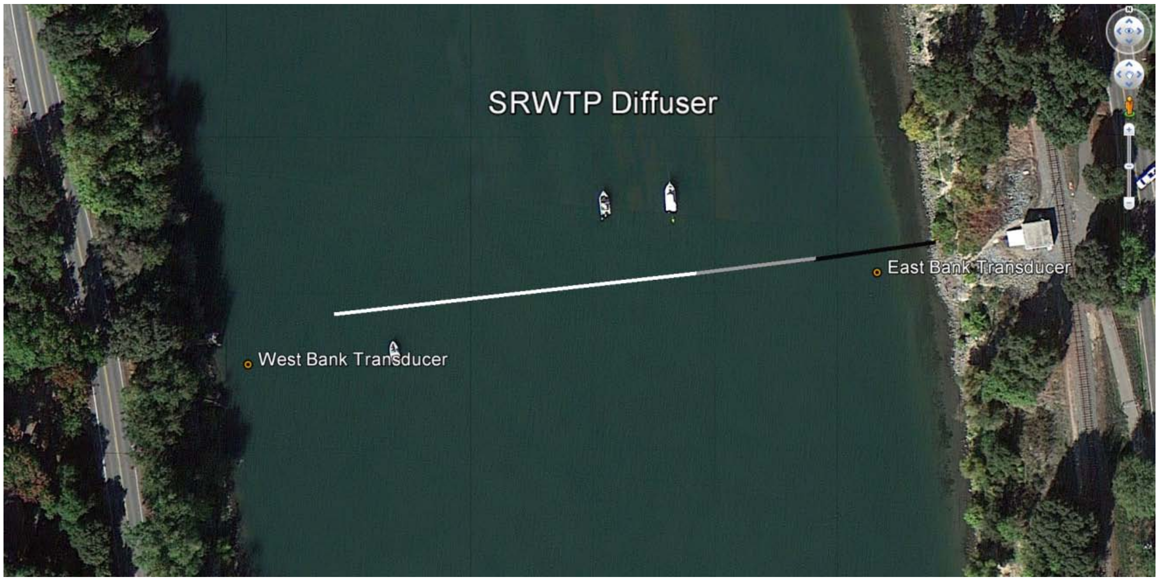


Figure 4. The location of the diffuser is illustrated by the line extending perpendicular to the river flow, where black represents the 100-ft section with no diffuser ports, grey represents the 100-ft section in which the ports occur but are capped (i.e., no discharge) and white represents the 300-ft section in which the ports are open and effluent is discharged from the diffuser.

4.2 SRWTP Effluent Temperatures

In comparison to background temperatures in the lower Sacramento River (Figure 3), SRWTP effluent temperatures are generally higher and less variable (**Table 5**). Like the Sacramento River background temperatures, the SRWTP effluent temperatures are coldest during the months of January and February and gradually increase with increasing ambient seasonal air temperatures through the spring and summer months. Median (i.e., 50^{th} percentile) effluent temperatures during the months January through July ranged from 67.3°F (February) to 78.8°F (July) (**Table 6**). The warmest (i.e., 100^{th} percentile) instantaneous effluent temperatures for each of these months ranged from 70.8°F (January) to 82.9°F (July).

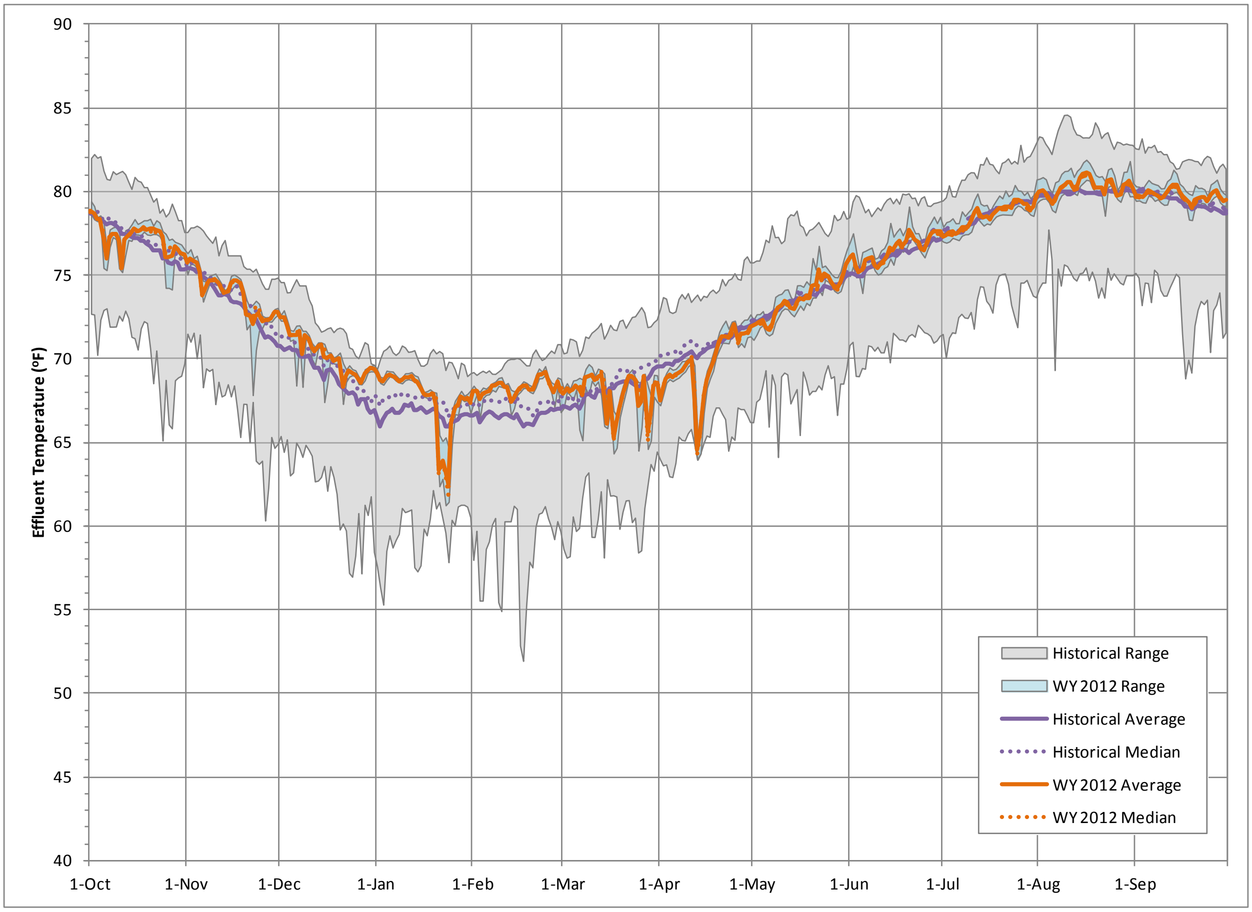


Figure 5. Daily average, median and range of SRWTP effluent temperatures during water year 2012 and during the historical period of record (January 1985 through September 2012).

Table 6. Exceedance probabilities for SRWTP effluent temperatures during the months of January-July based on hourly data for the period January 1985 through September 2012.

Percentile	Jan	Feb	Mar	Apr	May	Jun	Jul
100	70.80	70.88	73.10	76.14	78.88	79.92	82.93
99.9	70.60	70.66	72.55	75.73	78.66	79.73	82.18
99.8	70.47	70.37	72.35	75.47	78.45	79.62	82.01
99.7	70.40	70.28	72.30	75.32	78.35	79.52	81.83
99.6	70.40	70.26	72.22	75.08	78.31	79.43	81.81
99.5	70.40	70.22	72.15	74.82	78.22	79.37	81.72
99.4	70.40	70.17	72.14	74.76	78.13	79.32	81.69
99.3	70.35	70.15	72.09	74.69	78.03	79.32	81.65
99.2	70.25	70.06	72.04	74.60	77.99	79.30	81.61
99.1	70.20	70.04	72.01	74.55	77.95	79.29	81.57
99	70.20	70.00	71.97	74.49	77.89	79.24	81.54
98	69.80	69.73	71.69	74.10	77.43	79.00	81.28
97	69.55	69.51	71.49	73.86	77.16	78.86	81.10
96	69.38	69.33	71.34	73.66	76.93	78.75	80.95
95	69.23	69.18	71.22	73.52	76.80	78.65	80.84
75	68.20	68.20	69.82	71.96	75.05	77.60	79.64
50	67.44	67.34	68.60	71.00	73.55	76.38	78.75
25	65.83	65.47	66.96	69.56	72.18	74.95	77.80
5	61.89	61.59	63.24	66.45	69.69	71.91	75.23
1	59.58	59.29	60.71	64.74	68.59	70.84	72.82

4.3 Effluent-River Temperature Differentials

The difference in instantaneous SRWTP effluent and Sacramento River background temperatures was calculated for all hourly co-occurring effluent and river temperatures. Hourly temperature differentials were calculated for each pair of hourly temperatures by subtracting Sacramento River hourly temperatures measured at the Freeport Bridge (i.e., upstream of the influence of the SRWTP discharge) from concurrently measured SRWTP effluent hourly temperatures (i.e., recorded at the effluent building just prior to entering the diffuser pipe) for the available historic record (i.e., January 1985 through September 2012). This resulted in a total of 166,572 hourly effluent-river temperature difference values.

Hourly effluent-river temperature differences ranged from 0.9°F (May 2011) to 24.2°F (January 2009) during the January-July period in which delta smelt may be present in the lower Sacramento River (**Figure 6**, **Table 7**). Monthly average effluent-river temperature differences ranged from 8.9°F (June) to 18.6°F (January) (Table 7).

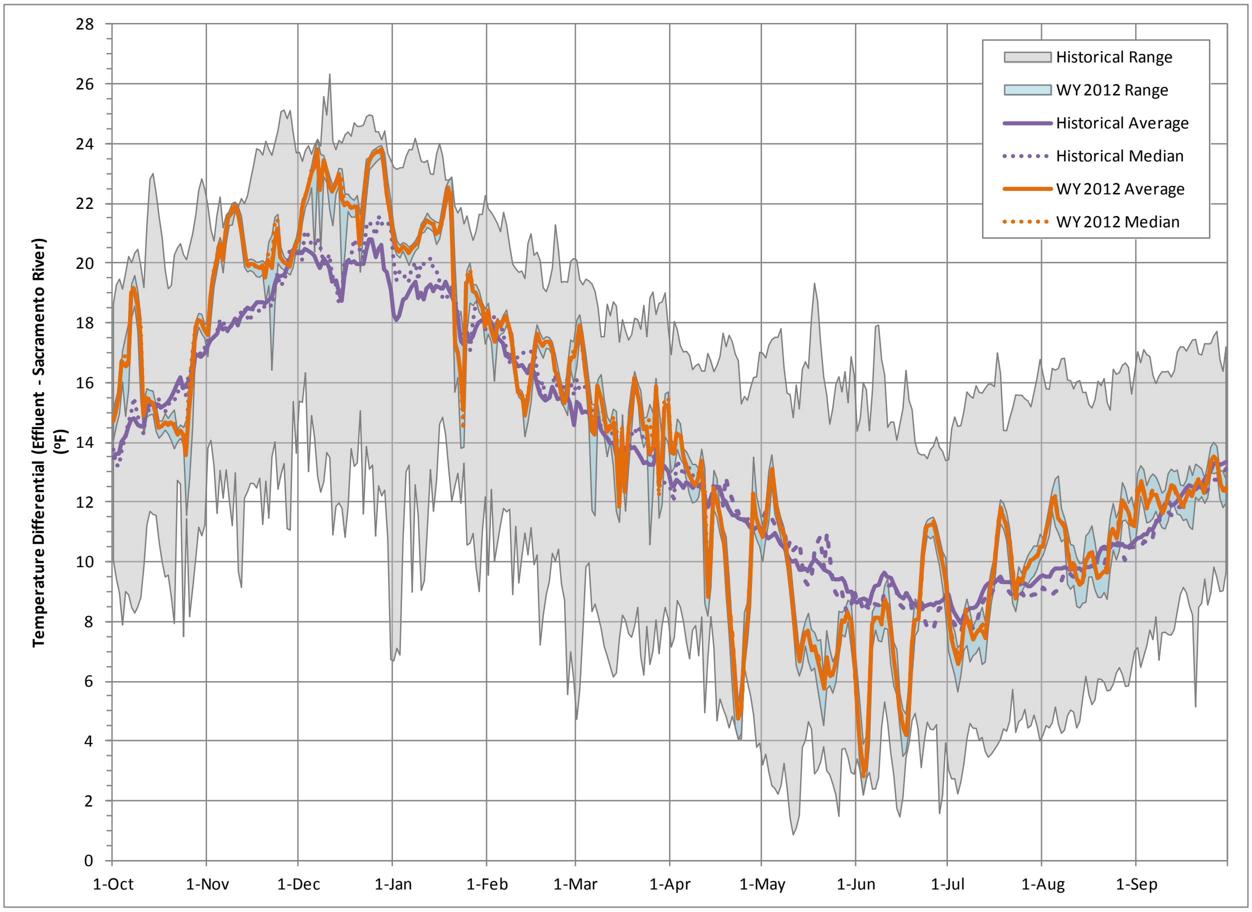


Figure 6. Daily average, median and range of the SRWTP effluent to Sacramento River temperature differential during water year 2012 and during the historical period of record (January 1985 through September 2012), based on paired hourly data.

Table 7. Monthly minimum, average, and maximum of the SRWTP effluent to Sacramento River temperature differentials for the months of January-July during the historical period of record (January 1985 through September 2012), based on paired hourly data.

Month	Effluent-River Temperature Difference (°F)		
	Minimum	Average	Maximum
January	6.7	18.6	24.2
February	5.6	16.3	21.8
March	4.7	14.0	20.1
April	3.8	12.0	18.1
May	0.9	9.9	19.3
June	1.5	8.9	17.9
July	2.2	9.0	17.0

As illustrated in Figure 6 for WY 2012 (red line), the effluent-river temperature differentials can be highly variable within small timeframes (e.g., from day to day). This variability is primarily in response to relatively large fluctuations in river temperatures driven by local weather (Figure 3), rather than the less variable changes in SRWTP effluent temperatures (Figure 5). In other words, the largest effluent temperature differences occur when Sacramento River background temperatures are cold in response to sudden decreases in ambient air temperatures, wet weather precipitation (i.e., snow and cold rain) events in the upper watershed, and releases of cold water from upstream reservoirs. Consequently, the largest effluent-river temperature differentials (e.g., 20°F or more) occur when the river temperature drops more quickly than the relatively stable SRWTP effluent temperatures in response to regional weather and CVP/SWP operations. This is illustrated in the scatter plots of monthly Sacramento River temperatures (X-axis) by effluent-river temperature differences (Y-axis) in Appendix B. Each point in this graph is shaded to indicate the corresponding SRWTP effluent temperature percentile. These graphs illustrate that, in each month, the highest effluent-river temperature differences occur when Sacramento River background temperatures are at or near their lowest values. The effluent temperatures that correspond with the largest effluent-river temperature differentials are typically between the 10th and 75th percentile of effluent temperatures. For example, in January (Appendix B, Figure B-1), the maximum effluent-river temperature difference of 24.2°F (Table 7), occurred when the river was near the historic low at 43.7°F, while the effluent temperature was 67.9°F (i.e., just above the median January temperature of 67.4°F, (Table 6). The warmest effluent temperatures (light red to dark red dots) are rarely associated with the highest effluent-river temperature differences. These figures illustrate that the sudden large decreases in Sacramento River temperatures are the primary driver of the largest effluent-temperature differences, rather than increases in SRWTP effluent temperatures.

The distributions of hourly effluent-river temperature differences are summarized in 1°F increments in **Appendix C** for the months of January through July. These tables show, for each month, the count and relative proportion (i.e., percent of monthly totals) of hourly effluent-river temperature differential values that have been recorded over the period of record February 1992 through September 2012 for each 1°F increment, and the corresponding minimum, average, and maximum river and effluent temperatures that were recorded for each of the temperature differential increments. These values indicate that, during the month of January, the majority (>60%) of temperature differential values were between 16-22°F, while no effluent-river differential values less than 6°F were observed (Appendix C; Table C-1). Only three values comprising 0.02% of all historic January differential values were between 24-25°F. In February, approximately 85% of all historic temperature differences were between 13-20°F, and no temperature differences less than 5°F or greater than 22°F were observed (Appendix C, Table C-2). In March, approximately 88% of all historic temperature differences were between 10-18°F, and no temperature differences less than 4°F or greater than 21°F were observed (Appendix C, Table C-3). In April, approximately 88% of all historic temperature differences were between 8-15°F, and no temperature differences less than 3°F or greater than 19°F were observed (Appendix C, Table C-4). In May, all temperature differential values were below 20°F, and approximately 84% of all historic temperature differences were between 5-15°F (Appendix C, Table C-5). In June, all temperature differential values were less than 18°F, and approximately 89% of all historic temperature differences were between 5-14°F (Appendix C, Table C-6). In July, all temperature differential values were less than 18°F, and approximately 85% of all historic temperature differences were between 5-12°F (Appendix C, Table C-7).

These data also indicate that, when river background temperatures are at or near their historic monthly maxima, any delta smelt moving through the warmest part of the SRWTP thermal plume would encounter temperature differences that are below the average for any given month. In February, the warmest river temperature on record (i.e., 58.1°F) occurred when effluent temperatures were 70.7°F, resulting in a temperature difference of approximately 12.6°F (Appendix C, Table C-2), which is approximately the lowest 10th percentile of effluent-river temperature differences for the month of February. In all other months (i.e., January, March-July), the warmest river temperatures correspond to effluent-river temperature differentials of 12°F or less (Appendix C).

4.4 SRWTP Effluent Discharge Rates and Flow Ratios

The SRWTP's current average dry weather flow discharge rate to the Sacramento River is 141 mgd (218 cfs). Permitted capacity of the SRWTP is 181 mgd (280 cfs). Relative to January through July monthly average Sacramento River flows, the SRWTP current average dry weather flow and permitted capacity discharge rates represents 0.6 – 1.2 and 0.8 -1.6 percent of total river flow, respectively. The current peak daily wet weather flow discharge rate from the SRWTP is 337 mgd (521 cfs). Such peak effluent flows occur during periods when flow in the river also is elevated and represent a very small percent of total river flow. The discharge of treated effluent from the SRWTP creates a thermal plume that occupies an area approximately 300 feet wide in the center of the river channel that attenuates with distance downstream of the SRWTP diffuser.

SRWTP effluent discharge rates for the months of January-July ranged from 0 mgd (no discharge) to a maximum of 400 mgd during the historical period of record (**Table 8**). Average monthly effluent discharge rates during the historic period of record ranged from 139 mgd (June and July) to approximately 164 mgd in February. Average and maximum effluent discharge rates were generally higher during the winter months and declined steadily from March through July (Table 8).

Table 8. Minimum, average, and maximum SRWTP effluent discharge rates for the months of January-July during the historical period of record (January 1985 through September 2012).

Month	SRWTP Effluent Flow Rate (mgd)			
	Count	Minimum	Average	Maximum
January	19,370	0.0	157.4	364.5
February	18,908	0.0	163.9	397.7
March	20,325	0.0	157.5	400.0
April	19,287	0.0	145.1	370.4
May	19,882	0.0	142.1	314.0
June	19300	0.0	139.0	283.5
July	19,773	0.0	139.0	268.2

Flow ratios were calculated on an hourly basis for the January 1985 through September 2012 period of record by dividing each hourly Sacramento River flow value (in cfs, as measured at the Freeport Bridge) by the concurrently measured SRWTP effluent flow (in cfs, as measured at the effluent building immediately before discharge to the Sacramento River). The total number of hourly flow ratio values in each month ranged from 18,169 (June) to 19,769 (March) (**Table 9**). As discussed in Section 3.1, effluent discharge rates are decreased when the flow ratio decreases and approaches 14:1. Consequently, flow ratios between 14:1 and 15:1 comprise 0.1% or less of all hourly values during the months of January-July over the January 1985 to September 2012 period of record (Table 9). Flow ratios less than 19:1 comprise less than 1% of all hourly ratios in any month during the months of January-July. Flow ratios of 25:1 or greater comprise between 95.6% (May) and 99.4 (February) of all hourly values in each of these seven months (Table 9).

Table 9. Frequency of Sacramento River:SRWTP effluent flow ratios ($Q_{River÷Effluent}$) for the months of January-July over the January 1, 1985 through September 30, 2012 period of record.

Dilution Ratio ($Q_{River÷Effluent}$)	**January**		**February**		**March**		**April**		**May**		**June**		**July**	
	Count (*n*)	**Percent of Total (%)**	**Count (*n*)**	**Percent of Total (%)**	**Count (*n*)**	**Percent of Total (%)**	**Count (*n*)**	**Percent of Total (%)**	**Count (*n*)**	**Percent of Total (%)**	**Count (*n*)**	**Percent of Total (%)**	**Count (*n*)**	**Percent of Total (%)**
15 > Q ≥ 14	5	0.03	6	0.03	1	0.01	7	0.04	13	0.1	9	0.05	17	0.1
16 > Q ≥ 15	19	0.1	16	0.1	5	0.03	29	0.2	48	0.3	39	0.2	41	0.2
17 > Q ≥ 16	30	0.2	20	0.1	9	0.05	39	0.2	68	0.4	39	0.2	35	0.2
18 > Q ≥ 17	31	0.2	24	0.1	8	0.04	47	0.3	80	0.4	51	0.3	35	0.2
19 > Q ≥ 18	45	0.2	29	0.2	12	0.1	40	0.2	74	0.4	61	0.3	32	0.2
20 > Q ≥ 19	49	0.3	22	0.1	11	0.1	42	0.2	73	0.4	65	0.4	29	0.2
25 > Q ≥ 20	229	1.2	125	0.7	87	0.4	255	1.4	467	2.5	333	1.8	158	0.9
50 > Q ≥ 25	2,342	12.4	1,851	10.2	1,521	7.7	2,715	14.6	4,628	24.8	3,830	21.1	1,769	9.7
100 > Q ≥ 50	7,204	38.2	5,990	32.8	6,865	34.7	7,879	42.3	6,503	34.8	7,819	43.0	10,856	59.7
Q ≥ 100	8,897	47.2	10,153	55.7	11,277	57.0	7,587	40.7	6,710	36.0	5,923	32.6	5,205	28.6
Total:	***18,851***	***100.0***	***18,236***	***100.0***	***19,796***	***100.0***	***18,640***	***100.0***	***18,664***	***100.0***	***18,169***	***100.0***	***18,177***	***100.0***

4.5 THERMAL PLUME

4.5.1 Characterization of the SRWTP Thermal Plume through Modeling

4.5.1.1 Plume Modeling Conducted

The temperature gradients, and horizontal and vertical distribution of the SRWTP thermal plume within the lower Sacramento River channel at Freeport has been modeled by Flow Science, Inc. under a range of river and effluent flow and temperature conditions since 1999 (Temperature Study Report; RBI 2013). Most recently, the effects of the SRWTP discharge on Sacramento River temperatures was modeled by Flow Science, Inc. using the Computational Fluid Dynamics (CFD) model FLOWMOD to simulate the SRWTP plume under a median flow ratio scenario and several minimum flow ratio scenarios (**Appendix D**). These modeling scenarios enable the characterization of the most affected half of all thermal conditions that can occur within the plume, immediately downstream of the SRWTP diffuser. The other half of thermal conditions that would occur within the plume would have lesser temperature differences within the plume, relative to ambient background temperatures, than shown for the median flow ratio scenario.

For the median flow scenario, an approximate median SRWTP discharge rate of 154 mgd was modeled with an approximate median river flow rate of 16,000 cfs, which results in an approximate median flow ratio of 67:1. The three minimum flow ratio scenarios were all modeled at a 14:1 flow ratio, which is the flow ratio at which the SRWTP must cease discharge to the river under its NPDES permit. The discharge rates of 60 mgd, 181 mgd, and 410 mgd were chosen for the minimum flow ratio analysis for the following reasons: 1) 60 mgd is the minimum rate at which the SRWTP can continuously discharge based on their NPDES permit discharge prohibition that does not allow discharge to the lower Sacramento River at river flows below 1,300 cfs (840 mgd); 2) 181mgd is the permitted capacity of the SRWTP; and 3) 410 mgd is the maximum capacity that the SRWTP can discharge to the lower Sacramento River based on the plant infrastructure.

For each of these four flow conditions modeled (one median flow ratio condition and three minimum flow ratio conditions), temperature output was obtained for the initial 990 ft of the thermal plume downstream of the diffuser at three depths within the footprint of the plume, which are: 1) along the centerline of the thermal plume at the river surface, 2) along the centerline of the thermal plume at 10 feet below the river surface, and 3) at 20 feet below the river surface (i.e., at or near the river bottom) along the warmest potential fish migration path extending downstream of the SRWTP diffuser. Finally, the plume was simulated for each of the four flow conditions at effluent-river temperature differentials of 5°F, 10°F, 15°F, 20°F, and 25°F. This resulted in obtaining modeling output that characterizes plume temperatures, relative to river background temperatures, for 20 simulated flow ratio and effluent:river temperature differential scenarios (4 flow ratios x 5 temperature differentials = 20 scenarios) at the river surface, 10 ft below the surface, and at the river bottom (Appendix D, Attachments A Figures and Attachment B Tables).

4.5.1.2 Plume Modeling Results

The results of Flow Science's modeling efforts (FSI 2015) are provided in Appendix D. Appendix D, Attachment A, Figures 1-20 provide plan-view and longitudinal cross-sectional views of the gradient of temperatures above ambient background temperatures (depicted by a color gradient) that occur within the plume in the initial 700 ft downstream of the diffuser for each of the 20 scenarios modeled and described above. Appendix D, Attachment A, Figures 21-40 provide channel cross-sectional views of the gradient of temperatures above ambient background temperatures (depicted by a color gradient) that occur 60 ft, 175 ft, and 700 ft downstream of the diffuser. Appendix D, Attachment B, Tables 1 through 12 provide tabular data for the simulated river velocity, drift time, and simulated temperature above ambient river background temperature in each model grid cell along a particle path beginning at the diffuser and extending to the downstream end of the modeled domain (i.e., 990 feet downstream of the diffuser) for each of the three depths (i.e., surface, 10 ft, and 20 ft). These data are provided in these tables at 6 ft intervals between the diffuser and the end of the downstream modeling domain at 990 ft downstream of the diffuser. The simulated drift time is the cumulative travel time for a drifting particle or organism from the SRTWP diffuser to specified distances downstream of the diffuser.

The effluent is discharged from the diffuser ports near the river bottom. The warmer, buoyant effluent initially mixes near the river bottom and gradually rises as the plume travels downstream. Water temperatures are highest at the diffuser ports and decrease with increasing distance downstream from the diffuser, as a result of the effluent continuing to mix with the river water. Hence, the highest temperature within the plume occurs near the river bottom where the diffuser ports are located. The plume rises towards the surface somewhat more quickly on the western side of the river channel. The highest longitudinal velocities typically occur near the surface and the lowest near the river bottom.

River velocities restrict the lateral spread of the plume and, consequently, the plume remains roughly 300 ft wide (i.e., the width of the open diffuser ports) over the entire length of the modeled domain. As shown in Appendix D, Attachment A, Figures 1-20, this results in approximately half of the river cross-section being unaffected by the SRWTP thermal plume. The unaffected area of the channel occurs along both sides of the river, and exists for the entire length of the plume modeled for all months and conditions. An approximately 100 ft-wide zone, unaffected by the plume, occurs along the west bank of the river between the last diffuser port and the west bank. Likewise, an approximately 200 ft-wide zone, unaffected by the plume, occurs along the east bank of the river between the first diffuser port and the east bank. Hence, there exists under all discharge conditions a combined total (along both east and west banks) area of approximately 300 ft in width that is unaffected by the plume, which is approximately one-half of the river's 600 ft width at the diffuser's location.

Effluent concentrations and water temperatures are highest near the diffuser and decrease with increasing distance downstream of the diffuser. The highest temperatures within the plume are located near the bottom of the river whereas water temperatures at the surface are affected little under all conditions. As the plume moves downstream it rises towards the surface and further mixes, which lowers the water temperatures in the plume. The highest longitudinal velocities typically occur near the river surface and the lowest velocities occur near the river bottom in the downstream "shadow" of the SRWTP diffuser.

4.5.1.2.1 Median Flow Ratio Scenario

Table 10 and Appendix D, Attachment A, Figures 16-20 and 36-40 and Attachment B, Tables 10-12 provide a color-gradient, graphical depiction of the thermal plume modeled and tabular data defining the river velocity, drift time, and temperature differentials within the plume at various distances downstream of the diffuser for the median flow (154 mgd; 67:1 flow ratio) scenario. The computed drift time along the centerline of the plume at the surface is 170 seconds (2.8 minutes) and at the 10 ft deep is 180 seconds (3 minutes). At the surface, the warmest temperatures along the centerline of the plume occur about 900 ft downstream of the diffuser, with decreasing temperature occurring further downstream due to continued effluent mixing with river water. At 10 ft deep, the warmest temperatures along the centerline of the

Table 10. River velocity, drift time, and temperature differences from ambient background (i.e., $T_{effluent}$ - T_{river}) at a SRWTP effluent discharge rate of 154 mgd and river flow rate of 16,000 cfs (67:1 flow ratio) at 90-ft increments downstream of the diffuser at the river surface, 10 feet below the river surface, and 20 feet below the river surface.

Distance Downstream of Diffuser (ft)	Velocity (fps)	Drift Time (sec)	Temperature Difference ($T_{effluent}$ - T_{river}) (°F)				
			5°F	10°F	15°F	20°F	25°F
River Surface							
0	5.66	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
90	5.32	16.6	0.0000	0.0000	0.0000	0.0000	0.0000
180	5.45	33.4	0.0000	0.0000	0.0000	0.0000	0.0000
270	5.54	49.8	0.0000	0.0000	0.0000	0.0000	0.0000
360	5.63	65.9	0.0001	0.0002	0.0002	0.0003	0.0004
450	5.84	81.5	0.0016	0.0033	0.0049	0.0065	0.0081
540	5.94	96.7	0.0202	0.0405	0.0607	0.0809	0.1011
630	5.92	111.9	0.0535	0.1069	0.1604	0.2138	0.2673
720	6.01	127.0	0.0763	0.1527	0.2290	0.3053	0.3817
810	6.08	141.9	0.0886	0.1772	0.2658	0.3544	0.4430
900	6.25	156.5	0.0929	0.1858	0.2787	0.3716	0.4645
990	6.40	170.7	0.0919	0.1839	0.2758	0.3677	0.4596
10 Feet Below the River Surface							
0	5.75	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
90	5.33	16.6	0.0010	0.0019	0.0029	0.0039	0.0048
180	5.30	33.5	0.0662	0.1324	0.1985	0.2647	0.3309
270	5.16	50.8	0.1271	0.2542	0.3813	0.5084	0.6355
360	5.16	68.2	0.1349	0.2697	0.4046	0.5395	0.6743
450	5.35	85.2	0.1333	0.2667	0.4000	0.5333	0.6667
540	5.45	101.9	0.1289	0.2578	0.3867	0.5156	0.6446
630	5.51	118.3	0.1242	0.2483	0.3825	0.4967	0.6209
720	5.71	134.4	0.1219	0.2438	0.3658	0.4877	0.6096
810	5.85	149.9	0.1202	0.2404	0.3606	0.4807	0.6009
900	6.06	165.1	0.1178	0.2357	0.3535	0.4713	0.5892
990	6.24	179.7	0.1125	0.2251	0.3376	0.4501	0.5627
20 Feet Below the River Surface							
0	0.39	0.0	5.00	10.00	15.00	20.00	25.00
90	3.09	56.2	0.74	1.47	2.21	2.95	3.68
180	3.85	82.0	0.47	0.93	1.40	1.87	2.33
270	4.20	104.2	0.36	0.71	1.07	1.42	1.78
360	4.48	125.0	0.29	0.57	0.86	1.15	1.43
450	4.54	144.8	0.24	0.48	0.72	0.96	1.20
540	4.77	164.1	0.21	0.42	0.62	0.83	1.04
630	5.00	182.5	0.19	0.37	0.56	0.74	0.93
720	5.14	200.8	0.18	0.35	0.53	0.70	0.88
810	5.29	218.1	0.17	0.34	0.50	0.67	0.84
900	5.47	234.7	0.16	0.32	0.49	0.65	0.81
990	5.76	250.7	0.16	0.31	0.47	0.63	0.79

plume occur about 400 ft downstream of the diffuser, with decreasing temperature occurring further downstream. Consequently, temperatures within the plume along the center line at the 10 ft depth at locations further downstream than the 990 ft end of the modeled domain will be lower than the temperatures modeled at 990 ft. The warmest path at the 20 ft depth occurs near the eastern edge of the plume. The computed drift time along the warmest path to the end of the modeled domain is 250 seconds (4.2 minutes). At the end of the modeled domain, the temperature along the warmest path is modeled to range from 0.2°F above ambient river temperature for the 5°F effluent discharge differential to 0.8°F above ambient river temperature for the 25°F differential. In comparison to the 14:1 river-to-effluent flow ratio scenarios (Section 4.5.1.2.2), the plume under a median flow scenario (67:1 river-to-effluent flow ratio) mixes more quickly (due to increased turbulence) as it travels the length of the modeled domain.

It should be noted that the factors that dictate the size and internal temperature gradients of the SRWTP thermal plume within the river immediately downstream of the diffuser are: 1) the river channel bathymetry, 2) river discharge rate, 3) SRWTP effluent discharge rate, 4) temperature difference between the effluent and the river, and 5) diffuser design. The current exception to Thermal Plan objective 5.A.(1)a is to allow up to a 25°F temperature difference between the effluent and river versus a 20°F difference, as defined in Thermal Plan objective 5.A.(1)a. Hence, whenever the effluent-river temperature differential is less than or equal to 20°F, there is no difference in plume thermal characteristics between operating the SRWTP to the Thermal Plan objective 5.A.(1)a versus operating to the exception to this objective. Conversely, whenever the effluent-river temperature differential is greater than 20°F, the internal temperature gradients within the plume would differ somewhat from that which would occur if the SRWTP were operated to limit the effluent-river temperature differential to no more than 20°F.

To see the maximum difference in internal thermal gradients within the plume from operating the SRWTP to the exception versus always meeting objective 5.A.(1)a, simply compare the incremental temperature increases above river background in the 20°F column to that shown in the 25°F column in Table 10. Based on this comparison, the temperatures within the thermal plume at various distances downstream of the river when operating to the exception would never be greater than 0.1°F at the surface, 0.13°F at 10 ft below the surface within the initial 990 ft downstream of the diffuser, under the median flow scenario. At the river bottom, the greatest difference would occur at the diffuser ports. However, this difference is rapidly attenuated by rapid mixing of effluent with river water such that the incremental temperature increase is less than 1.0°F within 90 ft of the diffuser. Based on these findings, the internal thermal gradients of the plume show only minor difference between operating to Thermal Plan objective 5.A.(1)a or the exception to this objective at all distances from the diffuser at the river surface and at 10ft below the surface, and at all locations within the plume beyond about 90 ft from the diffuser ports near the river bottom.

4.5.1.2.2 Minimum Flow Ratio Scenarios

60 MGD Scenario

Table 11 and Appendix D, Attachment A, Figures 1-5 and 21-25 and Attachment B, Tables 1-3 provide a color-gradient, graphical depiction of the thermal plume modeled and tabular data defining the river velocity, drift time, and temperature differentials within the plume at various distances downstream of the diffuser for the 60 mgd flow scenario. The modeled drift time along the centerline of the plume at the surface is 2,148 seconds (35.8 minutes) and at 10 ft deep is 2,194 seconds (36.6 minutes). At the surface, the plume would not be fully mixed within the modeled domain (i.e., 990 ft downstream of the diffuser), therefore, the warmest temperatures would occur downstream. However, temperature increases at the river's surface that would occur under this flow condition at locations more than 990 ft downstream of the diffuser, as the plume more fully mixes to the surface, are expected to be on the order of approximately 1°F or less. At 10 ft deep, the warmest temperatures along the centerline of the plume would occur about 800 ft downstream of the diffuser, with decreasing temperature occurring further downstream. The edge of the plume (as defined by the 0.1°F temperature differential contour) at the centerline is predicted to not reach the surface within the modeled domain for the five effluent temperature differentials modeled. The modeled drift time along the warmest path at 20 ft depth from the diffuser to the end of the modeled domain (990 ft downstream) is 4,232 seconds (70.5 minutes). At the end of the modeled domain, the temperature along the warmest path is predicted to range from 1.9°F above ambient river temperature for the 5°F effluent discharge differential to 9.3°F above ambient river temperature for the 25°F differential.

Table 11. River velocity, drift time, and temperature differences from ambient background (i.e., $T_{effluent} - T_{river}$) at a SRWTP effluent discharge rate of 60 mgd and river flow rate of 1,300 cfs (14:1 flow ratio) at 90-ft increments downstream of the diffuser at the river surface, 10 ft below the river surface, and 20 ft below the river surface.

Distance Downstream of Diffuser (ft)	Velocity (fps)	Drift Time (sec)	Temperature Difference ($T_{effluent} - T_{river}$) (°F)				
			5°F	10°F	15°F	20°F	25°F
River Surface							
0	0.47	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
90	0.45	202.9	0.0039	0.0078	0.0116	0.0155	0.0194
180	0.44	405.4	0.0245	0.0491	0.0736	0.0982	0.1227
270	0.44	608.6	0.0503	0.1007	0.1510	0.2014	0.2517
360	0.44	812.4	0.0699	0.1398	0.2097	0.2796	0.3495
450	0.45	1014.0	0.1068	0.2135	0.3203	0.4270	0.5338
540	0.45	1214.6	0.1590	0.3180	0.4770	0.6359	0.7949
630	0.45	1414.9	0.2094	0.4189	0.6283	0.8377	1.0471
720	0.46	1613.7	0.2579	0.5157	0.7736	1.0314	1.2893
810	0.46	1810.0	0.2644	0.5289	0.7933	1.0577	1.3221
900	0.47	2003.7	0.2632	0.5264	0.7896	1.0528	1.3160
990	0.47	2194.0	0.2671	0.5343	0.8014	1.0685	1.3357
10 Feet Below the River Surface							
0	0.47	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
90	0.45	202.9	0.0039	0.0078	0.0116	0.0155	0.0194
180	0.44	405.4	0.0245	0.0491	0.0736	0.0982	0.1227
270	0.44	608.6	0.0503	0.1007	0.1510	0.2014	0.2517
360	0.44	812.4	0.0699	0.1398	0.2097	0.2796	0.3495
450	0.45	1014.0	0.1068	0.2135	0.3203	0.4270	0.5338
540	0.45	1214.6	0.1590	0.3180	0.4770	0.6359	0.7949
630	0.45	1414.9	0.2094	0.4189	0.6283	0.8377	1.0471
720	0.46	1613.7	0.2579	0.5157	0.7736	1.0314	1.2893
810	0.46	1810.0	0.2644	0.5289	0.7933	1.0577	1.3221
900	0.47	2003.7	0.2632	0.5264	0.7896	1.0528	1.3160
990	0.47	2194.0	0.2671	0.5343	0.8014	1.0685	1.3357
20 Feet Below the River Surface							
0	0.16	0.0	5.00	10.00	15.00	20.00	25.00
90	0.19	395.8	3.72	7.44	11.16	14.88	18.60
180	0.20	862.3	3.46	6.91	10.37	13.82	17.28
270	0.22	1286.8	3.33	6.66	9.99	13.33	16.66
360	0.24	1679.9	3.17	6.34	9.51	12.67	15.84

450	0.23	2066.4	2.93	5.86	8.79	11.72	14.65
540	0.23	2462.1	2.72	5.44	8.16	10.88	13.60
630	0.22	2881.8	2.52	5.03	7.55	10.07	12.59
720	0.26	3267.6	2.30	4.61	6.91	9.22	11.52
810	0.26	3616.4	2.14	4.27	6.41	8.55	10.69
900	0.28	3936.1	1.96	3.91	5.87	7.83	9.79
990	0.35	4232.0	1.85	3.70	5.56	7.41	9.26

Based on comparing the incremental temperature increases above river background in the 20°F column to that shown in the 25°F column in Table 11, the temperatures within the thermal plume at various distances downstream of the river when operating to the exception would never be greater than 0.3°F at the surface, 0.27°F at 10 ft below the surface within the initial 990 ft downstream of the diffuser, under the median flow scenario. At the river bottom, the greatest difference would occur at the diffuser ports. However, this difference is attenuated by mixing of effluent with river water such that the incremental temperature increase is less than 3.0°F within 426 ft of the diffuser.

Based on these findings, the internal thermal gradients of the plume show only minor difference between operating to Thermal Plan objective 5.A.(1)a versus the exception to this objective at all distances from the diffuser at the river surface and at 10ft below the surface. Although greater incremental increases occur under this flow scenario near the river bottom, it should be further noted that effluent-river temperature differentials as high as 25°F occur only in the month of December when river temperatures are in the low 40 degree range and delta smelt are not in the vicinity of the SRWTP diffuser. In the months of January, February, and March, when the effluent-river temperature differentials occasionally exceed 20°F, which occurs about 4.6% of the time, river background temperatures range from 42.2°F to 50.4°F.

181 MGD Scenario

Table 12 and Appendix D, Attachment A, Figures 6-10 and 26 through 30 and Attachment B, Tables 4-6 provide a color-gradient, graphical depiction of the thermal plume modeled and tabular data defining the river velocity, drift time, and temperature differentials within the plume at various distances downstream of the diffuser for the 181 mgd flow scenario. The modeled drift time along the centerline of the plume at the surface is 630 seconds (10.5 minutes) and at 10 ft deep is 670 seconds (11.2 minutes). The plume would not fully reach the river surface within the modeled domain; therefore, the greatest incremental temperature increase at the surface would occur beyond 990 ft downstream of the diffuser. However, temperature increases at the river's surface that would occur under this flow condition at locations more than 990 ft downstream of the diffuser, as the plume more fully mixes to the surface, are expected to be on the order of approximately 1^{o}F or less. At 10 ft deep, the warmest temperatures along the centerline of the plume would occur about 700 ft downstream of the diffuser, with decreasing temperature occurring further downstream. The edge of the plume (as defined by the 0.1°F temperature differential contour) at the centerline is predicted to not reach the surface within the domain for the five effluent temperature differentials considered. However, portions of the plume, starting first on the western side of the river channel, do begin surfacing before the end of the modeled domain. The warmest path at 20 ft depth occurs near the eastern edge of the plume. The computed drift time along the warmest path is 790 seconds (13.2 minutes). At the end of the modeled domain, the temperature along the warmest path is predicted to range from 1.0°F above ambient river temperature for the 5°F effluent discharge differential to 5.1°F above ambient river temperature for the 25°F differential. In comparison to the 60 mgd scenario, the effluent in the 181 mgd scenario mixes more quickly (due to increased turbulence) as it travels the length of the modeled domain.

Table 12. River velocity, drift time, and temperature differences from ambient background (i.e., $T_{effluent}$ - T_{river}) at a SRWTP effluent discharge rate of 181 mgd and river flow rate of 3,921 cfs (14:1 flow ratio) at 90-ft increments downstream of the diffuser at the river surface, 10 ft below the river surface, and 20 ft below the river surface.

Distance Downstream of Diffuser (ft)	Velocity (fps)	Drift Time (sec)	Temperature Difference ($T_{effluent}$ - T_{river}) (°F)				
			5°F	10°F	15°F	20°F	25°F
River Surface							
0	1.40	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
90	1.38	66.3	0.0000	0.0000	0.0000	0.0000	0.0000
180	1.42	130.6	0.0000	0.0000	0.0000	0.0000	0.0000
270	1.45	193.3	0.0000	0.0000	0.0000	0.0000	0.0000
360	1.48	254.8	0.0000	0.0000	0.0000	0.0000	0.0000
450	1.55	313.8	0.0000	0.0000	0.0000	0.0000	0.0000
540	1.60	371.1	0.0000	0.0001	0.0001	0.0001	0.0002
630	1.63	426.8	0.0002	0.0005	0.0007	0.0010	0.0012
720	1.70	480.9	0.0010	0.0020	0.0030	0.0040	0.0050
810	1.75	533.1	0.0024	0.0047	0.0071	0.0094	0.0118
900	1.83	583.4	0.0039	0.0078	0.0117	0.0156	0.0195
990	1.89	631.7	0.0050	0.0101	0.0151	0.0201	0.0252
10 Feet Below the River Surface							
0	1.42	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
90	1.37	66.4	0.0056	0.0111	0.0167	0.0223	0.0278
180	1.40	131.3	0.0573	0.1146	0.1720	0.2293	0.2866
270	1.40	195.4	0.3356	0.6712	1.0068	1.3424	1.6780
360	1.39	259.9	0.5411	1.0822	1.6233	2.1643	2.7054
450	1.45	322.8	0.6387	1.2774	1.9161	2.5548	3.1935
540	1.48	384.4	0.6818	1.3637	2.0455	2.7274	3.4092
630	1.50	444.9	0.6892	1.3785	2.0677	2.7570	3.4462
720	1.57	503.7	0.6999	1.3997	2.0996	2.7995	3.4994
810	1.63	560.1	0.6697	1.3394	2.0091	2.6788	3.3485
900	1.72	614.0	0.6194	1.2388	1.8583	2.4777	3.0971
990	1.80	665.1	0.5472	1.0943	1.6415	2.1886	2.7358
20 Feet Below the River Surface							
0	0.47	0.0	5.00	10.00	15.00	20.00	25.00
90	1.03	91.6	3.22	6.45	9.67	12.89	16.12
180	1.08	178.5	2.45	4.90	7.35	9.85	12.25
270	1.14	259.7	2.09	4.17	6.26	8.35	10.43
360	1.19	337.1	1.83	3.67	5.50	7.33	9.17
450	1.23	410.9	1.52	3.03	4.55	6.07	7.58
540	1.29	482.3	1.31	2.62	3.94	5.25	6.56
630	1.35	550.3	1.18	2.36	3.53	4.71	5.89
720	1.41	615.5	1.11	2.22	3.34	4.45	5.56
810	1.47	678.4	1.05	2.10	3.15	4.20	4.24
900	1.57	738.0	1.03	2.05	3.08	4.10	5.13
990	1.63	794.4	1.01	2.02	3.03	4.05	5.06

Based on comparing the incremental temperature increases above river background in the 20°F column to that shown in the 25°F column in Table 12, the temperatures within the thermal plume at various distances downstream of the river when operating to the exception would never be greater than 0.005°F at the surface, 0.7°F at 10 ft below the surface within the initial 990 ft downstream of the diffuser, under the median flow scenario. At the river bottom, the greatest difference would occur at the diffuser ports. However, this difference is attenuated by mixing of effluent with river water such that the incremental temperature increase is less than 2.0°F within 300 ft of the diffuser.

Based on these findings, the internal thermal gradients of the plume show only minor difference between operating to Thermal Plan objective 5.A.(1)a versus the exception to this objective at all distances from the diffuser at the river surface and at 10ft below the surface. Although greater incremental increases occur under this flow scenario near the river bottom, it should be further noted that effluent-river temperature differentials as high as 25°F occur only in the month of December when river temperatures are in the low 40 degree range and delta smelt are not in the vicinity of the SRWTP diffuser. In the months of January, February, and March, when the effluent-river temperature differentials occasionally exceed 20°F, which occurs about 4.6% of the time, river background temperatures range from 42.2°F to 50.4°F.

410 MGD Scenario

Table 13 and Appendix D, Attachment A, Figures 11-15 and 31-35, and Attachment B, Tables 7-9 provide a color-gradient, graphical depiction of the thermal plume modeled and tabular data defining the river velocity, drift time, and temperature differentials within the plume at various distances downstream of the diffuser for the 410 mgd flow scenario. The modeled drift time along the centerline of the plume at the surface is 280 seconds (4.7 minutes) and at 10 ft depth is 300 seconds (5 minutes). At the surface, the plume would not be fully mixed within the modeled domain, therefore, the warmest temperatures would occur downstream. However, temperature increases at the river's surface that would occur under this flow condition at locations more than 990 ft downstream of the diffuser, as the plume more fully mixes to the surface, are expected to be on the order of approximately 1-1.5^{o}F or less. At 10 ft deep, the warmest temperatures along the centerline of the plume would occur about 600 ft downstream of the diffuser, with decreasing temperature occurring further downstream. The edge of the plume (as defined by the 0.1°F temperature differential contour) at the centerline is predicted to reach the surface within the modeled domain for the five effluent temperature differentials considered. The plume begins surfacing first in the western half of the river channel. Like the 181 mgd scenario, the warmest path at 20 ft depth occurs near the eastern edge of the plume under the 410 mgd flow scenario. The computed drift time along the warmest path is 350 seconds (5.8 minutes). At the end of the modeled domain, the temperature along the warmest path is predicted to range from 0.8°F above ambient river temperature for the 5°F effluent discharge differential to 4.2°F above ambient river temperature for the 25°F differential. In comparison to the 60 mgd and 181 mgd scenarios, the effluent in the 410 mgd scenario mixes more quickly as it travels the length of the modeled domain (due to increased turbulence).

Table 13. River velocity, drift time, and temperature differences from ambient background (i.e., $T_{effluent}$ - T_{river}) at a SRWTP effluent discharge rate of 410 mgd and river flow rate of 8,880 cfs (14:1 flow ratio) at 90-ft increments downstream of the diffuser at the river surface, 10 ft below the river surface, and 20 ft below the river surface.

Distance Downstream of Diffuser (ft)	Velocity (fps)	Drift Time (sec)	Temperature Difference ($T_{effluent}$ - T_{river}) (°F)				
			5°F	10°F	15°F	20°F	25°F
River Surface							

0	3.19	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
90	3.13	29.1	0.0000	0.0000	0.0000	0.0000	0.0000
180	3.22	57.5	0.0000	0.0000	0.0000	0.0000	0.0000
270	3.28	85.2	0.0000	0.0000	0.0000	0.0000	0.0000
360	3.35	112.3	0.0000	0.0000	0.0000	0.0000	0.0000
450	3.49	138.5	0.0000	0.0000	0.0000	0.0000	0.0000
540	3.58	163.9	0.0003	0.0006	0.0010	0.0013	0.0016
630	3.64	188.9	0.0060	0.0120	0.0180	0.0240	0.0301
720	3.76	213.2	0.0447	0.0894	0.1341	0.1788	0.2235
810	3.83	236.9	0.1331	0.2663	0.3994	0.5325	0.6657
900	3.94	260.0	0.1980	0.3960	0.5941	0.7921	0.9901
990	4.05	282.5	0.2164	0.4329	0.6493	0.8658	1.0822
10 Feet Below the River Surface							
0	3.24	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
90	3.12	29.2	0.0033	0.0066	0.0098	0.0131	0.0164
180	3.19	57.7	0.0536	0.1072	0.1608	0.2143	0.2679
270	3.17	86.0	0.3381	0.6762	1.0143	1.3524	1.6905
360	3.16	114.5	0.5010	1.0021	1.5031	2.0041	2.5051
450	3.28	142.2	0.5722	1.1444	1.7167	2.2889	2.8611
540	3.34	169.4	0.5965	1.1930	1.7895	2.3859	2.9824
630	3.37	196.2	0.5943	1.1887	1.7830	2.3773	2.9717
720	3.50	222.4	0.5916	1.1832	1.7747	2.3663	2.9579
810	3.60	247.8	0.5778	1.1555	1.7333	2.3110	2.8888
900	3.75	272.3	0.5588	1.1177	1.6765	2.2353	2.7941
990	3.88	2958.9	0.5237	1.0473	1.5710	2.0947	2.6183
20 Feet Below the River Surface							
0	1.05	0.0	5.00	10.00	15.00	20.00	25.00
90	2.36	39.7	3.41	6.82	10.24	13.65	17.06
180	2.44	77.5	2.57	5.14	7.71	10.28	12.86
270	2.58	113.3	2.12	4.24	6.36	8.48	10.60
360	2.72	147.3	1.73	3.45	5.18	6.91	8.63
450	2.79	179.8	1.39	2.79	4.18	5.58	6.97
540	2.92	211.3	1.18	2.36	3.54	4.72	5.89
630	3.07	241.2	1.02	2.04	3.06	4.07	5.09
720	3.08	271.0	0.94	1.88	2.82	3.76	4.70
810	3.26	299.3	0.89	1.79	2.68	3.57	4.47
900	3.39	326.3	0.86	1.72	2.58	3.44	4.30
990	3.54	352.2	0.83	1.66	2.49	3.32	4.15

Based on comparing the incremental temperature increases above river background in the 20°F column to that shown in the 25°F column in Table 12, the temperatures within the thermal plume at various distances downstream of the river when operating to the exception would never be greater than 0.22°F at the surface, 0.6°F at 10 ft below the surface within the initial 990 ft downstream of the diffuser, under this minimum flow ratio scenario. At the river bottom, the greatest difference would occur at the diffuser ports. However, this difference is attenuated by mixing of effluent with river water such that the incremental temperature increase is less than 2.0°F within 300 ft of the diffuser.

Based on these findings, the internal thermal gradients of the plume show only minor difference between operating to Thermal Plan objective 5.A.(1)a versus the exception to this objective at all distances from the diffuser at the river surface and at 10ft below the surface. Although greater incremental increases occur under this flow scenario near the river bottom, it should be further noted that effluent-river temperature differentials as high as 25°F occur only in the month of December when river temperatures are in the low 40 degree range and delta smelt are not in the vicinity of the SRWTP diffuser. In the months of January, February, and March, when the effluent-river temperature differentials occasionally exceed 20°F, which occurs about 4.6% of the time, river background temperatures range from 42.2°F to 50.4°F.

4.5.1.2.3 Minimum Flow Ratio Plume Temperatures Relative to River Background Temperatures

In addition to the modeling output summarized above and presented in detail in Appendix D, the highest ambient river background temperature that has historically co-occurred with 5°F, 10°F, 15°F, 20°F, and 25°F effluent:river temperature differentials during each month of the January through July period was determined. This defined the highest ambient background temperature that a delta smelt larvae or post-spawn adult would experience as it moved downstream past the SRWTP diffuser and through the thermal plume as it emigrated to the Delta. These data were then combined with the modeled temperature increases from the diffuser ports to 990 ft downstream of the diffuser (shown in the summary tables above and in Appendix D, Tables 1-12) to produce graphics for each month and modeled condition that define the warmest thermal exposure that a delta smelt larvae or post-spawn adult would experience as is emigrates past the diffuser, at the surface, at 10 ft below the surface, and at the river bottom. These graphics are provided in **Appendix E** for the median flow scenario and in **Appendix F** for the minimum flow ratio conditions, at 60 mgd, 181mgd, and 410 mgd.

The initial step in calculating each line on the Appendix E and F graphics was to determine the maximum monthly ambient river background temperature that has historically co-occurred with each effluent-river temperature differential (+/- 0.1°F), during the February 22, 1992 through September 30, 2012 period of record. To do this, the database of SRWTP effluent temperatures, Sacramento River background temperatures, and effluent-river temperature differential values was queried. For each month, all lower Sacramento River background temperatures were sub-queried to determine all historical river temperatures within 0.1°F of each of effluent-river temperature differential values examined by the model (i.e., 5°F, 10°F, 15°F, 20°F, and 25°F). The maximum lower Sacramento River background temperature that occurred with each of the effluent-river temperature differential values examined by the model (+/- 1°F) was selected as the highest background temperature that has co-occurred with the defined temperature differential. For example, the maximum river temperature that occurred historically in the month of January when the effluent-river temperature difference was 10°F (+/- 0.1°F; i.e., between 9.9°F and 10.1°F) was 54.1°F. Consequently, this number represents the warmest background river temperature that a delta smelt moving downstream past the diffuser would be acclimated to when it encounters a 10°F temperature differential at the diffuser ports (for fish emigrating near the bottom of the river, where the diffuser ports are located). Similarly, the highest river background temperature observed historically during an effluent-river temperature differential of 15°F in the month of January was approximately 53°F and thus this value was used as the highest acclimation temperature. This process was repeated for all months and effluent-river temperature differentials.

Drift time is provided on the X-axis in the Appendix E and F Figures to define the travel time for drifting larvae and post-spawn adult fish to pass through the initial 990 ft downstream of the diffuser. As indicated by the "River Flow" arrow, the graph represents the amount of time drifting through the plume on the bottom X-axis and the total distance traveled downstream of the SRWTP diffuser on the top X-axis. The Y-axis provides absolute river temperatures (versus incremental temperature increases provided above and in Appendix D). Thus, the lines on the graphs define the highest temperatures that the fish would experience as they emigrate through the initial 990 ft of the thermal plume.

Temperatures within the boundary of the thermal plume (depicted by the lines on the graphics) were determined by adding the values at each distance and drift time downstream of the diffuser from the Appendix D, Attachment B Tables. The values in these tables represent the temperature increase at defined distances downstream of the diffuser, relative to river background temperatures, for each modeled scenario and each of the five temperature differentials. Because the values in the Appendix D, Attachment B Tables are added to the highest river background temperatures that have historically occurred, the resultant in-plume temperatures depict the highest temperatures at each incremental distance downstream of the diffuser for each modeled scenario and depth of emigration through the plume (i.e., river surface, 10 ft below the surface, and 20 ft below the surface, which is near the river bottom). As such, the lines represent, for each effluent-river temperature differential, the highest temperatures that a delta smelt would encounter under each modeled flow condition.

Appendix E and F graphics are provided by model scenario and month, with up to five lines on each graph depicting the thermal exposure that would be experience by the fish if the effluent:river temperature differential were 5°F, 10°F, 15°F, 20°F, or 25°F. If a temperature differential as low as 5°F or as high as 20°F or 25°F has never occurred in a given month, then only lines for the temperature differentials that have historically occurred in that month are presented. The graphics presented in Appendix E and F are used to assess the thermal effects of operating the SRWTP to the current Thermal Plan exceptions and associated NPDES temperature limitations on delta smelt larvae or post-spawn adults emigrating past the diffuser, along migration pathways that take them through the thermal plume at the river surface, at 10 ft below the surface, and at 20 ft below the river surface, which is near the river bottom.

The graphs in Appendix E and F indicate that, regardless of the SRWTP discharge rate, the SRWTP discharge has little or no thermal effect on temperatures at the river surface (Appendix E, Figures E-1 through E-7; Appendix F, Figures F-1 through F-21).

At 10 feet below the river surface, the 60 mgd SRWTP discharge scenario indicates a minimal temperature increase within the initial 990 ft of the thermal plume, ranging from 0°F to approximately 1.1°F above river background temperatures (Appendix E, Figures E-8 through E-14; Appendix F, Figures F-22 through F-28). Under the median discharge scenario, at 10 feet below the surface, temperatures increases reach up to 0.7°F above river background temperatures. Under the 181 SRWTP discharge scenario, at 10 feet below the river surface, temperature increases within the plume are slightly more pronounced at approximately 300 feet downstream of the diffuser, reaching up to 2.8°F above river background temperatures for the 20°F effluent-river temperature differential scenario (Appendix F, Figures F-29 through F-35). Similarly, under the 410 discharge scenario, temperatures within the plume may be as high as 2.4°F above river background temperatures, but the plume rises more rapidly under this discharge rate and may reach a depth of 10 ft below the river surface within 60-70 feet of the SRWTP diffuser (Appendix F, Figures F-36 through F-42).

Temperature differences from river background within the plume are most pronounced along the warmest potential migration pathway within the thermal plume, which is at 20 feet below the river surface near the river bottom (Appendix F, Figures F-43 through F-63). At this depth, temperatures increase abruptly at the diffuser ports in all months and under all discharge scenarios. Based on how the modeling was performed, temperatures at the diffuser ports were assumed to increase by the amount of the effluent-river temperature differential being assessed (i.e., the 5°F temperature differential exposure line increases by 5°F, the 10°F temperature differential exposure line increases by 10°F, and so forth). As discussed in Section 4.3, the largest effluent-river temperature differentials typically occur when lower Sacramento River temperatures are at or near their coldest (i.e., in 40 degree range). As such, the largest temperature increases seen at the diffuser ports, relative to ambient background temperatures, are associated with the coldest background river temperatures during the winter months. Notably, because the velocities are generally the lowest at the river bottom downstream of the SRWTP diffuser, the drift time through the plume and the distance downstream at which plume temperatures are attenuated are substantially longer for each discharge scenario compared to temperatures in the plume at the river surface and 10 feet below the surface. Under the 60 mgd SRWTP discharge scenario, the drift time through the initial 990 ft of the thermal plume is the longest of all scenarios at over 70 minutes (Appendix F, Figures F-43 through F-49).

4.5.2 Frequency of Occurrence of Minimum Flow Ratio Modeling Scenarios

The available lower Sacramento River and SRWTP effluent flow and temperature data indicate that the minimum flow ratio scenario of 14:1 has never co-occurred with effluent-river temperature differences of 20°F or 25°F, as modeled by Flow Science (Appendix D). A total of 58 hourly dilution ratios between 14:1 and 15:1 occurred during the February 1992 through September 2012 period of record. Of these 58 hourly dilution values, a total of 35 concurrently recorded temperature values were available for both the SRWTP effluent and Sacramento River background temperatures during the months of January through July (**Table 14**). These data indicate that, historically, effluent-river temperature differences have ranged from 2.7°F (May 25, 2001) to 15.2°F (April 2, 2009) when river:effluent dilution ratios have ranged from 14:1 to 15:1 (Table 14). Based on these historic data, the likelihood of the minimum flow ratio simulated plume conditions (i.e., 14:1 dilution and effluent-river temperature differences of 20°F or 25°F) occurring in the future are negligible. Moreover, because dilution ratios of less than 15:1 are a transient (i.e., occurring over periods of minutes) condition that would only occur while the SRWTP is ceasing flows operationally to comply with the 14:1 discharge prohibition, the minimum flow ratio condition of 14:1 modeled would occur only for a matter of minutes to hours in any year. Consequently, the minimum flow ratio scenarios presented and discussed herein are considered highly conservative for the purposes of this assessment of potential thermal effects to delta smelt.

Table 14. Hourly SRWTP effluent-Sacramento River temperature differences recorded concurrently with river:effluent flow ratios between 14:1 and 15:1 for the months of January through July over the February 1992 through September 2012 period of record.

Month	Date	River Flow (cfs)	SRWTP Effluent Flow (mgd)	River:Effluent Flow Ratio [1]	River Temperature (°F) [2]	SRWTP Effluent Temperature (°F)	ΔT (°F)
January	1/13/2010	4310	193.1	14.4:1	50.0	64.7	14.7
April	4/12/1994	3110	139.0	14.5:1	62.8	72.6	9.8
	4/13/1994	3060	135.9	14.6:1	63.9	72.8	8.9
	4/2/2009	4190	186.0	14.6:1	54.7	69.9	15.2
	4/14/1994	2660	117.7	14.6:1	64.8	73.1	8.3
	4/25/1992	1540	67.2	14.8:1	66.6	74.6	8.0
	4/18/1997	3570	154.9	14.9:1	64.3	73.2	8.9
May	5/3/1992	2000	91.5	14.1:1	71.5	75.0	3.5
	5/22/1992	450	20.4	14.3:1	69.7	77.5	7.8

	5/9/1997	3560	158.1	14.6:1	67.9	75.5	7.6
	5/18/2012	2880	127.1	14.6:1	66.2	73.3	7.1
	5/25/2001	3810	167.9	14.7:1	74.1	76.8	2.7
	5/11/1997	3740	164.2	14.7:1	69.1	75.4	6.3
	5/12/1997	3090	135.6	14.7:1	69.5	76.2	6.7
	5/9/1992	1590	69.5	14.8:1	71.1	76.9	5.8
	5/20/2008	3140	136.2	14.9:1	67.6	75.4	7.8
	6/7/1994	2720	121.3	14.5:1	71.0	77.1	6.1
	6/30/1992	1780	78.1	14.7:1	68.2	78.0	9.8
	6/14/2009	3490	152.9	14.8:1	62.3	74.9	12.6
June	6/28/1992	3170	138.3	14.8:1	71.9	77.8	5.9
	6/13/2002	3010	131.0	14.9:1	67.8	76.2	8.4
	6/9/1992	2870	124.8	14.9:1	69.7	78.3	8.6
	6/13/1992	2900	125.8	14.9:1	68.5	78.3	9.8
	6/17/1992	3290	142.6	14.9:1	70.0	78.8	8.8
	7/28/1994	3070	137.8	14.4:1	72.5	81.0	8.5
	7/14/1992	3590	161.1	14.4:1	70.6	81.2	10.6
	7/15/1992	2650	116.9	14.7:1	71.7	81.2	9.5
	7/26/1994	3300	145.4	14.7:1	73.2	81.3	8.1
	7/28/1994	3630	160.0	14.7:1	72.5	81.1	8.6
July	7/2/1992	3670	161.5	14.7:1	71.7	78.7	7.0
	7/27/1994	3480	153.0	14.7:1	72.7	81.0	8.3
	7/31/1992	3060	134.0	14.8:1	73.3	81.4	8.1
	7/31/1994	2960	129.5	14.8:1	71.2	80.1	8.9
	7/3/1992	3430	149.1	14.9:1	70.5	78.6	8.1
	7/28/1994	2980	129.4	14.9:1	72.4	80.9	8.5

[1] River flow in cfs divided by SRWTP effluent flow (converted from mgd to cfs).
[2] Lower Sacramento River temperatures measured at Freeport Bridge approximately 600 ft upstream of the SRWTP outfall.

4.6 River Thermal Conditions Upon Full Effluent Mixing with River Water

An evaluation of the incremental increase in fully mixed lower Sacramento River temperatures under: 1) regulation of the SRWTP to the Thermal Plan objectives, and 2) regulation of the SRWTP discharge to the current exception to Thermal Plan objective 5.A.(1)a was conducted. Thermal Plan objective 5.A.(1)a limits the effluent temperature to not be more than 20°F higher than the river background temperature. As such, it is this objective (and corresponding exception) that dictate the incremental increase to river temperature that will occur under fully mixed conditions for any given SRWTP discharge rate.

This evaluation used modeling to define the incremental increase in fully mixed river temperatures that occur when the thermal load of the SRWTP discharge is fully assimilated into river flows, and whether resultant temperatures are protective of delta smelt that occur in the lower Sacramento River. This evaluation further determines whether the frequency with which specified river temperatures that occur upon initial full mixing of effluent and river flows (2-3 miles downstream of the outfall) changes substantially depending upon the temperature limitations imposed on the discharge through the NPDES permit (i.e., regulation to the Thermal Plan objective 5.A.(1)a year-round versus regulation to the current exception to Thermal Plan objective 5.A.(1)a).

The intent of this “far-field” thermal analysis was to evaluate the resultant lower Sacramento River temperatures downstream of the SRWTP diffuser after the effluent is fully mixed with river water. The fully mixed downstream temperature was determined using a thermal mass-balance of the effluent discharge and river flow rates and temperatures. Existing effluent seasonal and diurnal flow rates were simulated for the 181 mgd ADWF permitted discharge rate (i.e., modeled effluent flow rates reflect both seasonal and diurnal patterns that occur when average dry weather flow for the SRWTP is at 181 mgd).

To capture the range of river flows into which the SRWTP discharges, including low-flow conditions, an 82-year (1922–2003) time-series of hourly river flows was derived from the U.S. Bureau of Reclamation's CALSIM-II model output[1,] which was post-processed to derive hourly flows using the Department of Water Resources Delta Simulation Model II (DSM2). SRWTP effluent flow rates were calculated using the simulated hourly flow rates in the lower Sacramento River at Freeport and the SRWTP's operating rules (e.g., effluent flow ceases when a river-to-effluent flow ratio of 14:1 is reached, and incorporating the SRWTP's current observed diurnal flow patterns). Fully mixed temperature conditions downstream of the SRWTP diffuser were simulated for the 82-year hourly flow record using statistically generated time series of SRWTP effluent temperature and of lower Sacramento River background temperature (at Freeport Bridge). The approach, methods, and statistical relationships developed for the assessment of fully mixed river temperature conditions downstream of the SRWTP discharge are presented in Section 3.2.1.2 of the Temperature Study Report (RBI 2013). Monthly cumulative probability distribution plots of the fully mixed lower Sacramento River temperature at the point where effluent initially mixes completely with river water (i.e., approximately 2-3 miles downstream of the diffuser) are presented in Appendix B of the Temperature Study Report (RBI 2013) for each month of the year. The results of the cumulative probability assessment are summarized in Table 15 for exceedance percentile values of 0.09 (occurring one day in three years), 5, 25, 50, 75, and 99.91.

Table 15. Percent exceedance of modeled hourly lower Sacramento River water temperatures for the 82-year (1922-2003) hydrologic period of record for the months of January - July when complying with the Thermal Plan objective 5.A.(1)a year-round (20°F ΔT) **and the current exception (25°F ΔT) at a 181 mgd (ADWF) SRWTP discharge condition.**

Percent Exceedance	River Temperature (°F)				
	20°F ΔT	**25°F ΔT, Instantaneous**	**Background Temperature**	**Change from Background[1]**	**Change due to Exceptions**
January					
0.09%	54.37	54.37	54.27	0.10	0.00
5%	51.61	51.61	51.45	0.16	0.00
25%	49.38	49.38	49.17	0.22	0.00
50%	47.93	47.93	47.66	0.27	0.00
75%	46.69	46.69	46.39	0.29	0.00
99.91%	41.64	41.70	41.11	0.59	0.06
February					
0.09%	57.17	57.17	57.10	0.07	0.00
5%	53.43	53.43	53.23	0.20	0.00
25%	50.93	50.93	50.74	0.19	0.00
50%	49.07	49.07	48.88	0.19	0.00
75%	47.44	47.44	47.23	0.21	0.00
99.91%	41.87	41.88	41.77	0.11	0.01

[1] CALSIM-II model output used was from the California Department of Water Resources (DWR) Water Supply Reliability Study (2011) which represents monthly river flows at Freeport under current integrated Central Valley Project/State Water Project operations.

Percent Exceedance	River Temperature (°F)				
	20°F ΔT	**25°F ΔT, Instantaneous**	**Background Temperature**	**Change from Background[1]**	**Change due to Exceptions**
March					
0.09%	62.24	62.24	61.99	0.25	0.00
5%	59.42	59.42	59.22	0.20	0.00
25%	56.08	56.08	55.88	0.19	0.00
50%	54.20	54.20	54.00	0.20	0.00
75%	51.95	51.95	51.79	0.17	0.00
99.91%	44.73	44.73	44.62	0.11	0.00
April					
0.09%	65.88	65.88	65.70	0.17	0.00
5%	63.14	63.14	62.92	0.22	0.00
25%	60.23	60.23	60.02	0.21	0.00
50%	58.03	58.03	57.82	0.21	0.00
75%	56.02	56.02	55.82	0.20	0.00
99.91%	50.02	50.02	49.89	0.13	0.00
May					
0.09%	74.85	N/A	74.79	0.06	N/A
5%	70.36	N/A	70.22	0.13	N/A
25%	66.95	N/A	66.79	0.16	N/A
50%	64.29	N/A	64.12	0.18	N/A
75%	61.61	N/A	61.43	0.17	N/A
99.91%	52.29	N/A	52.19	0.09	N/A
June					
0.09%	75.44	N/A	75.41	0.04	N/A
5%	72.10	N/A	72.01	0.10	N/A
25%	69.71	N/A	69.57	0.14	N/A
50%	68.21	N/A	68.06	0.15	N/A
75%	66.42	N/A	66.27	0.15	N/A
99.91%	60.21	N/A	60.07	0.15	N/A
July					
0.09%	77.68	N/A	77.66	0.02	N/A
5%	73.19	N/A	73.10	0.09	N/A
25%	71.03	N/A	70.92	0.11	N/A
50%	69.54	N/A	69.43	0.12	N/A
75%	68.04	N/A	67.91	0.13	N/A
99.91%	63.68	N/A	63.55	0.14	N/A

[1] Change from background is resultant fully mixed river temperature minus background temperature when operating to the current exception to Thermal Plan objective 5.A.(1)a when it applies during the months October through April (i.e., incremental thermal effect of the SRWTP discharge on the fully mixed river condition).
N/A – Not Applicable (i.e., the SRWTP does not have an exception to Thermal Plan objective 5.A.(1)a during these months of the year.

Cumulative probability plots for river temperature indicate that the probability with which any given fully mixed lower Sacramento River temperature would occur would change minimally upon the thermal load from the SRWTP discharge becoming fully assimilated into the river (see Appendix B of the Temperature Study Report (RBI 2013)). These cumulative probability plots show that for all months, the relative magnitude by which the frequency of exceeding specified lower Sacramento River temperatures would increase upon full effluent and river mixing is small in all cases (i.e., increased frequency of exceeding specified temperatures of 0–5%). The magnitude by which the frequency of exceeding any given temperature is increased by the SRWTP's thermal load fully mixing with the river is virtually the same at all times whether the Thermal Plan objective 5.A.(1)a (20°F instantaneous temperature differential) is met year-round or whether the SRWTP is operated to meet the current exception to this objective (i.e., 25°F instantaneous temperature differential, October through April) (Temperature Study Report, Appendix B; RBI 2013).

The greatest increase (about 5%) in the frequency of exceeding any given river temperature due to the assimilation of the SRWTP's thermal load by the lower Sacramento River occurs during the months October, November, and December when the greatest effluent-river temperature differentials occur and when delta smelt do not occur in the vicinity of the diffuser. The modeling results indicate that the warmest temperatures in all months would not occur with notably greater frequency with the SRWTP discharging versus without the discharge. This is because the lowest effluent-river temperature differentials occur for any given month when the river temperatures are at their highest. Based on the typical river flow rates and discharge rates of the SRWTP, typical effluent-river temperature differentials that occur in June and July result in an incremental increase in fully mixed river temperature of only a few tenths of a degree Fahrenheit, or less.

When fully mixed river temperature changes between the river background condition and the condition under operation of the SRWTP with the current exceptions were examined for each individual hour in the modeled simulation, it was determined that instantaneous temperature increases ranging from approximately 0.1 –1.5ºF can occur during the time period January-July (

Table 16). Instantaneous increases of greater than 1ºF occurred very infrequently during the period January-April (i.e., 0.09% in January, 0.03% in February and not at all in March and April) and occurred during time periods when the background river temperatures are below 58.7 ºF.

Table 16. Percent of time exceeding specified magnitudes of incremental increases in fully mixed lower Sacramento River temperature due to discharge from the SRWTP when operating under the current Thermal Plan exceptions, compared to a no discharge condition, at monthly discharge rates associated with an average dry weather flow of 181 mgd. Percentages determined from hourly modeled output for the 82-year (1922-2003) hydrologic period of record.

Temperature Increase (°F)	Percent of Time Exceeding (%)						
	January	February	March	April	May	June	July
2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.50	0.00	0.01	0.00	0.00	0.00	0.00	0.00
1.25	0.09	0.02	0.00	0.00	0.00	0.00	0.00
1.00	0.65	0.16	0.01	0.01	0.00	0.00	0.00
0.90	1.14	0.36	0.04	0.01	0.01	0.00	0.00
0.80	1.82	0.75	0.13	0.08	0.02	0.00	0.00
0.70	3.01	1.38	0.43	0.30	0.08	0.00	0.01
0.60	5.52	2.49	1.12	0.92	0.29	0.03	0.03
0.50	10.27	5.23	2.54	2.42	0.91	0.17	0.13
0.40	20.65	10.79	5.88	6.43	2.61	0.88	0.38
0.30	37.45	23.86	13.33	16.44	7.93	3.89	1.29
0.20	57.68	40.73	34.42	39.69	25.24	16.74	5.86
0.10	79.54	69.72	73.95	78.49	69.74	69.23	59.60

Fully mixed river temperature changes that occur when meeting the Thermal plan objective 5.A.(1)a year-round were also evaluated. It was determined that instantaneous temperature increases ranging from approximately 0.1 –1.5ºF can occur during the time period January-July, which is the same range of incremental temperature increases that would occur when operating to the exception to objective 5.A.(1)a, as discussed above. The additional percent of time exceeding specified magnitudes of incremental increases in fully mixed lower river temperature due to operating the SRWTP to the current Thermal Plan exception to objective 5.A.(1)a compared to meeting the Thermal Plan objective 5.A.(1)a year-round is zero for the months March through July and is negligible (0.01-0.14% and 0.03-0.57% more frequent) for all incremental temperature increases in January and February, respectively (Table 17). In other words, the frequency with which specified magnitudes of incremental temperature increases in the fully mixed river would occur would differ negligibly, if at all, when operating to Thermal Plan objective 5.A.(1)a versus operating to the exception to this objective during the January through April period of the year.

Table 17. The additional percent of time exceeding specified magnitudes of incremental increases in fully mixed lower Sacramento River temperature due to discharge from the SRWTP when operating under the current Thermal Plan exceptions compared to meeting the Thermal Plan objective 5.A.(1)a year-round (20°F ΔT). Monthly discharge rates associated with an average dry weather flow of 181 mgd. Percentages determined from hourly modeled output for the 82-year (1922-2003) hydrologic period of record.

Temperature Increase (°F)	**Percent of Time Exceeding (%)**						
	January	**February**	**March**	**April**	**May**	**June**	**July**
2.00	0.00	0.00	0.00	0.00	N/A	N/A	N/A
1.50	0.00	0.00	0.00	0.00	N/A	N/A	N/A
1.25	0.03	0.00	0.00	0.00	N/A	N/A	N/A
1.00	0.05	0.00	0.00	0.00	N/A	N/A	N/A
0.90	0.06	0.00	0.00	0.00	N/A	N/A	N/A
0.80	0.06	0.00	0.00	0.00	N/A	N/A	N/A
0.70	0.16	0.01	0.00	0.00	N/A	N/A	N/A
0.60	0.30	0.04	0.00	0.00	N/A	N/A	N/A
0.50	0.57	0.05	0.00	0.00	N/A	N/A	N/A
0.40	0.52	0.08	0.00	0.00	N/A	N/A	N/A
0.30	0.43	0.06	0.00	0.00	N/A	N/A	N/A
0.20	0.34	0.03	0.00	0.00	N/A	N/A	N/A
0.10	0.15	0.14	0.00	0.00	N/A	N/A	N/A

N/A = Not applicable because the SRWTP does not currently operate under an exception to Thermal Plan objective 5.A.(1)a during these months of the year.

Potential impacts of these fully mixed temperature increases on delta smelt life stages are discussed in Section 5 below.

4.7 RIVER THERMAL CONDITIONS UNDER REVERSE-FLOW EVENTS

The lower Sacramento River flow at Freeport is affected by tidal currents and, as a result, the river flow can reverse (i.e., water can flow in the upstream direction) when high tides are coupled with low river flows. To minimize the effects of the SRWTP effluent on lower Sacramento River water quality, including temperature, during reverse flow conditions, Regional San only discharges effluent to the river when the instantaneous ratio of river flow to effluent flow is higher than 14:1. When the river to effluent flow ratio approches14:1, which occurs under concurrent low river flow and high tide conditions, effluent discharge to the river is stopped (typically well before reaching 14:1 and prior to the river flow reaching 1,300 cfs). The NPDES permit for the SRWTP prohibits discharge to the river when river flow is below 1,300 cfs. Discharge following a reverse-flow event resumes after the river's downstream flow exceeds 1,300 cfs and the river flow to effluent flow ratio is maintained above 14:1.

For any reverse flow event, the following sequential conditions occur:

- the SRWTP discharge is ceased as the minimum 14:1 (river:effluent) flow ratio is approached,
- the river flow velocities decrease, stop at slack tide, and then gradually reverse direction and temporarily flows in an upstream direction for about 1–5 hours,
- a second flow reversal occurs and river flow resumes movement in the downstream direction,
- SRWTP discharge resumes into the river that has some effluent present that had moved upstream under the reverse-flow event, and
- the previously discharged effluent fully passes the diffuser and typical discharge conditions resume.

A reverse-flow event can be characterized as having three stages that differ hydraulically from normal continuous downstream river flow and continuous SRWTP discharge. In stage 1, effluent discharge is ceased, river flow velocities decrease, yet net downstream movement of flow continues for 20–60 minutes prior to flow direction reversing. During this time, the effluent last discharged from the diffuser continues to move downstream, mixing with river water, and attenuate in temperature with time and distance. In stage 2, flow moves in an upstream direction for 1–5 hours, depending upon the magnitude of the reverse-flow event. The effluent plume continues to be diluted by river water within the channel and temperatures continue to attenuate with time. This second stage ends when the flow again reverses direction. In stage 3, after river flow resumes in a downstream direction, SRWTP discharge resumes (upon achieving the minimum 14:1 flow ratio) and the effluent plume that was transported upstream of the diffuser passes over the diffuser once again, temporarily resulting in river "background" having a low concentration of effluent and a slightly elevated temperature, until all previously discharged effluent passes the diffuser. The approach and methods for determining the thermal effect of the SRWTP discharge on each of the three stages of a reverse-flow event are detailed in Section 3.2.1.2 of the Temperature Study Report (RBI 2013).

4.7.1 River Thermal Conditions under Stage 1 of Reverse-flow Events

Stage 1 occurs from the time the SRWTP effluent discharge is ceased until the downstream river flow reaches zero. River temperatures within the effluent plume downstream of the diffuser attenuate in a manner essentially the same as when continuous discharge is occurring during the 20–60 minutes that effluent continues to be transported downstream prior to the river flow velocity reaching zero. By the time the river flow initially reverses and moves upstream, the last effluent discharged from the diffuser has moved hundreds of feet downstream, and possibly further, depending upon how long prior to flow reversal the discharge ceased and the strength of the tide for that event. Over this time and distance, the temperature of the effluent last discharged from the diffuser attenuates to near river background temperatures throughout most of the vertical water column, typically resulting in the river water temperature within the plume front being 1–2^{o}F higher, or less, than the river background temperature, depending upon the size of the river-effluent temperature differential at the time of the reverse-flow event (Temperature Study Report, Appendix A). Somewhat higher temperature differentials may occur at the plume front near the river bottom.

Because net downstream flow typically continues for 20–60 minutes after the SRWTP discharge has ceased, river temperatures within the plume (as it moves downstream of the diffuser following the ceasing of discharge) will be similar to temperatures at the same locations downstream under continuous flow and discharge conditions. Thus, the thermal exposure for young-of-the-year fishes, such as larval delta smelt, moving downstream with the last discharged effluent (e.g., larval fishes that have just entered the plume at the diffuser location when discharge is ceased) would be very similar to the thermal exposure for fishes drifting through the plume under continuous discharge conditions. This is because the effluent at the diffuser at the time discharge is ceased will continue to flow downstream (for 20–60 minutes) during which time effluent will continue to mix with river water and plume temperatures will continue to attenuate with time and distance downstream. Although river flow velocities are reducing in magnitude during this 20–60 minutes period, sufficient time elapses prior to flow reversal to carry larval delta smelt hundreds of feet downstream of the diffuser, and possibly further, before flow reversal occurs.

The discussion above addresses how the last effluent discharged from the diffuser, just prior to ceasing discharge (i.e., the "effluent front"), attenuates as it moves downstream prior to flow reversal. During this same time of stage 1, river temperature remains at river background levels upstream of the diffuser, because flow reversal has not yet occurred and thus no effluent exists upstream of the diffuser. Likewise, at the end of stage 1, just prior to flow reversal, there exists a stretch of river from the diffuser downstream to where the last discharged effluent (i.e., effluent front) exists which also is at river background temperatures because no effluent exists in this reach of river at this time.

4.7.2 River Thermal Conditions under Stage 2 of Reverse-flow Events

Stage 2 occurs from the time the river flow initially reverses and begins flowing upstream until upstream flow reaches zero. Any larval delta smelt drifting downstream with the river flows that do not reach the plume area on the downstream side of the diffuser prior to flow reversal occurring will simply be carried back upstream by the negative (upstream) flows in river water outside (i.e., upstream) of the plume during stage 2. There would be no discharge-related thermal effects on these fishes.

Conversely, young-of-the-year fishes that drifted downstream of the diffuser within the plume during stage 1 are now (during stage 2) transported back upstream as the plume continues to mix and plume temperatures continue to attenuate. The relative magnitude to which temperature at the front of the plume (i.e., last discharged effluent) remains above river background as the plume front passes the Freeport Bridge moving upstream on the reverse flow was calculated and compiled into histograms for the entire period of record (**Figure 7**) and for each month of the year separately (**Figure 8**; **Figure 9**).

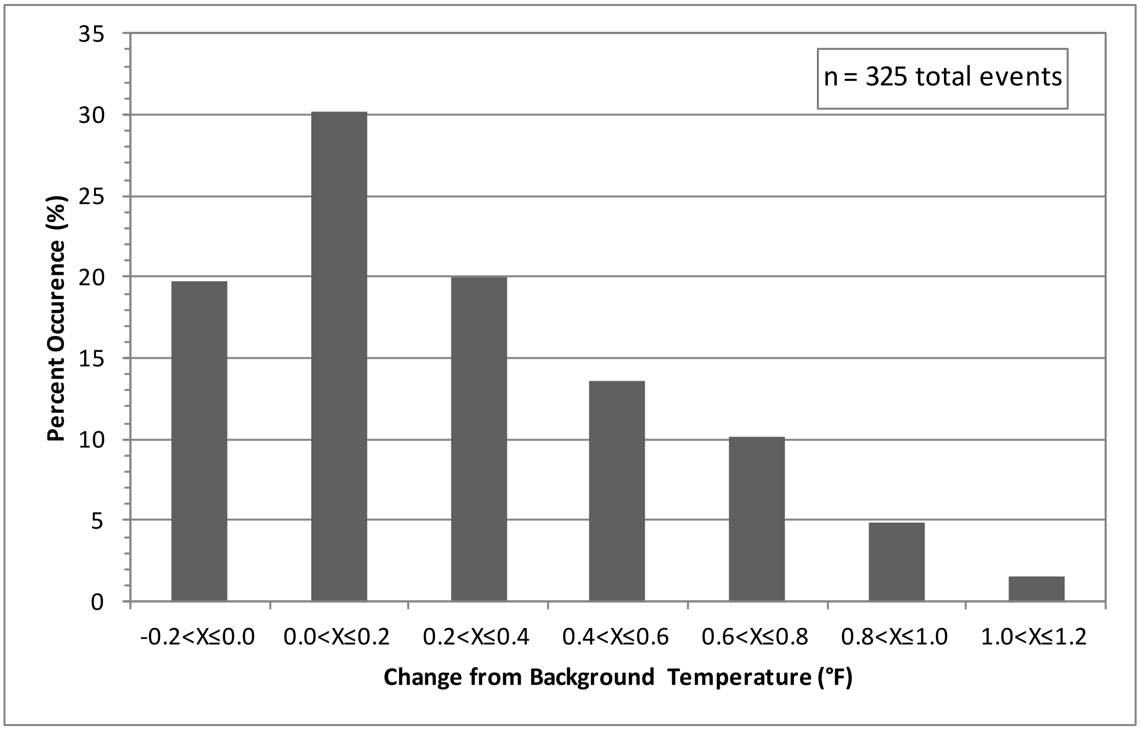


Figure 7. Percent occurrence of various magnitudes of temperature change from river background in the lower Sacramento River at Freeport Bridge during 325 reverse-flow events that occurred during the period February 21, 1992 through September 30, 2012.

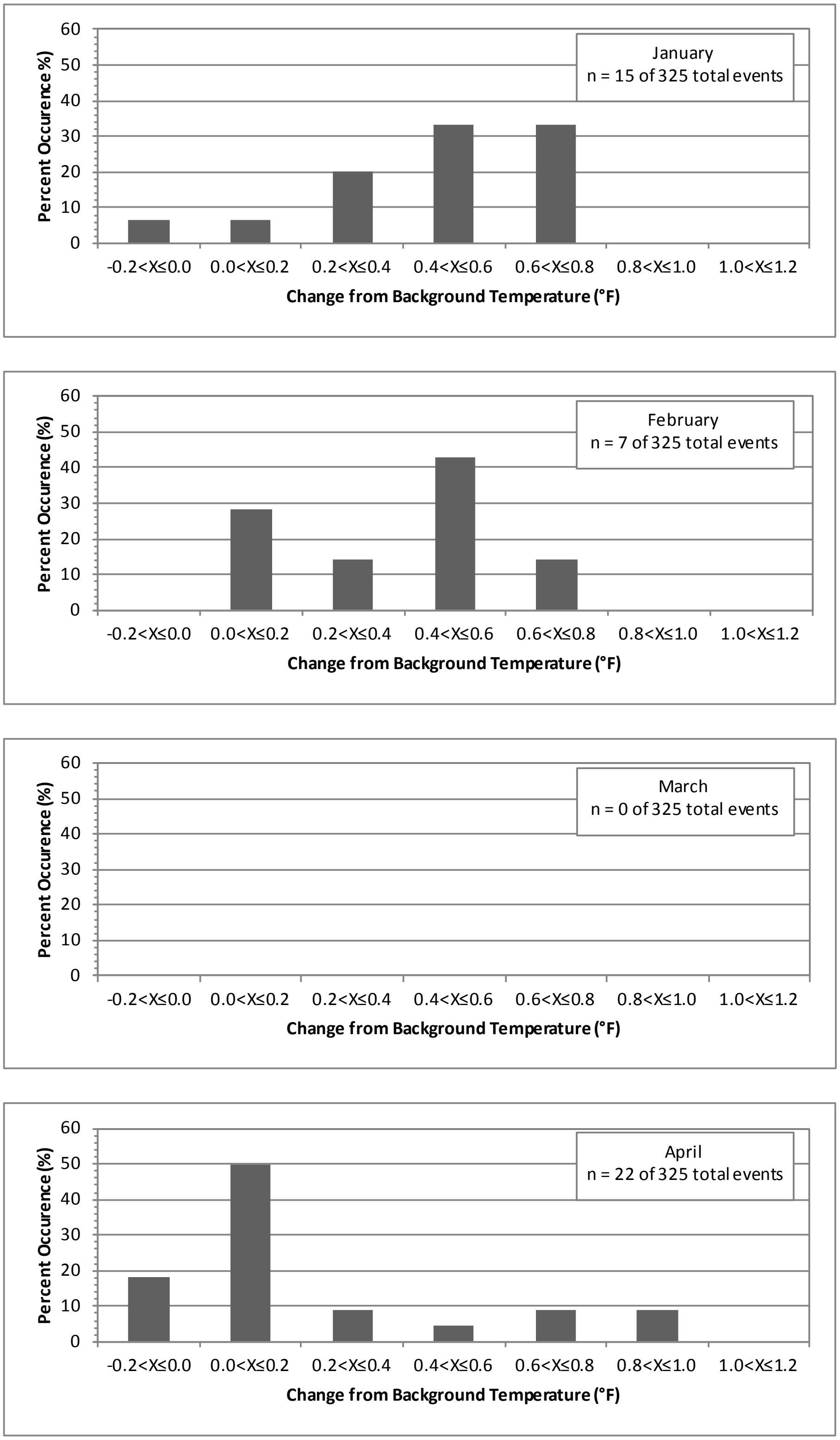
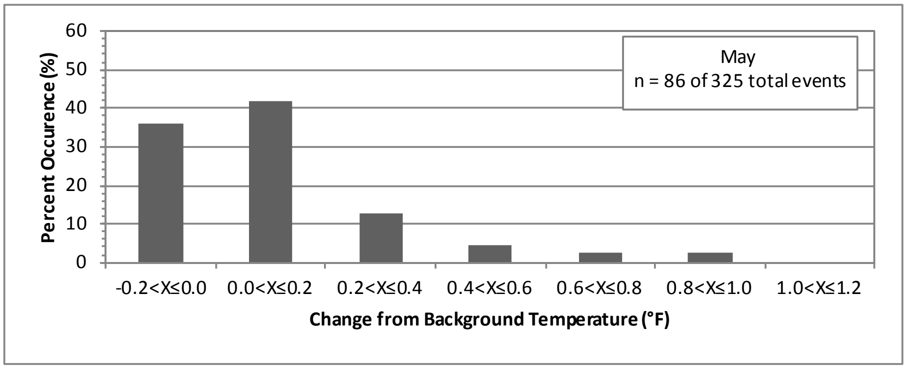
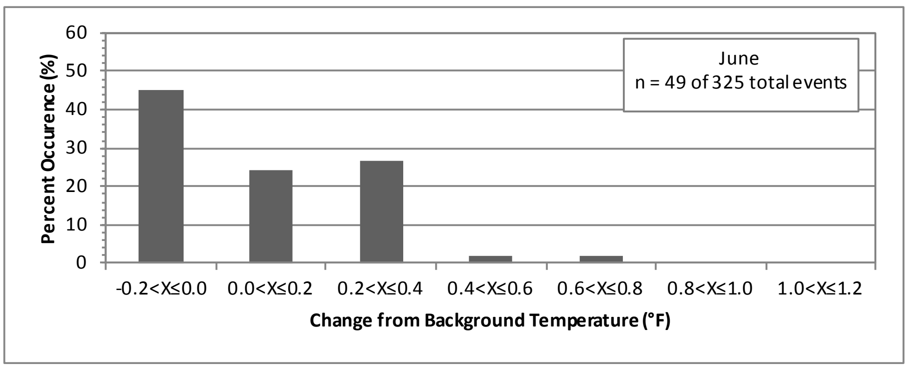


Figure 8. Percent occurrence of various magnitudes of temperature change from river background in the lower Sacramento River at Freeport Bridge during reverse-flow events that occurred in the months of January through April during the period February 21, 1992 to September 30, 2012.





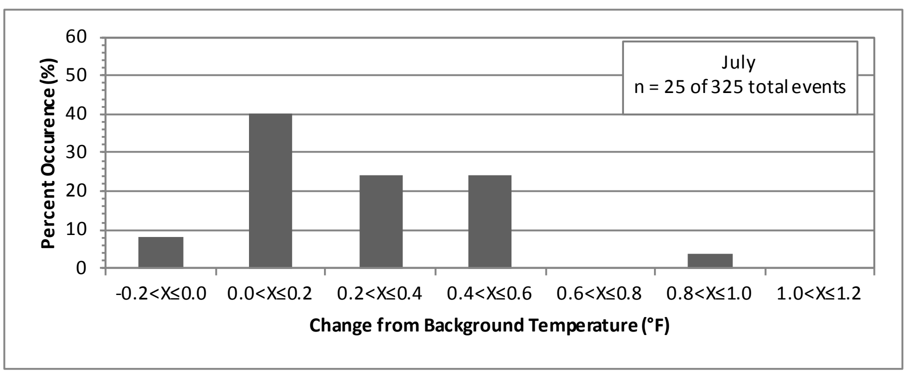


Figure 9. Percent occurrence of various magnitudes of temperature change from river background in the lower Sacramento River at Freeport Bridge during reverse-flow events that occurred in the months of May through July during the period February 21, 1992 to September 30, 2012.

Of the 325 reverse-flow events evaluated during the 1992–2012 period, nearly 20% showed no increase in temperature at the Freeport Bridge as the plume front moved upstream past the bridge. This is partly explained by reverse-flow events that occurred when the effluent-to-river temperature differentials were low and thus the plume temperature was attenuated to river background temperatures by the time it was transported upstream to the Freeport Bridge during stage 2 of the event. Approximately 70% of the 325 reverse-flow events showed a 0.4^{o}F or less increase in temperature at the Freeport Bridge, with only about 2% showing an increase in river temperature at the bridge of >1ºF (Figure 7).

The monthly assessment (Figure 8; Figure 9) shows a maximum change in river temperature at the Freeport Bridge, compared to river background temperature, of 1.0ºF for the months January through April, with the majority of reverse-flow events showing a change in temperature of 0.6ºF or less. No reverse flow events occurred in the period of record assessed during March, and reverse-flow events were relatively infrequent during the months of January, February, and April (Figure 8). Likewise, during the months May through July, the majority of events showed temperature increases of 0.6ºF or less at Freeport Bridge, with a maximum increase of 1.0ºF. Reverse-flow events occurred somewhat more frequently during May, June, and July (Figure 9).

Figure 10 shows that reverse-flow events that began in early to mid-afternoon had the largest temperature increases at the Freeport Bridge (up to 1.2ºF), and those where initial reverse flow began at night generally had the lowest (typically less than 0.5ºF) temperature increases at the bridge as the plume moved upstream past the bridge. When reverse flow began early to mid-afternoon, the maximum temperature recorded at the bridge during the reverse-flow event occurred at approximately the same time of the day that river temperatures reached their diurnal maximum. Because background temperature was recorded at the bridge several hours earlier, some portion of the temperature increase calculated for these reverse-flow events is believed to be due to natural diurnal increase in river temperature between about 11:00 am–12:00 pm (when background temperature was recorded) and 2:00–5:00 pm, when the peak temperature at the Freeport Bridge is recorded. Conversely, when the reverse flow begins at night, after dark, the natural diurnal fluctuation causes river temperature to decrease between when river background is recorded and when the plume initially passes the Freeport Bridge as it moves upstream of the reverse flow.

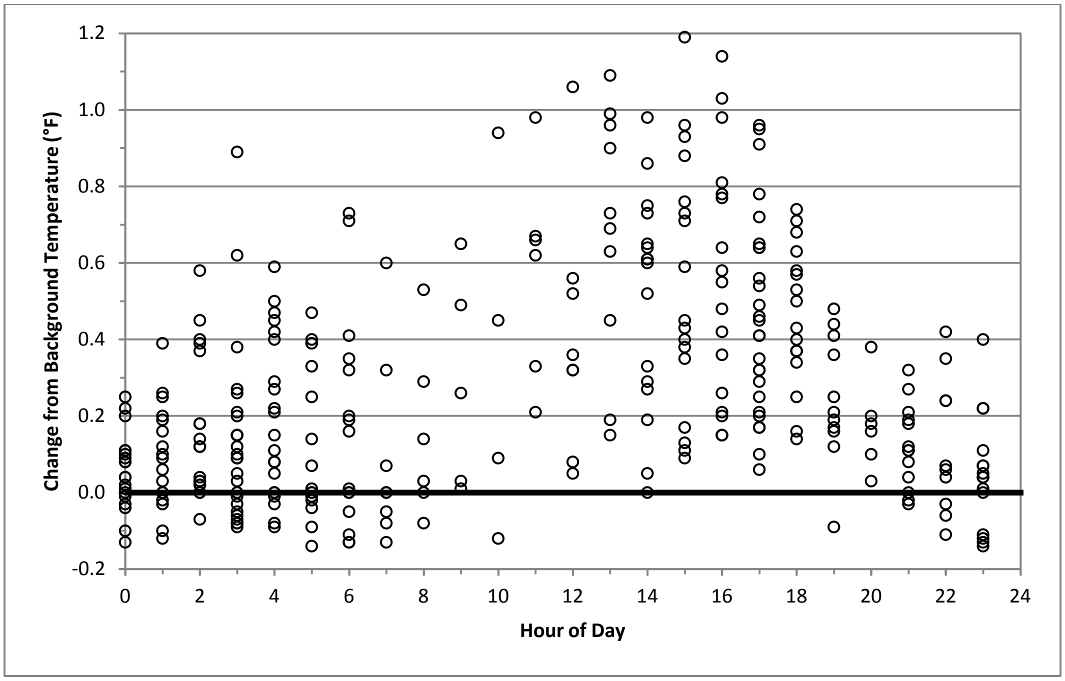


Figure 10. Change from background temperature of the lower Sacramento River recorded at the Freeport Bridge during reverse-flow events versus hour of the day that peak temperature under reverse flow was recorded. Records span the period of February 21, 1992 through September 30, 2012.

The diurnal fluctuation in ambient river temperature across a given day (i.e., 24-hour period) can be up to about 0.3ºF (Temperature Study Report; RBI 2013, p. 80-81). Hence, up to approximately 0.3ºF of the total temperature increase determined at the Freeport bridge for afternoon reverse-flow events using this methodology appears to be due to normal diurnal variation in river temperature across the day, with the remaining temperature increase due to previously discharged effluent passing the bridge as the reverse flow moves the effluent plume upstream. Based on this finding, it appears that SRWTP discharge-related increases in temperature at the Freeport Bridge due to the effluent plume being transported upstream on reverse flows is nearly always less than 1ºF, and certainly no more than 1.2ºF. Any discharge-related temperature increase further upstream of the Freeport Bridge would be even lesser than 1ºF because the plume continues to mix with river water and plume temperatures continue to attenuate over time and distance. Under reverse-flow events, zones of passage remain well into the event due to the laminar flow in this section of the river.

In summary, during stage 2, when the attenuated thermal plume is transported upstream due to reverse flows, delta smelt transported within the plume are exposed to river temperatures that would be similar to continuous discharge conditions because the plume continues to mix with river water and temperatures within the plume continue to attenuate, just as occurs under normal discharge conditions.

4.7.3 River Thermal Conditions under Stage 3 of Reverse-Flow Events

Stage 3 occurs from the time the river flow reverses the second time and resumes movement in the downstream direction until all previously discharged effluent that was transported upstream has passed the diffuser. For most reverse-flow events, stage 3 lasts about 1–2 hours. It is difficult to determine the relative amount of additional temperature attenuation that occurs in the effluent plume between the time the plume front passes Freeport Bridge during stage 2 and when the same portion of the plume crosses back over the diffuser during stage 3, but it can be concluded based on the discussion above that the discharge-related incremental increase in river background temperature when the plume passes back across the diffuser during stage 3 would be less than 1.2°F in all cases, and would typically be on the order of just a few tenths of a degree Fahrenheit.

An increase of river background temperature by a few tenths of a degree up to a maximum of 1.2°F for the initial 1–2 hours when the SRWTP discharge is resumed during the latter portion of stage 3 would not change the characteristics of the thermal plume downstream of the diffuser by magnitude or duration that would result in any different thermal effect on larval or post-spawn adult delta smelt passing through the plume at this time (i.e., final 1–2 hours of stage 3) compared to times outside of reverse-flow events. Consequently, delta smelt life stages would be exposed to essentially the same temperature gradients within the plume as they would under constant downstream flow conditions.

5 ANALYSES OF POTENTIAL IMPACTS OF THE SRWTP THERMAL DISCHARGE ON DELTA SMELT AND CRITICAL HABITAT

This section provide analyses of potential impacts of the SRWTP thermal discharge on all of the life stages of delta smelt that could occur in the reach of the lower Sacramento River that is influenced by the SRWTP effluent, including eggs, larvae, adults, and post-spawn adults. This section also provides analyses on the potential impacts to critical habitat for delta smelt. Potential impacts to juvenile delta smelt from the thermal plume near the diffuser are not assessed in this addendum, as agreed upon by the Service, because juvenile delta smelt are highly unlikely to be present in the area of the lower Sacramento River near the SRWTP outfall (see Section 2.2).

Some of the data and analyses contained in the sections below were derived from the Temperature Study Report (RBI 2013) and repackaged in a format that allows for a complete evaluation of all delta smelt life stages and critical habitat, as requested by the Service in their comment letter on the Temperature Study. In addition, the assessments below incorporate more recent information that has become available since the Temperature Study Report was completed. The new information primarily includes new delta smelt thermal tolerance information from Komoroske et al. (2014) and the results of additional modeling efforts (Appendices D, E and F) conducted to further characterize the SRWTP thermal plume during the periods that delta smelt life stages may be present near the SRWTP outfall.

The modeling output that characterizes SRWTP near-field plume temperature differentials from ambient river background temperatures under the median flow scenario and the three minimum flow ratio scenarios (which define the most affected half of all thermal conditions that occur within the plume) (Appendix D), along with Appendix E and Appendix F Figures, was used to assess the potential thermal effects on delta smelt migrating through the plume.

5.1 Potential Impacts of the Fully Mixed SRWTP Thermal Discharge to All Life Stages of Delta Smelt in the Delta and Suisun Marsh

As discussed in Section 4.5, the SRWTP thermal discharge has the potential to increase lower Sacramento River water temperatures once the effluent becomes fully mixed approximately 2-3 miles downstream. When fully mixed river temperature increases under operation of the SRWTP to the current Thermal Plan exceptions were examined for each individual hour in the simulation, it was determined that instantaneous temperature increases ranging from approximately 0.1 –1.5ºF can occur during the time period January-July (Table 16). Instantaneous increases of greater than 1ºF occurred very infrequently and only during the period January-April (i.e., 0.09% of the time in January, 0.03% of the time in February and did not occur at all in March and April). Moreover, such incremental increases in the fully mixed river temperature occurred during time periods when the background river temperatures were below 58.7 ºF.

The additional percent of time exceeding specified magnitudes of incremental increases in fully mixed river temperature due to operating the SRWTP to the current Thermal Plan exception to objective 5.A.(1)a compared to meeting the Thermal Plan objective 5.A.(1)a at all times is zero for the months March through July and is negligible (0.01-0.14% and 0.03-0.57% more frequent) for all incremental temperature increases in January and February, respectively (Table 17). In other words, the frequency with which specified magnitudes of incremental temperature increases in the fully mixed river would occur would differ negligibly, if at all, when operating to Thermal Plan objective 5.A.(1)a versus operating to the exception to this objective during the January through April period of the year.

During the May-July period, fully-mixed temperature increases are always below 0.9 ºF and are typically below 0.2 ºF. In addition, these incremental temperature increases would further attenuate (i.e., decrease in magnitude) with increasing distance downstream, as the lower Sacramento River water further mixes with the Delta and Suisun Marsh water on the tidal cycle. Consequently, the effects of the SRWTP discharge on lower Sacramento River temperatures miles downstream of the diffuser, in the greater Delta, and in Suisun Marsh are small to immeasurable (i.e., typically tenths of a degree Fahrenheit or less). It should be noted that the SRWTP does not operate under an exception to Thermal Plan objective 5.A.(1)a during these months of the year.

These fully-mixed temperature increases would not be of a magnitude and geographic extent that would adversely affect the survival of individual adult, larval, juvenile, or post-spawn delta smelt existing in these areas, nor would this thermal effect of the SRWTP discharge affect the continued existence or recovery of the delta smelt population.

5.2 Potential Impacts of the SRWTP Thermal Discharge to Upstream Migrating Pre-spawn Adult Delta Smelt

5.2.1 Potential Effects Associated with Exposure to Elevated Temperatures

Adult delta smelt migrating upstream past the SRWTP outfall in the approximately 100 ft and 200-ft wide “zones of passage” that exist along the west and east banks of the river, respectively, would follow a migration pathway that is thermally unaffected by the effluent plume. Adult delta smelt immigration past the SRWTP diffuser through these zones of passage would not experience temperatures higher than ambient background and thus would not be affected thermally by the existence of the plume, which is located more centrally within the river channel.

Adult delta smelt that are moving through the 300-ft wide cross section of the river that is affected by the thermal plume would encounter a gradually increasing (i.e., relative to background) gradient of temperatures as they move upstream through the river and approach the diffuser. As the fish moves closer to the diffuser, the portion of the cross-section occupied by the thermal plume becomes smaller and closer to the river bottom, and is characterized by increasing temperature elevations above river background (Appendix D, Attachment A, Figures 1-40). At all times, a zone of passage on either side of the plume exists, where water temperatures are unaffected by the SRWTP discharge. As the fish gets closer to the diffuser, a large zone of passage also occurs above the thermal plume, where the plume has not yet risen to the river's surface. As such, an adult delta smelt moving upstream through the plume can make relatively short vertical or horizontal movements to find favorable temperatures within the plume, or a zone of passage that is thermally unaffected by the plume.

Numerous studies have shown that fish, when presented with a range of temperatures, will seek a temperature that is preferred, and will not submit themselves to temperatures sufficiently high to cause adverse physiological effects when given options (Cherry et al. 1975, Gray et al. 1977, Biro 1998). As such, adult delta smelt moving upstream through the lower Sacramento River to reaches above Freeport are not expected to expose themselves to unfavorable temperatures in the SRWTP thermal plume. Adult delta smelt could simply avoid unfavorable temperatures by moving laterally or vertically in the water column to find thermally acceptable migration routes, if necessary. This would be the case whether the SRWTP were operated to meet the Thermal Plan objectives year-round or whether it is operated to met the current Thermal Plan exceptions. Therefore, the SRWTP thermal plume would not adversely affect the survival of immigrating adult delta smelt.

As discussed in Section 4.6, the lower Sacramento River in the vicinity of the SRWTP diffuser is tidally influenced, which can result in reverse flow conditions during periods of high tides and low outflow. Three distinct phases occur during these reverse flow events. Stage 1 occurs from the time the SRWTP effluent discharge is ceased until the downstream river flow reaches zero. During this stage adult delta smelt thermal exposures would not differ substantially from exposures that would occur during continuous discharge conditions. Stage 2 occurs from the time the river flow initially reverses and begins flowing upstream until upstream flow reaches zero. During this phase, drifting or slowly upstream swimming delta smelt transported within the plume would be exposed to river temperatures elevated somewhat above river background over the time period that flow moves in the upstream direction, with plume temperatures continuing to attenuate over this stage of the event. Plume temperatures as they pass by the Freeport Bridge during reverse-flow events during the January through July time period have been shown to be about 1ºF or less above river background temperatures and typically about 0.6 ºF or less. Stage 3 occurs from the time the river flow reverses the second time and resumes movement in the downstream direction until all previously discharged effluent that was transported upstream has passed the diffuser. During this phase, which lasts for up to 2 hours, the elevation of river temperatures over background is less than that during Phase 2 because the plume continues to mix across the river channel. When the SRWTP discharge resumes, the minor elevation of river background temperature would not change the characteristics of the thermal plume downstream of the diffuser by magnitude or duration that would result in any different thermal effect on delta smelt passing through the plume at this time (i.e., final 1–2 hours of stage 3) compared to times outside of reverse-flow events. Based on these findings, reverse-flow events would not thermally affect the river by magnitudes or geographic extent that would adversely affect the survival of individual immigrating adult delta smelt.

5.2.2 Potential Energetic and Metabolic Effects Associated with Potential Plume Avoidance

As discussed in Section 5.2.1, immigrating adult delta smelt are not expected to expose themselves to unfavorable temperatures in the SRWTP thermal plume. However, avoidance of the plume by delta smelt, should it occur, could result in increased energetic output and metabolic expenditures. The lower Sacramento River near the diffuser is approximately 600 ft wide and 20 ft deep. The thermal plume occupies a 300-ft wide section of the river, with boundaries located approximately 200 ft from the east and 100 ft from the west bank. The vertical height of the plume ranges from a few feet immediately downstream of the diffuser at the river bottom to the entire depth of the river (i.e., approximately 20 ft) where the plume has risen to the surface approximately 400 ft to greater than 990 ft downstream of the diffuser, depending upon flow conditions. Based on the size of the plume and the portion of the river cross-section that it may occupy, an adult delta smelt moving upstream would only have to make a maximum horizontal movement of 150 ft (i.e., assuming that it is located in the center of the 300-ft wide plume) to find a zone of passage that is thermally unaffected by the SRWTP discharge or a vertical movement of about 10-15 ft to find a zone of passage minimally affected or unaffected by the discharge. Adult delta smelt utilize a "stroke-and-glide" swimming method at velocities below 10 cm/sec (Moyle 2002; Bennett 2005). Assuming that an adult delta smelt was swimming upstream at a relatively slow rate of 10 cm/sec (0.33 ft/sec), it would require approximately 7.6 minutes to move 150 ft horizontally or about 30-45 seconds to move 10-15 ft vertically and avoid thermally unfavorable areas of the plume, should delta smelt do so. This would be the case whether the SRWTP were operated to meet the Thermal Plan objectives year-round or whether it is operated to met the current Thermal Plan exceptions. When considering that an adult delta smelt swims 50 or more miles against river currents over a period of weeks to months to reach spawning habitats in the lower Sacramento River north of Freeport, the bioenergetic and metabolic costs of moving such short distances to avoid unfavorable temperatures within the plume, should such avoidance behavior occur, are considered negligible. These negligible additional energetic expenditures would not be expected to affect the survival of individual adult delta smelt immigrating past the SRWTP diffuser, nor would such movements adversely affect immigrating adult delta smelt in sublethal ways that would adversely affect the continued existence or recovery of the delta smelt population.

5.2.3 Potential for Increased Predation

Based on findings from six study elements that examined the species composition, movements, distribution, behavior, and predation rates of predatory fishes, the Temperature Study Report (RBI 2013), concluded that the rate of predation at the SRWTP diffuser is not higher than elsewhere in the lower Sacramento River. The key findings from the Temperature Study Report that support this conclusion are listed below.

- Fish trajectory and velocity information indicated that fish were moving through the study area, rather than holding at the diffuser and within the plume for extended periods.

- None of the 246 tagged Chinook salmon smolts were preyed upon near the diffuser and thermal plume as they emigrated past the diffuser.

- 51 fish that had previously preyed upon tagged Chinook salmon smolts in other locations showed no evidence of long-term holding at the diffuser or in the thermal plume upon being detected there.

- Of the 99 predatory fishes captured, tagged, and released near the diffuser, only one tagged predatory fish held near the diffuser and in the footprint of the plume for an extended period of time.

- Nearly half of all tagged predatory fishes left the area of the diffuser within one hour after being tagged.

- Predatory fish ‘tracks’ were variable and illustrated no obvious preference for holding near the diffuser or thermal plume.

- No delta smelt were found in the stomachs of the 97 predatory fishes captured at the diffuser site and only three of the 97 predatory fishes captured near the diffuser had prey fish in their stomachs.

The Temperature Study Report (RBI 2013) further concluded that the rate at which predators, such as striped bass and largemouth bass, would prey upon delta smelt moving past the SRWTP diffuser during their seasonal spawning migrations would not be increased due to operation of the SRWTP under the current Thermal Plan exceptions compared to operation of the SRWTP to meet all Thermal Plan objectives, year-round. As such, operation of the SRWTP under the current Thermal Plan exceptions and associated temperature limitations in the NPDES permit does not cause high levels of predation on delta smelt migrating past the diffuser. Based on the temperature Study (RBI 2013) findings, the predation rates of delta smelt at the SRWTP outfall are not believed to be higher than elsewhere in the lower Sacramento River and thus predation levels that exist here would not adversely affect the continued existence or recovery of the delta smelt population.

5.2.4 Potential Effects of the SRWTP Thermal Discharge on Delta Smelt Prey and Food Web Dynamics

Adult life stages of delta smelt primarily consume adult zooplankton, including planktonic copepods, cladocerans, and amphipods (Bennett 2005; Moyle 2002), and occasionally insect larvae (Moyle 2002). Pennak (1978) concluded that most freshwater invertebrates, including zooplankton, are tolerant of high temperatures, with thermal lethality for most freshwater invertebrates occurring at water temperatures ranging from 86ºF–104ºF. Kivivuori and Lahdes (1996) concluded that a water flea (*Daphnia magna*), cultured at 20ºC (68ºF), had a “LD_{50} value” (i.e., the temperature level that resulted in lethality to 50% of experimental organisms) of 34.8ºC (94.6ºC) when subjected to an acute 24-hour heat exposure and 37.8ºC (100.0ºF) following an instantaneous temperature increase followed by a 15 minute exposure. Goss and Bunting (1976) determined that *Daphnia pulex* acclimated from 5 to 30ºC (41 to 86ºF) and *Daphnia magna* acclimated from 10 to 30ºC (50 to 86ºF) can withstand immersion for 48 hours or more in temperatures that differed from acclimation temperatures by 10ºC (18ºF) or more without experiencing any appreciable mortality directly attributable to the temperature change.

Sustained high water temperatures can induce chronic effects on zooplankton, such as shifting metabolic and growth rates, which can result in altered species composition and biomass. It is generally known that copepods are able to reduce their metabolic rate and enter diapauses under harsh environmental conditions, and such adaptations result in an ability to live at sustained temperatures in excess of 28ºC (82.4ºF) (Thorp and Covich 1991). Two cladocerans, *Ceriodaphnia* and *Diaphanosoma*, inhabit waters with temperatures of 27–30ºC (80.6–86ºF) (Thorp and Covich 1991). Much like the coping mechanism exhibited by copepods, Synchaeta sp., a cold water rotifer, showed depressed metabolic rate when exposed to a temperature of 28ºC (82.4ºF) (Stelzer 1998). Furthermore, reproduction of some rotifers (e.g. Brachionus sp.) can continue successfully in water temperatures of 40ºC (104ºF) (Thorp and Covich 1991).

Based on the literature cited above, zooplankton can incur lethality at sustained temperatures of 86ºF and above. This value is greater than the maximum historic river and effluent temperatures during the January through July period of 76.3ºF and 82.9ºF, respectively, for the time period February 1992 through September 2012 (Table 3; Table 6). Moreover, because effluent temperatures attenuate rapidly, any planktonic organisms that would drift through the warmest portion of the SRWTP diffuser would do so rapidly (i.e., seconds to minutes) and, therefore, would not be exposed to temperatures in the high 70s or low 80s, due to the SRWTP discharge for a sustained period of time. Consequently, the SRWTP discharge would not cause lethality to zooplankton as a result of brief exposure to elevated temperatures as they drift past the SRWTP diffuser and through the thermal plume, when operated to meet the current Thermal Plan exceptions.

As discussed above, sublethal effects may occur at temperatures below the lethal threshold for zooplankton. At temperatures of 82.4ºF and above, zooplankton may incur altered metabolic and reproduction rates when exposure to such temperature is sustained for many days or weeks. This threshold is well above the maximum temperature (i.e., 76.3ºF) that occurs in the lower Sacramento River near Freeport for extended periods of time during the January through July time period. However, during the month of July, SRWTP maximum effluent temperature can reach this threshold. Based on historical effluent hourly temperatures, the probability of equaling or exceeding 82.4ºF during July is less than 0.1% (Table 6). However, as discussed above for lethal effects, the duration with which any zooplankton would drift through the warmest portion of the plume and thus be exposed to temperatures that equal or exceed 82.4ºF would be extremely short (i.e., seconds) and under no conditions would they be subjected to sustained exposures that would measurably affect their metabolic or reproductive rates according to the cited literature. Therefore, based on short exposure durations and the thermal conditions that occur in the lower Sacramento River downstream of the SRWTP diffuser as operated under the current Thermal Plan exceptions, exposure to elevated temperatures in the SRWTP thermal plume would not adversely affect zooplankton populations in the lower Sacramento River.

Although not a primary dietary component, adult delta smelt may opportunistically feed upon insect larvae. Like the zooplankton discussed above, benthic macroinvertebrate (BMI) larvae, including insects, have relatively high thermal tolerances and are generally resistant to short-term, rapid changes in temperature. As discussed in Section 3.1.2.11 of the Temperature Study Report (RBI 2013), the BMI community of the lower Sacramento River is dominated by organisms that are considered tolerant of environmental perturbation and relatively high water temperatures, with the most thermally sensitive BMI species including some taxa of mayflies (*Ephemeroptera*) and caddisflies (*Trichoptera*). Regarding the thermal tolerances of these taxa, Wood et al. (1996) tested caddis and mayfly larvae for their response to rapid changes in temperature and found that with acclimation at 82.4°F *Helicopsyche borealis*, a caddisfly, could withstand one-hour exposures of up to 101.3°F (LC_{50}). This represents a temperature change of 19^{o} F for a one-hour exposure. Another caddisfly in the same study, *Gumaga nigricula*, had a one-hour exposure tolerance of 100°F (LC_{50}), and a mayfly, *Centroptilum convexum*, had an one-hour exposure tolerance of 97.3°F (LC_{50}). Wood et al. (1996) suggested that the magnitude of the change in temperature is not as important as the acclimation of the insects, the duration of the exposure to the higher temperature, and the absolute maximum temperature to which the BMIs are exposed.

Many of the BMI taxa occurring in the lower Sacramento River are found commonly throughout warmwater bodies of the Central Valley, where temperatures regularly reach and exceed the maximum temperatures of the SRWTP effluent. Moreover, the maximum lower Sacramento River and SRWTP effluent temperatures that BMI taxa may be exposed to during the January through July (i.e., 76.3ºF and 82.9ºF, respectively, based on the February 1992 through September 2012 period of record), is lower than the thresholds identified by these researchers for the most thermally sensitive species (i.e., mayflies and caddisflies) occurring in the lower Sacramento River. In addition, the duration for which any insects would drift through the warmest portion of the plume (i.e., immediately adjacent to the diffuser ports) and thus be exposed to the highest plume temperatures would be extremely short in duration (i.e., seconds) and under no condition would they be subjected to sustained exposures to temperatures sufficiently high to cause lethality or adversely affect their metabolic or reproductive rates. As such, the absolute temperatures and the exposure durations that would be experienced within the SRWTP thermal plume, when operated to the current exceptions, would be well below the exposure thresholds cited above to cause any measurable adverse effects on the BMI community of the lower Sacramento River from such exposure.

Therefore, based on the thermal conditions that occur in the lower Sacramento River downstream of the SRWTP diffuser under current permitted operations, exposure to elevated temperatures in the SRWTP thermal plume would not cause adverse affects on zooplankton or BMI abundance in the lower Sacramento River and thus would not adversely affect the food supply for adult delta smelt.

5.3 Potential Impacts to Spawning and Eggs

As discussed in Section 2.2.2, delta smelt eggs have never been collected in the wild and, therefore, much of the information inferred about delta smelt spawning locations, habitat, and behavior is derived from laboratory studies, and from monitoring studies developed to determine the seasonal movements and distribution of larvae, juvenile, and adults. It is thought that delta smelt spawn over sandy substrates in shallow areas (Bennett 2005). Observations of delta smelt spawning in laboratory conditions indicate that delta smelt spawn primarily at night, broadcasting their eggs near the substrate (Lindberg et al. 1997). Delta smelt eggs are demersel, adhesive, and attach to suitable substrate material via an "adhesive stalk" formed on the chorion of the egg (Bennett 2005). Delta smelt eggs incubate for 9-13 days at temperatures of approximately 59-62°F (Moyle 2002).

Based on the assumption that delta smelt spawn over sandy substrates in shallow areas and prefer cold water (e.g., below 68ºF) and that the SRWTP thermal plume is confined to the middle of the channel, where the river is 20-25 ft deep, with unaffected areas on both banks, delta smelt would not be expected to spawn in areas of the lower Sacramento River affected by the SRWTP thermal plume.

Based on what is known about delta smelt spawning behavior, eggs would not be expected to occur in the SRWTP thermal plume, downstream of the diffuser. If spawning did occur in the vicinity of the diffuser, it would be expected that eggs would be deposited in the channel margins (i.e., 100-200-ft wide zones of passage where river temperatures are unaffected by the SRWTP discharge), where depths are shallower and velocities are lower, rather than in the deeper thalweg where velocities are higher, depth is 20-25 ft, and where the SRWTP thermal plume is located. Because delta smelt eggs are demersel and attach to substrate, rather than drift in the water column, they would not drift through the SRWTP thermal plume. Consequently, the SRWTP discharge would not be expected to have adverse affects on delta smelt eggs.

Based on what is known about delta smelt spawning, the SRWTP thermal discharge would not have direct or indirect adverse effects on delta smelt spawning or egg incubation and thus would not adversely affect individual delta smelt reproductive success or the continued existence or recovery of the delta smelt population.

5.4 POTENTIAL IMPACTS TO DOWNSTREAM MIGRATING POST-SPAWN AND LARVAL DELTA SMELT

5.4.1 Potential Effects Associated with Exposure to Elevated Temperatures

Larvae and post-spawn adult delta smelt emigrating downstream past the SRWTP outfall in the approximately 100 ft and 200-ft wide "zones of passage" that exist along the west and east banks of the river, respectively, would follow a migration pathway that is thermally unaffected by the effluent plume. Larval and post-spawn adult delta smelt emigrating past the SRWTP diffuser through these zones of passage would not experience temperatures higher than ambient background and thus would not be affected thermally by the existence of the plume which is located more centrally within the river channel.

The processed modeling output presented in Appendices D, E and F was used as the primary basis from which to assess the thermal effect to larval and post-spawn adult delta smelt that emigrate through the SRWTP thermal plume on their route to habitats within the Delta and Suisun Marsh. **Table 18** provides a reference to the specific Appendix Tables and Figures that were used as the basis for assessing thermal effects to emigrating larval and post-spawn adult delta smelt by month (January through July) and by depth at which they move through the plume (river surface, 10 ft below the surface, and 20 ft below the surface, near the river bottom).

Table 18. Flow scenario modeled and Appendices D, E, and F Figure and Table references by modeled scenario and depth within the plume.

Flow Scenario Modeled	Plume Depths	Appendix D, Attachment A References	App. D, Attach. B Table App. E and App. F Figure References
Median Flow Ratio Condition $Q_{Effl.:}$=154 mgd; Q_{River}=16,000 cfs; Flow Ratio: 67:1		Figures 16-20 and 36-40	
	River Surface		Table 10 Figures E-1 (January) through E-7 (July)
	10 ft		Table 11 Figures E-8 through E-14
	River Bottom		Table 12 Figures E-15 through E-21
Minimum Flow Ratio Condition (Flow Ratio: 14:1)		Figures 1-15 and 21-35	
60 mgd (Q_{River}=1,300 cfs)	River Surface		Table 1 Figures F-1 through F-7
	10 ft		Table 2 Figures F-8 through F-14
	River Bottom		Table 3 Figures F-43 through F-49
181 mgd	River Surface		Table 4

(Q_{River}=3,921 cfs)			Figures F-8 through F-14
	10 ft		Table 5 Figures F-29 through F-35
	River Bottom		Table 6 Figures F-50 through F-56
410 mgd (Q_{River}=8,800 cfs)	River Surface		Table 7 Figures F-15 through F-21
	10 ft		Table 8 Figures F-36 through F-42
	River Bottom		Table 9 Figures F-57 through F-63

By assessing the median flow scenario modeled and three minimum flow ratio (14:1) scenarios modeled, the assessment focused on the "worst-half" of all possible thermal conditions that can occur within the thermal plume. The other half of thermal conditions that would occur within the plume would have lesser temperature differences within the plume, relative to ambient background temperatures, than shown for the median flow scenario.

The thermal tolerance for delta smelt life stages are presented in Table 1 and were reported as critical thermal maximum (CTM) and chronic lethal thermal maximum (CLT_{max}) temperature values. CTM studies are conducted by acclimating fish to one temperature and exposing them to uniform rates of increasing temperature until loss of equilibrium (LOE) occurs. Research conducted by Becker and Genoway (1979) demonstrated that higher CTM values were attained for freshwater fishes when the rate of heating was increased. In other words, when fish are exposed to a more abrupt temperature increase, a higher CTM value is achieved. Consequently, CTM values, which are commonly reported as upper thermal tolerance thresholds for long-term survival, are a conservative estimate of fishes' tolerance to abrupt and short-term increases in temperatures and, as such, may underestimate the tolerance thresholds of fish moving downstream that may be exposed to a brief and instantaneous increase in temperatures when passing through the SRWTP thermal plume. CLT_{max} temperature values are determined by slowly increasing temperatures every day until 100% lethality occurs. These studies are used for determining lethal temperatures for chronic exposure durations.

Larval and post-spawn delta smelt that are emigrating from areas upstream of the SRWTP diffuser to areas downstream, near the river bottom, will encounter an abrupt temperature increase as they pass by the diffuser ports, followed by rapid temperature reductions as the effluent mixes with river water and the higher temperatures within the plume attenuate (i.e., decrease) with increasing distance downstream of the outfall. Studies of this nature are relatively rare in the published literature, primarily due to the widespread belief among fisheries biologists that, regardless of acclimation temperature, fish can tolerate brief (e.g., seconds or minutes) exposures to substantially elevated or depressed temperatures with no direct adverse effects, provided that the exposure temperature is within the upper and lower lethal temperature thresholds for the species (USFWS1991; McCullough 1999; Meldrim and Sherwood 2005).

When fish encounter abrupt temperature increases, the shorter the exposure time, the greater the temperature increase that fish can tolerate (Schubel 1975; Burton et al. 1976). Hart (1947, 1952; as cited by Hokanson et al. 1977) reported that most fish species can tolerate short-term increases in temperature of 27–32 ºF above acclimation temperature, provided that the higher exposure temperature is within the lethal thresholds for the species. This is supported by more recent work conducted by Cech et al. (1990), where several species of native California fishes (including salmonids, a surrogate species for delta smelt thermal tolerance; L. Zweig, pers. comm. 2015) were acclimated to certain temperatures (i.e., 50, 59, 68, 77, 86ºF) and then exposed to a 9ºF temperature increase over a 3–5 hour period. Findings from this study showed that fish metabolic rates were generally, but not always, elevated following such rapid changes in temperature, but that mortality did not occur unless the elevated temperature to which fish were rapidly exposed was at or higher than their upper incipient lethal temperature (UILT).

Findings from Komoroske et al. (2014) indicate that larval delta smelt acclimated at 61.5ºF can tolerate exposures up to 85.8ºF before losing equilibrium, and have the highest thermal tolerance of all delta smelt life stages (Table 1). This was the only acclimation temperature examined for the larval life stage of delta smelt. However, as discussed above and shown in Table 1 for other life stages, delta smelt that are acclimated at higher temperatures would be expected to have somewhat higher CTM values.

A final consideration to provide further context to the thermal assessment below is that the likelihood of any larval delta smelt encountering the minimum flow ratio temperatures modeled for the bottom of the river is very low. As discussed in Section 4.4, the 14:1 flow scenario modeled for the plume graphics has occurred in only 0.005% of all hourly readings during the months of January-July during the January 1985 through September 2012 period of record, and this minimum flow ratio scenario typically only occurs as a transient condition when the SRWTP is ceasing discharges in order to comply with its 14:1 flow requirement. Consequently, the probability that a larval delta smelt emigrating along the river bottom would pass through any of the minimum flow ratio plumes modeled at a 14: flow ratio is negligible. Even so, should such a rare event occur, it is assessed below.

5.4.1.1 Median Flow Ratio Condition (67:1 Flow Ratio)

5.4.1.1.1 River Surface

Negligible (i.e., <0.5^{o}F) temperature increases would occur at the river surface within the near-field plume area modeled (990 ft downstream of diffuser) during all months of the January-July period, with temperature increases peaking at 918 ft downstream of the diffuser. Temperature increases at the river's surface that would occur under this median flow condition at locations more than 990 ft downstream of the diffuser would be even lesser than 0.5^{o}F, as the effluent more fully mixes across the river channel. The thermal exposure experienced by larval and post-spawn adult delta smelt emigrating past the SRWTP diffuser near the river surface under this median flow condition would not cause acute lethality or any adverse sublethal effects.

5.4.1.1.2 <u>10 ft below River Surface</u>

Negligible (i.e., <0.7^{o}F) temperature increases would occur within the near-field plume area modeled (990 ft downstream of diffuser), at 10 ft below the surface, during all months of the January-July period, with the incremental temperature increases peaking at 378 ft downstream of the diffuser. Temperature increases at 10 ft below the surface that would occur under this median flow condition at locations more than 990 ft downstream of the diffuser would be even lesser than 0.7^{o}F, as the effluent more fully mixes across the river channel. The thermal exposure experienced by larval and post-spawn adult delta smelt emigrating past the SRWTP diffuser at 10 ft below the surface under this median flow condition would not cause acute lethality or any adverse sublethal effects.

5.4.1.1.3 River Bottom (20 ft depth)

For the purposes of this assessment, the temperature at the diffuser ports was set equal to the effluent temperature which resulted in the temperature differential at the ports being equal to the river:effluent temperature differential modeled. Elevated temperature at the diffuser ports is attenuated down to within 0.7°F-3.5°F of background temps within the initial 100 ft downstream of the diffuser (within about one minute drift time), January-July. The greatest temperature increase of 3.5°F would occur during the winter months when river background temperatures are in the 40 to 50 degree range and thus effluent:river temperature differentials are at their maximum. In the late spring and early summer, the greatest temperature increase within the initial 100 ft would be 2.1°F based on the maximum river:effluent temperature differential of approximately 15°F, with temperatures further attenuating downstream of 100 ft as the effluent fully mixes with river water.

The CTM value for the larval lifestage is not reached in any month at the diffuser ports, and temperatures are rapidly attenuated to lower levels downstream of the diffuser. For the post-spawn adult lifestage, the CTM value of 80.8°F (at an acclimation temperature of 65.7°F) (Table 1) is not reached at the diffuser ports in any month, when river background temperatures are in the mid 60°F range. When river background temperatures are about 65°F in June and July, this CTM value of 80.8°F is approached in June and slightly exceeded in July at the diffuser ports. Exposure to such temperatures would occur for only seconds, with temperatures reducing 4-5°F as fish pass through the initial 100 ft of the plume over a drift time of approximately one minute. Plume temperatures continue to decline with increasing distance downstream, ultimately returning to near-background levels (i.e., between 0.2 and 0.8°F) 990 ft downstream of the diffuser, as the effluent continues to mix with river water. Post-spawn adult fish acclimated to higher river background temperatures (i.e., in low to mid 70°F range) during June and July would be expected to have a CTM value higher than 80.8°F. Moreover, post-spawn adult fish would be able to move laterally or vertically in the water column to find more thermally favorable migration pathways, as needed. Exposure of larval and post-spawn adult delta smelt to temperatures at or near CTM values for just seconds followed by exposure to rapidly declining temperatures until returning to near river background levels within a few minutes (i.e., approximately four minutes) would not cause acute lethality or adverse sublethal effects to either larval or post-spawn adult delta smelt.

5.4.1.2 Minimum Flow Ratio Conditions (14:1 Flow Ratio)

5.4.1.2.1 60 mgd

River Surface

Negligible (i.e., <0.02°F) temperature increases would occur at the river surface within the near-field plume area modeled (990 ft downstream of diffuser) during all months of the January-July period. The plume would not fully reach the surface within the modeled domain (i.e., 990 ft downstream of the diffuser); therefore, the greatest incremental temperatures increase at the surface would occur further downstream. However, temperature increases at the river's surface that would occur under this flow condition, at locations more than 990 ft downstream of the diffuser, as the plume more fully mixes to the surface, are expected to be on the order of approximately 1°F or less. The thermal exposure experienced by larval and post-spawn adult delta smelt emigrating past the SRWTP diffuser near the river surface under this minimum flow condition would not cause acute lethality or any adverse sublethal effects.

10 ft below River Surface

Small (i.e., <1.4°F) temperature increases would occur within the near-field plume area modeled (990 ft downstream of diffuser), at 10 ft below the surface, during all months of the January-July period, with the incremental temperature increases peaking at 828 ft downstream of the diffuser. Temperature increases within the plume at locations more than 990 ft downstream of the diffuser would be approximately 1.3°F or less, as the effluent more fully mixes across the river channel. The thermal exposure experienced by larval and post-spawn adult delta smelt emigrating past the SRWTP diffuser at 10 ft below the surface under this minimum flow condition would not cause acute lethality or any adverse sublethal effects.

River Bottom (20 ft depth)

For the purposes of this assessment, the temperature at the diffuser ports was set equal to the effluent temperature which resulted in the temperature differential at the ports being equal to the river:effluent temperature differential modeled. Elevated temperature at the diffuser ports is attenuated down about 2°F-6°F within the initial 150 ft downstream of the diffuser (within about 12 minutes drift time), January-July.

Temperatures at the diffuser ports do not reach or exceed the CTM value for the larval life stage during the January-July period, and attenuate to lower temperatures with increasing distance downstream. The CTM value reported in the literature for post-spawn adult fish acclimated to 65.7°F is 80.8°F (Table 1). When river background temperatures are about 65°F, this CTM value is approached at the diffuser ports in July only. Exposure to such temperatures (at the diffuser ports) would occur for only seconds, with temperatures reducing about 4°F as fish pass through the initial 100 ft of the plume over a drift time of approximately 9 minutes. Plume temperatures continue to decline with increasing distance downstream, ultimately returning to near-background levels as the effluent fully mixes with river water. In July, temperatures at the diffuser ports can reach 80°F-82.4°F when river background temperatures are in the low to mid 70 degree range. Fish acclimated to higher river background temperatures (i.e., in low to mid 70°F range) during June and July would be expected to have a CTM value higher than 80.8°F. Moreover, if post-spawn adult delta smelt were to encounter temperatures approaching their CTM and CLT_{50}, these fish would be expected to simply move vertically or horizontally in the water column to find thermally suitable migration pathways, if necessary. The bioenergetic and metabolic effects associated with potential avoidance of portions of the thermal plume are addressed below in Section 5.4.2.2.

Due to the low flow rates in the river under this modeled condition, larval and post-spawn adult delta smelt passing through the plume, on or near the river bottom, would be exposed to elevated plume temperatures for up to several hours prior to sufficient effluent mixing with river water occurring that plume temperatures would be attenuated to near river background temperatures (i.e., within about 1°F of background temperatures). As a result, the metabolic rates of these emigrating fish may be temporarily increased somewhat due to their exposure to elevated temperatures over this several hour period. However, as emigration continues downstream and river temperatures along their migration pathway approach river background temperatures (due to effluent mixing throughout the river channel), fish metabolic rates would return to “baseline” levels, and would not be expected to remain chronically elevated upon river temperatures returning to near background levels. This thermal exposure scenario would not cause acute lethality or chronic adverse sublethal effects to either larval or post-spawn adult delta smelt.

5.4.1.2.2 181 mgd

River Surface

Negligible (i.e., <0.03°F) temperature increases would occur at the river surface within the near-field plume area modeled (990 ft downstream of diffuser) during all months of the January-July period. The plume would not fully reach the surface within the modeled domain (i.e., 990 ft downstream of the diffuser); therefore, the warmest surface temperatures would occur further downstream. However, temperature increases at the river's surface that would occur under this flow condition at locations more than 990 ft downstream of the diffuser, as the plume more fully mixes to the surface, are expected to be on the order of approximately 1°F or less. The thermal exposure experienced by larval and post-spawn adult delta smelt emigrating past the SRWTP diffuser near the river surface under this minimum flow condition would not cause acute lethality or any adverse sublethal effects.

10 ft below River Surface

Small (i.e., ≤3.5°F) temperature increases would occur within the near-field plume area modeled (990 ft downstream of diffuser), at 10 ft below the surface, during all months of the January-July period, with temperature increases peaking at 714 ft downstream of the diffuser. Temperature increases within the plume at locations more than 990 ft downstream of the diffuser would be 2.8°F or less, as the effluent more fully mixes across the river channel. Plume temperatures at 10 ft below the surface would not approach CTM values for either larval or past-spawn adult delta smelt. The thermal exposure experienced by larval and post-spawn adult delta smelt emigrating past the SRWTP diffuser at 10 ft below the surface under this minimum flow condition would not cause acute lethality or any adverse sublethal effects.

River Bottom (20 ft depth)

For the purposes of this assessment, the temperature at the diffuser ports was set equal to the effluent temperature which resulted in the temperature differential at the ports being equal to the river:effluent temperature differential modeled. Elevated temperature at the diffuser ports is attenuated down about 3°F-15°F within the initial 300 ft downstream of the diffuser (within about 5 minutes drift time), January-July, with the lower attenuation occurring when effluent:river temperature differential is only 5°F.

Temperatures at the diffuser ports do not reach or exceed the CTM value for the larval life stage during the January-July period, and attenuate to lower temperatures with increasing distance downstream. The CTM value reported in the literature for post-spawn adult fish acclimated to 65.7°F is 80.8°F (Table 1). When river background temperatures are about 65°F, this CTM value is approached at the diffuser ports in July only. Exposure to such temperatures at the diffuse ports would occur for only seconds, with temperatures reducing about 6°F (to 74°F) as fish pass through the initial 100 ft of the plume over a drift time of approximately 1.9 minutes. Plume temperatures continue to decline with increasing distance downstream, ultimately returning to near-background levels as the effluent fully mixes with river water. In July, temperatures at the diffuser ports can reach 80°F-82.4°F, which would be attenuated to 79°F or lower in all cases within about 100 ft downstream of the diffuser (within about 1.9 minutes drift time).

Fish acclimated to higher river background temperatures (i.e., in low to mid 70°F range) during June and July would be expected to have a CTM value higher than 80.8°F. Moreover, if post-spawn adult delta smelt were to encounter temperatures approaching their CTM and CLT_{50}, these fish would be expected to simply move vertically or horizontally in the water column to find thermally suitable migration pathways, if necessary. The bioenergetic and metabolic effects associated with potentially avoiding portions of the thermal plume are addressed below in Section 5.4.2.2. Total drift time through the initial 990 ft downstream of the diffuser would take approximately 13 minutes under this low-flow scenario, and plume temperature at 990 ft downstream of the diffuser would typically be within 1-3^{o}F of river background temperatures. The exception to this would occur during the winter months (when river background temperatures are in the 40s and 50s), when plume temperatures 990 ft downstream of the diffuser may be 4^{o}F-5^{o}F above river background, and continuing to attenuate downward with increasing distance downstream. Based on the short amount of time during which emigrating larval and post-spawn adult delta smelt would be exposed to plume temperatures more than a few degrees above river background (i.e., on the order of 15 minutes), and the fact that temperatures along their migration pathway would be rapidly declining throughout this short period of time, it is expected that the metabolic rates of emigrating fishes would not become elevated. This thermal exposure scenario would not cause acute lethality or adverse sublethal effects to either larval or post-spawn adult delta smelt.

5.4.1.2.3 410 mgd

River Surface

Small (i.e., ≤1.1^{o}F) temperature increases would occur at the river surface within the near-field plume area modeled (990 ft downstream of diffuser) during all months of the January-July period. The effluent plume would not fully reach the surface within the modeled domain (i.e., 990 ft downstream of the diffuser); therefore, the warmest temperatures at the river's surface would occur further downstream. However, temperature increases at the river's surface that would occur under this minimum flow ratio condition at locations more than 990 ft downstream of the diffuser, as the plume more fully mixes to the surface, are expected to be on the order of approximately 1-1.5^{o}F or less. Plume temperatures at the surface would not approach CTM values for either larval or past-spawn adult delta smelt. The thermal exposure experienced by larval and post-spawn adult delta smelt emigrating past the SRWTP diffuser near the river surface under this low-flow condition would not cause acute lethality or any adverse sublethal effects.

10 ft below River Surface

Small (i.e., ≤3.0^{o}F) temperature increases would occur within the near-field plume area modeled (990 ft downstream of diffuser), at 10 ft below the surface, during all months of the January-July period, with the incremental temperature increases peaking at 588 ft downstream of the diffuser. Temperature increases within the plume at locations more than 990 ft downstream of the diffuser would be 2.6^{o}F or less, as the effluent more fully mixes across the river channel. Plume temperatures at 10 ft below the surface would not approach CTM values for either larval or past-spawn adult delta smelt. The thermal exposure experienced by larval and post-spawn adult delta smelt emigrating past the SRWTP diffuser at 10 ft below the surface under this low-flow condition would not cause acute lethality or any adverse sublethal effects.

River Bottom (20 ft depth)

For the purposes of this assessment, the temperature at the diffuser ports was set equal to the effluent temperature which resulted in the temperature differential at the ports being equal to the river:effluent temperature differential modeled. Elevated temperature at the diffuser ports is attenuated down about 3°F-15°F within the initial 300 ft downstream of the diffuser (within about 2 minutes drift time) January-July, with the lesser magnitude of attenuation occurring when effluent:river temperature differential is only 5°F.

Temperatures at the diffuser ports do not reach or exceed the CTM value for the larval life stage during the January-July period, and attenuate to lower temperatures with increasing distance downstream. The CTM value reported in the literature for post-spawn adult fish acclimated to 65.7°F is 80.8°F (Table 1). When river background temperatures are about 65°F, this CTM value is approached at the diffuser ports in July only. Exposure to such temperatures at the diffuser ports would occur for only seconds, with temperatures reducing as fish move downstream. In July, temperatures at the diffuser ports can reach 80°F-82.4°F, which would be attenuated to about 79°F or lower in all cases within about 100 ft downstream of the diffuser, within about 48 seconds drift time. Plume temperatures continue to decline with increasing distance downstream, ultimately returning to near-background levels as the effluent fully mixes with river water.

Fish acclimated to higher river background temperatures (i.e., in low to mid 70°F range) during June and July would be expected to have a CTM value higher than 80.8°F. Moreover, if post-spawn adult delta smelt were to encounter temperatures approaching their CTM and CLT_{50}, these fish would be expected to simply move vertically or horizontally in the water column to find thermally suitable migration pathways, if necessary. The bioenergetic and metabolic effects associated with potential avoidance of portions of the thermal plume are addressed below in Section 5.4.2.2. Total drift time through the initial 990 ft downstream of the diffuser would take approximately 6 minutes under this low-flow scenario, and plume temperature at 990 ft downstream of the diffuser would typically be within 1-2.5°F of river background temperatures. The exception to this would occur during the winter months (when river background temperatures are in the 40s and 50s), when plume temperatures 990 ft downstream of the diffuser may be about 3°F-4°F above river background, and continuing to attenuate downward with increasing distance downstream. Based on the short amount of time during which emigrating larval and post-spawn adult delta smelt would be exposed to plume temperatures more than a few degrees above river background (i.e., on the order of 6 minutes), and the fact that temperatures along their migration pathway would be rapidly declining throughout this short period of time, it is expected that the metabolic rates of emigrating fishes would not become elevated. This thermal exposure scenario would not cause acute lethality or adverse sublethal effects to either larval or post-spawn adult delta smelt.

A final consideration to put the low flow ratio (14:1) assessments into context is that the likelihood of any post-spawn adult or larval delta smelt encountering the highest temperatures within the plume at the bottom of the river is very low. As discussed in Section 4.4, the 14:1 flow ratio modeled has occurred in less than 0.02% of all hourly readings during the months of January-July during the January 1985 through September 2012 period of record, and this scenario typically only occurs as a transient condition when the SRWTP is ceasing discharges in order to comply with its 14:1 discharge prohibition of the NPDES permit. Based on the frequency with which the modeled 14:1 flow condition occurs, coupled with the thermal exposure factors discussed above, there is a very small risk of thermal effect on any post-spawn adult or larval delta smelt moving through the plume. Overall, the risk of adverse temperature-related effects on post-spawn adult and larval delta smelt is considered to be negligible and thus not expected to adversely affect individual fish or the sustainability or recovery of the delta smelt population.

As discussed in Sections 4.6 and 5.1.1, maximum plume temperatures during reverse-flow events have been shown to be no worse than those in the plume under continuous discharge conditions as the plume moves downstream following the ceasing of discharge from the diffuser. When river flow reverses direction and moves upstream, the plume continues to mix with river water, with river temperatures measured at the Freeport Bridge being about 1ºF or less above river background and typically about 0.6 ºF or less as the plume moves past the bridge. When the flow again reverses and river water containing previously discharged effluent moves back downstream, the plume further mixes with river water resulting in river temperatures being <1ºF above ambient background temperatures as this water flows past the diffuser, which occurs for up to 2 hours. As such, reverse-flow events do not result in thermal exposure scenarios for emigrating post-spawn adult or larval delta smelt that are substantially worse than those that occur under continuous discharge conditions. Although exposure to the partially mixed plume may last somewhat longer, thermal limits for these life stages would not be approached or exceeded during the reverse-flow event. Little to no increase in temperature would be experienced by fish emigrating past the diffuser within the zones of passage along the channel margins or in the upper half of the water column. Based on these findings, reverse-flow events would not result in thermal conditions and exposure durations within the river channel that would adversely affect survival of post-spawn adult or larval delta smelt or the sustainability or recovery of the delta smelt population.

5.4.2 Potential Energetic and Metabolic Effects Associated with Potential Plume Avoidance

5.4.2.1 Delta Smelt Larvae

Larval delta smelt that drift through the plume as they emigrate to the Delta may experience a temporary elevation in metabolic rate due to exposure to higher water temperatures. However, the incremental increase in plume temperatures decreases with increasing distance downstream of the diffuser as the effluent mixes with river water until the differences in hourly river temperature, relative to ambient background temperature, becomes 1.5ºF or less, and typically just tenths of a degree upon effluent becoming fully mixed with river flows approximately 2-3 miles downstream of the diffuser. As such, any elevation in larval fish metabolic rate due to elevated plume temperatures would be temporary in nature, lasting on the order of hours as fish emigrate downstream of the diffuser, with metabolic rates returning to "baseline" levels as temperatures along their migration route return to river background levels as effluent becomes fully mixed with river flows. A temporary increase in metabolic rate lasting for hours during larval delta smelt emigrations to the Delta that last days to weeks is not expected to be sufficient to adversely affect larval fish growth or survival. Consequently, this temporary sublethal effect would not adversely affect larval fish survival, year-class production, or recovery of the delta smelt population.

For those larval delta smelt that have reached a sufficient developmental stage to make diel vertical movements, these fish could potentially move upward in the water column to avoid elevated temperatures within the thermal plume. Any larval delta smelt that encounters the warmest part of the thermal plume while moving downstream along the bottom of the river (i.e., 20 feet below the water surface) could move higher in the water column (i.e., no more than about 10 ft) to find temperatures that are less elevated above background temperatures (Appendix D, Attachments A and B). The rate at which larval delta smelt can make vertical movements while drifting downstream is not known. When considering that sufficiently developed larval delta smelt make routine vertical migrations on a daily basis, the bioenergetic and metabolic costs of moving vertically in the water column to seek favorable temperatures within the plume are considered negligible and would not be expected to adversely affect individual fish survival or the sustainability or recovery of the delta smelt population.

5.4.2.2 Post-spawning Adults

Post-spawning adult delta smelt may move downstream past the SRWTP diffuser and thermal plume to return to over-summering habitats in the Delta following spawning. In contrast to the upstream-migrating adult fish, post-spawning adults move downstream with the river currents and thus have lower bioenergetic requirements.

The distance that post-spawn adult delta smelt must travel downstream from spawning habitats located upstream of the SRWTP diffuser in the lower Sacramento River to over-summering habitats in the low salinity zone of the Delta is approximately 50 miles or greater, a distance that likely requires weeks to months to travel. As discussed above and illustrated in Appendix F, the upper half of the water column within the thermal plume is largely unaffected, or only minimally affected by SRWTP effluent temperatures. Any post-spawn adult delta smelt that encounters the warmest part of the thermal plume while moving downstream along the bottom of the river (i.e., 20 feet below the water surface) could simply move laterally or vertically to find a migration pathway that is minimally elevated, or not elevated, above ambient background temperatures, if necessary. A post-spawn adult would have to make a maximum horizontal movement of 150 ft (i.e., assuming that it is located in the center of the 300-ft wide plume) to find a zone of passage that is thermally unaffected by the SRWTP discharge or a vertical movement of about 10 ft to find a zone of passage minimally affected or unaffected by the discharge. Assuming that a post-spawn adult delta smelt moving downstream could move higher into the water column at a conservatively slow rate of 10 cm/sec (0.33 ft/sec; the same rate at which adult delta smelt move upstream), it would require approximately 30 seconds to move 10 ft vertically and avoid the warmest portion of the plume, if necessary. When considering that a post-spawn adult delta smelt emigrating past Freeport would have to travel downstream over a distance of 50 miles or more to reach low salinity zone habitats, the bioenergetic and metabolic costs of moving short horizontal or vertical distances in the water column to avoid the most elevated temperatures within the plume, should such avoidance behavior occur, are considered negligible and not expected to adversely affect individual post-spawn delta smelt or the sustainability or recovery of the delta smelt population.

5.4.3 Potential for Increased Predation

5.4.3.1 Delta Smelt Larvae

The Service's Five-year Status Review for delta smelt (74 FR 12878) identifies three non-native species in the Delta with the potential to prey on delta smelt: (1) striped bass (*Morone saxatilis*), (2) largemouth bass (*Micropterus salmoides*), and (3) inland silversides (*Menidia beryllina*). Striped bass and largemouth bass are opportunistic predators with a diverse diet but would not likely eat larval delta smelt due to their relative small size. Bennett (2005) also identifies the introduced inland silversides as a potential competitor and predator of delta smelt. Inland silversides were first introduced into Delta waters in the 1970s and have increased significantly in numbers and distribution since that time. Because these fish forage in large numbers in shallow-water habitats of the Delta where delta smelt spawn seasonally, inland silversides may prey upon delta smelt eggs and larvae, if and when they co-occur with these delta smelt life stages. In aquarium studies, inland silversides readily prey upon delta smelt eggs and larvae (Bennett 2005); however, there is no documented evidence of inland silversides preying upon any delta smelt life stages in the wild and it is unknown if predation by any fishes occur on delta smelt larvae.

The thermal plume does not affect the shallow-water habitats used by inland silversides or other small fishes for foraging nor would it expect to increase the population of inland silversides and other small foraging fishes, and thus would not affect the potential rate of predation on larval delta smelt by such fishes. In addition, based on the results of six study elements, the Temperature Study (RBI 2013) concluded that the rate of predation on ESA-listed fish species, including delta smelt, at the SRWTP diffuser is not higher than elsewhere in the lower Sacramento River, upstream or downstream of the SRWTP diffuser. Available evidence indicates that the risk of predation on larval delta smelt as they pass the SRWTP outfall and continue to emigrate downstream is not elevated compared to other locations elsewhere in the river and, therefore, not is expected to adversely affect annual larval delta smelt recruitment or the sustainability or recovery of the delta smelt population.

5.4.3.2 Post-spawning Adults

The Temperature Study (RBI 2013) evaluated risk of predation near the SRWTP diffuser for Chinook salmon smolts by placing acoustic tags in 302 smolts and releasing them in four separate release groups at Sherwood Marina (9 miles upstream of the SRWTP diffuser) between April 18 and May 10, 2012. None of the 246 tagged fall-run Chinook salmon smolts that emigrated past the SRWTP diffuser were preyed upon within 250 ft upstream, at, or within 400 ft downstream of the SRWTP diffuser (i.e., within the acoustic array). The study concluded that the risk of predation on Chinook salmon smolts (and similar sized fishes) was no greater at the SRWTP diffuser location than elsewhere in the lower Sacramento River. In addition, stomach analyses of 97 predatory fish captured at the SRWTP diffuser as part of the Temperature study (RBI 2013) found no delta smelt were consumed by these predators. Based on these findings and other data from the Temperature Study (RBI 2013), available evidence indicates that the risk of predation for emigrating post-spawn adult delta smelt at the SRWTP diffuser is not elevated compared to other locations elsewhere in the lower Sacramento River. Thus, operation of the SRWTP under current Thermal Plan exceptions is not expected to affect the survival rate of emigrating post-spawn adults or adversely affect the sustainability or recovery of the delta smelt population.

5.4.4 Potential Effects on Prey and Food Web Dynamics

5.4.4.1 Delta Smelt Larvae

Nobriga (2002) examined the feeding ecology of larval delta smelt by conducting a gut contents analysis of nearly 1,500 larval delta smelt collected in the field during spring ichthyoplankton surveys conducted by CDFW from 1992-94. This researcher identified ontogenetic shifts in prey preference, with the smallest feeding larvae feeding primarily on subadult (i.e., nauplii) cyclopoid and calanoid copepods and other small zooplankters (e.g., harpacicoid and oithonid copepods, rotifers), while the larger (i.e., ≥ 13 mm) delta smelt larvae fed primarily on larger adult copepods. Because larval delta smelt feed primarily on the same zooplankton prey species as adult delta smelt, albeit subadults, the assessment of SRWTP's thermal effects on zooplankton in Section 5.2.4 is also applicable here. This assessment concluded that the SRWTP thermal plume does not adversely affect zooplankton drifting through the plume, based on the thermal tolerances of zooplankton determined from the scientific literature.

5.4.4.2 Post-spawning Adults

Like adult (pre-spawn) delta smelt, post-spawn adult delta smelt would be expected to feed primarily on adult planktonic copepods, cladocerans, amphipods (Bennett 2005; Moyle 2002), and may opportunistically feed on insect larvae (Moyle 2002). Therefore, the assessment in Section 5.2.4 is also applicable to post-spawn adults. This assessment concluded that the SRWTP thermal plume does not adversely affect zooplankton or insects drifting through the plume, based on their thermal tolerances determined from the scientific literature.

5.5 CRITICAL HABITAT

The Service has identified four critical habitat PCEs, physical habitat, water, river flow, and salinity, which are essential to the conservation of delta smelt. However, as discussed in Section 3.3, the SRWTP thermal discharge does not affect physical habitat, river flow, or salinity as defined above. Therefore, the SRWTP thermal discharge does not adversely modify critical habitat relative to these PCEs.

As also discussed in Section 3.3, the thermal discharge does affect the water PCE, specifically water temperature, for adult, larval, and post-spawn adult delta smelt. Juvenile delta smelt are highly unlikely to occur near the SRWTP diffuser at Freeport because larval delta smelt are transported downstream by river flows to the tidal low salinity zone of the Delta, where they rear as juveniles. Nevertheless, in the rare event that a juvenile delta smelt were to pass through the SRWTP's thermal plume, the thermal effects would be essentially equivalent to those discussed herein for larval and adult delta smelt (based on the thermal tolerance of the juvenile lifestage relative to that of the larval and adult lifestages). Due to the very low probability of occurrence of juvenile delta smelt in the Freeport reach of the lower Sacramento River, and the expected level of effect on juveniles should they be present, the SRWTP's thermal effect on the water PCE with regards to the juvenile lifestage would be discountable and insignificant.. Although listed under the "water" PCE, temperature is a physical parameter of aquatic habitats. As such, effects on river temperature from operating the SRWTP under the current Thermal Plan exception and associated NPDES permit temperature limitations is a form of physical habitat modification that has been assessed herein.

The description of far-field temperatures provided in Section 4.6 indicate that the SRWTP discharge may have a small effect on temperatures outside the zone of initial mixing during the months of January-July, with fully mixed temperature increases ranging from approximately 0.1 –1.5ºF on an hourly basis (Table 16), and typically being 0.5ºF or less. The temperature effects of the SRWTP discharge are small where the effluent initially becomes fully mixed with river flows (2-3 miles downstream of the SRWTP outfall) and further reduce in magnitude with increasing distance downstream. Fully mixed temperature increases are not of sufficient magnitude to adversely affect delta smelt utilization of the lower Sacramento River, western Delta, or Suisun Marsh. As such, far-field thermal effects of the SRWTP discharge would not eliminate from use any portion of designated critical habitat. Moreover, the frequency with which specified magnitudes of incremental temperature increases in the fully mixed river would occur would differ negligibly, if at all, when operating to Thermal Plan objective 5.A.(1)a versus operating to the exception to this objective during the January through April period of the year. Consequently, the small thermal effects in the far-field, miles downstream of the diffuser, are not of sufficient magnitude and geographic extent to to prohibit the delta smelt population from existing or recovering. The thermal effect of the SRWTP discharge on fully mixed lower Sacramento River, Delta, and Suisun Marsh water temperatures would not result in significant adverse effects throughout the species range or appreciably diminish the capability of the critical habitat to satisfy essential requirements of the species. Therefore, the small far-field thermal effects that do occur would not constitute adverse modification of critical habitat.

As discussed in Sections 5.2 and 5.4, the greatest thermal effect of the SRWTP discharge occurs in the near-field area close to the diffuser, and in the middle portion of the river channel. The magnitude of temperature increases within the SRWTP thermal plume at the surface and mid-channel is very low, even under the low-flow modeled scenarios, which rarely occur. Although temperatures can be substantially elevated, relative to ambient river background temperatures, near the diffuser on the river bottom, exposure of delta smelt to such elevated temperatures would be short in duration and would not cause lethality or chronic, adverse sublethal effects to any life stage. Thermal exposures under reverse-flow events also would not cause lethality or chronic, adverse sublethal effects to any life stage. Moreover, the near-field SRWTP thermal plume where the greatest thermal effects of the discharge occur is approximately 300 ft in width and approximately 1,000 ft or less in length (under most flow conditions), thus occupying a total area of approximately 300,000 ft^2. This area represents less than 0.22% of the total wetted area in the 44-mile reach of the lower Sacramento River between the I Street Bridge and Rio Vista, and less than 0.1% of designated critical habitat. The thermal plume that exists downstream of the SRWTP diffuser, when operating to the Thermal Plan exceptions and associated NPDES permit limitations, does not eliminate access to any of the four PCEs identified by the Service, nor does the existence of the thermal plume prevent the maintenance or recovery of the delta smelt population. The presence of the near-field thermal plume would not result in significant adverse effects throughout the species range or appreciably diminish the capability of the critical habitat to satisfy essential requirements of the species. Consequently, the near-field thermal plume that exists downstream of the SRWTP diffuser, when operating to the Thermal Plan exceptions and associated NPDES permit limitations, would not constitute adverse modification of delta smelt critical habitat.

6 CONCLUSIONS

The purpose of this addendum is to address the Service's December 2013 comment letter on the Thermal Study Report. Specifically, this addendum is intended to provide the Service with all necessary information and analyses in a format that will allow for a complete evaluation of the potential thermal effects on delta smelt from operating the SRWTP under the current Thermal Plan exceptions and associated NPDES temperature limitations, such that a determination can be made as to whether the Thermal Plan exceptions are protective of delta smelt.

This addendum, using information from the Temperature Study Report (RBI 2013) and new information presented and discussed herein (Komoroski 2013 and FSI 2014), assessed the potential direct and indirect effects of the SRWTP thermal discharge on all delta smelt life stages that have the potential to occur near the SRWTP diffuser and on delta smelt critical habitat. Based on the assessments in Section 5 of this addendum, the SRWTP thermal discharge, as operated under the current Thermal Plan exceptions, poses a negligible risk for direct or indirect effects to individual delta smelt. Thermal conditions within the SRWTP plume would not be acutely lethal to any life stage of delta smelt, even under minimum flow ratio conditions. Consequently, operation of the SRWTP under the current Thermal Plan exceptions and NPDES permit limitations would not cause lethality to individual delta smelt, result in chronic, adverse sublethal effects, adversely modify delta smelt critical habitat, prevent sustainability or recovery of the delta smelt population, or eliminate access to critical habitat PCEs. Therefore, as determined in the Temperature Study Report (RBI 2013) and this addendum, operation of the SRWTP to the current Thermal Plan exceptions and associated NPDES permit temperature limitations is protective of delta smelt and delta smelt critical habitat.

7 REFERENCES

7.1 LITERATURE CITED

Bennett, W. A. 2005. *Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California*. San Francisco Estuary and Watershed Science. California Bay-Delta Authority Science Program and John Muir Institute of the Environment.

Biro, P. A. 1998. “Staying Cool: Behavioral Thermoregulation during Summer by Young-of-Year Brook Trout in a Lake.” Transactions of the American Fisheries Society 127:212–222.

Brown, R.L. and W.J. Kimmerer. 2001. *Environmental and institutional background for CALFED’s Environmental Water Account*. CALFED Bay-Delta Program, Sacramento, California.

Burton, D. T., Richardson, L. B., Margrey, S. L. & Abell, P. R. 1976. Effects of low Delta T power plant temperature on estuarine invertebrates. Journal Water Pollution Control Fed., 48(10) 2259-72.

CDWR and Reclamation (California Department of Water Resources and U.S. Bureau of Reclamation). 1994. *Biological Assessment: Effects of the Central Valley Project and State Water Project on Delta Smelt and Sacramento Splittail*. Sacramento, CA: U.S. Fish and Wildlife Service, Ecological Services, Sacramento Field Office.

Cherry, D. S., K. L. Dickson, and J. Cairns Jr. 1975. “Temperatures Selected and Avoided by Fish at Various Acclimation Temperatures.” Journal of the Fisheries Research Board of Canada. 32:485–491.

Flow Science, Inc. 2015. Temperature differentials between SRWTP 60/181/410 mgd effluent plume and Sacramento River at 14:1 river-to-effluent flow ratio and 154 mgd effluent plume at 67:1 river-to-effluent ratio. Draft Technical Memorandum. February 9.

Goss, L. B., and D. L. Bunting. 1976. Thermal tolerance of zooplankton. Water Res. 10: 387–398.

Gray, R. H., R. G. Genoway, and S. A. Barraclough 1977. “Behavior of Juvenile Chinook Salmon (Oncorhynchus tshawytscha) in Relation to Simulated Thermal Effluent.” Transactions of the American Fisheries Society 106(4): 366–370.

Grimaldo, L.F., Sommer, T., Van Ark, N., Jones, G., Holland, E., Moyle, P., Herbold, B., and Smith, P., 2009, Factors affecting fish entrainment into massive water diversions in a tidal freshwater estuary: Can fish losses be managed?: North American Journal of Fisheries Management, v. 29, p. 1253–1270.

Hokanson, K. E. F., C. F. Kleiner, and T. W. Thorsland. 1977. Effects on constant temperature and diel fluctuation on growth, mortality, and yield of juvenile rainbow trout, Salmo gairdneri (Richard-son). Journal of the Fisheries Research Board of Canada 34:639-648.

Kivivuori, L. and E. Lahdes. 1996. How to measure the thermal death of Daphnia ? A comparison of different heat tests and effects of heat injury. Journal of Thermal Biology 21, 305–311.

Komoroske, L.M., R.E. Connon, J. Lindberg, B.S. Cheng, G. Castillo, M. Hasenbein, N.A. Fangue. 2014. Ontogeny influences sensitivity to climate change stressors in an endangered fish. Conservation Physiology 2: doi:10.1093/ conphys/cou008.

Lindberg, J., R. Mager, B. Baskerville-Bridges and S. Doroshov . 1997. Status of delta smelt culture project. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter 10:3:31-32.

Merz, J., S. Hamilton, P. Bergman, and B. Cavallo. 2011. Spatial perspective for delta smelt: a summary of contemporary survey data. Series: California Fish and Game, Vol. 4, Num. 97, Page(s): 164-189.

Moyle, P. B. 2002. *Inland Fishes of California.* Berkeley and Los Angeles, CA: University of California Press.

Nobriga M. 2002. Larval delta smelt composition and feeding incidence: environmental and ontogenetic influences. Cal Fish Game 88:149-164.

Pennak, R. W. 1978. Freshwater Invertebrates of United States. First edition. New York, NY: John Wiley and Sons, Inc.

RBI (Robertson-Bryan, Inc). 2011. *Work Plan - Temperature Study To Assess the Thermal Impacts of the Sacramento Regional Wastewater Treatment Plant*. Prepared in association with HTI, Flow Science, and Larry Walker Associates for the Regional Water Quality Control Board, Central Valley Region, on behalf of the Sacramento Regional County Sanitation District. June.

RBI (Robertson-Bryan, Inc). 2013. *Temperature Study to Assess the Thermal Impacts of the Sacramento Regional Wastewater Treatment Plant Discharge on Aquatic Life of the Lower Sacramento River*. Prepared in association with Flow Science for the Regional Water Quality Control Board, Central Valley Region, on behalf of the Sacramento Regional County Sanitation District. March.

Schubel, J.R. 1975. Some comments on the thermal effect of power plants on fish eggs and larvae, In Fisheries and Energy Production: A Symposium (S.B. Saila, Ed.), pp 31-54. P.C. Health, Lexington, Mass.

Sommer, T., M. Nobriga, L. Grimaldo, F. Feyrer, F. Mejia. 2011. The spawning migration of delta smelt in the upper San Francisco Estuary. San Francisco Estuary and Watershed Science (9)2 http://escholarship.org/uc/item/86m0g5sz.

Stelzer, P. C. 1998. "Population Growth in Planktonic Rotifers. Does Temperature Shift the Competitive Advantage for Different Species?" Hydrobiologia 387/388: 349–353.

Swanson, C., and J. J. Cech. 1995. “Temperature and Salinity Tolerances of Delta Smelt.” *Interagency Ecological Studies Program for the Sacramento–San Joaquin Estuary Newsletter.* Autumn.

Swanson, C, Young, PS, Cech, JJ, Jr. 1998. Swimming performance of delta smelt: maximum performance, and behavioral and kinematic limitations on swimming at submaximal velocities. Journal of Experimental Biology 201:333-345.

Swanson, C., T. Reid, P. S. Young, and J. J. Cech, Jr. 2000. “Comparative Environmental Tolerances of Threatened Delta Smelt (*Hypomesus transpacificus*) and Introduced Wakasagi (*H. nipponensis*) in an Altered California Estuary.” *Oecologia* 123:384–390.

Thorp, J. H., and A. P. Covich. 1991. “An Overview of Freshwater Habitats.” In Ecology and Classification of North American Freshwater Invertebrates, edited by J. H. Thorp and A. P. Covich, pp. 17□36. New York, NY: Harcourt Brace Jovanovich.

USFWS (U.S. Fish and Wildlife Service). 2008. *Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP).* Reference no. 81420-2008-F-1481-5. Prepared for the U.S. Bureau of Reclamation, Central Valley Operations Office, Sacramento, CA.

Wang, J. 1986. *Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories.* Interagency Ecological Program Technical Report #9. January.

Wood, J. R., E. P. McElravy, and V. H. Resh. 1996. “Thermal-Shock Tolerance of Three Species of Aquatic Insects in a Northern California Geothermally Influenced Stream.” The Pan-Pacific Entomologist 72(4): 227-235.

7.2 Personal Communications

Zweig, L. 2015. Biologist, USFWS. Sacramento, CA. January — meeting with David Thomas and Keith Whitener of RBI regarding the delta smelt addendum and lack of thermal tolerance information relevant to the types of exposure that occur at the SRWTP outfall.

Appendix A

MARCH 14, 2012 USFWS LETTER TO REGIONAL WATER BOARD

Appendix B

SACRAMENTO RIVER-SRWTP EFFLUENT-RIVER TEMPERATURE DIFFERENCE PLOTS

Appendix C

DISTRIBUTION OF HOURLY EFFLUENT-RIVER TEMPERATURE DIFFERENTIALS

Appendix D

TEMPERATURE DIFFERENTIALS TECHNICAL MEMORANDUM

Appendix E

MEDIAN FLOW RATIO SRWTP THERMAL PLUME EXPOSURE SCENARIOS

Appendix F

MINIMUM FLOW RATIO SRWTP THERMAL PLUME EXPOSURE SCENARIOS

Appendix A

MARCH 14, 2012, USFWS LETTER REGIONAL WATER BOARD

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United States Department of the Interior
FISH AND WILDLIFE SERVICE
San Francisco Bay-Delta Fish and Wildlife Office
650 Capitol Mall, Suite 8-300
Sacramento, California 95814

U.S. FISH & WILDLIFE SERVICE

Mr. James Marshall
Regional Water Quality Control Board, Central Valley Region
1120 Sun Center Drive, #200
Rancho Cordova, California 95670-6114

Subject: Comments on the Thermal Study for Sacramento Regional Wastewater Treatment Plant, Sacramento County, California

Dear Mr. Marshall:

This letter provides the U.S. Fish and Wildlife Service's (Service) comments on the March 2013, *Temperature Study to Assess the Thermal Impacts of the Sacramento Regional Wastewater Treatment Plant Discharge on Aquatic Life of the Lower Sacramento River* (Thermal Study), prepared by Robertson-Bryan, Inc. At your request, our office reviewed the Thermal Study with an emphasis on the effects of any California State Thermal Plan (Thermal Plan) exception on delta smelt (*Hypomesus transpacificus*). Service staff have worked with the Sacramento Regional Sanitation District (District) and the Central Valley Regional Water Quality Control Board (Regional Board) in the development of the Thermal Study since early 2011.

Background
The District operates the Sacramento Regional Wastewater Treatment Plant (WWTP) which discharges secondary-treated municipal sewage into the Sacramento River near Freeport. The Thermal Study, required by the facility's 2010 National Pollutant Discharge Elimination System (NPDES) permit, was conducted to evaluate both the existing Thermal Plan exception and any proposed request for new exceptions.

The 2010 NPDES permit requires substantial sewage treatment upgrades to be implemented by 2020. The final upgraded treatment design has not been finalized so its associated temperature regime remains uncertain. It is the understanding of the Service that due to that uncertainty, the Thermal Study does not assess whether in-river conditions would be protective of aquatic life beneficial uses under the proposed Thermal Plan exceptions. The Service understands that such assessment of proposed exceptions will be conducted at a later date once treatment design is complete.

The lower Sacramento River including the WWTP outfall site is within the designated critical habitat for five federally-listed fish species including winter- and spring-run Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), delta smelt and green sturgeon (*Acipenser* *medirostris)*. Our comments in this letter will focus on the Thermal Study with emphasis on delta smelt.

Species Information

Description and Taxonomy

Delta smelt are slender-bodied fish, generally about 60 to 70 millimeters (mm) (2 to 3 inches (in)) long, although they may reach lengths of up to 120 mm (4.7 in) (Moyle 2002). Delta smelt are in the Osmeridae family (smelts) (Stanley et al. 1995). Live fish are nearly translucent and have a steely blue sheen to their sides (Moyle 2002). Delta smelt feed primarily on small planktonic (free-floating) crustaceans, and occasionally on insect larvae (Moyle 2002). Delta smelt usually aggregate into loose schools, but their discontinuous stroke-and-glide swimming behavior likely makes schooling difficult (Moyle 2002).

The delta smelt is one of six species currently recognized in the genus *Hypomesus* (Bennett 2005). Within the genus, delta smelt is most closely related to surf smelt (*H. pretiosis*), a marine species common along the western coast of North America. Delta smelt is primarily an annual species.

Distribution and Abundance

Delta smelt are endemic to (native and restricted to) the San Francisco Bay and Sacramento–San Joaquin Delta Estuary (Bay-Delta) in California, found only from the San Pablo Bay upstream through the Delta in Contra Costa, Sacramento, San Joaquin, Solano, and Yolo Counties (Moyle 2002). Their historical range is thought to have extended from San Pablo Bay upstream to at least the city of Sacramento on the Sacramento River and Mossdale on the San Joaquin River. They were once one of the most common pelagic (living in open water away from the bottom) fish in the upper Sacramento–San Joaquin Estuary (Moyle 2002). Due to its small size and current rarity, population estimates have not been obtained for this species. Several relative abundance indices have been developed using various net surveys as well as counts of individuals entrained by (drawn into) Federal and State water export facilities (Bennett 2005), and population assessments have been based on abundance index trends. Based on those indices, significant declines in delta smelt abundance occurred in 1975-76, 1980-81, and 1998-99 (Manly and Chotkowski 2006). The 1980-1981 abundance index decline was one of the factors that resulted in listing delta smelt as a threatened species in 1993 (58 FR 12854; Moyle 2002; California Department of Fish and Game (CDFG) 2008). With the exception of 2011, relative abundance has been very low since 2002.

Habitat and Life History as it pertains to the WWTP

Delta smelt are a euryhaline (tolerate a wide range of salinities) species; however, they rarely occur in water with more than 10-12 parts per thousand salinity (about one-third seawater). During the winter, adult Delta smelt disperse throughout the estuary to spawn. Most spawners are collected in Suisun Marsh and the Cache Slough region (http://www.dfg.ca.gov/delta/data/skt/DisplayMaps.asp); however, some fish do ascend the Sacramento River into the vicinity of the WWTP (Merz et al. 2011). Spawning can occur from late January through late June or early July, but most spawning occurs between March and May. Under laboratory conditions, eggs typically hatch after 9 to 14 days and larvae begin feeding 5 to

6 days later (Mager et al. 2004, Table 1). Larvae are generally most abundant in the Delta from mid-April through May (Bennett 2005). After hatching, Delta smelt larvae rear for some time in tidal freshwater habitats, but many individuals move into the estuary's "low salinity zone" as they grow (Dege and Brown 2004). Feyrer at al. (2007) found that relative abundance of delta smelt was related to fall salinity and turbidity (water clarity). Delta smelt probably evolved within the naturally turbid (silt and particulate-laden) environment of the Delta and likely rely on certain levels of background turbidity at different life stages and for certain behaviors. Laboratory studies found that delta smelt larval feeding increased with increased turbidity (Baskerville-Bridges et al. 2004).

Comments on the March 2013 Temperature Study

The final report of the temperature study is generally complete and is mostly consistent with the Work Plan developed with stakeholders that was completed in June 2011. There are, however, a few omissions in the study which prevent the Service from fully evaluating the thermal effects of the facility on delta smelt. The Service offers the following comments and recommendations.

<u>Chapter 3. Study Element 1-Delta smelt</u>

The intent of this Study Element was to compare existing, current knowledge of fish temperature tolerances for nine fish species, including four runs of Chinook salmon, to existing thermal plume conditions. As currently written this element is insufficient in its evaluation for delta smelt in several ways.

First, the context of the analysis of the effects of the thermal plume on the species is not appropriate. The delta smelt analysis in Study Element 1 included an evaluation of the presence and frequency of occurrence of delta smelt in the Sacramento River near Freeport. As the species is imperiled and its population size has been declining overall, a concomitant decline in the Sacramento River surveys is to be expected. Additionally, the WWTP thermal discharge is within designated critical habitat and thus its effects on delta smelt and critical habitat should be considered independent of recent local survey results. Delta smelt critical habitat includes the legal Delta north along the Sacramento River up to the I Street Bridge (http://ecos.fws.gov/docs/federal_register/fr2751.pdf). The critical habitat for delta smelt is the portion of the historical range which has been identified as essential to the conservation of the species. In addition, critical habitat for delta smelt must also include the necessary Primary Constituent Elements (PCEs); physical habitat, water, river flow, and salinity concentrations. Criteria for these PCEs vary depending on the delta smelt life history stage (Table 1). The Sacramento River near Freeport is within the critical habitat and all of the PCEs for spawning habitat, larval/juvenile transport and adult migration are present. The Service recommends that conditions within the Sacramento River critical habitat be protective of the PCEs for delta smelt in the adult, egg, and larval life stages.

Second, the evaluation of thermal effects does not consider the imperiled status of the species and the vulnerability of the life stage(s) present near the WWTP. Delta smelt in the proximity of the thermal plume could include vulnerable eggs or larvae as well as adults migrating upstream, having expended energy reserves migrating upstream and in developing gonads. Delta smelt have been characterized as "poor swimmers" (Moyle 2002). In actuality, they have swimming speeds that are similar to other small fishes (Swanson et al. 1998) and they can use tidal currents to effectively disperse throughout the Delta even during high spring outflows (Sommer et al. 2011). The Thermal Study states that:

"…under no circumstances would immigrating adult delta smelt be expected to swim into the areas of high discharge velocity where the highest temperatures associated with the SRWTP diffuser and thermal plume occur and, therefore, would not be adversely affected by elevated temperatures in the plume" (p. 42).

Table 1. Delta smelt Critical Habitat PCEs relevant for evaluating the effects of thermal discharge to lower Sacramento River.

Primary Constituent Element	Spawning Habitat	Larval/Juvenile Transport	Rearing Habitat	Adult Migration
Physical Habitat -structural components, e.g., substrate				
Water -of suitable quality, e.g., temperature, turbidity, food availability, entrainment risk, contaminants				
River Flow -transport, i.e., facilitate spawning migration and juvenile emigration, and minimize vulnerability to entrainment				
Salinity Concentrations -location of LSZ (0.5 – 6.0 psu) nursery habitat quality and quantity				

This above statement is not entirely accurate. Delta smelt are not demersal but pelagic, and though unlikely to be present near the diffuser at the bottom of the river, during low or reverse flows could be in the center of the channel and/or water column and thus be exposed to elevated temperatures. Although the Thermal Study is accurate in stating that fish are most likely to seek preferential temperatures, it ignores the metabolic and ecological consequences of such avoidance. As stated in the Thermal Study, delta smelt have been observed to survive in 82.4°F but the prior acclimation temperature of migrating fish, the physical conditions of spawning adults and life history stage suggest that temperature exposure at that extreme is highly undesirable. Thermal discharges resulting in river conditions of 82.4°F would not be protective of migrating delta smelt and would result in sublethal and possibly even lethal effects to individual delta smelt.

Thirdly, the level of analysis of the effect on individual delta smelt is not appropriate. The Service's recommendations to the Regional Board on current or future thermal exceptions would focus on ensuring conditions in the proximity of the outfall resulting from the discharge were protective of delta smelt. Thus the intent would be to prevent or minimize the "take" of delta smelt. The Endangered Species Act definition of "take" includes harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct. "Harm" is defined by the Service to include significant habitat modification impairing behavior patterns such as breeding, feeding, or sheltering. "Harass" is defined by the Service as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns including but not limited to breeding, feeding or sheltering. Thus the Service's level of concern is at evaluating "take" in a context beyond causing mortality and the analysis should address effects at such a level.

And finally, the analysis of this critical element did not include important comparisons of the fish thermal tolerances to temperatures observed in the thermal plume under various conditions within Study Element 1. This analysis is needed to answer Study Question 1 which seeks to determine if biota swimming or drifting past the diffuser would experience thermal exposures that would exceed lethal or sublethal thresholds. Some temperature conditions are evaluated in Study Element 2 which considers blockage of migration past the diffuser from reverse-flow but fully mixed river temperature conditions. Study Element 2 focuses on evaluating conditions believed to block Chinook salmon migration which include dissolved oxygen concentrations of less than 5 mg/L and temperatures greater than 66°F. These conditions may or may not be appropriate for analysis for delta smelt. Study Element 1 references several thresholds in addition to Critical Thermal Maxima (CTM) which may be appropriate to evaluate against thermal plume data. For example, monitoring studies indicate that delta smelt are most abundant in water temperatures less than 72 °F (Bennet 2005). Spawning success is limited to temperatures between 59 and 68 °F in aquaculture conditions, but the window of spawning success in the wild is likely 57-64 °F (Bennett 2005). How do absolute temperatures produced by the diffuser compare to these thresholds during various winter-spring river conditions, during fully mixed river conditions and reverse-flow events?

As a result of the issues discussed above, the Service is unable to fully evaluate the effects of the thermal plume on delta smelt or concur with the conclusions of SE1-1 (p. 55) in the Summary of Findings for Study Element 1 which states that "current operations would not cause acute lethality or sub-lethal adverse effects on special-status fish species, phytoplankton, or zooplankton passing through the plume at any time of year." The Service offers several ideas below to remedy this problem.

Recommendations

The Service recommends that the District modify the current study or provide additional analyses which presumes delta smelt migrating adults, and their eggs and larvae are present in the Sacramento River adjacent to the diffuser and provide an analysis on the effects to critical habitat PCEs. Compare relevant thermal conditions within the plume and river under reverse-flow events and fully mixed conditions (including temperature differentials and absolute temperatures) to delta smelt's thermal optima and tolerances. The information and temperature data needed to conduct this analysis exist in the Thermal Study in Study Element 2, Appendix A and the previous thermal plume analysis.

We appreciate the opportunity to comment on the Thermal Study for the WWTP. If you have any questions or comments about this letter, please contact Leanna Zweig, Fish and Wildlife Biologist, of my staff at (916) 930-5631.

Sincerely,

Michael Chotkowski
Field Supervisor

Literature Cited

Baskerville-Bridges, B., J. C. Lindberg and S. I. Doroshov. 2004. The effect of light intensity, algal concentration, and prey density on the feeding behavior of delta smelt larvae. Pages 445-496 *In* Fred Feyer et al., eds. Early life history of fishes in the San Francisco Estuary and watershed. American Fisheries Society Symposium 39. Bethesda, MD.

Bennett, W. A. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science 3. http://escholarship.org/uc/item/0725n5vk

CDFG (California Department of Fish and Game). 2011. Delta smelt abundance indices from 1967–2011. Retrieved from http://www.dfg.ca.gov/delta/data/fmwt/Indices/sld002.asp

Dege, M., L. R. Brown. 2004. Effect of Outflow on Spring and Summertime Distribution and Abundance of Larval and Juvenile Fishes in the Upper San Francisco Estuary. American Fisheries Society Symposium 39:49-65.

Feyrer, F., M. L. Nobriga and T. R. Sommer. 2007. Multi-decadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fisheries and Aquatic Sciences 64:723-734.

Manly, B. F. J. and M. Chotkowski. 2006. Two new methods for Regime Change Analysis. Archive fur Hydrobiologie 167(1-4):593-607.

Mager, R. C., S.I. Doroshov, J.P. Van Eenennaam and R.L. Brown. 2004. Early life stages of delta smelt. Pages 169-180 *In* F. Feyrer et al., eds. Early life history of fishes in the San Francisco Estuary and watershed. American Fisheries Society Symposium 39, Bethesda, MD, USA.

Merz, J. S. Hamilton, P. Bergman and B. Cavallo. 2011. Spatial perspective for delta smelt: a summary of contemporary survey data. Series: California Fish and Game 4(97):164-189.

Moyle, P. B. 2002. Inland fishes of California. University of California Press, Berkeley and Los Angeles, California.

Nobriga, M. 2002. Larval Delta Smelt Diet Composition and Feeding Incidence: Environmental and Ontogenetic Influences. California Fish and Game 88(4):149-164 2002.

Sommer, T., F. H. Mejia, M. L. Nobriga, F. Feyrer, L. Grimaldo. 2011. The spawning migration of 19 delta smelt in the Upper San Francisco Estuary. San Francisco Estuary and Watershed Science 20:9(2). http://escholarship.org/uc/item/86m0g5sz

Stanley, S. E, P.B. Moyle and H.B. Shaffer. 1995. Allozyme Analysis of Delta Smelt, *Hypomesus transpacificus* and Longfin Smelt, *Spirinchus thaleichthys* in the Sacramento-San Joaquin Estuary, California. Copeia 1995(2):390-396.

Swanson, C. P. S. Young and J. J. Cech. 1998. Swimming performance of delta smelt: maximum performance, and behavior and kinematic limitations on swimming at submaximal velocities. Journal of Experimental Biology 201:333-345. http://jeb.biologists.org/content/201/3/333.full.pdf

Wang, J. C. S. 1991. Early life stages and early life history of the delta smelt, *Hypomesus transpacificus,* in the Sacramento-San Joaquin Estuary, with comparison of early life stages of the longfin smelt, *Spirinchus thaleichthys.* Interagency Ecological Studies Program Technical Report 28, August 1991.

Appendix B

SACRAMENTO RIVER - SRWTP EFFLUENT-RIVER TEMPERATURE DIFFERENCE PLOTS

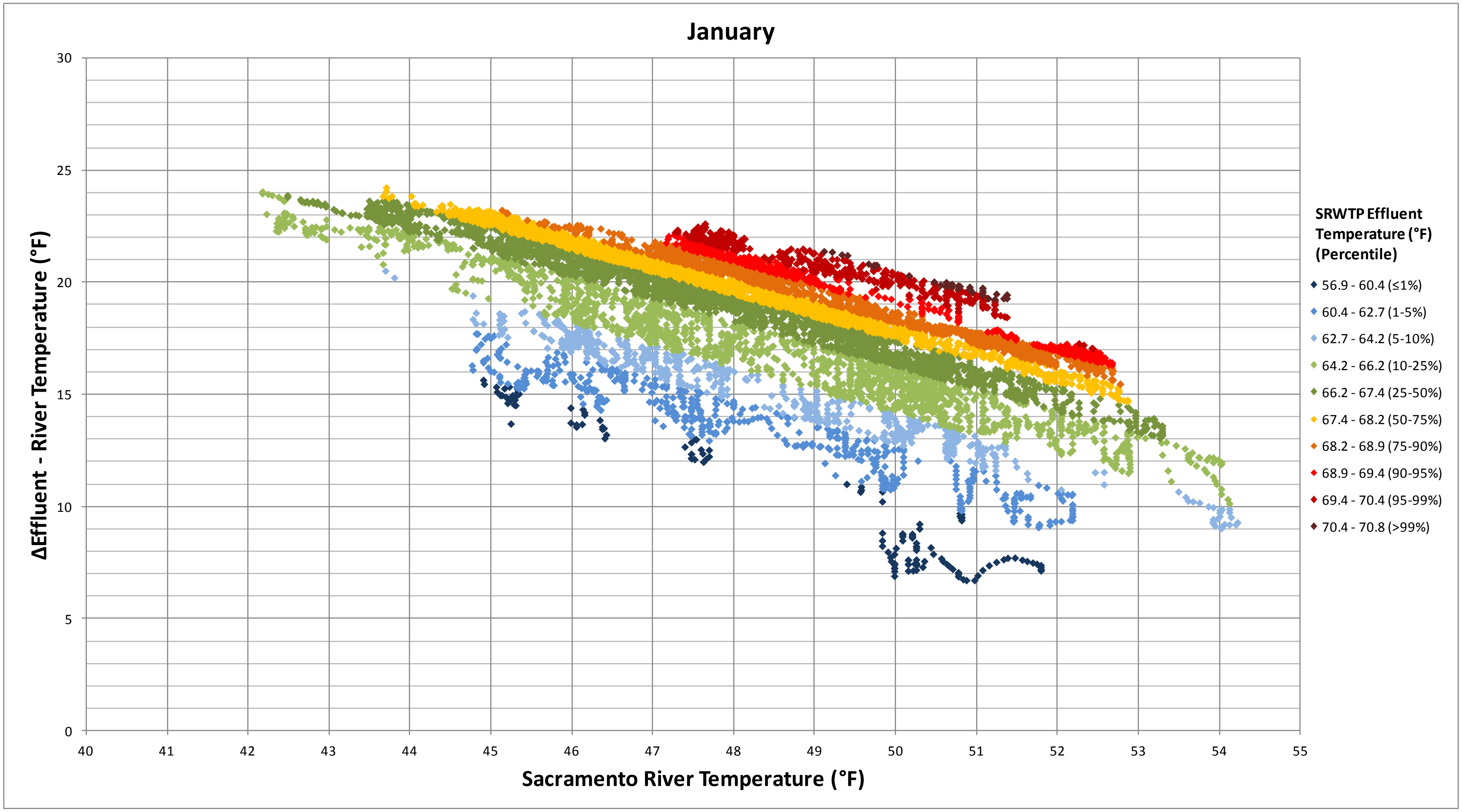

Figure B-1. Relationship between January Sacramento River background temperatures and the difference between SRWTP effluent and background river temperatures for the period of record February 1992 through September 2012. Colors represent the range of SRWTP effluent temperatures by percentiles (in parentheses).

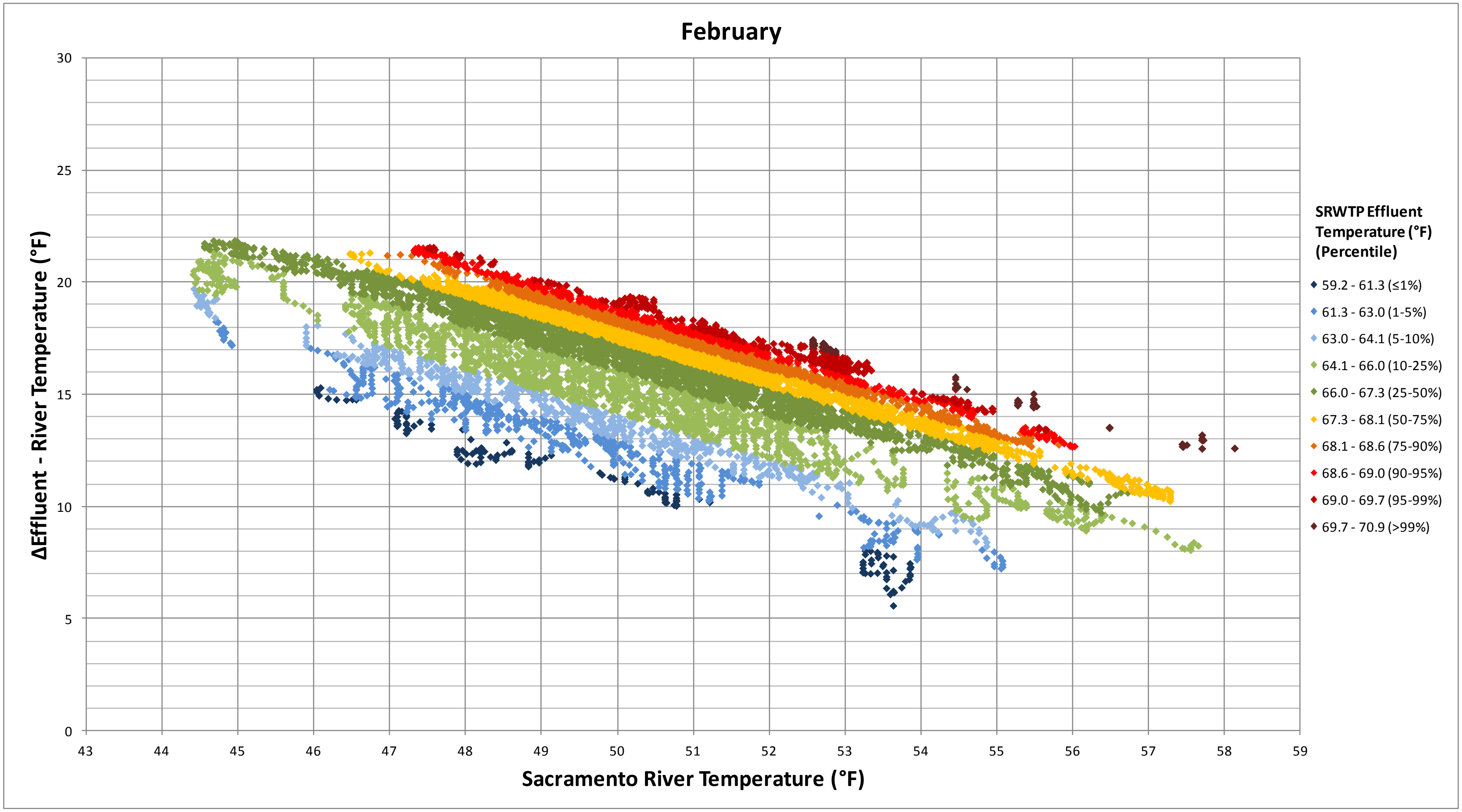

Figure B-2. Relationship between February Sacramento River background temperatures and the difference between SRWTP effluent and background river temperatures for the period of record February 1992 through September 2012. Colors represent the range of SRWTP effluent temperatures by percentiles (in parentheses).

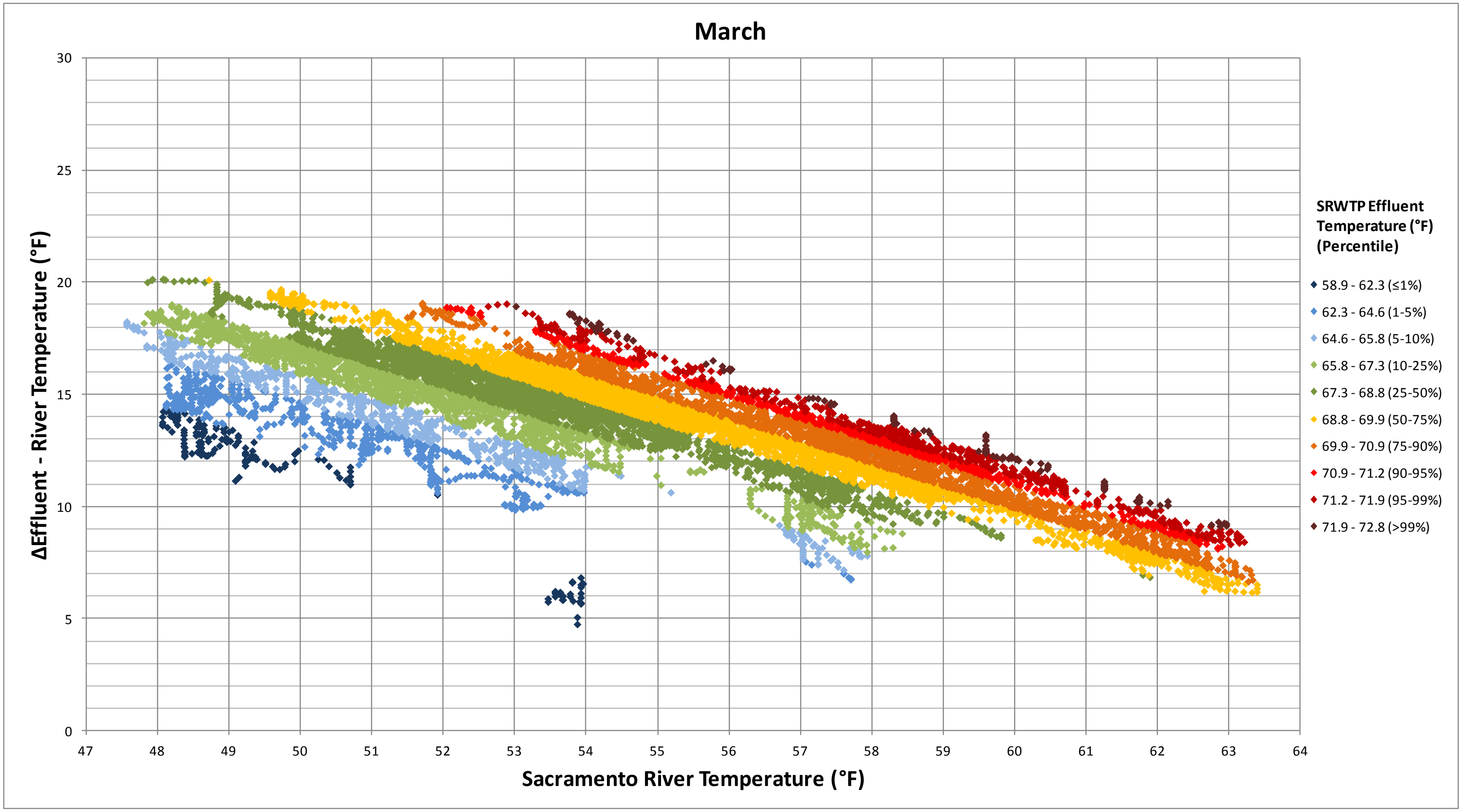

Figure B-3. Relationship between March Sacramento River background temperatures and the difference between SRWTP effluent and background river temperatures for the period of record February 1992 through September 2012. Colors represent the range of SRWTP effluent temperatures by percentiles (in parentheses).

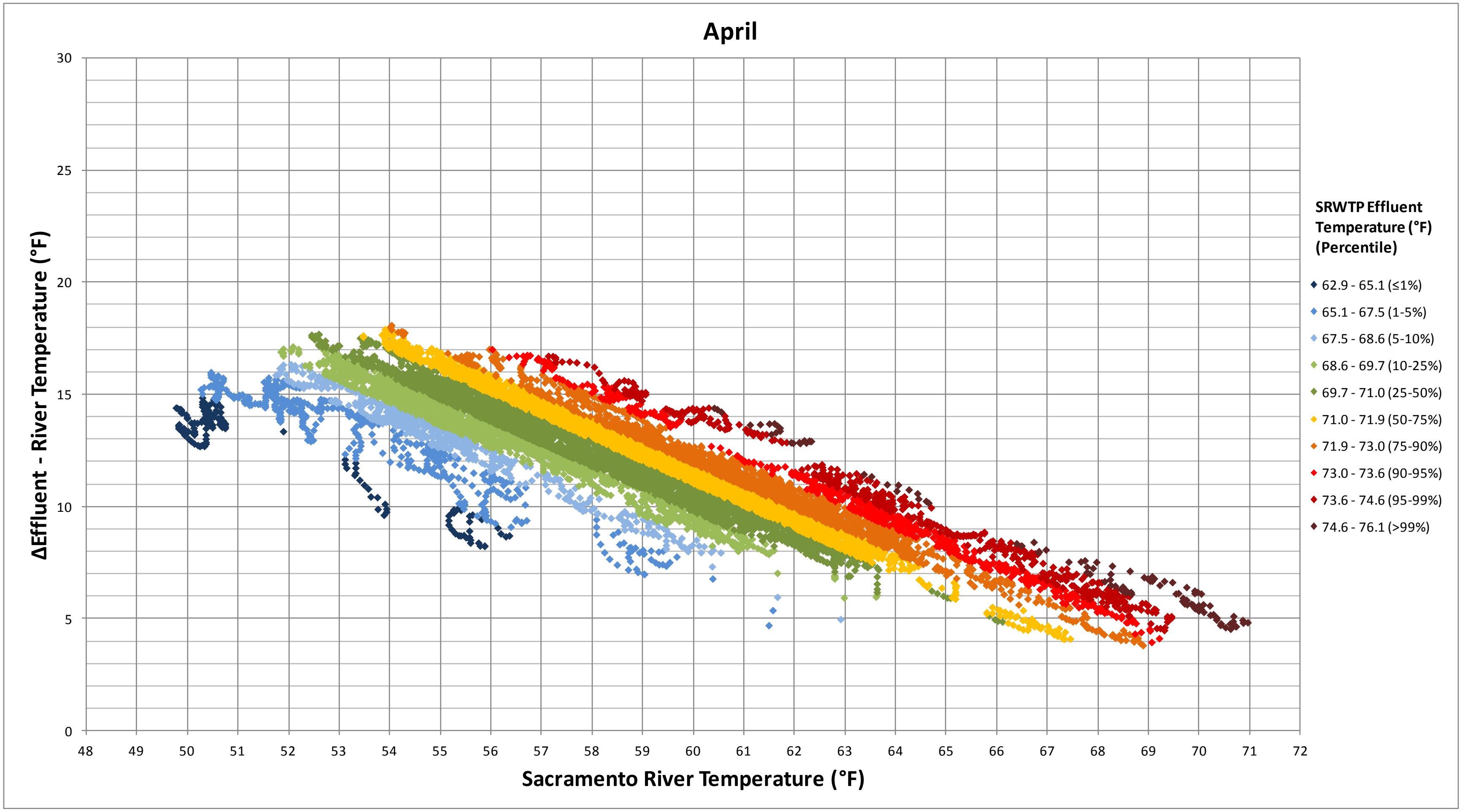

Figure B-4. Relationship between April Sacramento River background temperatures and the difference between SRWTP effluent and background river temperatures for the period of record February 1992 through September 2012. Colors represent the range of SRWTP effluent temperatures by percentiles (in parentheses).

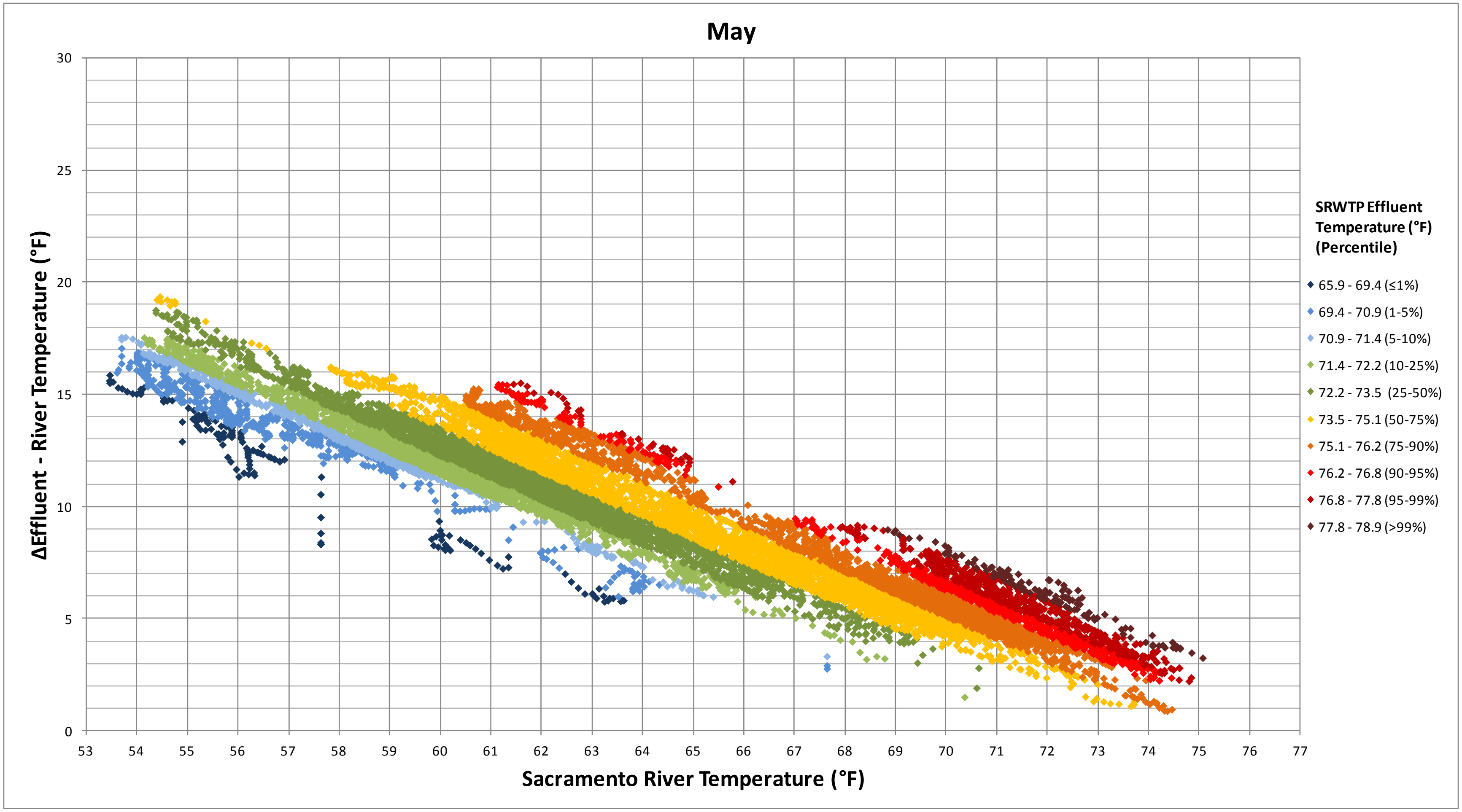

Figure B-5. Relationship between May Sacramento River background temperatures and the difference between SRWTP effluent and background river temperatures for the period of record February 1992 through September 2012. Colors represent the range of SRWTP effluent temperatures by percentiles (in parentheses).

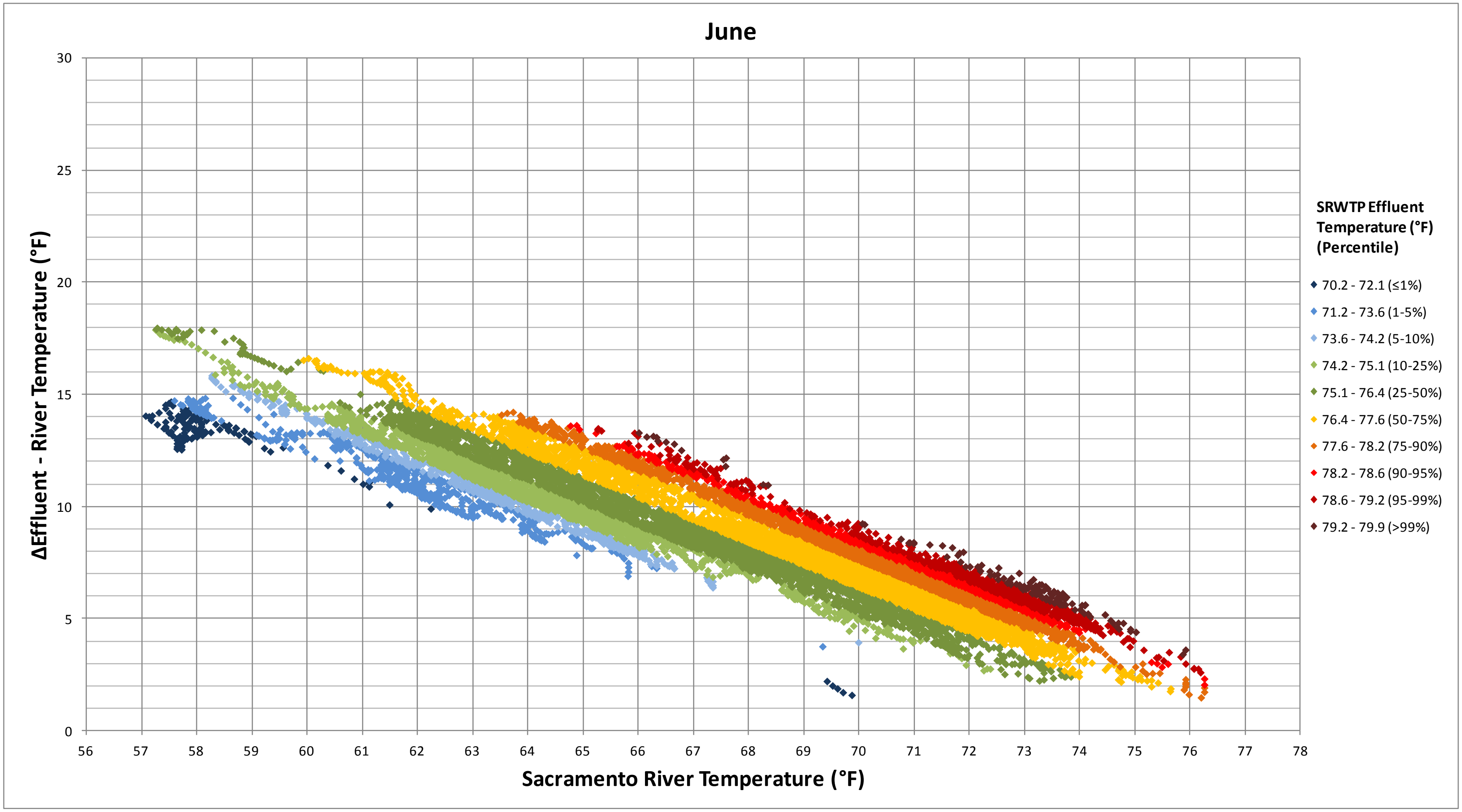

Figure B-6. Relationship between June Sacramento River background temperatures and the difference between SRWTP effluent and background river temperatures for the period of record February 1992 through September 2012. Colors represent the range of SRWTP effluent temperatures by percentiles (in parentheses).

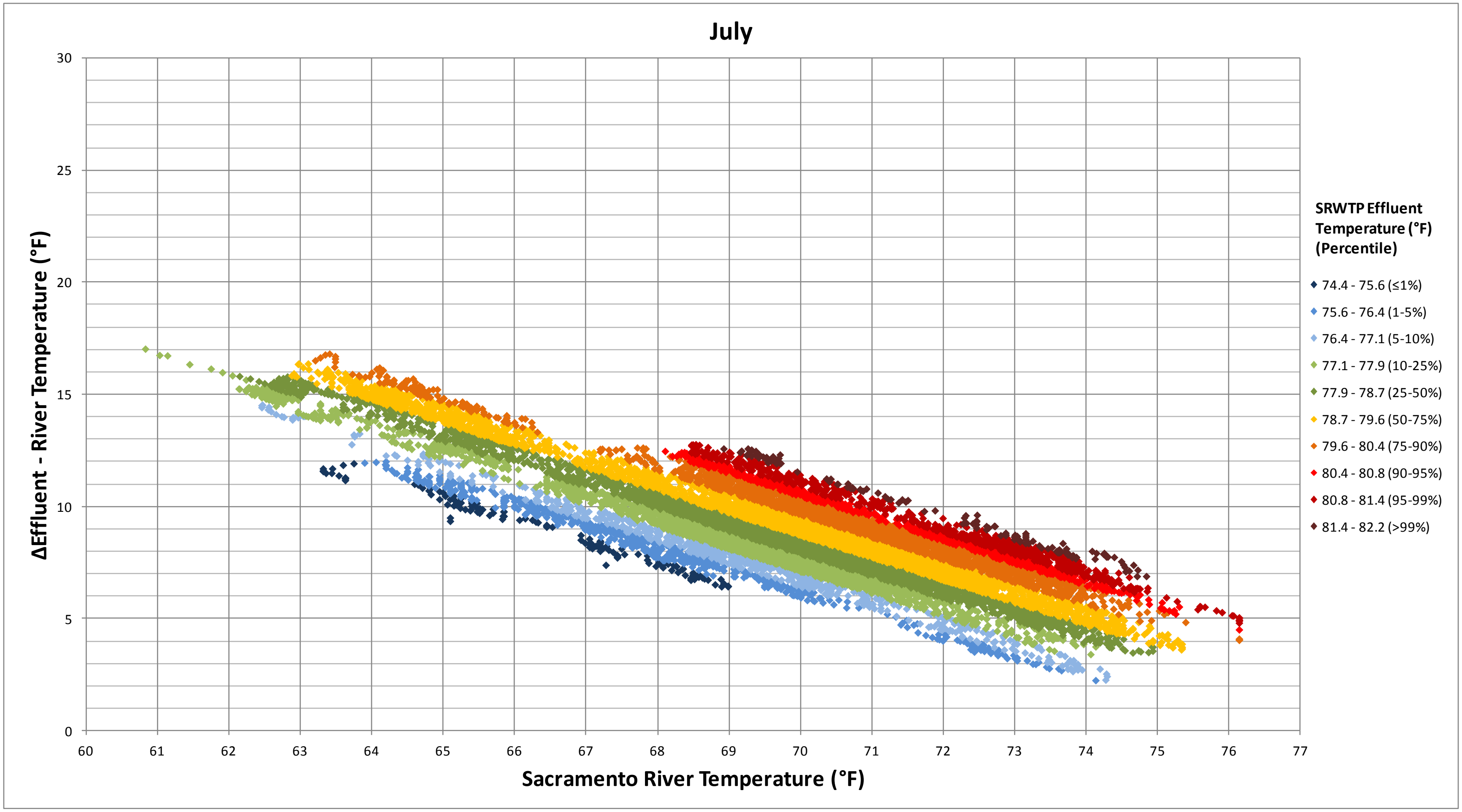

Figure B-7. Relationship between July Sacramento River background temperatures and the difference between SRWTP effluent and background river temperatures for the period of record February 1992 through September 2012. Colors represent the range of SRWTP effluent temperatures by percentiles (in parentheses).

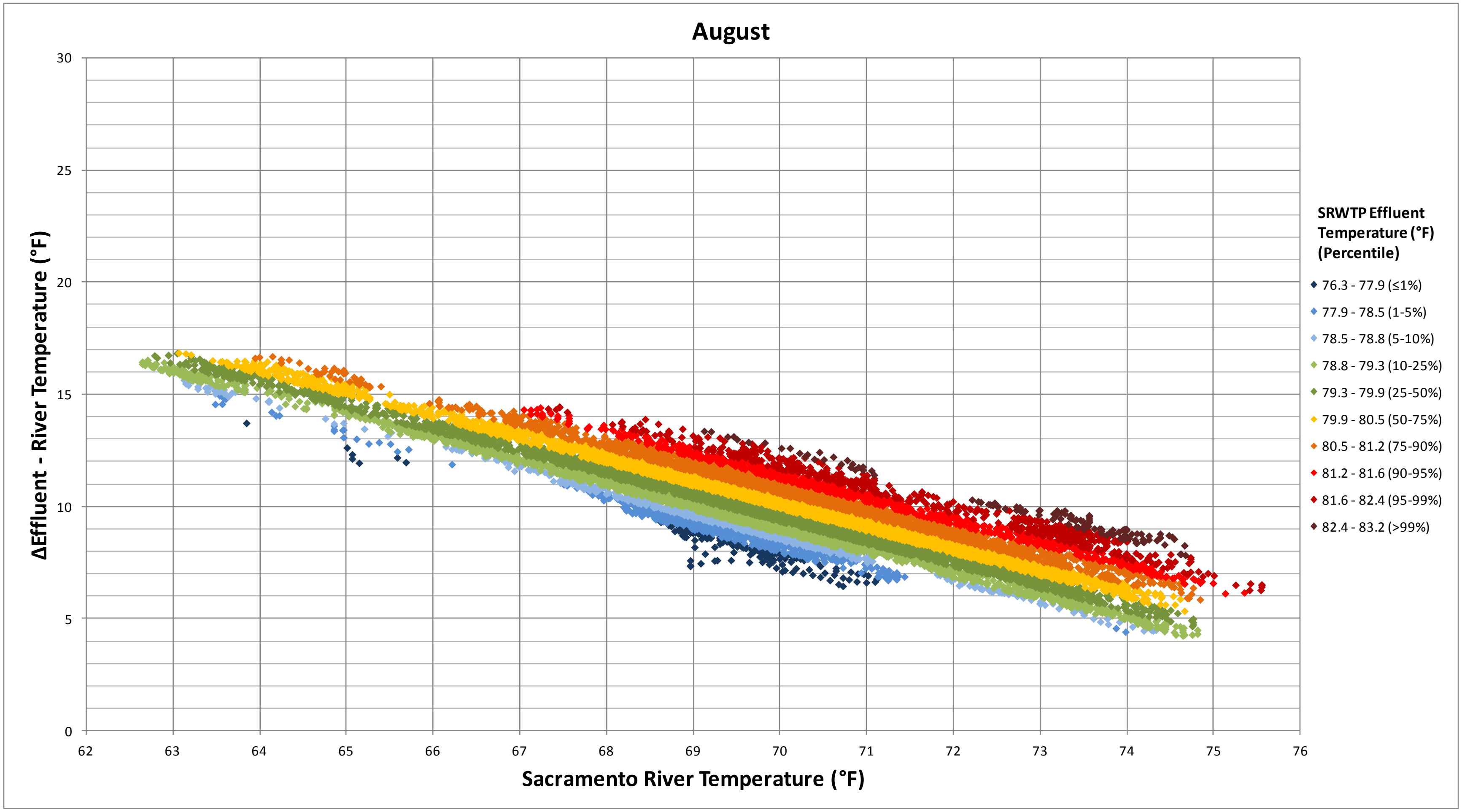

Figure B-8. Relationship between August Sacramento River background temperatures and the difference between SRWTP effluent and background river temperatures for the period of record February 1992 through September 2012. Colors represent the range of SRWTP effluent temperatures by percentiles (in parentheses).

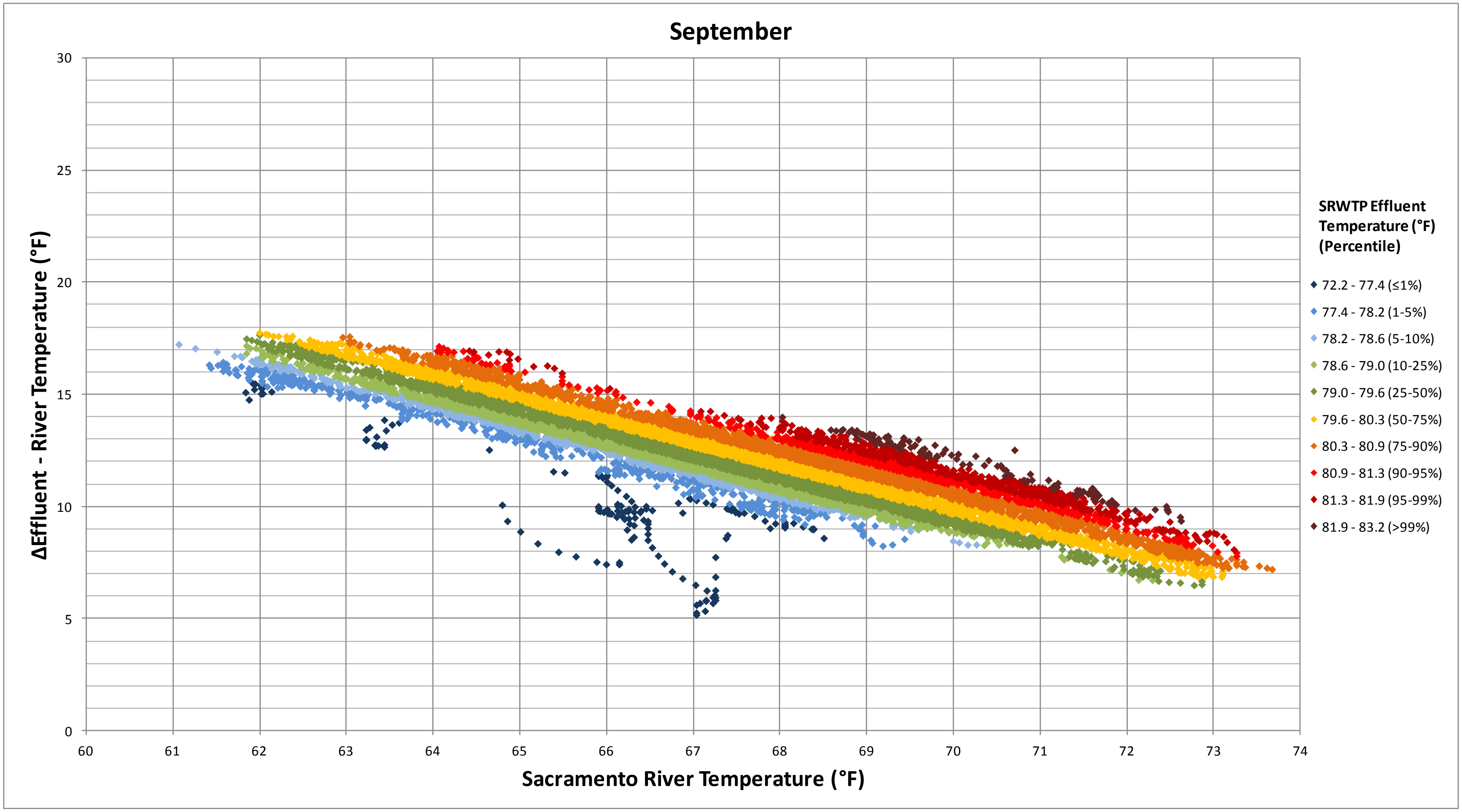

Figure B-9. Relationship between September Sacramento River background temperatures and the difference between SRWTP effluent and background river temperatures for the period of record February 1992 through September 2012. Colors represent the range of SRWTP effluent temperatures by percentiles (in parentheses).

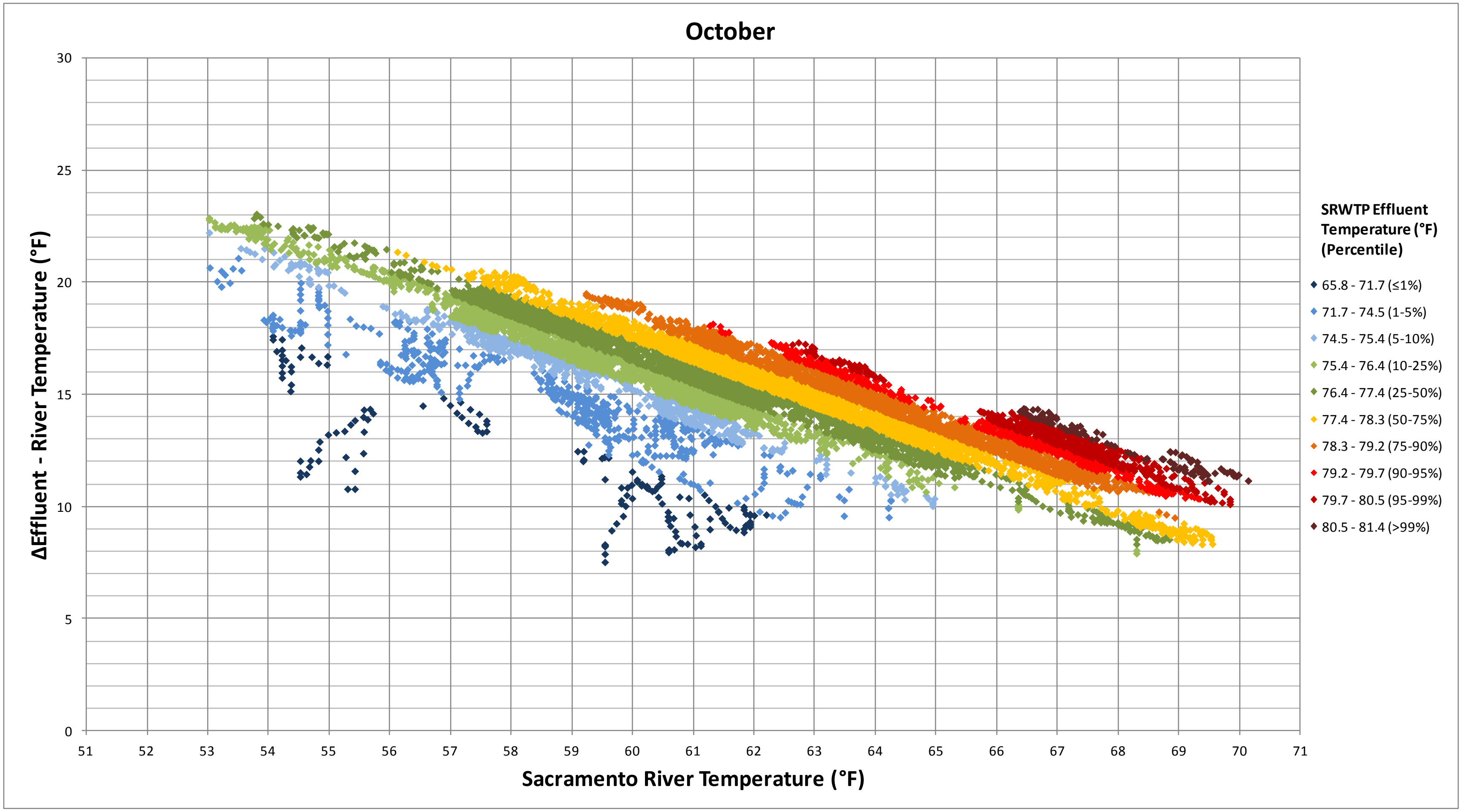

Figure B-10. Relationship between October Sacramento River background temperatures and the difference between SRWTP effluent and background river temperatures for the period of record February 1992 through September 2012. Colors represent the range of SRWTP effluent temperatures by percentiles (in parentheses).

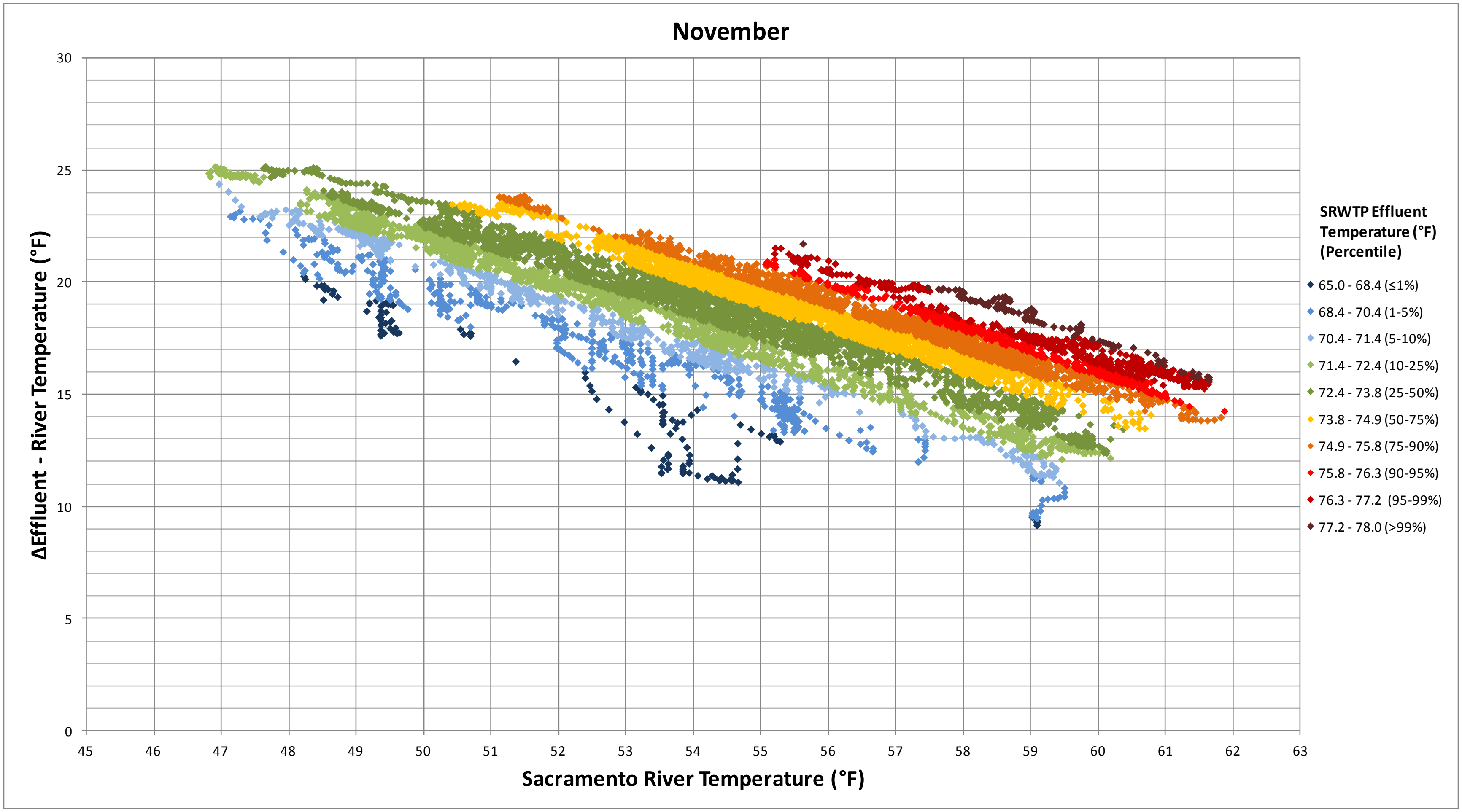

Figure B-11. Relationship between November Sacramento River background temperatures and the difference between SRWTP effluent and background river temperatures for the period of record February 1992 through September 2012. Colors represent the range of SRWTP effluent temperatures by percentiles (in parentheses).

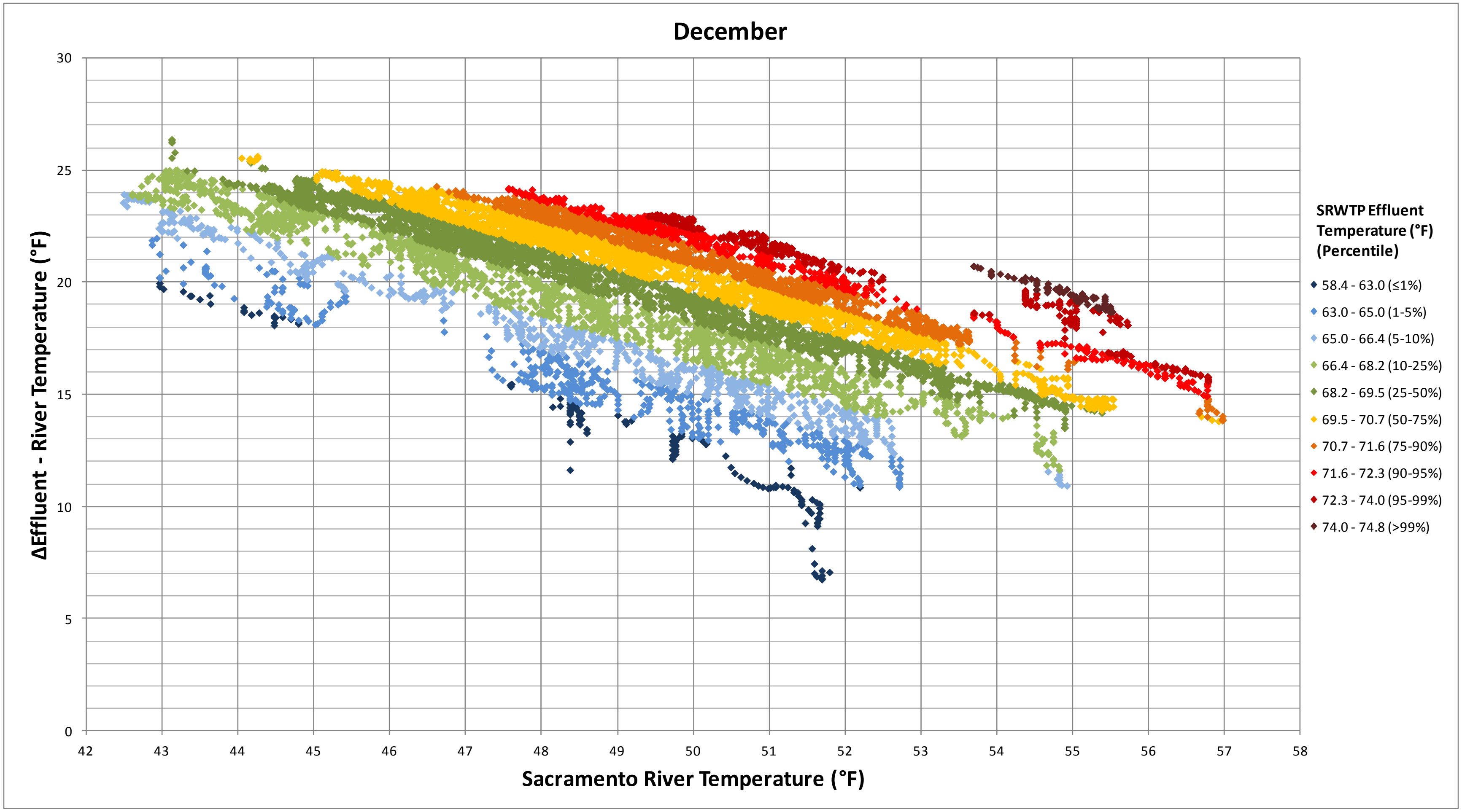

Figure B-12. Relationship between December Sacramento River background temperatures and the difference between SRWTP effluent and background river temperatures for the period of record February 1992 through September 2012. Colors represent the range of SRWTP effluent temperatures by percentiles (in parentheses).

Appendix C

DISTRIBUTION OF HOURLY EFFLUENT-RIVER TEMPERATURE DIFFERENTIALS

Table C-1. Count of SRWTP Effluent-Sacramento River temperature differences and minimum, average, and maximum monthly temperatures for the Sacramento River and SRWTP effluent during the month of **January** for the period of record February 1992 through September 2012.

Δ $_{\text{Effluent-River}}$ Temperature Values			**River Temperature (°F)**			**Effluent Temperature (°F)**		
Range	**Count**	**Percent of Total (%)**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
0-1	0	0.0	--	--	--	--	--	--
1.01 - 2	0	0.0	--	--	--	--	--	--
2.01 - 3	0	0.0	--	--	--	--	--	--
3.01 - 4	0	0.0	--	--	--	--	--	--
4.01 - 5	0	0.0	--	--	--	--	--	--
5.01 - 6	0	0.0	--	--	--	--	--	--
6.01 - 7	7	0.1	50.0	50.8	51.0	56.9	57.6	57.9
7.01 - 8	45	0.4	49.9	50.6	51.8	57.1	58.1	59.2
8.01 - 9	19	0.2	49.8	50.1	50.4	58.1	58.6	59.3
9.01 - 10	62	0.5	50.3	52.5	54.2	59.5	61.9	64.0
10.01 - 11	69	0.5	49.4	51.5	54.1	60.0	62.0	65.0
11.01 - 12	90	0.7	47.6	51.3	54.0	59.6	62.8	66.0
12.01 - 13	217	1.7	47.4	50.9	54.0	59.6	63.4	66.2
13.01 - 14	422	3.4	45.3	50.5	53.3	58.9	64.0	67.1
14.01 - 15	487	3.9	45.1	49.9	53.0	59.8	64.5	67.7
15.01 - 16	849	6.7	44.9	49.9	52.8	60.2	65.5	68.6
16.01 - 17	4290	10.3	44.8	50.2	52.7	60.9	66.7	69.4
17.01 - 18	1256	10.0	44.8	49.5	52.4	61.9	67.1	69.5
18.01 - 19	1592	12.7	44.8	48.8	51.4	63.0	67.3	70.2
19.01 - 20	1624	12.9	44.5	48.3	51.4	64.2	67.8	70.8
20.01 - 21	1820	14.5	43.7	47.4	50.4	64.0	68.0	70.5
21.01 - 22	1658	13.2	42.9	46.5	49.4	64.8	68.0	70.6
22.01 - 23	859	6.8	42.4	45.0	48.0	64.6	67.5	70.2
23.01 - 24	211	1.7	42.2	43.9	45.2	65.3	67.2	68.3
24.01 - 25	3	<0.1	42.2	43.2	43.7	66.2	67.3	67.9
25.01 - 26	0	0.0	--	--	--	--	--	--
26.01 - 27	0	0.0	--	--	--	--	--	--
Monthly Total:	***12,580***	***100.0***	***42.2***	***48.4***	***54.2***	***56.9***	***66.9***	***70.8***

Table C-2. Count of SRWTP Effluent-Sacramento River temperature differences and minimum, average, and maximum monthly temperatures for the Sacramento River and SRWTP effluent during the month of **February** for the period of record February 1992 through September 2012.

$\Delta_{\text{Effluent-River}}$ Temperature Values			River Temperature (°F)			Effluent Temperature (°F)		
Range	**Count**	**Percent of Total (%)**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
0-1	0	0.0	--	--	--	--	--	--
1.01 - 2	0	0.0	--	--	--	--	--	--
2.01 - 3	0	0.0	--	--	--	--	--	--
3.01 - 4	0	0.0	--	--	--	--	--	--
4.01 - 5	0	0.0	--	--	--	--	--	--
5.01 - 6	1	<0.1	53.6	53.6	53.6	59.2	59.2	59.2
6.01 - 7	12	0.1	53.3	53.7	53.9	59.7	60.2	60.8
7.01 - 8	35	0.3	53.2	53.9	55.1	60.3	61.4	62.9
8.01 - 9	55	0.4	53.3	54.8	57.7	61.3	63.3	66.0
9.01 - 10	113	0.9	52.7	55.1	57.0	62.2	64.7	66.3
10.01 - 11	236	1.8	50.4	54.7	57.3	60.8	65.2	68.0
11.01 - 12	350	2.6	48.0	53.1	56.9	59.9	64.7	68.1
12.01 - 13	607	4.6	47.9	52.7	58.1	60.0	65.3	70.7
13.01 - 14	1101	8.3	47.1	52.5	57.7	60.5	66.0	70.9
14.01 - 15	1123	8.5	46.1	51.6	55.5	61.0	66.1	70.3
15.01 - 16	1474	11.2	46.0	51.0	55.5	61.1	66.5	70.5
16.01 - 17	2062	15.6	46.1	50.7	53.4	62.5	67.2	69.8
17.01 - 18	2379	18.0	44.8	50.1	52.8	62.1	67.6	70.0
18.01 - 19	1852	14.0	44.5	49.0	51.3	62.9	67.5	69.4
19.01 - 20	1289	9.7	44.4	48.3	50.5	63.5	67.7	69.7
20.01 - 21	388	2.9	44.4	46.7	49.1	64.6	67.1	69.3
21.01 - 22	149	1.1	44.6	46.0	48.2	65.8	67.3	69.3
22.01 - 23	0	0.0	--	--	--	--	--	--
23.01 - 24	0	0.0	--	--	--	--	--	--
24.01 - 25	0	0.0	--	--	--	--	--	--
25.01 - 26	0	0.0	--	--	--	--	--	--
26.01 - 27	0	0.0	--	--	--	--	--	--
Monthly Total:	***13,215***	***100.0***	***44.4***	***50.5***	***58.1***	***59.2***	***66.8***	***70.9***

Table C-3. Count of SRWTP Effluent-Sacramento River temperature differences and minimum, average, and maximum monthly temperatures for the Sacramento River and SRWTP effluent during the month of **March** for the period of record February 1992 through September 2012.

$\Delta_{\text{Effluent-River}}$ Temperature Values			River Temperature (°F)			Effluent Temperature (°F)		
Range		**Percent of Total (%)**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
0-1	0	0.0	--	--	--	--	--	--
1.01 - 2	0	0.0	--	--	--	--	--	--
2.01 - 3	0	0.0	--	--	--	--	--	--
3.01 - 4	0	0.0	--	--	--	--	--	--
4.01 - 5	1	<0.1	53.9	53.9	53.9	58.6	58.6	58.6
5.01 - 6	14	0.1	53.5	53.8	53.9	58.9	59.5	59.9
6.01 - 7	87	0.6	53.6	60.7	63.4	59.7	67.3	70.3
7.01 - 8	224	1.5	57.0	61.7	63.3	64.6	69.3	70.6
8.01 - 9	400	2.7	56.8	61.0	63.2	65.1	69.5	71.9
9.01 - 10	505	3.4	53.0	59.8	63.0	62.8	69.3	72.2
10.01 - 11	846	5.7	50.7	58.5	62.2	61.7	69.0	72.4
11.01 - 12	1167	7.8	49.1	57.3	61.3	60.2	68.9	72.4
12.01 - 13	1733	11.6	48.4	56.3	60.1	60.6	68.9	72.6
13.01 - 14	1906	12.8	48.1	54.9	59.6	61.5	68.5	72.8
14.01 - 15	2256	15.1	48.1	53.6	58.3	62.2	68.1	72.3
15.01 - 16	2306	15.4	48.1	52.8	56.7	63.2	68.3	71.9
16.01 - 17	1958	13.1	48.1	51.7	56.0	64.3	68.2	72.3
17.01 - 18	1000	6.7	47.7	50.6	54.8	64.9	68.0	72.1
18.01 - 19	395	2.6	47.6	50.0	54.2	65.6	68.4	72.4
19.01 - 20	137	0.9	47.9	49.7	52.9	67.8	68.9	71.9
20.01 - 21	13	0.1	47.9	48.2	48.7	68.0	68.3	68.8
21.01 - 22	0	0.0	--	--	--	--	--	--
22.01 - 23	0	0.0	--	--	--	--	--	--
23.01 - 24	0	0.0	--	--	--	--	--	--
24.01 - 25	0	0.0	--	--	--	--	--	--
25.01 - 26	0	0.0	--	--	--	--	--	--
26.01 - 27	0	0.0	--	--	--	--	--	--
Monthly Total:	***14,948***	***100.0***	***47.6***	***54.5***	***63.4***	***58.6***	***68.5***	***72.8***

Table C-4. Count of SRWTP Effluent-Sacramento River temperature differences and minimum, average, and maximum monthly temperatures for the Sacramento River and SRWTP effluent during the month of **April** for the period of record February 1992 through September 2012.

Δ $_{\text{Effluent-River}}$ Temperature Values			River Temperature (°F)			Effluent Temperature (°F)		
Range	**Count**	**Percent of Total (%)**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
0-1	0	0.0	--	--	--	--	--	--
1.01 - 2	0	0.0	--	--	--	--	--	--
2.01 - 3	0	0.0	--	--	--	--	--	--
3.01 - 4	5	<0.1	68.7	68.9	69.1	72.7	72.8	73.0
4.01 - 5	102	0.7	61.5	68.0	71.0	66.2	72.6	75.8
5.01 - 6	185	1.3	61.6	67.9	70.7	66.9	73.5	75.8
6.01 - 7	242	1.7	59.0	66.8	70.1	66.0	73.3	76.1
7.01 - 8	412	2.9	58.3	63.9	68.6	65.9	71.6	75.7
8.01 - 9	972	6.9	55.2	62.8	67.0	64.0	71.3	75.1
9.01 - 10	1407	10.0	53.8	61.7	64.9	63.5	71.2	74.6
10.01 - 11	1673	11.9	53.5	61.0	64.7	64.0	71.5	75.0
11.01 - 12	1747	12.4	53.1	59.5	63.6	64.6	71.0	74.9
12.01 - 13	1584	11.3	50.0	58.0	62.3	62.9	70.5	75.2
13.01 - 14	2029	14.5	49.8	56.4	61.7	63.1	70.0	75.3
14.01 - 15	1749	12.5	49.8	55.4	60.6	64.1	69.9	74.8
15.01 - 16	1232	8.8	50.3	54.6	59.1	65.5	70.0	74.3
16.01 - 17	565	4.0	51.8	54.4	58.1	68.0	70.9	74.3
17.01 - 18	131	0.9	51.9	53.7	54.8	68.9	71.1	72.0
18.01 - 19	1	<0.1	54.0	54.0	54.0	72.1	72.1	72.1
19.01 - 20	0	0.0	--	--	--	--	--	--
20.01 - 21	0	0.0	--	--	--	--	--	--
21.01 - 22	0	0.0	--	--	--	--	--	--
22.01 - 23	0	0.0	--	--	--	--	--	--
23.01 - 24	0	0.0	--	--	--	--	--	--
24.01 - 25	0	0.0	--	--	--	--	--	--
25.01 - 26	0	0.0	--	--	--	--	--	--
26.01 - 27	0	0.0	--	--	--	--	--	--
Monthly Total:	***14,036***	***100.0***	***49.8***	***58.7***	***71.0***	***62.9***	***70.8***	***76.1***

Table C-5. Count of SRWTP Effluent-Sacramento River temperature differences and minimum, average, and maximum monthly temperatures for the Sacramento River and SRWTP effluent during the month of **May** for the period of record February 1992 through September 2012.

Δ $_{\text{Effluent-River}}$ Temperature Values			River Temperature (°F)			Effluent Temperature (°F)		
Range	**Count**	**Percent of Total (%)**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
0-1	3	<0.1	74.3	74.4	74.5	75.2	75.3	75.4
1.01 - 2	34	0.2	70.4	73.4	74.3	71.9	74.9	75.6
2.01 - 3	121	0.8	67.7	73.1	74.9	70.4	75.7	77.4
3.01 - 4	399	2.7	67.7	72.4	75.1	71.0	76.0	78.4
4.01 - 5	874	6.0	67.4	70.8	74.1	71.9	75.4	78.3
5.01 - 6	1181	8.1	63.0	69.8	73.1	69.0	75.4	78.6
6.01 - 7	1436	9.8	62.5	68.4	72.6	69.0	74.9	78.9
7.01 - 8	901	6.2	60.8	66.9	71.2	68.5	74.4	78.4
8.01 - 9	961	6.6	57.6	65.4	70.1	65.9	73.9	78.2
9.01 - 10	885	6.1	57.6	63.9	68.6	67.1	73.4	77.6
10.01 - 11	1102	7.5	57.6	62.4	66.1	68.2	72.9	76.4
11.01 - 12	1678	11.5	55.9	61.3	65.8	67.3	72.8	76.9
12.01 - 13	1905	13.0	54.9	60.3	64.9	67.8	72.7	77.1
13.01 - 14	1288	8.8	54.9	59.4	63.6	68.7	72.9	76.8
14.01 - 15	878	6.0	54.0	58.4	62.8	69.0	72.8	77.3
15.01 - 16	497	3.4	53.5	56.7	62.2	68.9	72.1	77.3
16.01 - 17	339	2.3	53.6	55.2	58.0	69.7	71.7	74.1
17.01 - 18	94	0.6	53.7	55.0	56.6	70.7	72.3	73.6
18.01 - 19	25	0.2	54.4	54.8	55.4	72.9	73.2	73.6
19.01 - 20	9	0.1	54.4	54.6	54.8	73.6	73.8	73.9
20.01 - 21	0	0.0	--	--	--	--	--	--
21.01 - 22	0	0.0	--	--	--	--	--	--
22.01 - 23	0	0.0	--	--	--	--	--	--
23.01 - 24	0	0.0	--	--	--	--	--	--
24.01 - 25	0	0.0	--	--	--	--	--	--
25.01 - 26	0	0.0	--	--	--	--	--	--
26.01 - 27	0	0.0	--	--	--	--	--	--
Monthly Total:	***14,610***	***100.0***	***53.5***	***63.7***	***75.1***	***65.9***	***73.6***	***78.9***

Table C-6. Count of SRWTP Effluent-Sacramento River temperature differences and minimum, average, and maximum monthly temperatures for the Sacramento River and SRWTP effluent during the month of **June** for the period of record February 1992 through September 2012.

$\Delta_{\text{Effluent-River}}$ Temperature Values			River Temperature (°F)			Effluent Temperature (°F)		
Range	**Count**	**Percent of Total (%)**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
0-1	0	0.0	--	--	--	--	--	--
1.01 - 2	13	0.1	69.5	74.0	76.3	71.4	75.8	78.2
2.01 - 3	109	0.8	69.4	74.1	76.3	71.6	76.7	78.9
3.01 - 4	251	1.8	69.4	73.1	75.9	73.1	76.7	79.5
4.01 - 5	720	5.1	69.6	72.4	75.0	74.3	77.0	79.6
5.01 - 6	1413	9.9	68.8	71.8	74.5	74.5	77.3	79.7
6.01 - 7	1716	12.1	65.8	70.9	73.7	72.7	77.4	79.9
7.01 - 8	1772	12.5	64.9	69.3	72.9	72.7	76.8	79.9
8.01 - 9	1838	12.9	63.9	67.7	71.7	72.7	76.2	79.9
9.01 - 10	1403	9.9	62.3	66.2	70.1	72.1	75.7	79.3
10.01 - 11	1299	9.1	61.0	64.9	68.7	71.6	75.4	79.3
11.01 - 12	1333	9.4	60.4	64.1	68.0	72.1	75.6	79.4
12.01 - 13	1044	7.3	57.7	63.1	67.6	70.2	75.6	79.8
13.01 - 14	885	6.2	57.1	61.8	66.3	70.7	75.3	79.4
14.01 - 15	255	1.8	57.1	60.1	63.9	71.1	74.4	77.9
15.01 - 16	92	0.6	58.3	60.0	61.9	73.6	75.5	77.5
16.01 - 17	46	0.3	58.2	59.6	61.3	74.7	75.9	77.3
17.01 - 18	37	0.3	57.3	57.8	58.9	75.0	75.4	76.2
18.01 - 19	0	0.0	--	--	--	--	--	--
19.01 - 20	0	0.0	--	--	--	--	--	--
20.01 - 21	0	0.0	--	--	--	--	--	--
21.01 - 22	0	0.0	--	--	--	--	--	--
22.01 - 23	0	0.0	--	--	--	--	--	--
23.01 - 24	0	0.0	--	--	--	--	--	--
24.01 - 25	0	0.0	--	--	--	--	--	--
25.01 - 26	0	0.0	--	--	--	--	--	--
26.01 - 27	0	0.0	--	--	--	--	--	--
Monthly Total:	***14,226***	***100.0***	***57.1***	***67.4***	***76.3***	***70.2***	***76.3***	***79.9***

Table C-7. Count of SRWTP Effluent-Sacramento River temperature differences and minimum, average, and maximum monthly temperatures for the Sacramento River and SRWTP effluent during the month of **July** for the period of record February 1992 through September 2012.

Δ $_{\text{Effluent-River}}$ Temperature Values			**River Temperature (°F)**			**Effluent Temperature (°F)**		
Range	**Count**	**Percent of Total (%)**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
0-1	0	0.0	--	--	--	--	--	--
1.01 - 2	0	0.0	--	--	--	--	--	--
2.01 - 3	24	0.2	73.3	73.8	74.3	76.2	76.6	76.9
3.01 - 4	116	0.8	72.0	73.5	75.4	75.9	77.1	79.2
4.01 - 5	341	2.3	71.4	73.5	76.2	76.0	78.1	81.1
5.01 - 6	611	4.1	70.0	73.0	76.2	75.9	78.5	81.2
6.01 - 7	1433	9.7	68.4	71.9	74.9	75.2	78.5	81.7
7.01 - 8	2751	18.6	67.2	71.1	74.7	74.7	78.7	82.2
8.01 - 9	3355	22.7	66.9	70.3	73.7	75.2	78.8	82.0
9.01 - 10	2268	15.3	65.1	69.2	72.7	74.4	78.7	82.1
10.01 - 11	1457	9.8	64.6	68.5	71.5	75.1	79.0	81.8
11.01 - 12	763	5.2	63.3	67.7	70.4	74.8	79.1	81.6
12.01 - 13	485	3.3	63.7	66.4	69.7	76.5	78.9	82.0
13.01 - 14	442	3.0	62.7	65.1	66.4	76.7	78.6	80.0
14.01 - 15	451	3.0	62.3	64.1	65.9	76.8	78.6	79.9
15.01 - 16	280	1.9	61.9	63.3	64.9	77.4	78.7	80.3
16.01 - 17	22	0.1	61.0	63.0	64.2	77.8	79.4	80.3
17.01 - 18	1	<0.1	60.8	60.8	60.8	77.8	77.8	77.8
18.01 - 19	0	0.0	--	--	--	--	--	--
19.01 - 20	0	0.0	--	--	--	--	--	--
20.01 - 21	0	0.0	--	--	--	--	--	--
21.01 - 22	0	0.0	--	--	--	--	--	--
22.01 - 23	0	0.0	--	--	--	--	--	--
23.01 - 24	0	0.0	--	--	--	--	--	--
24.01 - 25	0	0.0	--	--	--	--	--	--
25.01 - 26	0	0.0	--	--	--	--	--	--
26.01 - 27	0	0.0	--	--	--	--	--	--
Monthly Total:	***14,800***	***100.0***	***60.8***	***69.7***	***76.2***	***74.4***	***78.7***	***82.2***

Appendix D

TEMPERATURE DIFFERENTIALS TECHNICAL MEMORANDUM

Flow Science Incorporated
48 S. Chester Ave., Ste. 200, Pasadena, CA 91106
(626) 304-1134 • FAX (626) 304-9427

DRAFT TECHNICAL MEMORANDUM

February 9, 2015

Mr. Keith Whitener
Robertson-Bryan
9888 Kent Street
Elk Grove, CA 95624

RE: Temperature differentials between SRWTP 60/181/410 mgd effluent plume and Sacramento River at 14:1 river-to-effluent flow ratio and 154 mgd effluent plume at 67:1 river-to-effluent ratio
FSI 104120.2

This Technical Memorandum summarizes the methodology and results of a recent analysis by Flow Science Incorporated to simulate the effects of Sacramento Regional Wastewater Treatment Plant (SRWTP) effluent discharges on Sacramento River water temperatures downstream of the SRWTP diffuser. Results presented herein are intended to inform biological studies related to Delta Smelt to be performed by Robertson-Bryan, Inc. The Computational Fluid Dynamics (CFD) model, FLOWMOD, was used to simulate SRWTP discharge rates of 60 mgd, 181 mgd, and 410 mgd at a river-to-effluent flow ratio of 14:1, as well as a SRWTP discharge rate of 154 mgd at a river-to-effluent ratio of 67:1. The SRWTP diffuser was modeled with 25 of the 99 available discharge ports closed to reflect current conditions. Results are provided for each flow scenario and for effluent temperature increments of 5 ºF, 10 ºF, 15 ºF, 20 ºF, and 25 ºF above ambient river temperatures.

METHODOLOGY

Flow in the Sacramento River at Freeport is tidal, and during periods of low net flow in the river tidal forcing may result in low or reverse (upstream) flows in the river at Freeport. To remain within the effective operational range of the diffuser, the SRWTP NPDES Permit requires that the ratio of Sacramento River flow at Freeport to SRWTP effluent flow must never drop below 14:1, evaluated as a 1-hour average. Therefore, the 14:1 flow condition represents the "worst-case" mixing scenario observable downstream of the SRWTP diffuser.

As in previous analyses performed since 1999, the computational fluid dynamics model FLOWMOD[1] was used to simulate the effluent plume in the Sacramento River immediately

[1] FLOWMOD is a computational fluid dynamics program that consists of a set of conservation equations (mass, momentum, and energy). The conservation equations are solved using the numerical method of finite differences. The computational domain is subdivided into small computational elements over which the conservation equations are solved. Inputs to the model consist of a geometrical description of the water body (i.e., the river topography), and a set of initial and boundary conditions (i.e., inflow velocities and geometry). The model output produces spatial and temporal solutions for the variables (pressure, velocity, tracer concentration) in graphical and tabular forms. FLOWMOD has been widely used in published peer-reviewed studies that evaluate mixing in water bodies.

downstream of the SRWTP diffuser. For this analysis, FLOWMOD was generally configured as described in the 2003 DEIR report (SCDERA 2003, Appendix F, esp., pp. 3-25 through 3-30), with two major exceptions. First, a 74-port diffuser was simulated instead of a 99-port diffuser. Second, the river bathymetry data from a detailed survey conducted in November 2007 were used. The model domain extends from 100 ft upstream of the diffuser to 1,000 ft downstream.

FLOWMOD was used to calculate the steady-state concentration of effluent in each grid cell of the model domain for three effluent flow rates: 60 mgd, 154 mgd, 181 mgd, and 410 mgd[2]. In the case of the 60 mgd, 181 mgd, and 410 mgd effluent discharges, a river-to-effluent flow ratio of 14:1 (the "worst-case" condition) was simulated, corresponding to river flow rates of 1,300 cfs for the 60 mgd scenario, 3,920 cfs for the 181 mgd scenario, and 8,880 cfs for the 410 mgd scenario. In the case of the 154 mgd effluent discharge, a river-to-effluent flow ratio of 67:1 was simulated, corresponding to a river flow rate of 16,000 cfs.

Based on a 2010 analysis of hourly observations of river flow and stage at Freeport for the water year 2009, there is no one-to-one correspondence between flow and stage for the range of river flows modeled (a one-to-one stage-flow relationship was observed only for river flows greater than 25,000 cfs). Thus, for each flow scenario, the median value of observed stage corresponding to a given river flow rate was used in the FLOWMOD simulations[3]. The selected river stage was 103.2 ft for the 410 mgd scenario, 103.3 ft for each of the 60 mgd and 181 mgd scenarios, and 103.5 ft for the 154 mgd scenario.

The effluent concentrations within the discharge plume for the four flow conditions were used to calculate[4] and plot five temperature differential conditions, i.e., five cases in which the difference between effluent temperature and river temperature varied. Temperature differentials of 5 ^{o}F, 10 ^{o}F , 15 ^{o}F , 20 ^{o}F , and 25 ^{o}F were used. **Table 1** summarizes the 20 different cases plotted as part of this analysis.

Table 1: Summary of Cases Plotted

Effluent Flow Rate	River Flow Rate	River-to-Effluent Flow Ratio	Temperature Differential Between Effluent and Ambient River Temperatures
60 mgd	1,300 cfs	14:1	5 ^{o}F
			10 ^{o}F
			15 ^{o}F
			20 ^{o}F

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2 The results of the 181 mgd simulation were presented in 2010 (see "DRAFT Potential Alternative Thermal Compliance Models, Sacramento Regional Wastewater Treatment Plant," Prepared for Sacramento Regional County Sanitation District, August 30, 2010, FSI 034023), and the results were used to calculate the temperature differential conditions for the present work.

3 "DRAFT Potential Alternative Thermal Compliance Models, Sacramento Regional Wastewater Treatment Plant," Prepared for Sacramento Regional County Sanitation District, August 30, 2010, FSI034023.

4 The temperature was calculated on a concentration-weighted basis, assuming no external heat inputs or outputs.

Effluent Flow Rate	River Flow Rate	River-to-Effluent Flow Ratio	Temperature Differential Between Effluent and Ambient River Temperatures
			25 ºF
181 mgd	3,920 cfs	14:1	5 ºF
			10 ºF
			15 ºF
			20 ºF
			25 ºF
410 mgd	8,880 cfs	14:1	5 ºF
			10 ºF
			15 ºF
			20 ºF
			25 ºF
154 mgd	16,000 cfs	67:1	5 ºF
			10 ºF
			15 ºF
			20 ºF
			25 ºF

RESULTS

Results of the FLOWMOD thermal mixing analysis are shown in Attachment A, Figures 1 through 40. Figures 1 through 20 show a longitudinal profile along the plume centerline and a plan-view of temperature conditions downstream of the SRWTP diffuser, for each flow and temperature case modeled. The longitudinal plots show the simulated temperature difference above ambient river temperature along the plume centerline. The location of the plume centerline, as plotted in the longitudinal profiles, is shown as a dashed-and-dotted black line on the plan-view plot. The location of the 10 ft and 20 ft depths below the water surface are shown on the longitudinal profiles as black dashed lines. The plan-view plots show the highest simulated temperature difference above ambient river temperature at any depth in the water column. The dashed pink line on the plan-view plot shows the warmest path (i.e., path with highest temperature differential) at a depth of 20 ft below the river water surface.

Figures 21 through 40 show temperatures above ambient river temperature at cross-sections located 60-, 175-, and 700-feet downstream of the SRWTP diffuser. The locations of the plume centerline, and the 10 ft and 20 ft depths, are shown on the river cross-sections, which are presented facing downstream (i.e., the east bank is on the left of the figure). The location of the warmest path at a depth of 20 ft is also noted on each cross-section with pink circles.

In addition to the figures, Tables 1 through 12 in Attachment B detail the simulated drift velocity, drift time, and simulated temperature above ambient river temperature in each model grid cell along a particle path beginning at the diffuser and extending to the downstream end of the domain. Results are provided for each flow and temperature case modeled and at three discrete depths: surface, 10 ft deep, and 20 ft deep. For the surface and 10 ft depths, the particle paths are along the plume centerline. For the 20 ft depth, the particle path is along the warmest path as noted in the figures. The drift velocity is the simulated downstream velocity in each cell along the particle path. The drift time is the cumulative travel time from the SRTWP diffuser along the particle path based on the incremental distance between cells and individual cell velocities.

The results of the analysis are generally as expected. The effluent plume initially mixes near the river bottom and gradually rises as the plume travels downstream. Due to the downstream river velocity being the dominant velocity field, the width of the plume (as defined by the 0.1 ^{o}F temperature differential contour) remains roughly the width of the diffuser discharge over the length of the model domain. Water temperatures (and effluent concentrations) are highest near the diffuser and lower farther away from the diffuser discharge. Predicted water temperatures are highest for the cases in which the differential between effluent and ambient river water temperature is highest (e.g., 25 ^{o}F), and are lower for the cases in which the temperature differential is lower (e.g., 5 ^{o}F). The highest temperatures within the plumes typically occur near the river bottom, and the plume rises towards the surface more quickly on the western side. The highest longitudinal velocities typically occur near the surface and the lowest near the river bottom.

60 MGD Flow Scenario

For the 60 mgd flow scenario (Figures 1 through 5 and 21 through 25, and Tables 1 through 3), the computed drift time along the warmest path (at 20 feet depth) from the diffuser to the end of the domain 1,000 ft downstream is 4,230 seconds. Along this path, the warmest temperature occurs at the diffuser. At the end of the domain, the temperature along the warmest path is predicted to range from 1.9 ^{o}F above ambient river temperature for the 5 ^{o}F effluent discharge differential to 9.3 ^{o}F above ambient river temperature for the 25 ^{o}F differential. In comparison, the computed drift time along the centerline of the plume at the surface is 2,150 seconds and at 10 ft deep is 2,190 seconds. At the surface and at 10 ft deep, the warmest temperatures along the centerline of the plume occur near the end of the domain. The edge of the plume (as defined by the 0.1 ^{o}F temperature differential contour) at the centerline is predicted to not reach the surface within the domain for the five effluent temperature differentials considered.

It is noted that FLOWMOD has been validated in previous studies for river flows exceeding 3,800 cfs[5]. For lower river flows, the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.

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[5] "Water Quality Modeling in Support of Impact Assessments for the Sacramento Regional Wastewater Treatment Plant 2020 Master Plan EIR, in Sacramento Regional County Sanitation District (SRCSD), 2003. Draft Environmental Impact Report, Sacramento Regional Wastewater Treatment Plant 2020 Master Plan. Volume 2", August 2003: Technical Appendices, Appendix F. July 19, 2002.

"Model Sensitivity Analysis for FLOWMOD Simulations of the SRCSD Effluent Discharge to the Sacramento River at Freeport, CA". Prepared for Sacramento Regional County Sanitation District. September 15, 2006. FSI 034023.

181 MGD Flow Scenario

The warmest path at 20 ft depth for the 181 mgd flow scenario (Figures 6 through 10 and 26 through 30, and Tables 4 through 6) occurs near the eastern edge of the plume. The computed drift time along the warmest path is 790 seconds, and the warmest temperature occurs at the diffuser. At the end of the domain, the temperature along the warmest path is predicted to range from 1.0 ^{o}F above ambient river temperature for the 5 ^{o}F effluent discharge differential to 5.1 ^{o}F above ambient river temperature for the 25 ^{o}F differential. In comparison to the 60 mgd scenario, the effluent in the 181 mgd scenario mixes more quickly (due to increased turbulence) as it travels the length of the domain.

The computed drift time along the centerline of the plume at the surface is 630 seconds and at 10 ft deep is 670 seconds. At the surface and at 10 ft deep, the warmest temperatures along the centerline of the plume occur near the end of the domain. The edge of the plume (as defined by the 0.1 ^{o}F temperature differential contour) at the centerline is predicted to not reach the surface within the domain for the five effluent temperature differentials considered. However, portions of the plume, starting first in the western half, do begin surfacing before the end of the domain.

410 MGD Flow Scenario

For the 410 mgd flow scenario (Figures 11 through 15 and 31 through 35, and Tables 7 through 9), the warmest path at 20 ft depth occurs near the eastern edge of the plume as for the 181 mgd flow scenario. The computed drift time along the warmest path is 350 seconds, and the warmest temperature occurs at the diffuser. At the end of the domain, the temperature along the warmest path is predicted to range from 0.8 ^{o}F above ambient river temperature for the 5 ^{o}F effluent discharge differential to 4.2 ^{o}F above ambient river temperature for the 25 ^{o}F differential. In comparison to the 60 mgd and 181 mgd scenarios, the effluent in the 410 mgd scenario mixes more quickly as it travels the length of the domain (due to increased turbulence).

The computed drift time along the centerline of the plume at the surface is 280 seconds and at 10 ft deep is 300 seconds. At the surface and at 10 ft deep, the warmest temperatures along the

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“Model Verification Results for FLOWMOD Simulations of SRCSD Effluent Discharge to the Sacramento River at Freeport, October 2005 Field Study”. Prepared for Sacramento Regional County Sanitation District. October 20, 2006. FSI 054076.

“Model Verification Results for FLOWMOD Simulations of SRCSD Effluent Discharge to the Sacramento River at Freeport, June 2006 Field Study”. Prepared for Sacramento Regional County Sanitation District. November 17. 2006. FSI 054076.

“Model Verification Results for FLOWMOD Simulations of SRCSD Effluent Discharge to the Sacramento River at Freeport, November 2006 Field Study”. Prepared for Sacramento Regional County Sanitation District. June 11, 2007. FSI 054076.

“Model Verification Results for FLOWMOD Simulations of SRCSD Effluent Discharge to the Sacramento River at Freeport, November 2007 Field Study”. Prepared for Sacramento Regional County Sanitation District. June 9. 2008. FSI 054076.

centerline of the plume occur near the end of the domain. The edge of the plume (as defined by the 0.1 ^{o}F temperature differential contour) at the centerline is predicted to reach the surface within the domain for the five effluent temperature differentials considered. The plume begins surfacing first in the western half.

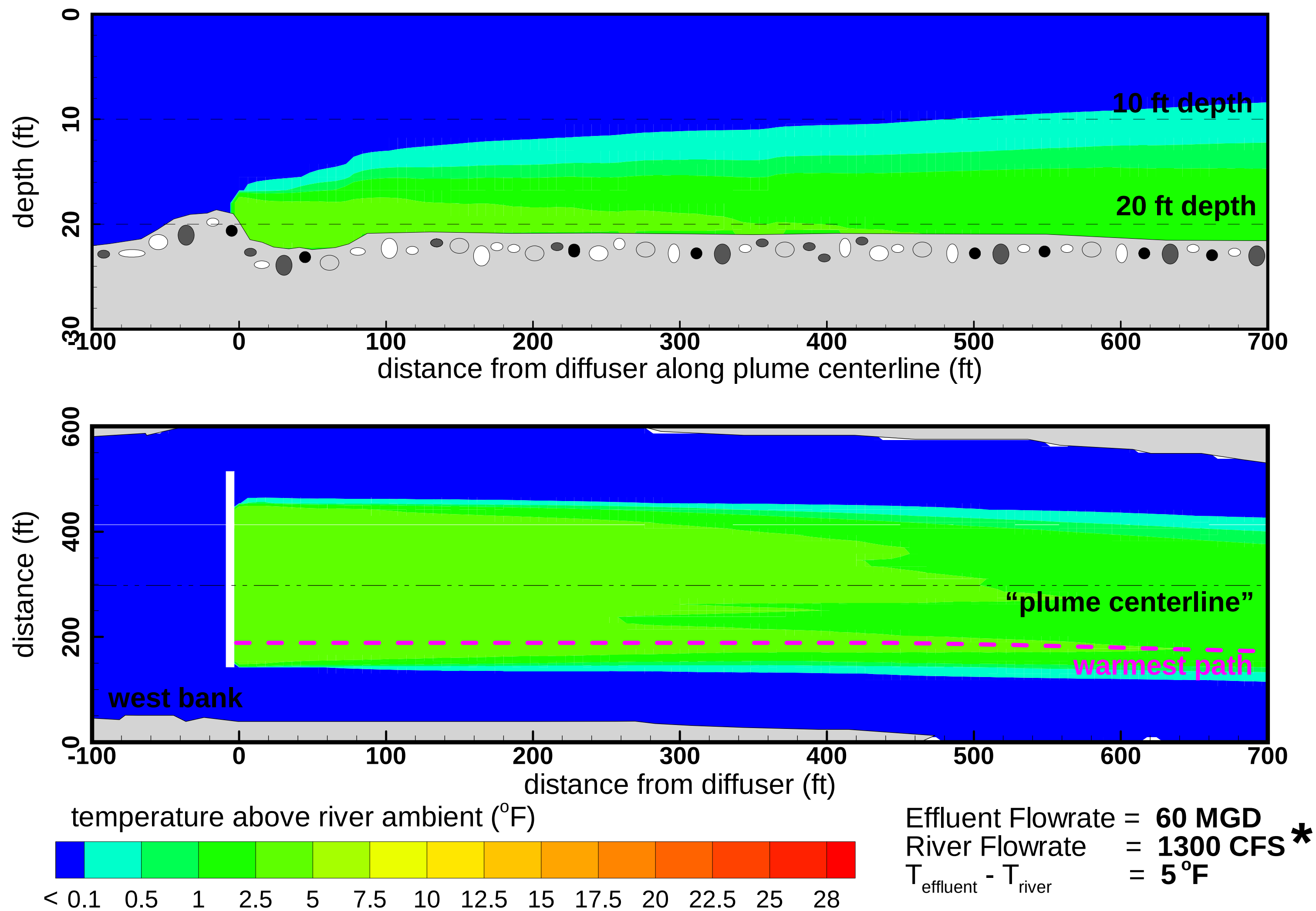
154 MGD Flow Scenario

For the 154 mgd flow scenario (Figures 16 through 20 and 36 through 40, and Tables 10 through 12), the warmest path at 20 ft depth occurs near the eastern edge of the plume. The computed drift time along the warmest path to the end of the domain 1,000 ft downstream is 250 seconds. Along this path, the warmest temperature occurs at the diffuser. At the end of the domain, the temperature along the warmest path is predicted to range from 0.2 ^{o}F above ambient river temperature for the 5 ^{o}F effluent discharge differential to 0.8 ^{o}F above ambient river temperature for the 25 ^{o}F differential. In comparison to the 14:1 river-to-effluent flow ratio scenarios above, the plume in the 67:1 river-to-effluent flow ratio mixes more quickly (due to increased turbulence) as it travels the length of the domain.

The computed drift time along the centerline of the plume at the surface is 170 seconds and at 10 ft deep is 180 seconds. At the surface, the warmest temperatures along the centerline of the plume occur near the end of the domain. At 10 ft deep, the warmest temperatures along the centerline of the plume occur about 400 ft downstream of the diffuser. The edge of the plume (as defined by the 0.1 ^{o}F temperature differential contour) at the centerline is predicted to reach the surface within the domain for the 10 ^{o}F, 15 ^{o}F, 20 ^{o}F, and 25 ^{o}F temperature differentials considered. The plume first begins surfacing in the western half of the River.

ATTACHMENT A: FIGURES

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **60 MGD**
14:1 DILUTION RATIO AND **5 °F** TEMPERATURE DIFFERENCE



* FLOWMOD has been validated for river flows exceeding 3,800 cfs. For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.

Figures.ppt
FSI 104120.2
February 9, 2015

Figure 1 - DRAFT

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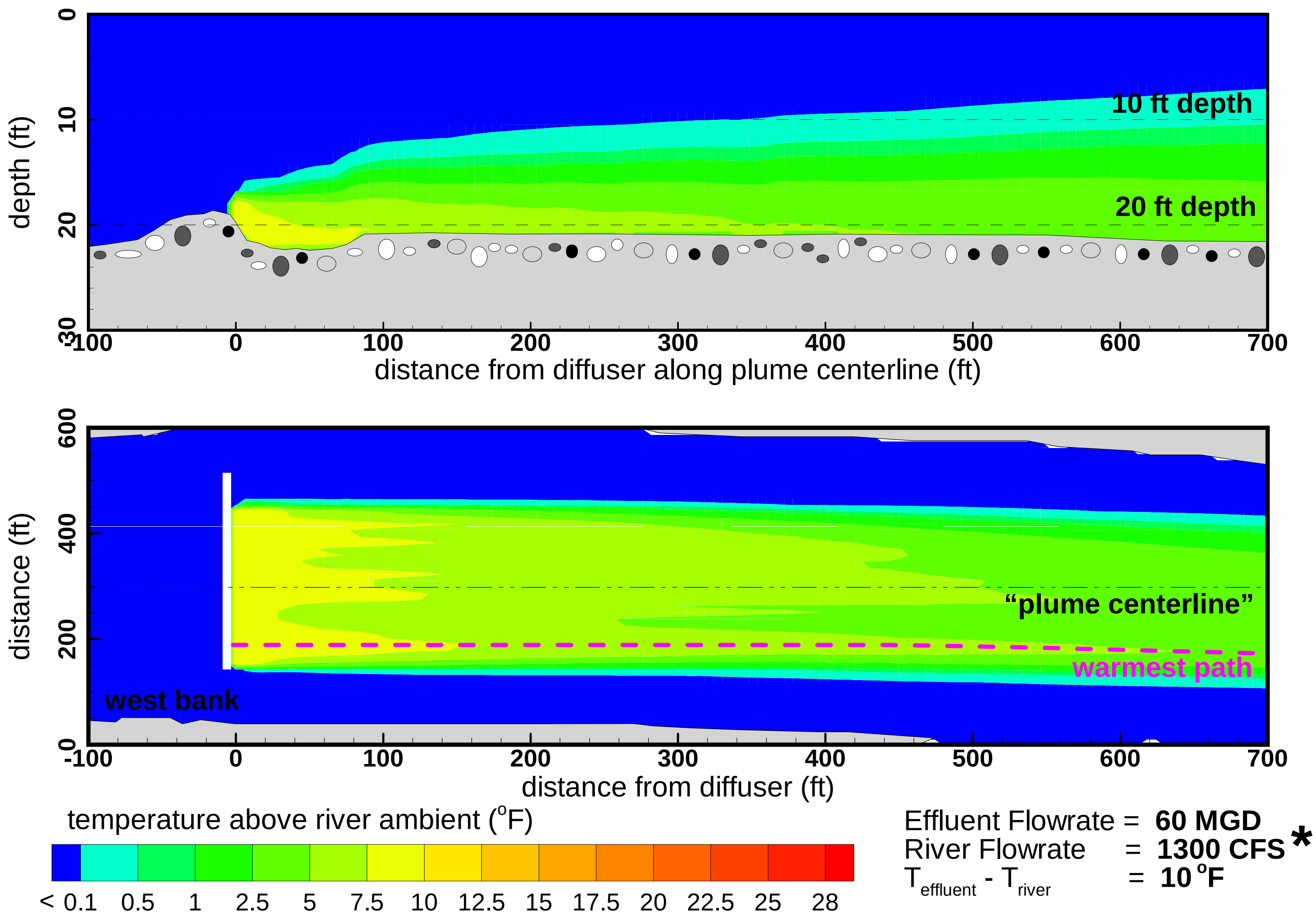
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **60 MGD**
14:1 DILUTION RATIO AND **10 °F** TEMPERATURE DIFFERENCE



* FLOWMOD has been validated for river flows exceeding 3,800 cfs. For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.

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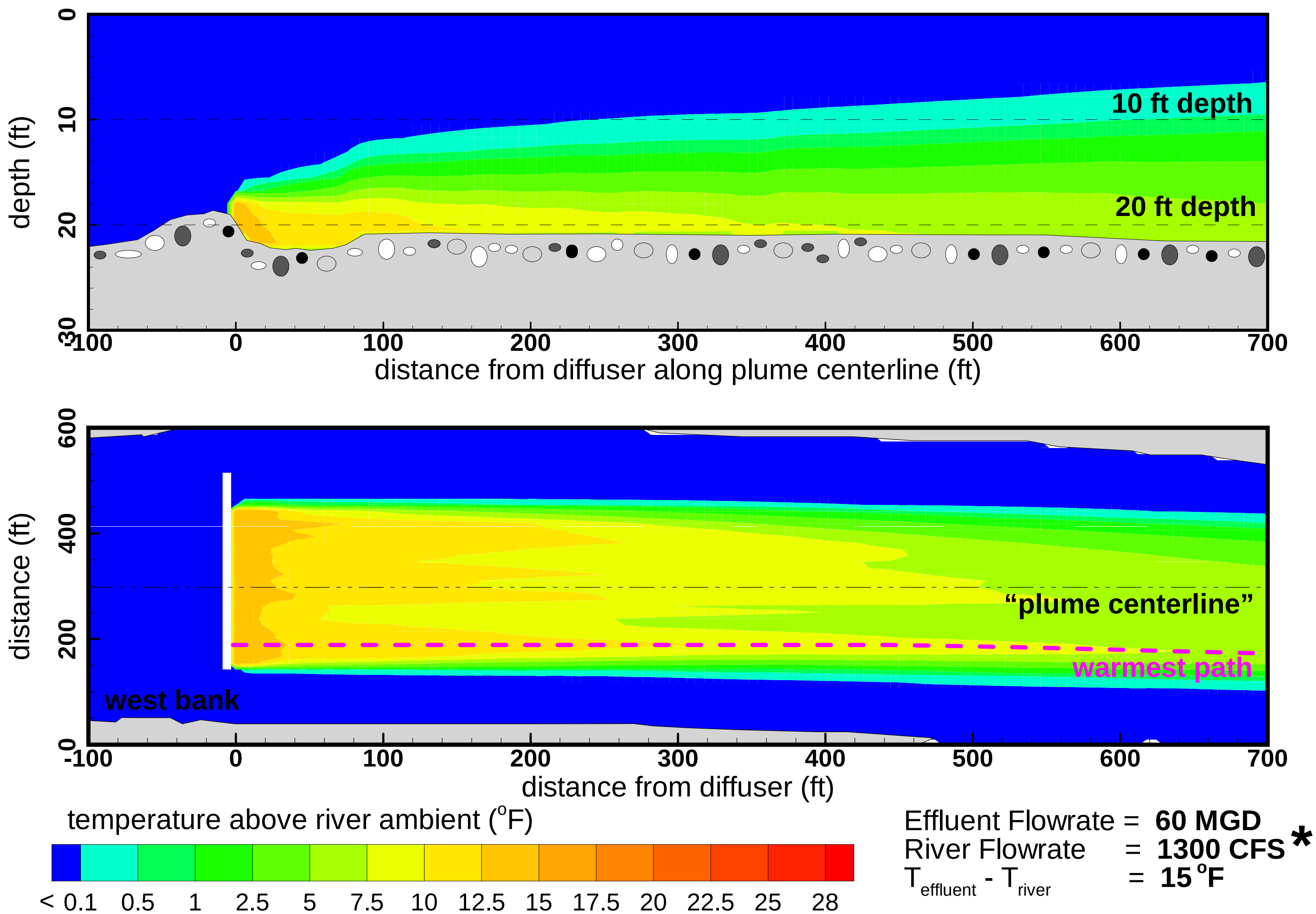
FSI 104120.2
February 9, 2015

Figure 2 - DRAFT

FLOW SCIENCE®

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **60 MGD**
14:1 DILUTION RATIO AND **15 °F** TEMPERATURE DIFFERENCE



* FLOWMOD has been validated for river flows exceeding 3,800 cfs. For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.

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Figure 3 - DRAFT

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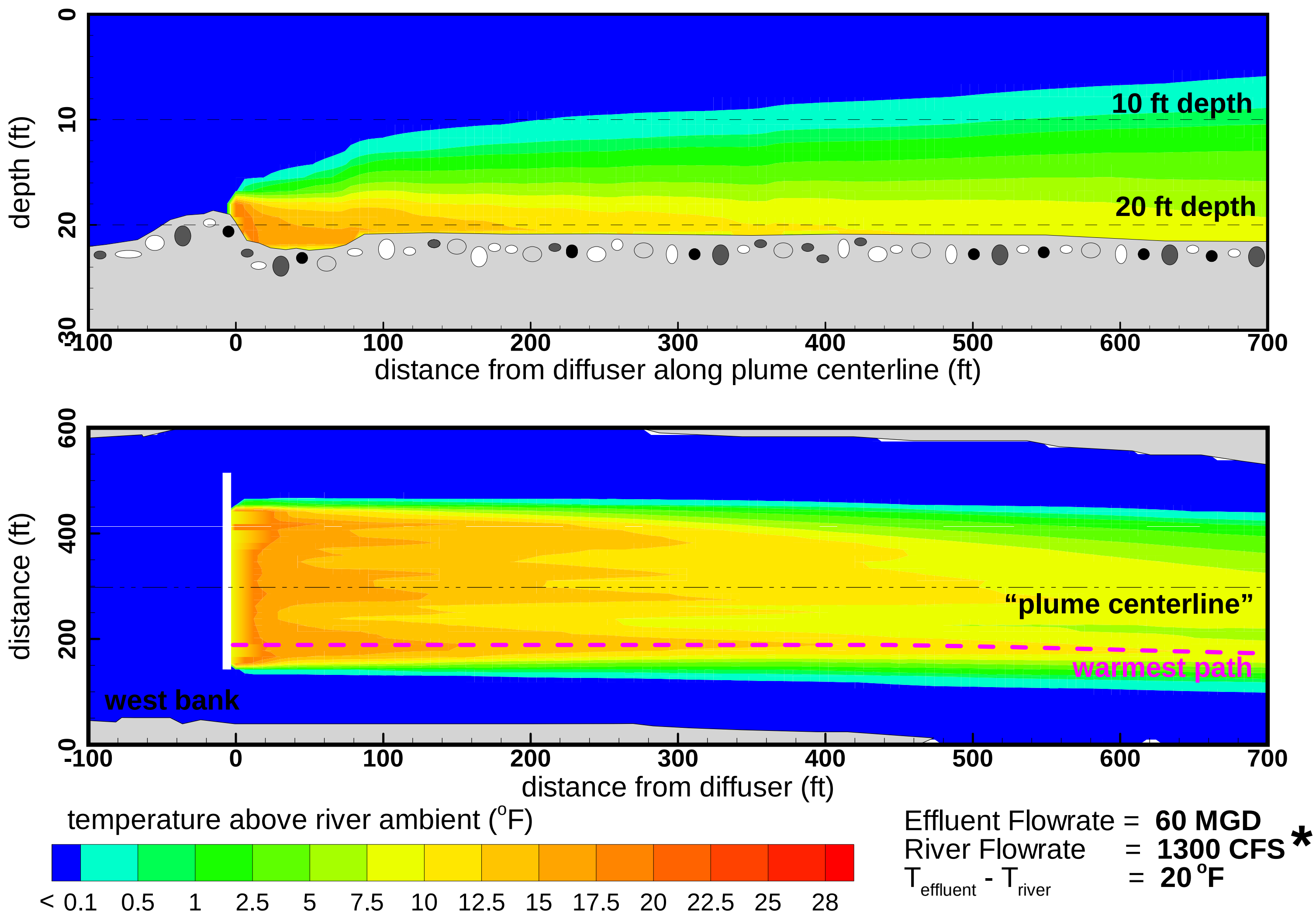
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **60 MGD**
14:1 DILUTION RATIO AND **20 °F** TEMPERATURE DIFFERENCE



* FLOWMOD has been validated for river flows exceeding 3,800 cfs. For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.

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Figure 4 - DRAFT

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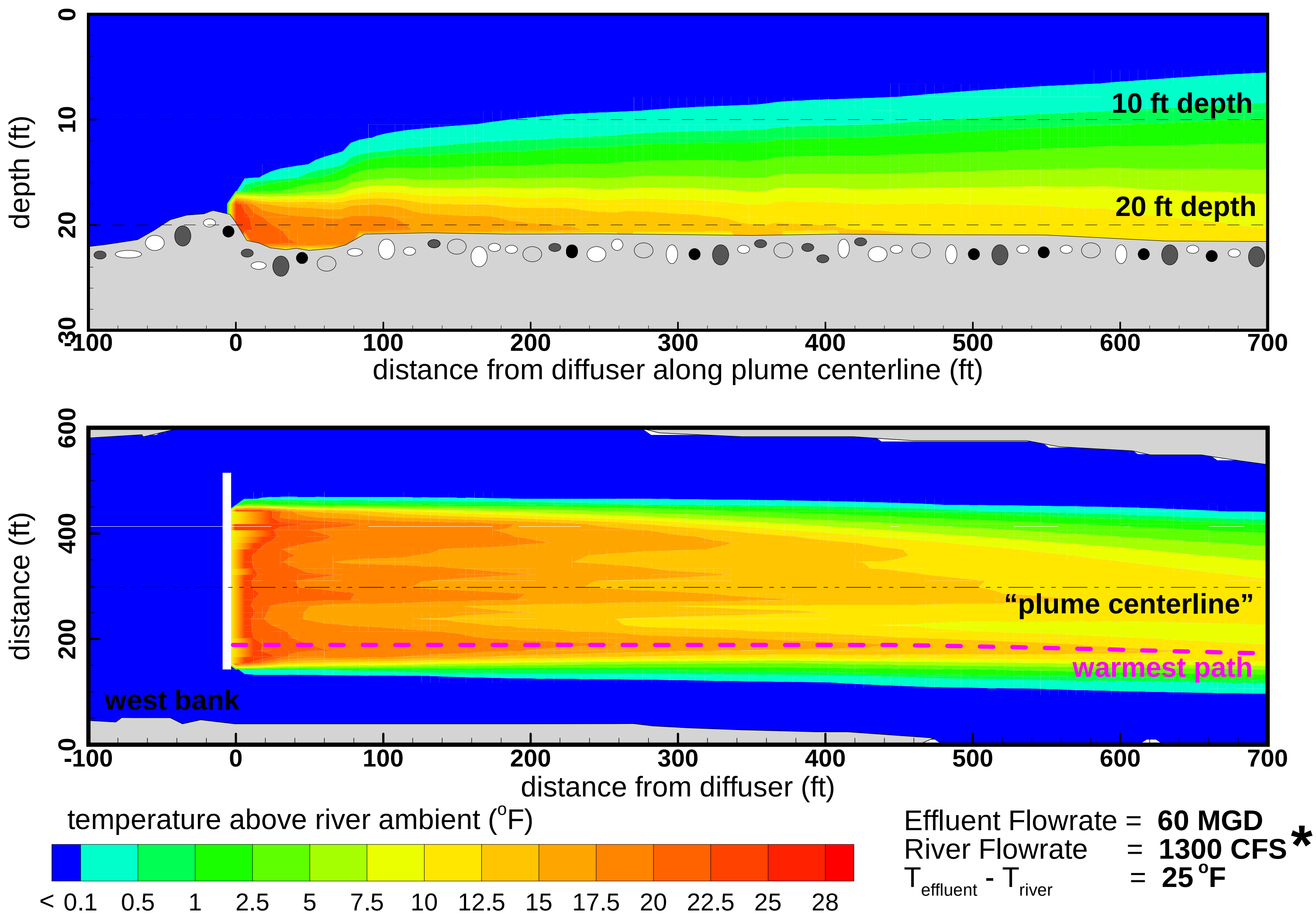
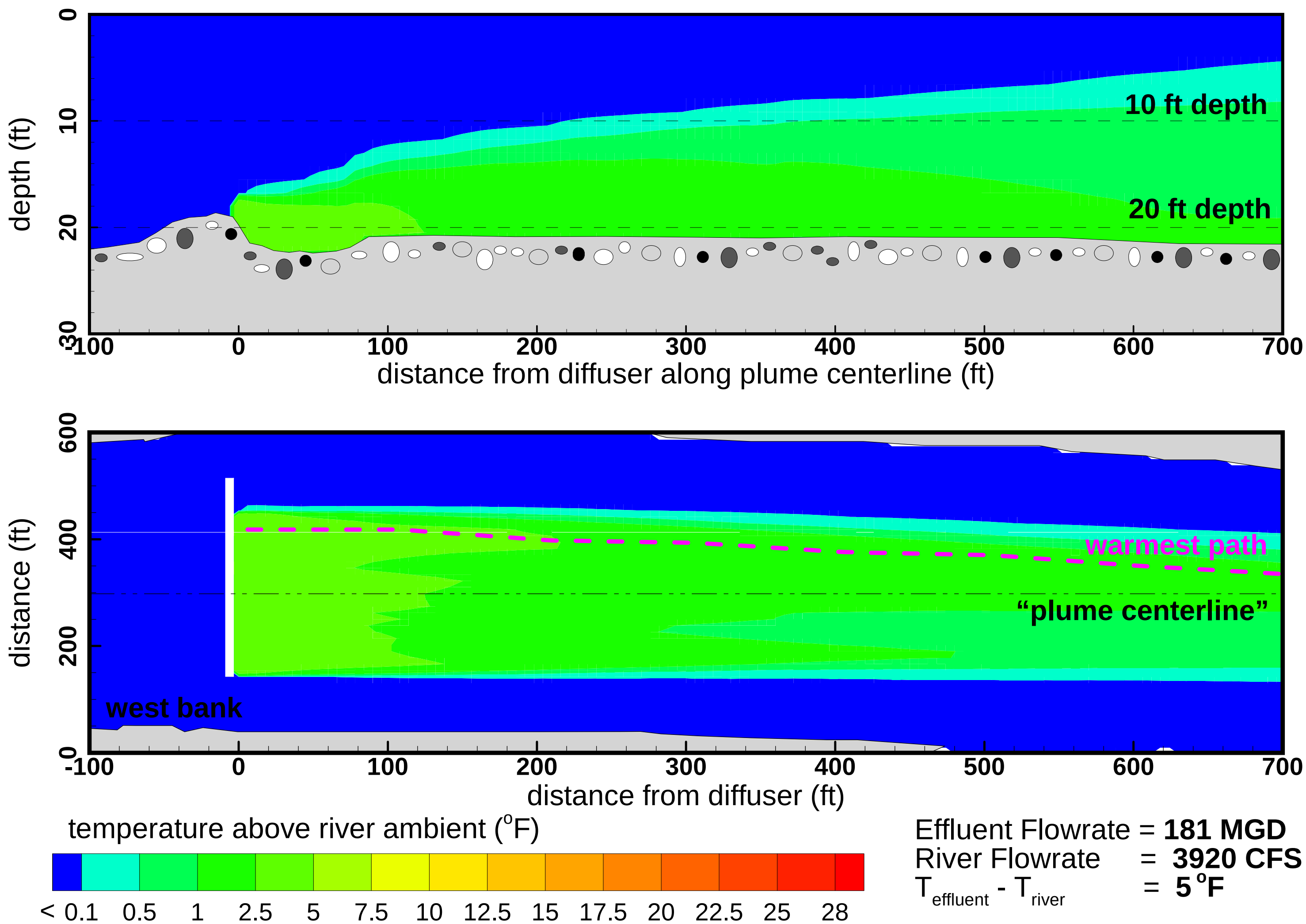
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **60 MGD**
14:1 DILUTION RATIO AND **25 °F** TEMPERATURE DIFFERENCE



* FLOWMOD has been validated for river flows exceeding 3,800 cfs. For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.

Figure 5 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **181 MGD**
14:1 DILUTION RATIO AND **5 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **181 MGD**
River Flowrate = **3920 CFS**
$T_{effluent} - T_{river}$ = **5 °F**

Figure 6 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **181 MGD**
14:1 DILUTION RATIO AND **10 °F** TEMPERATURE DIFFERENCE

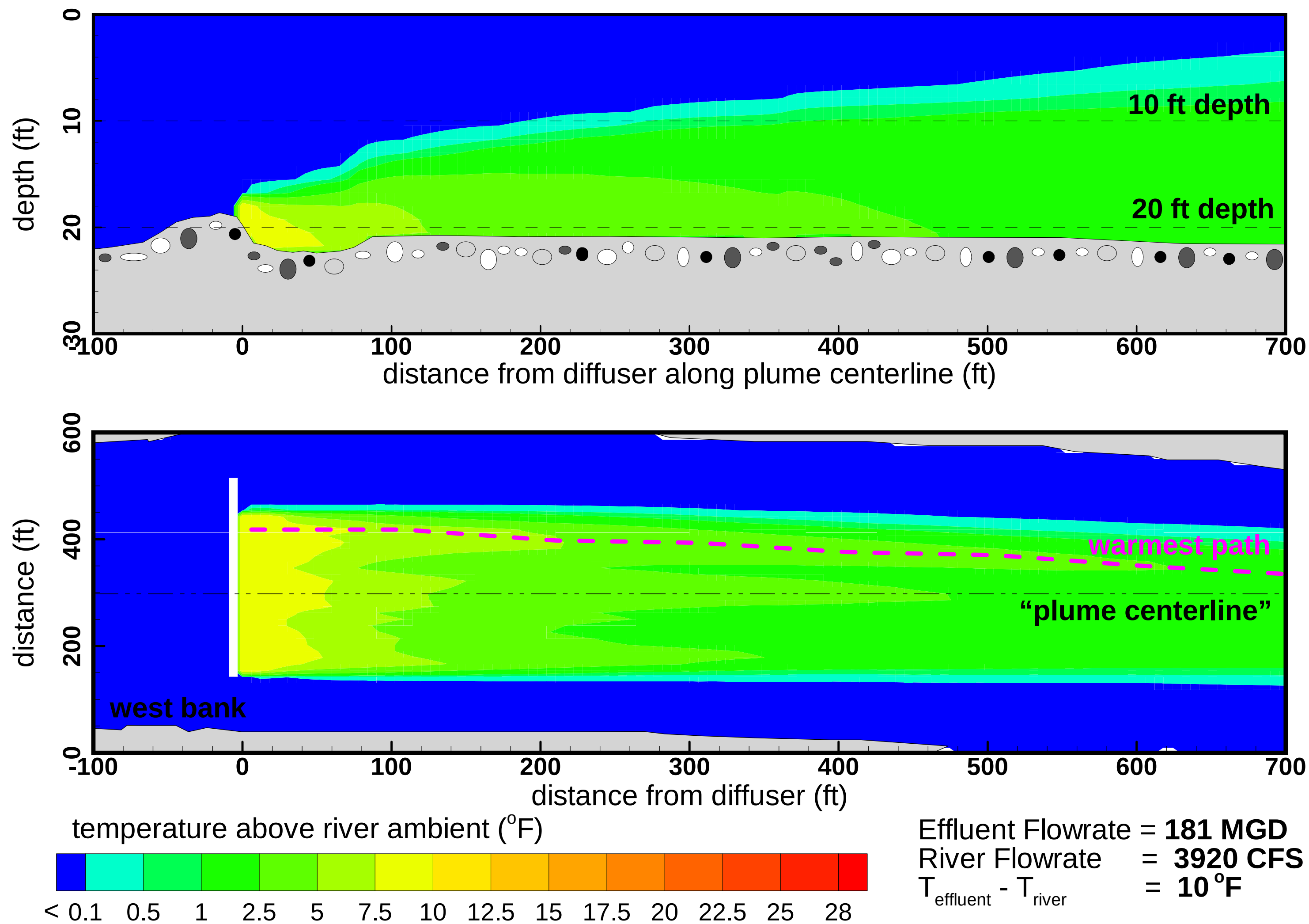


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Figure 7 - DRAFT

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SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **181 MGD**
14:1 DILUTION RATIO AND **15 ^{o}F** TEMPERATURE DIFFERENCE

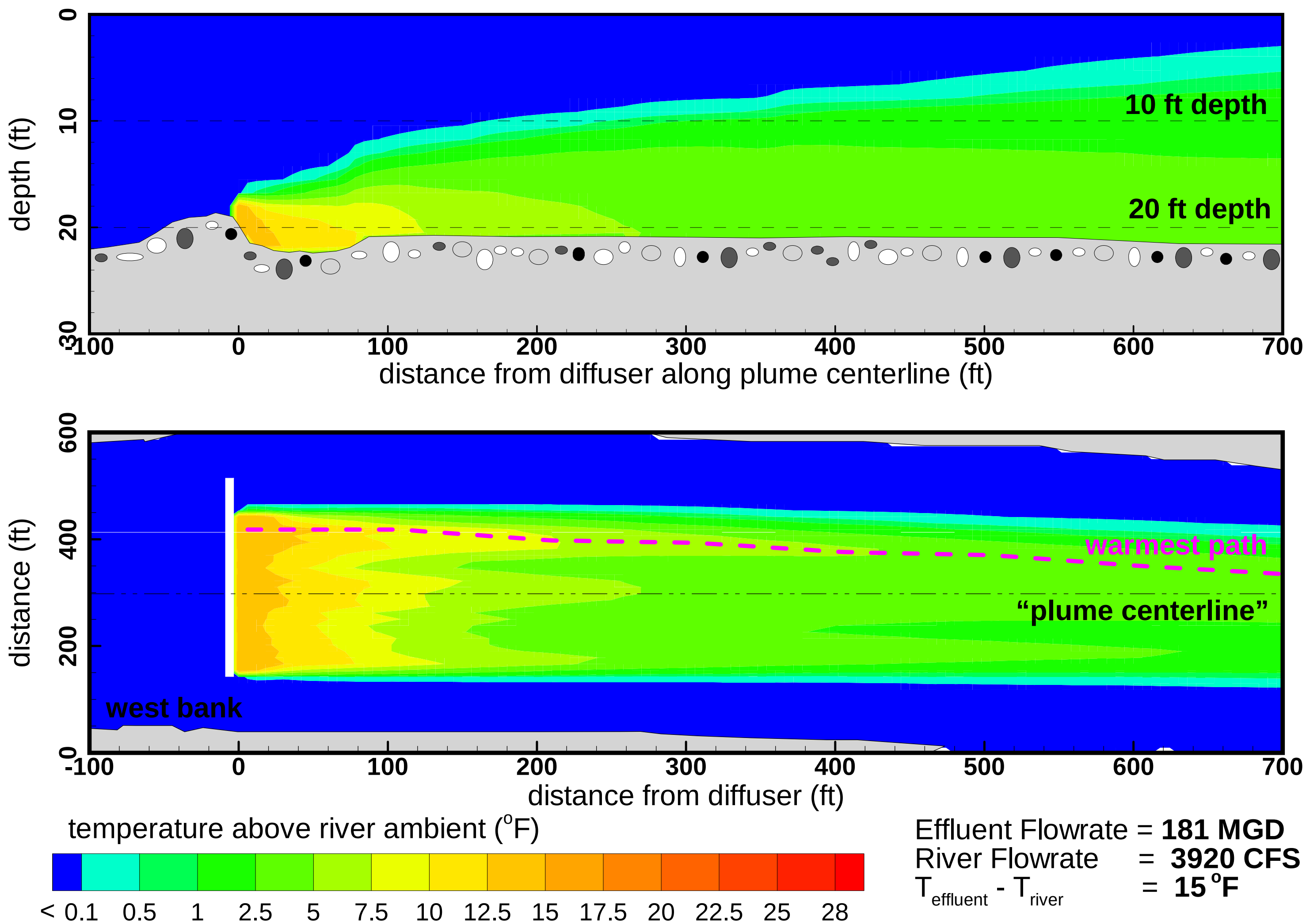


Figure 8 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **181 MGD**
14:1 DILUTION RATIO AND **20 °F** TEMPERATURE DIFFERENCE

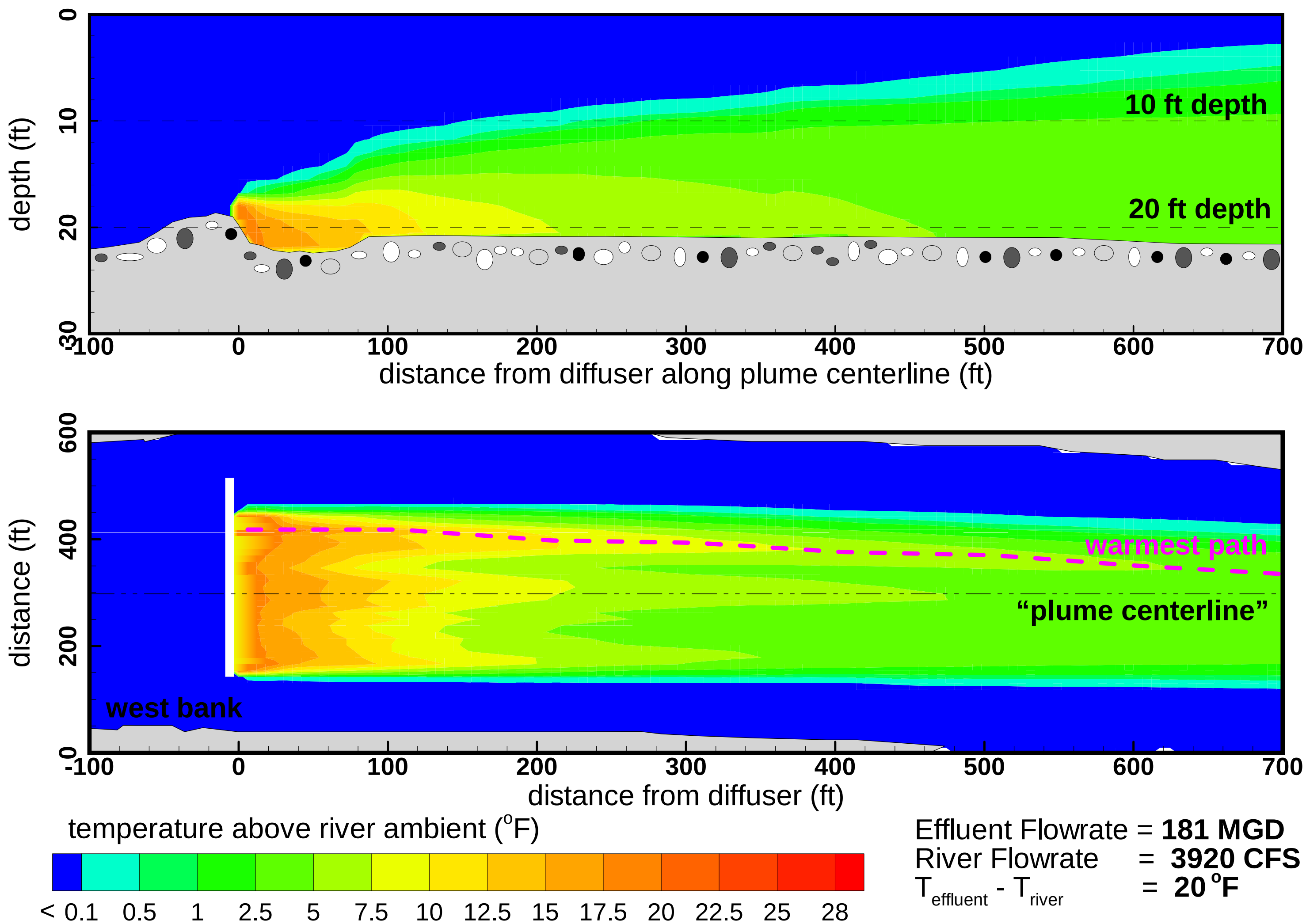


Figure 9 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **181 MGD**
14:1 DILUTION RATIO AND **25 °F** TEMPERATURE DIFFERENCE

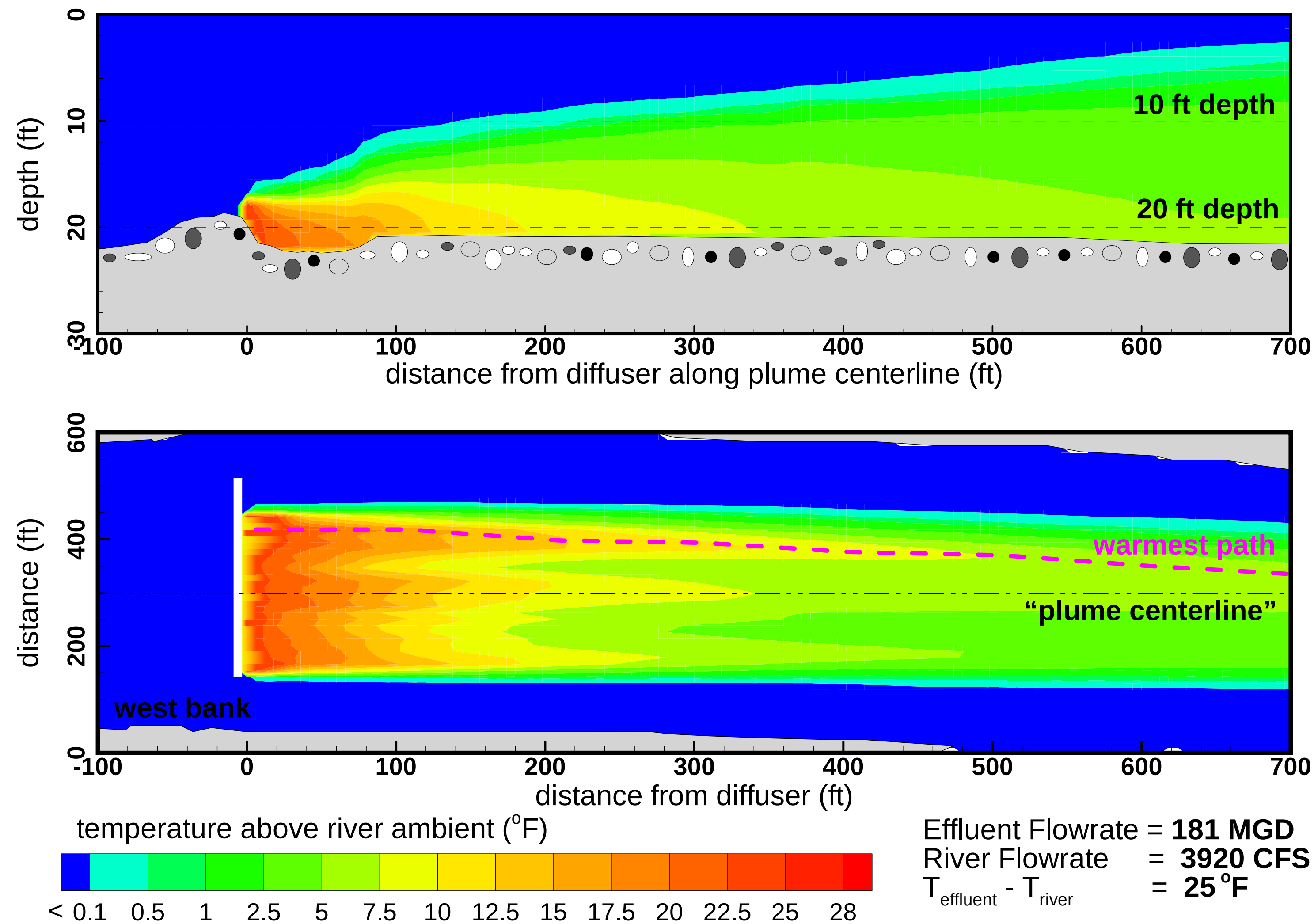


Figure 10 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **410 MGD**
14:1 DILUTION RATIO AND **5 °F** TEMPERATURE DIFFERENCE

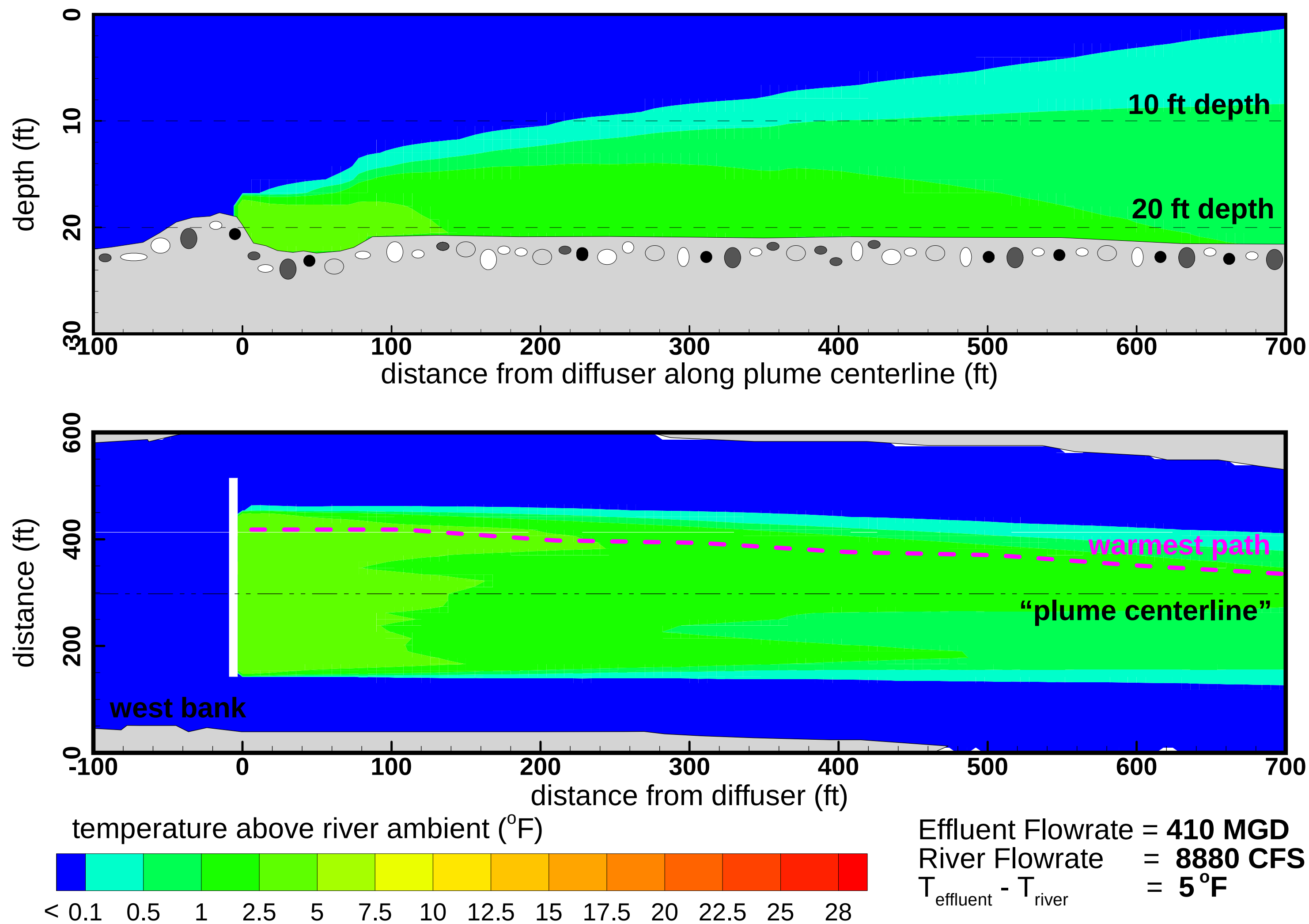
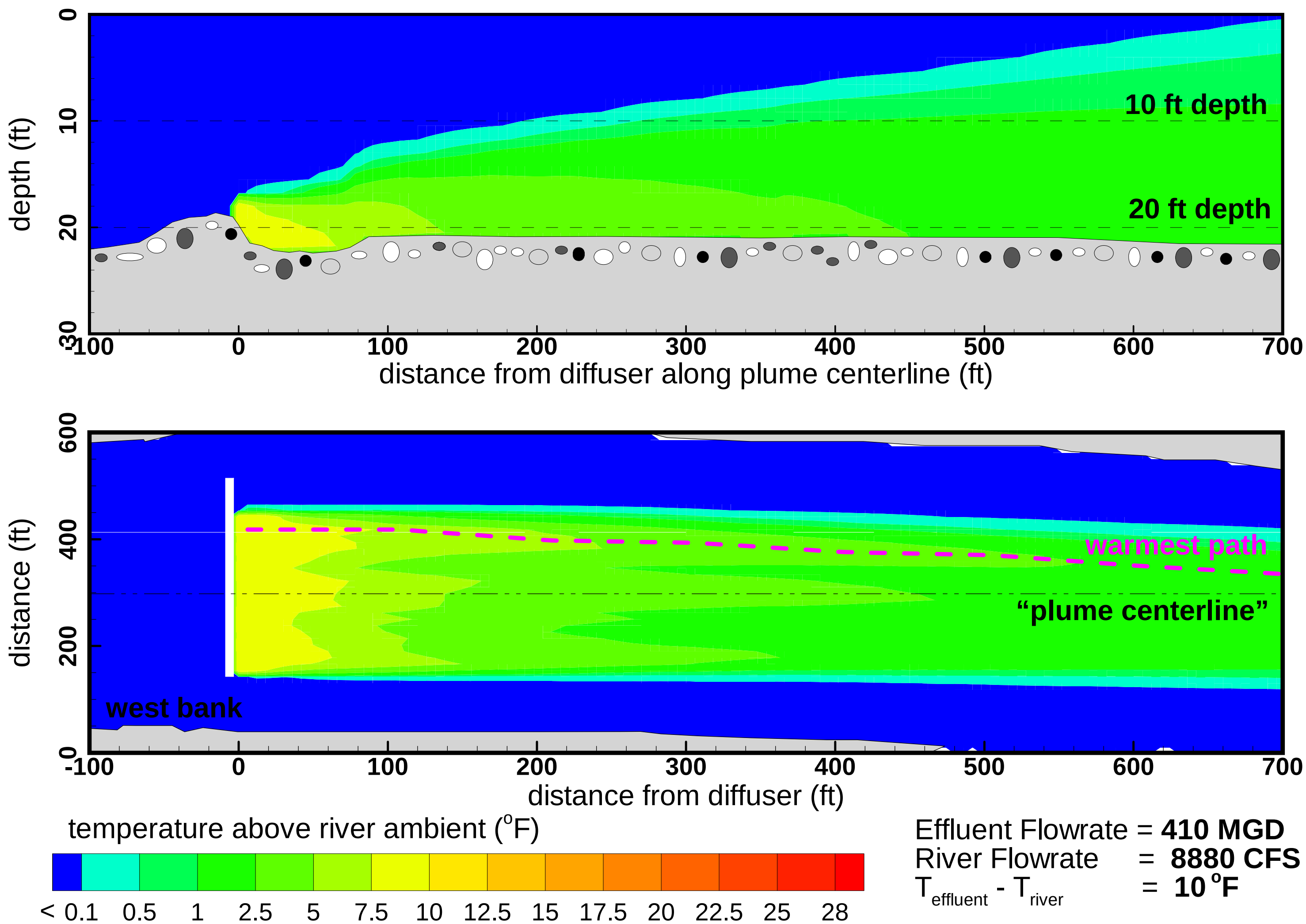


Figure 11 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **410 MGD**
14:1 DILUTION RATIO AND **10 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **410 MGD**
River Flowrate = **8880 CFS**
$T_{effluent} - T_{river}$ = **10 °F**

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February 9, 2015

Figure 12 - DRAFT

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SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **410 MGD**
14:1 DILUTION RATIO AND **15 ^{o}F** TEMPERATURE DIFFERENCE

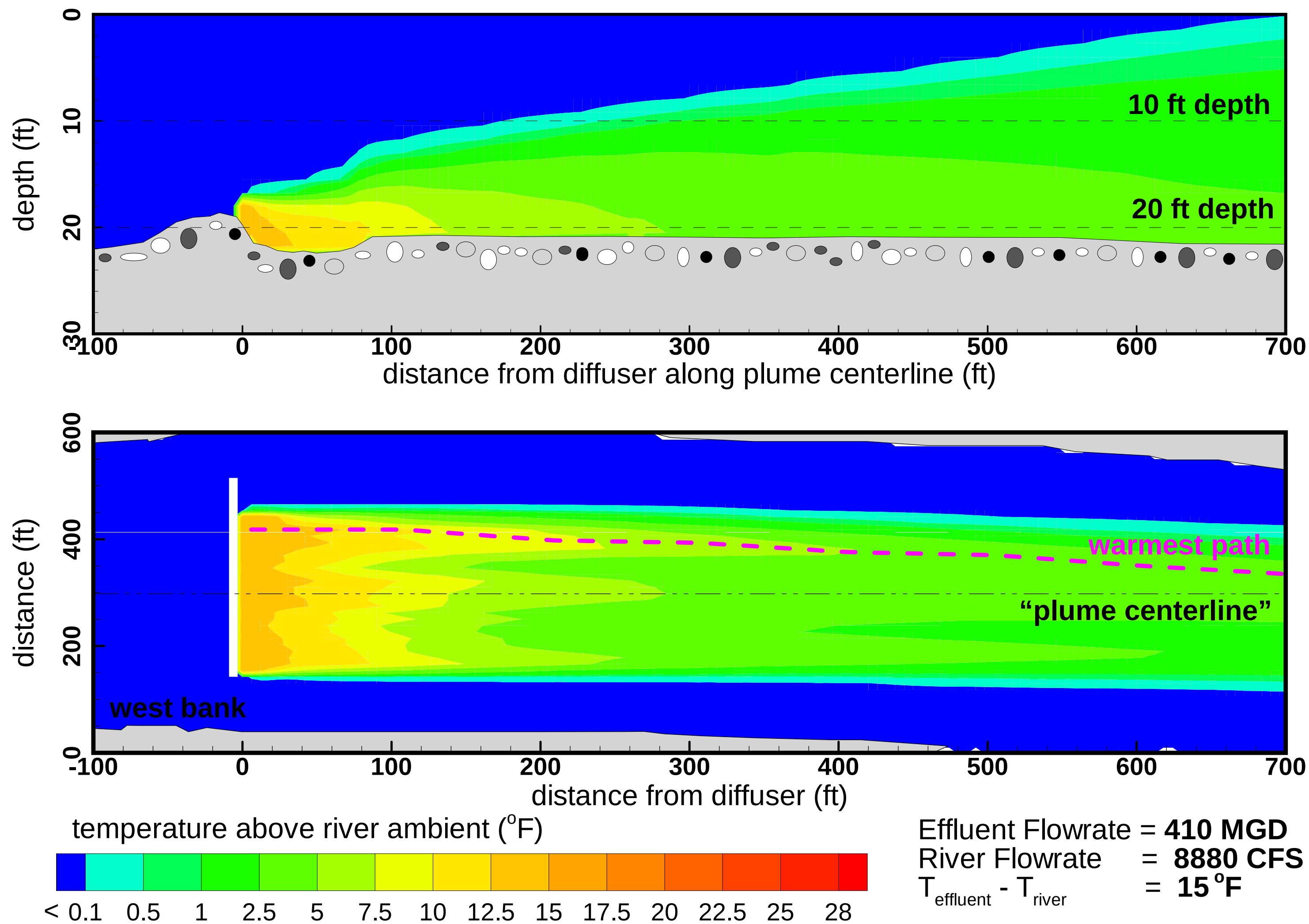

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Figure 13 - DRAFT

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SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **410 MGD**
14:1 DILUTION RATIO AND **20 °F** TEMPERATURE DIFFERENCE

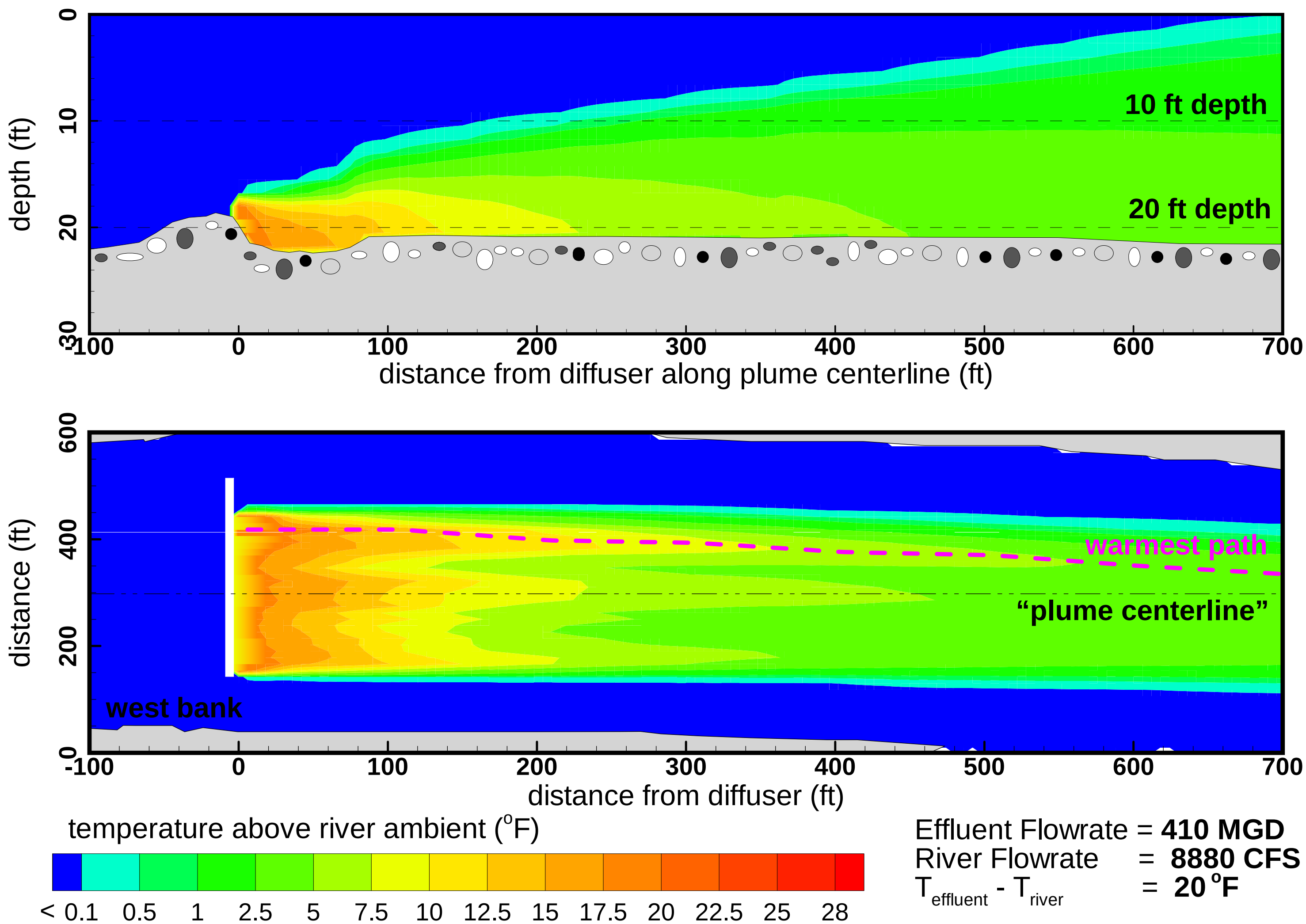


Figure 14 - DRAFT

FLOW SCIENCE

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **410 MGD**
14:1 DILUTION RATIO AND **25 °F** TEMPERATURE DIFFERENCE

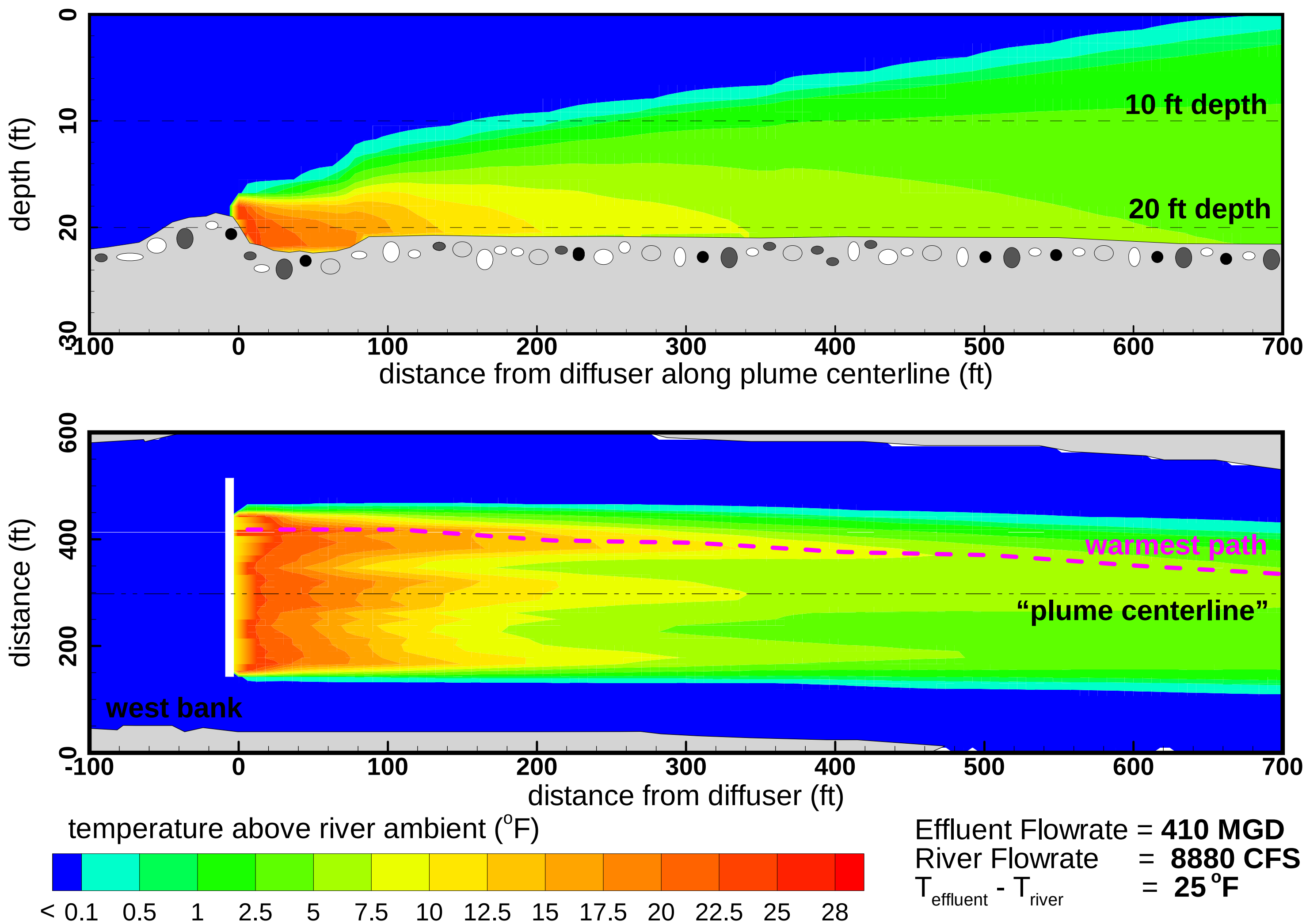
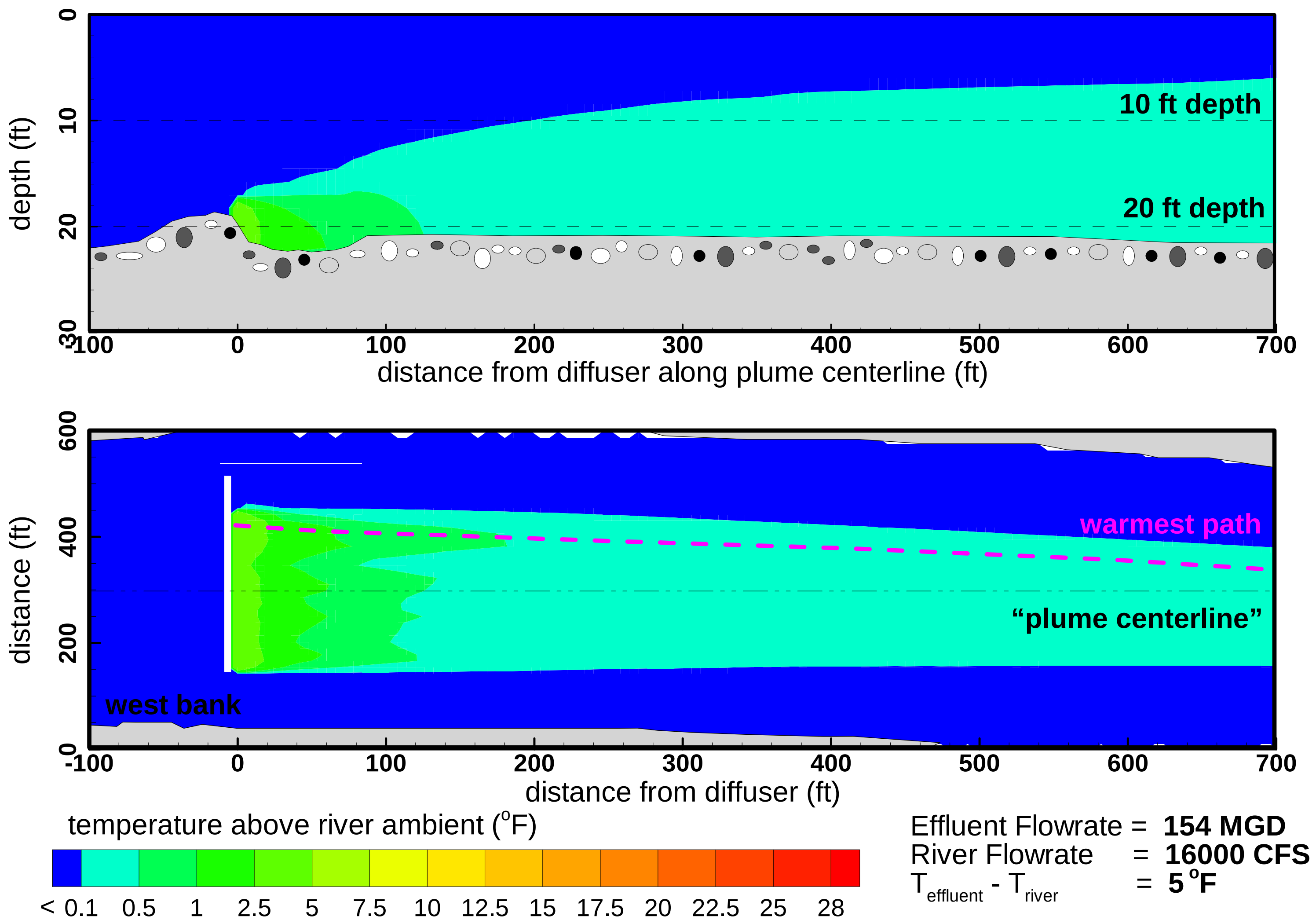


Figure 15 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **154 MGD**
67:1 DILUTION RATIO AND **5 °F** TEMPERATURE DIFFERENCE



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FSI 104120.2
February 9, 2015

Figure 16 - DRAFT

FLOW SCIENCE

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **154 MGD**
67:1 DILUTION RATIO AND **10 °F** TEMPERATURE DIFFERENCE

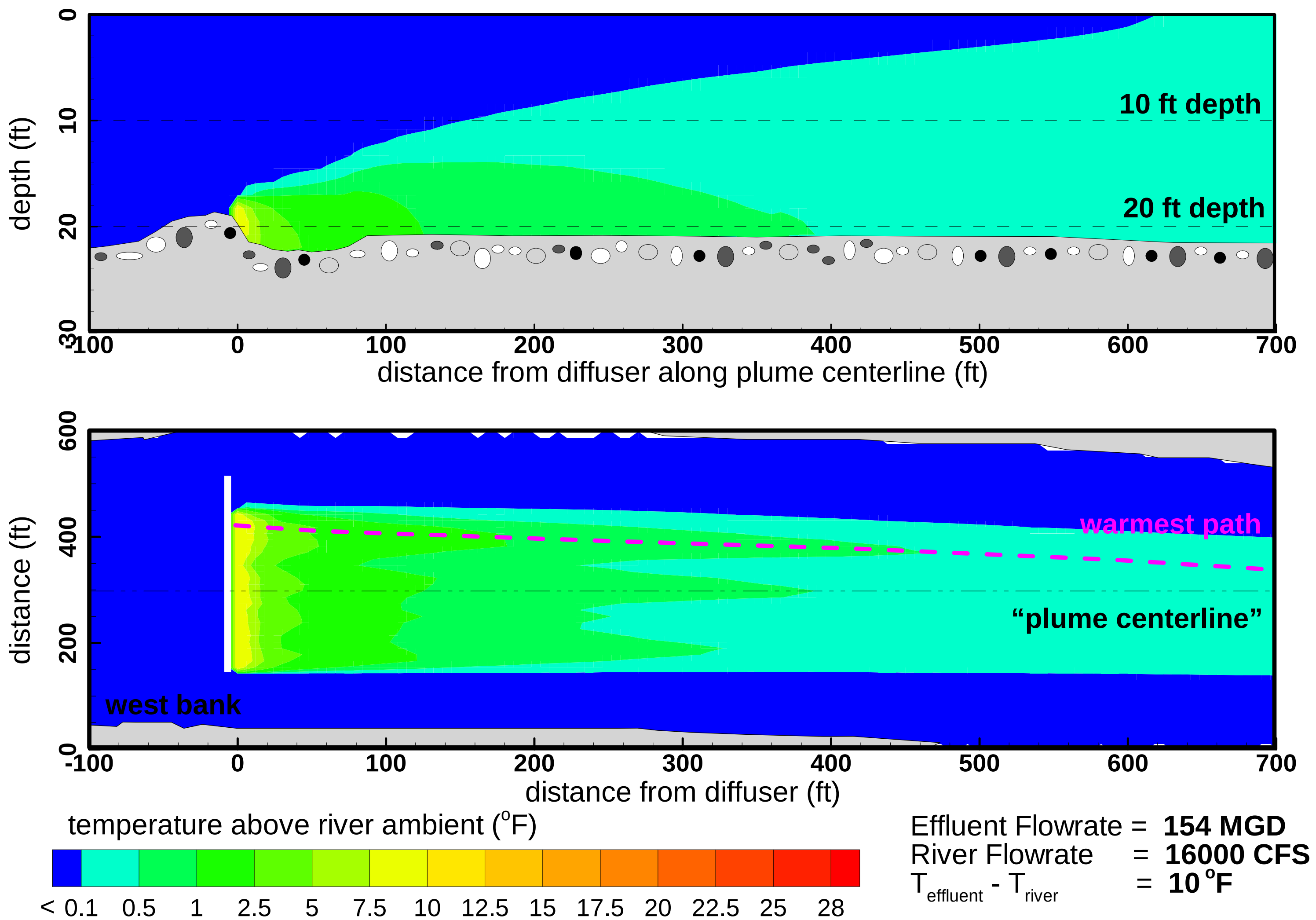

Figure 17 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **154 MGD**
67:1 DILUTION RATIO AND **15 °F** TEMPERATURE DIFFERENCE

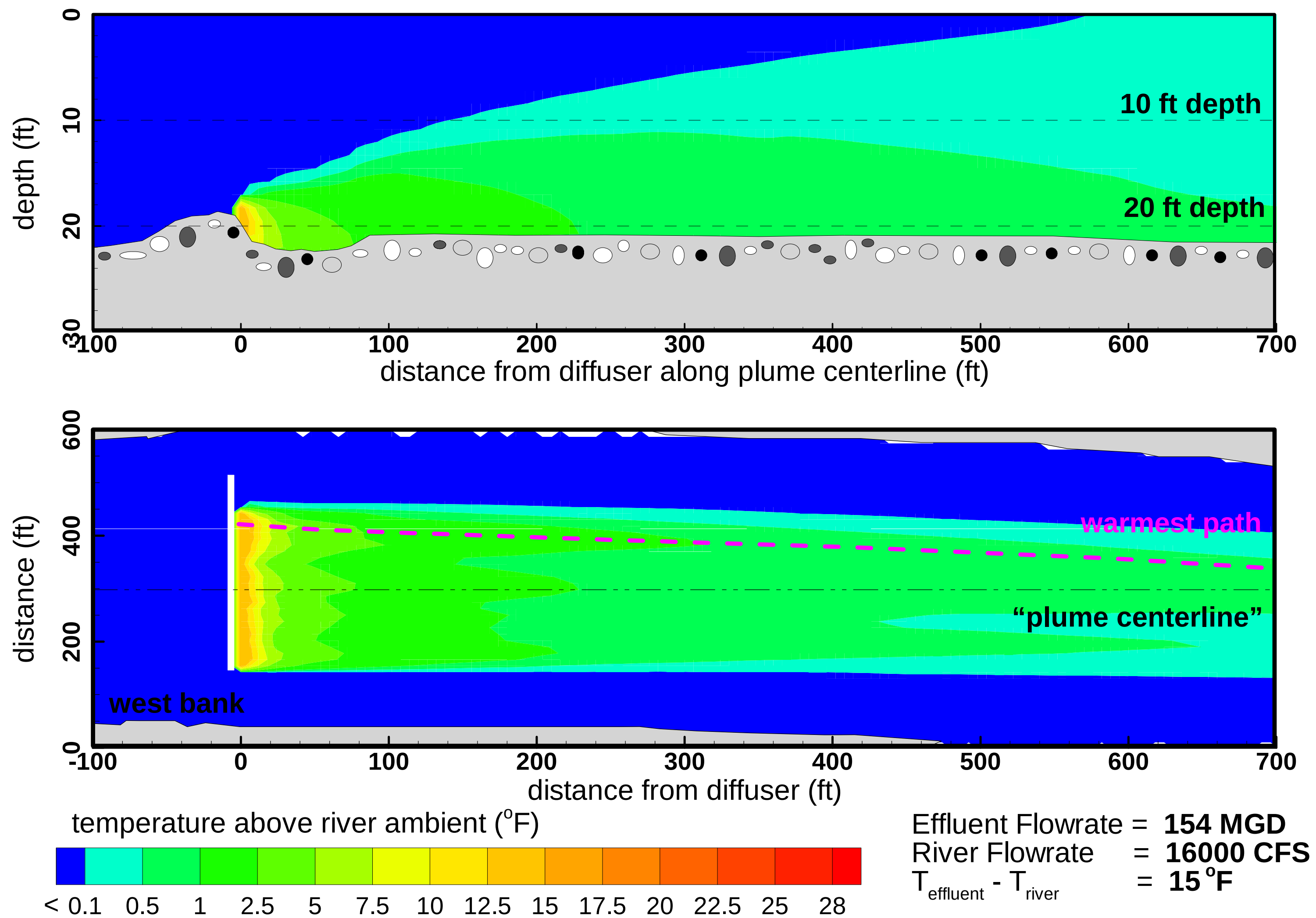

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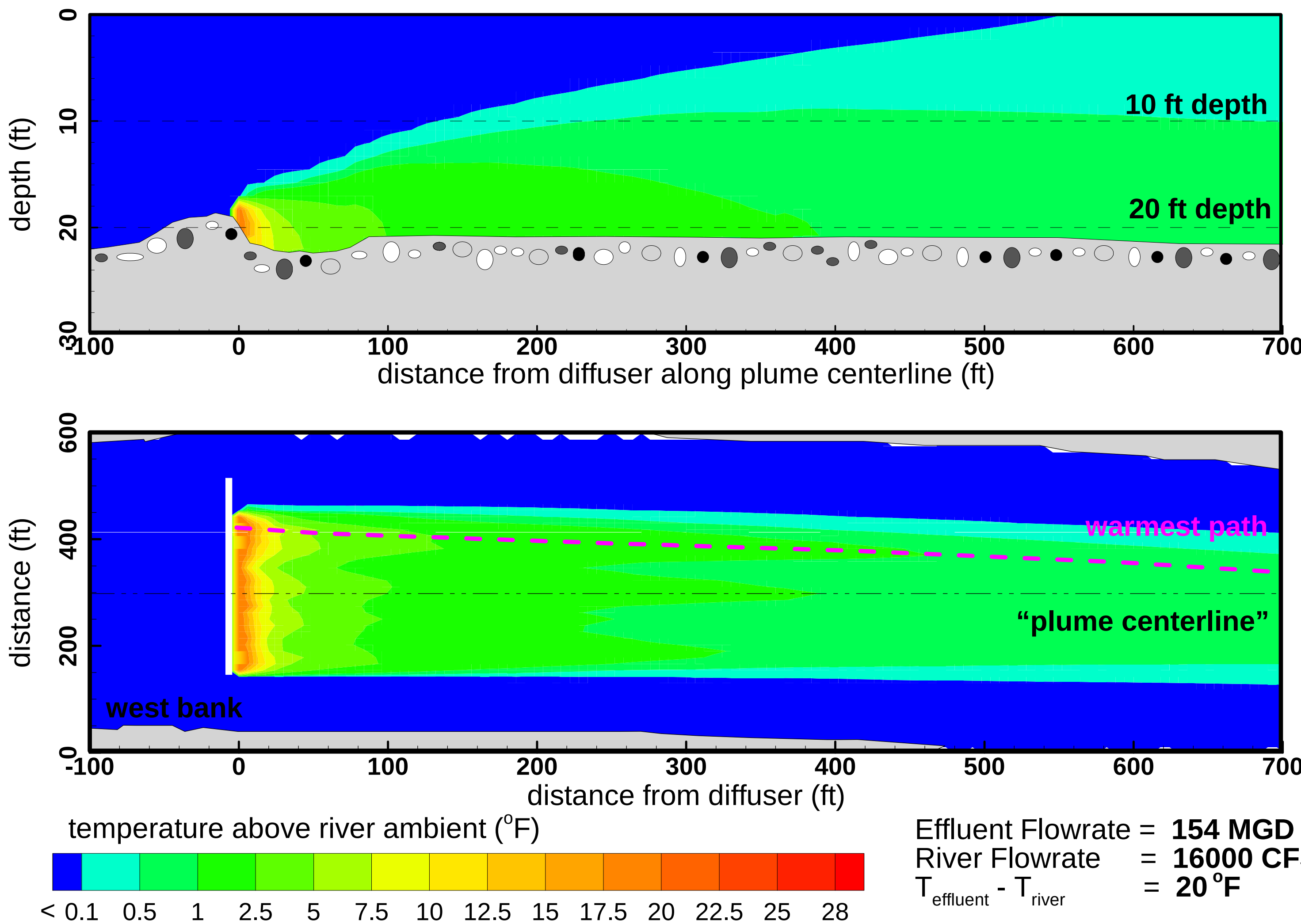
Figure 18 - DRAFT

FLOW SCIENCE®

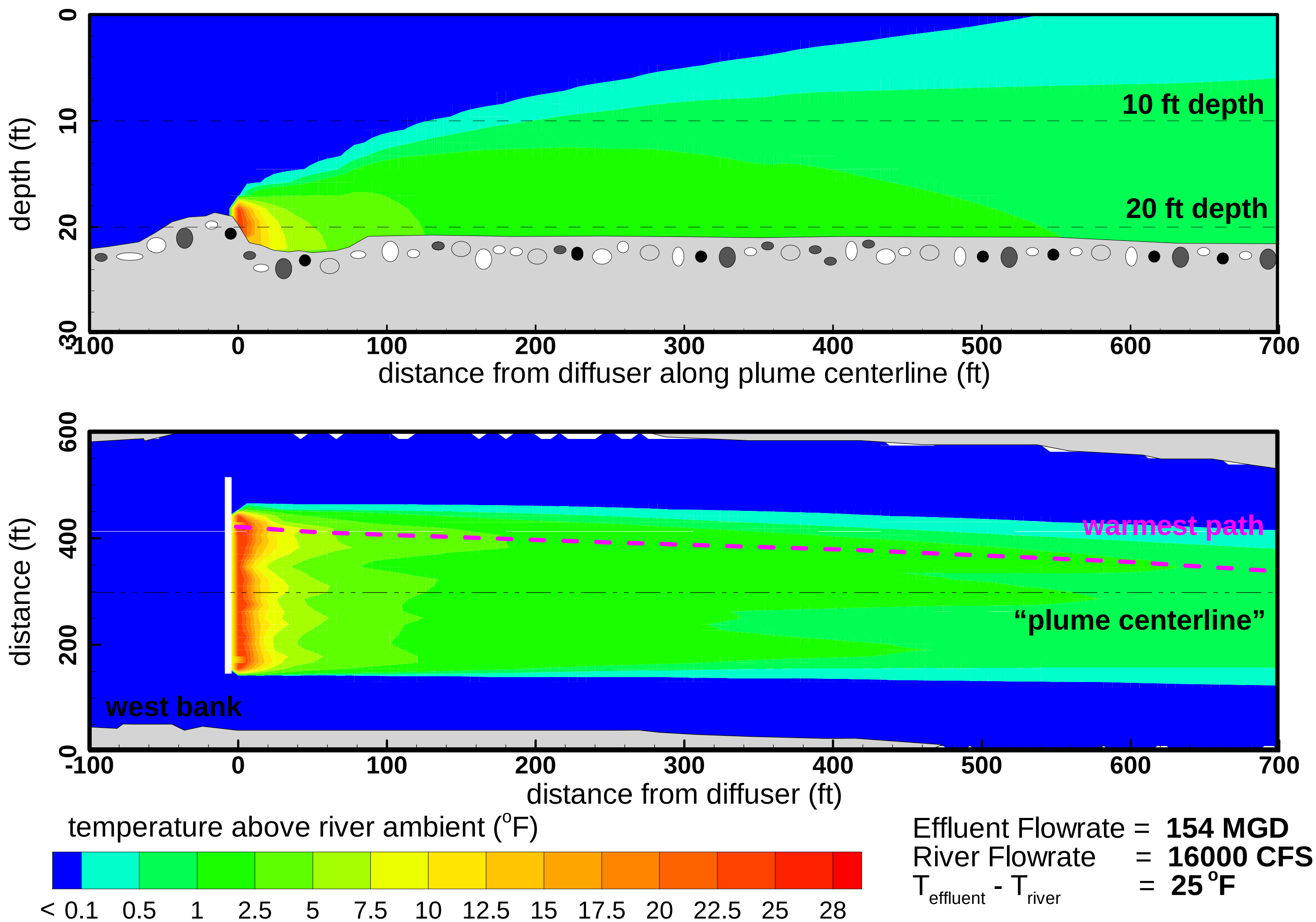
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **154 MGD**
67:1 DILUTION RATIO AND **20 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **154 MGD**
River Flowrate = **16000 CFS**
$T_{effluent} - T_{river}$ = **20 °F**

Figure 19 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME (DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **154 MGD**
67:1 DILUTION RATIO AND **25 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **154 MGD**
River Flowrate = **16000 CFS**
$T_{effluent} - T_{river}$ = **25 °F**

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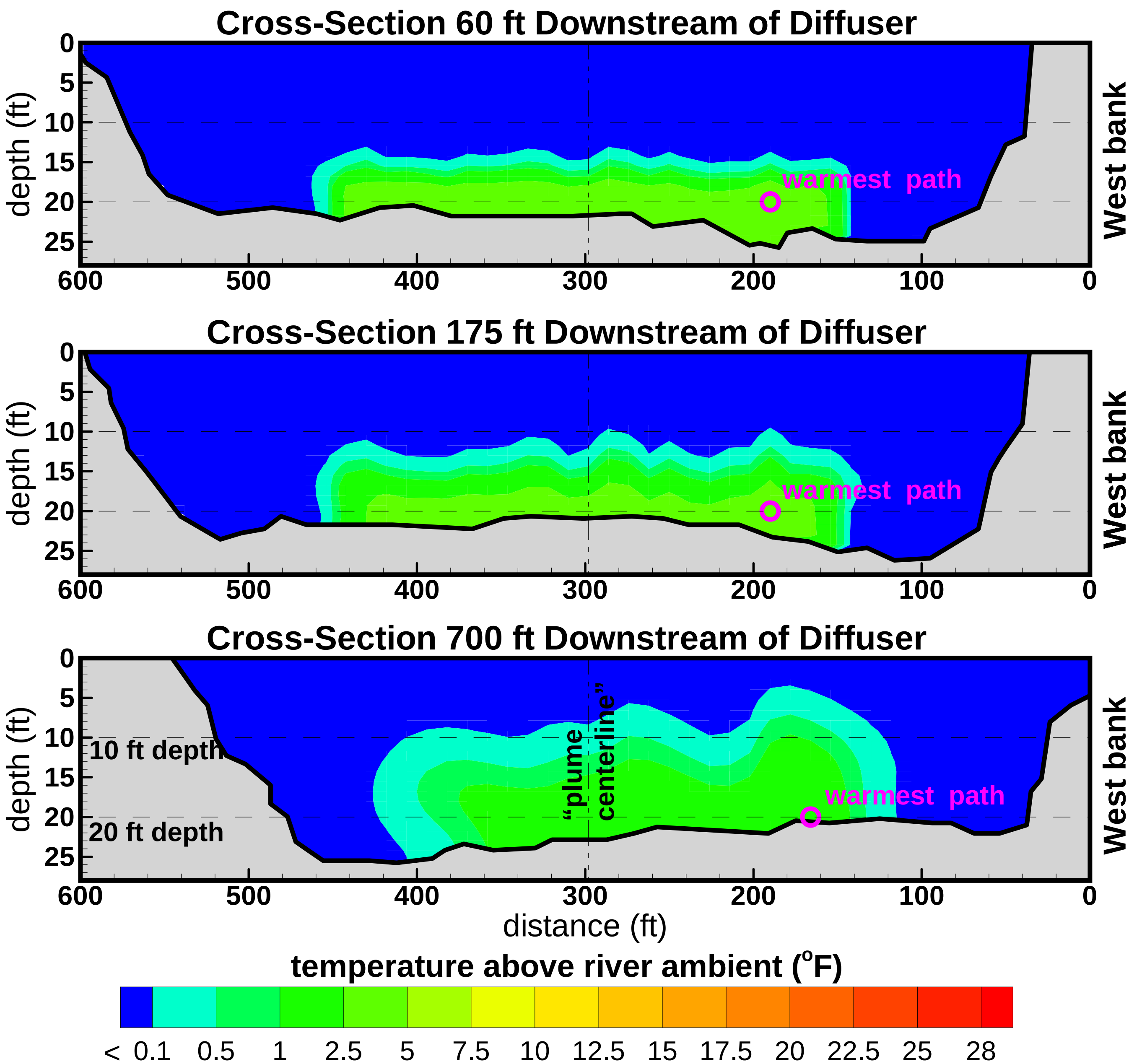
Figure 20 - DRAFT

FLOW SCIENCE®

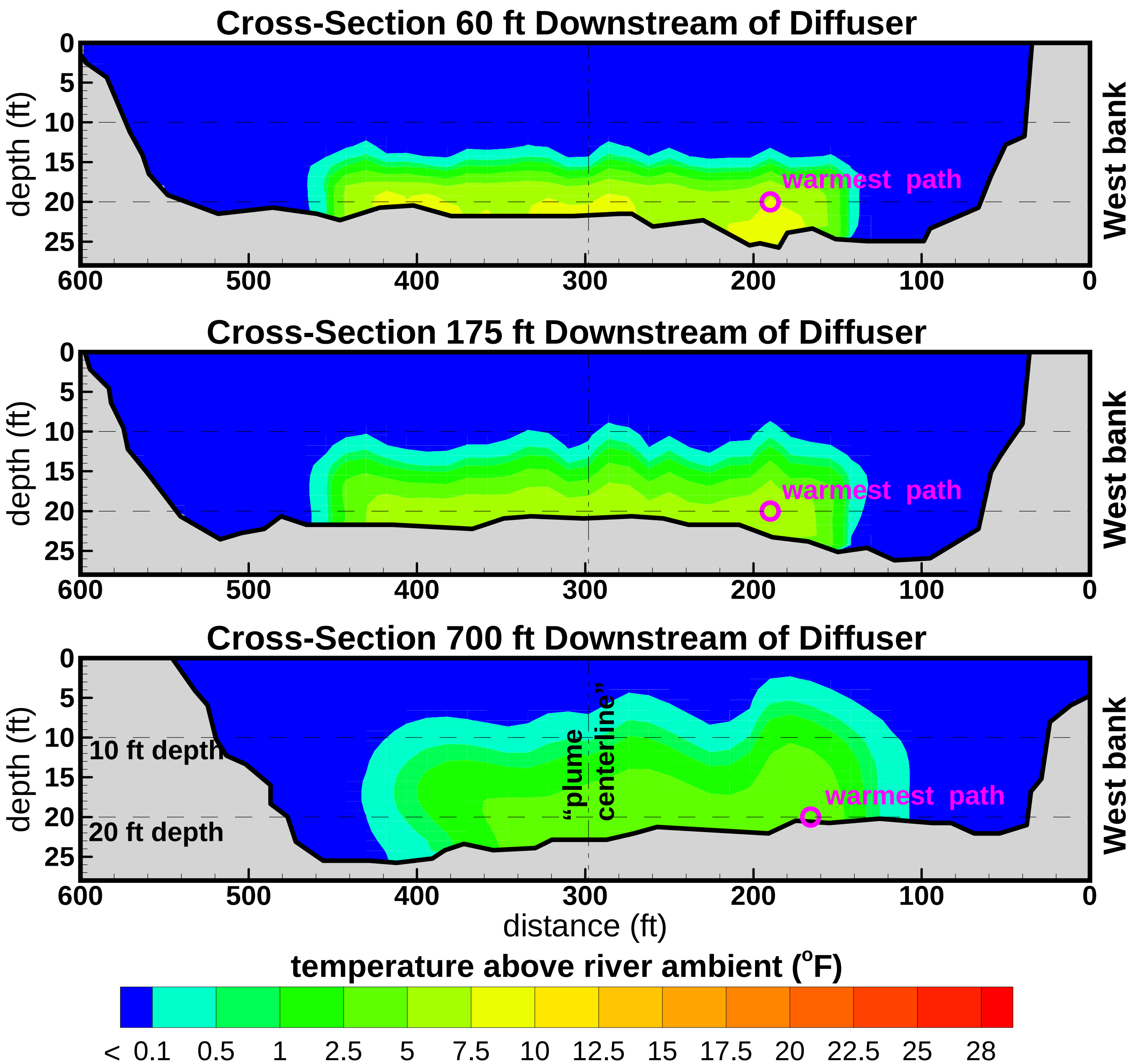
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **60 MGD**
14:1 DILUTION RATIO AND **5 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **60 MGD**
River Flowrate = **1300 CFS** *
$T_{effluent} - T_{river}$ = **5 °F**

* FLOWMOD has been validated for river flows exceeding 3,800 cfs.
For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **60 MGD**
14:1 DILUTION RATIO AND **10 °F** TEMPERATURE DIFFERENCE

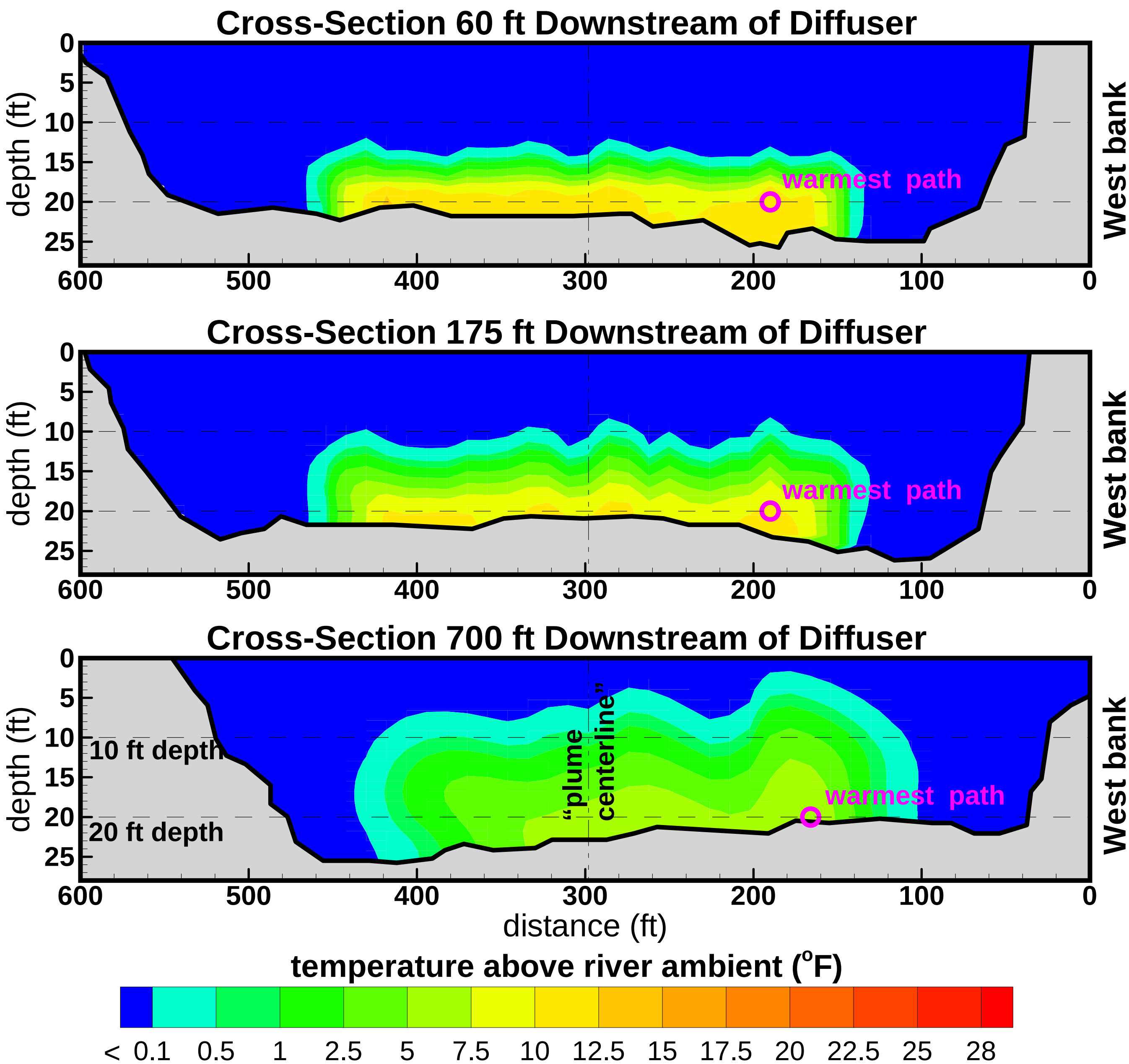


Effluent Flowrate = **60 MGD**
River Flowrate = **1300 CFS** *
$T_{effluent}$ - T_{river} = **10 °F**

* FLOWMOD has been validated for river flows exceeding 3,800 cfs.
For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.

Figure 22 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **60 MGD**
14:1 DILUTION RATIO AND **15 °F** TEMPERATURE DIFFERENCE

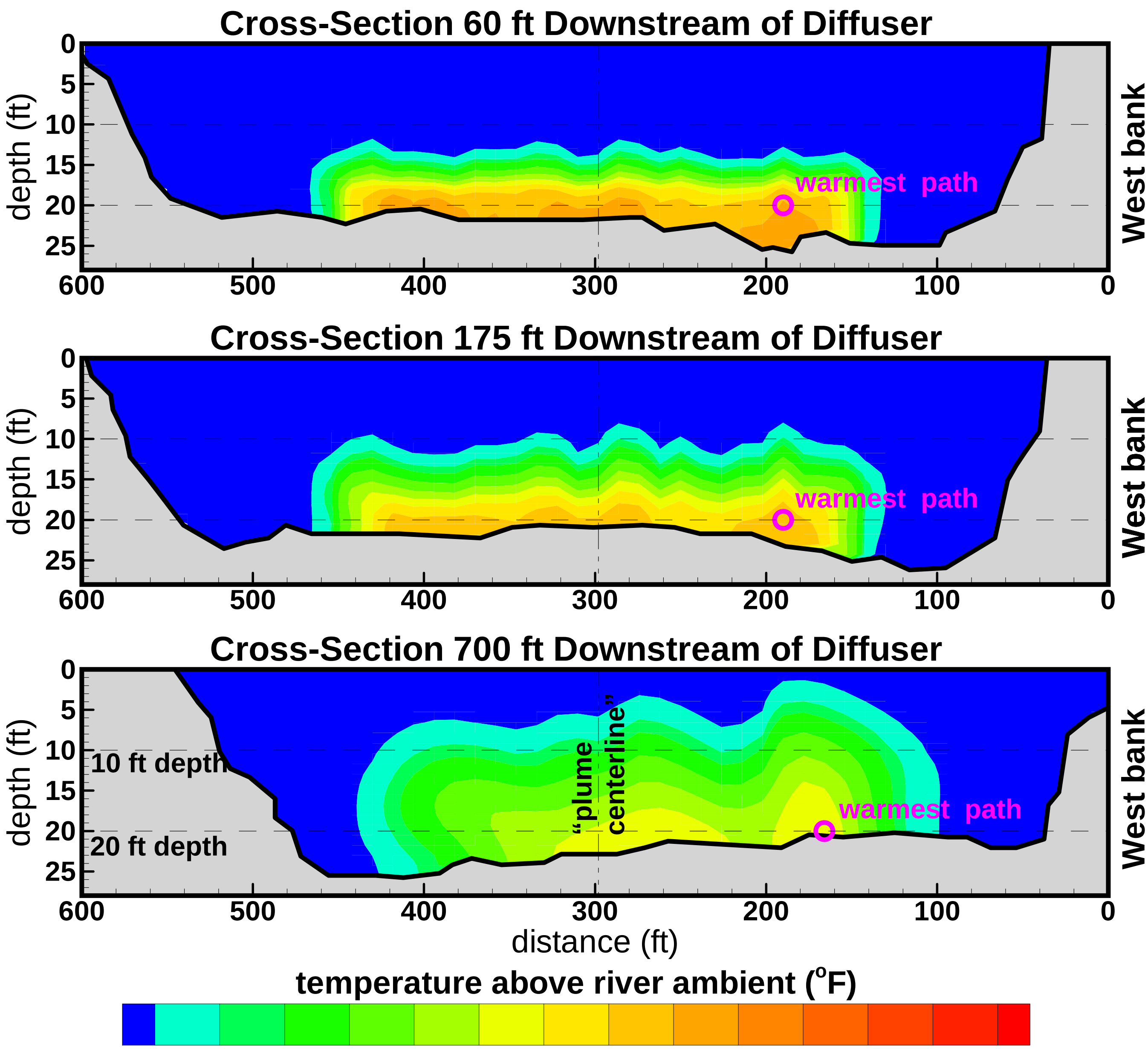


Effluent Flowrate = **60 MGD**
River Flowrate = **1300 CFS ***
$T_{effluent} - T_{river}$ = **15 °F**

* FLOWMOD has been validated for river flows exceeding 3,800 cfs.
For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.

Figure 23 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **60 MGD**
14:1 DILUTION RATIO AND **20 °F** TEMPERATURE DIFFERENCE

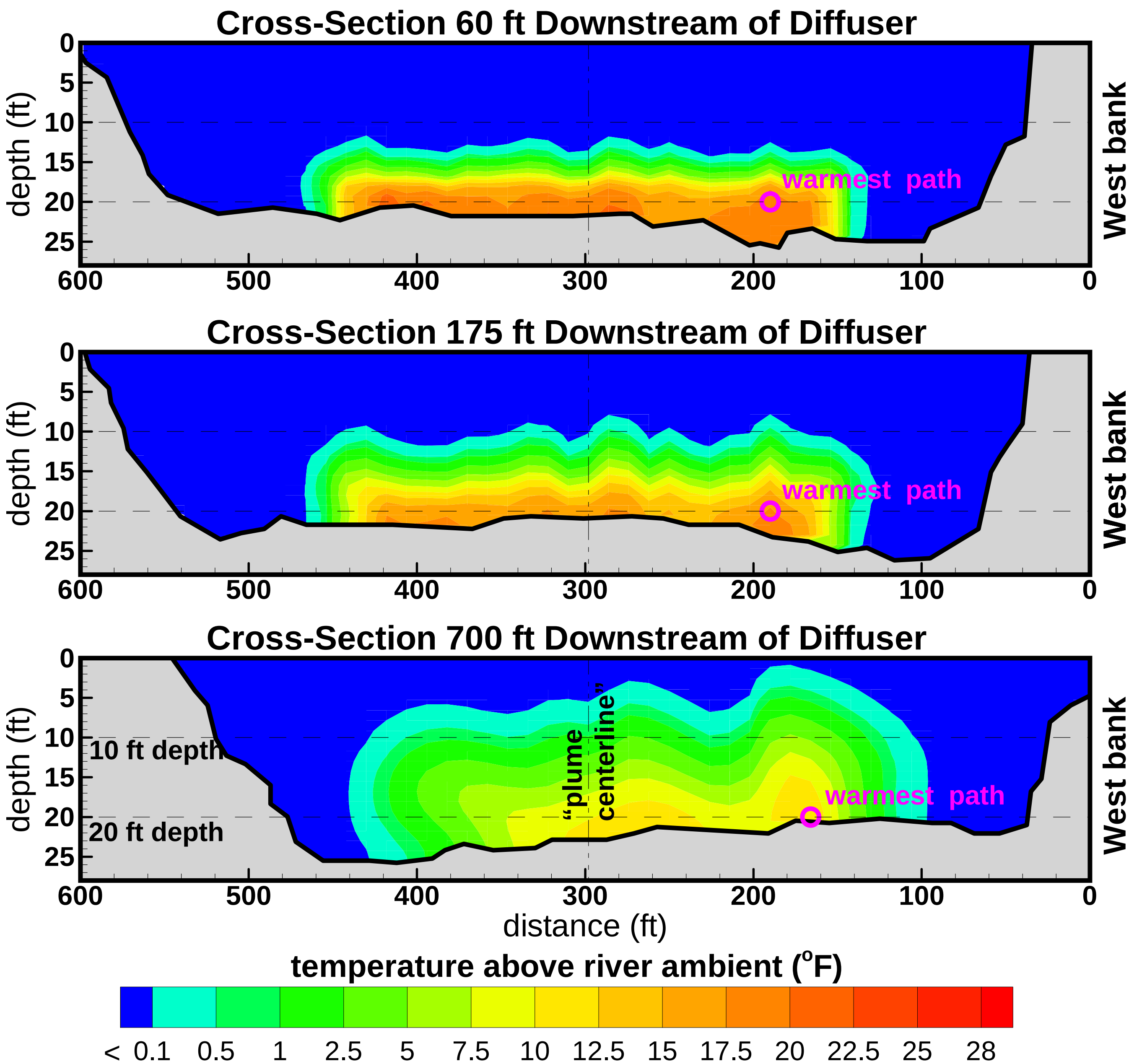


Effluent Flowrate = **60 MGD**
River Flowrate = **1300 CFS ***
$T_{effluent} - T_{river}$ = **20 °F**

* FLOWMOD has been validated for river flows exceeding 3,800 cfs.
For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.

Figure 24 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **60 MGD**
14:1 DILUTION RATIO AND **25 °F** TEMPERATURE DIFFERENCE

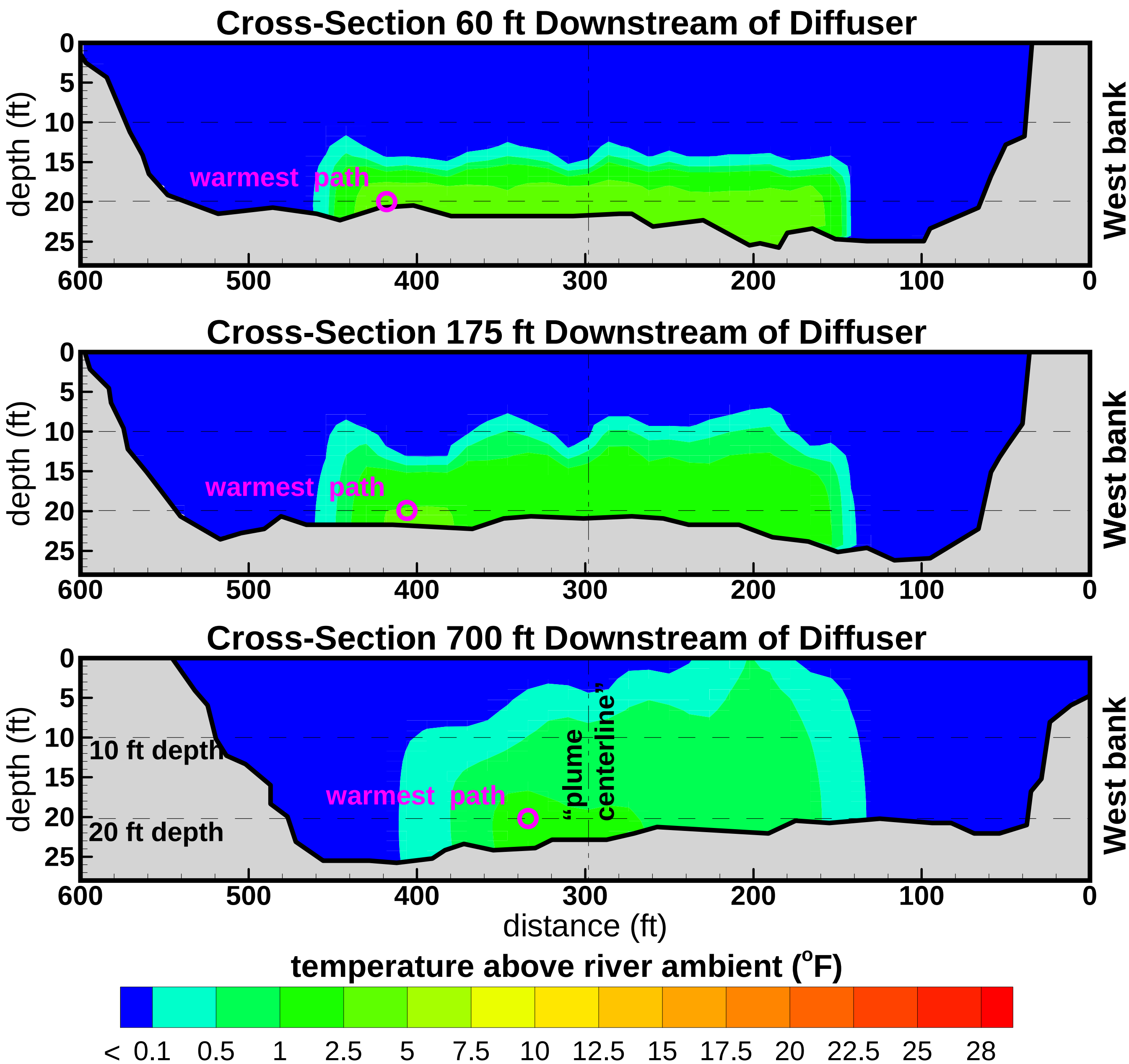


Effluent Flowrate = **60 MGD**
River Flowrate = **1300 CFS ***
$T_{effluent} - T_{river}$ = **25 °F**

* FLOWMOD has been validated for river flows exceeding 3,800 cfs.
For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.

Figure 25 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **181 MGD**
14:1 DILUTION RATIO AND **5 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **181 MGD**
River Flowrate = **3920 CFS**
$T_{effluent} - T_{river}$ = **5 °F**

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Figure 26 - DRAFT

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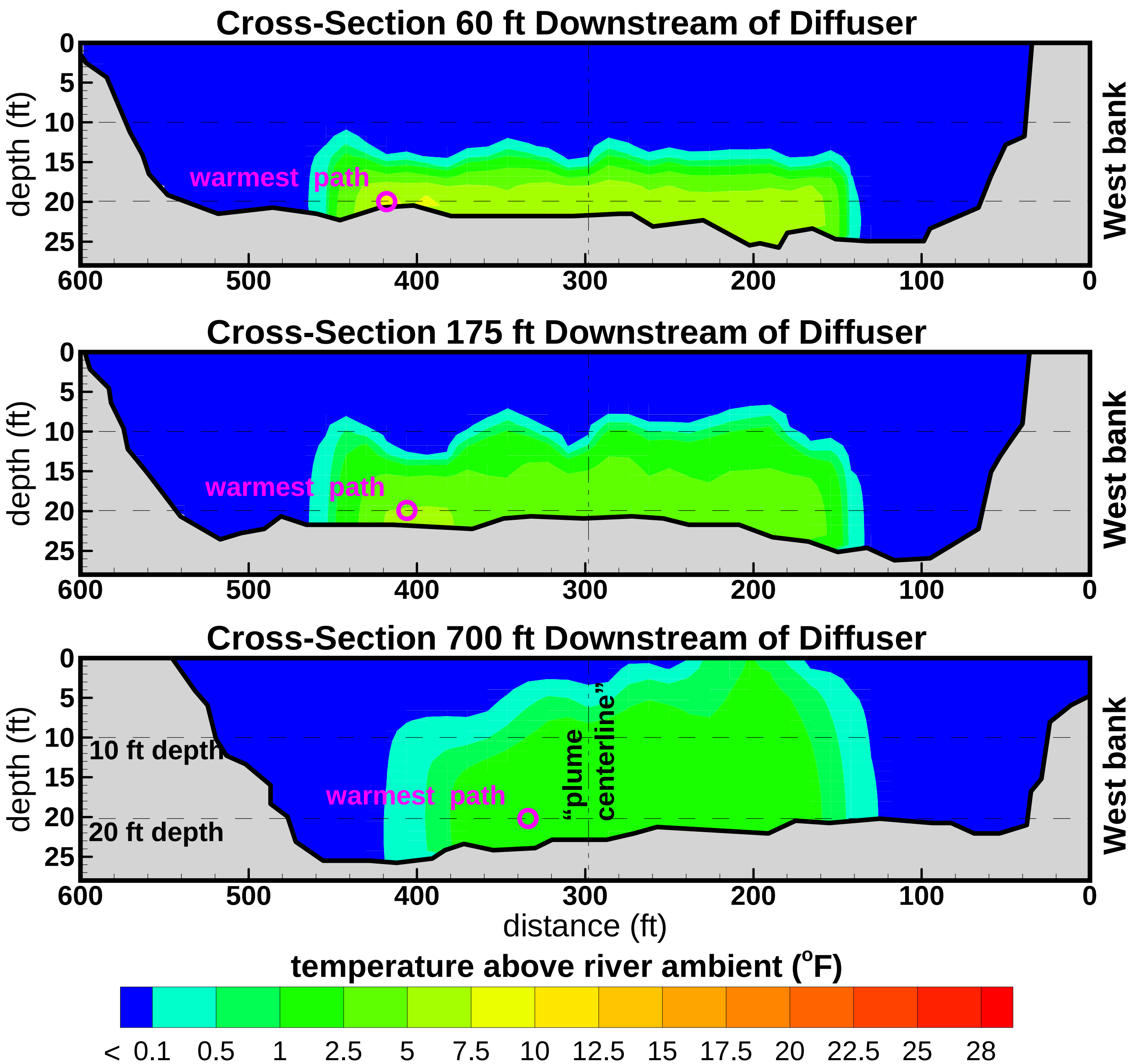
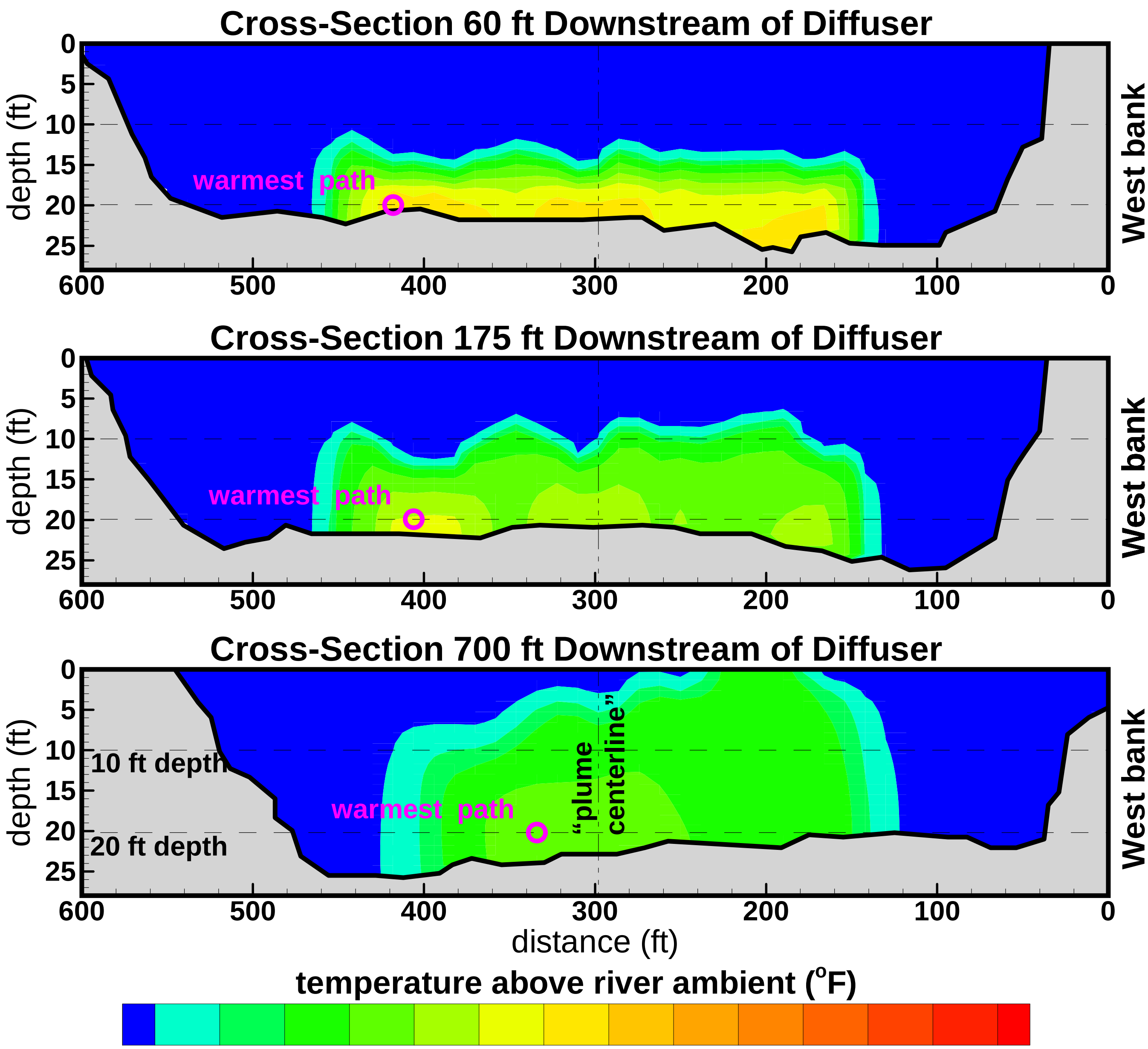
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **181 MGD**
14:1 DILUTION RATIO AND **10 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **181 MGD**
River Flowrate = **3920 CFS**
$T_{effluent} - T_{river}$ = **10 °F**

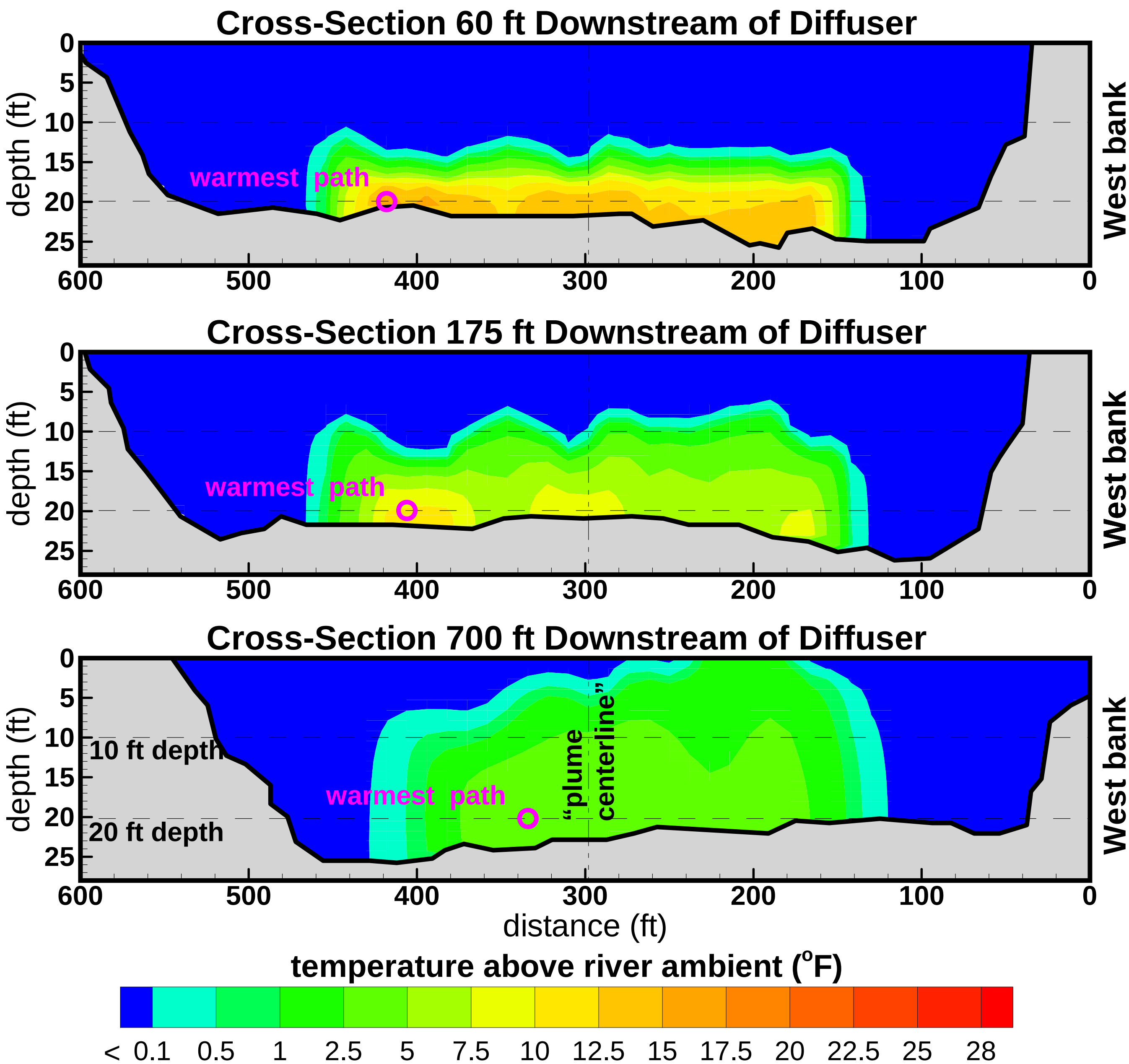
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **181 MGD**
14:1 DILUTION RATIO AND **15 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **181 MGD**
River Flowrate = **3920 CFS**
$T_{effluent} - T_{river}$ = **15 °F**

Figure 28 - DRAFT

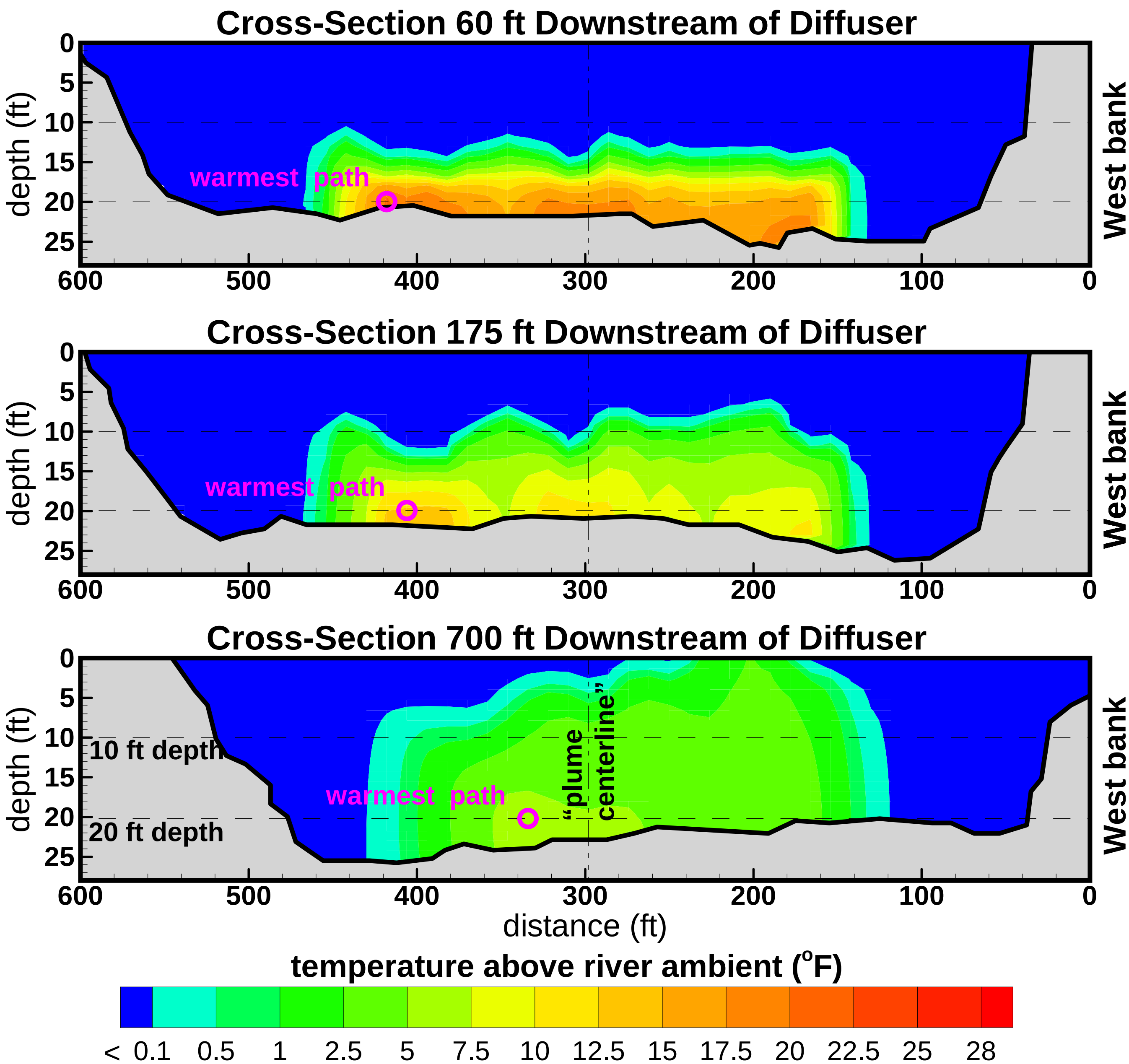
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **181 MGD**
14:1 DILUTION RATIO AND **20 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **181 MGD**
River Flowrate = **3920 CFS**
$T_{effluent} - T_{river}$ = **20 °F**

Figure 29 - DRAFT

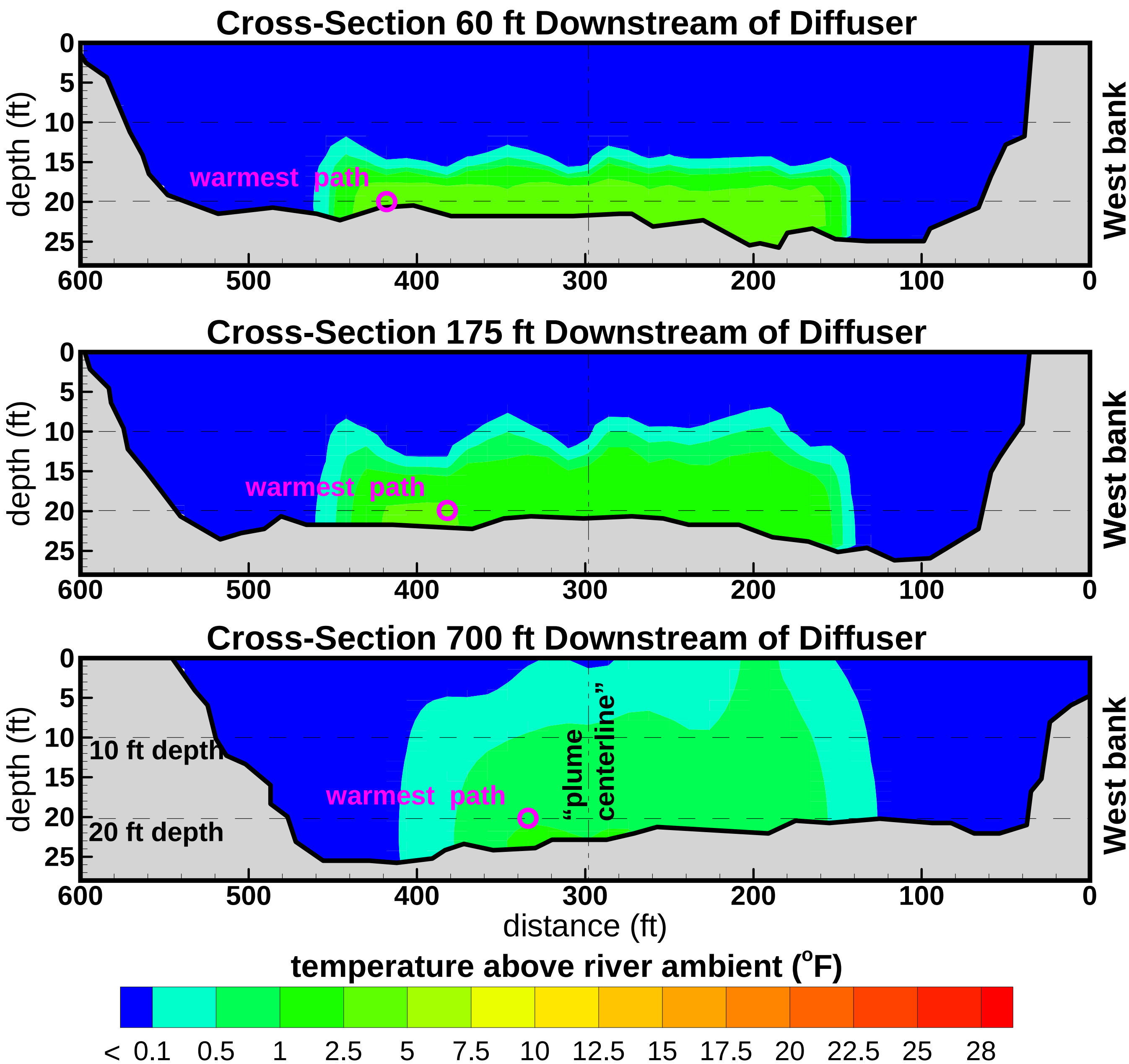
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **181 MGD**
14:1 DILUTION RATIO AND **25 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **181 MGD**
River Flowrate = **3920 CFS**
$T_{effluent} - T_{river}$ = **25 °F**

Figure 30 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **410 MGD**
14:1 DILUTION RATIO AND **5 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **410 MGD**
River Flowrate = **8880 CFS**
$T_{effluent} - T_{river}$ = **5 °F**

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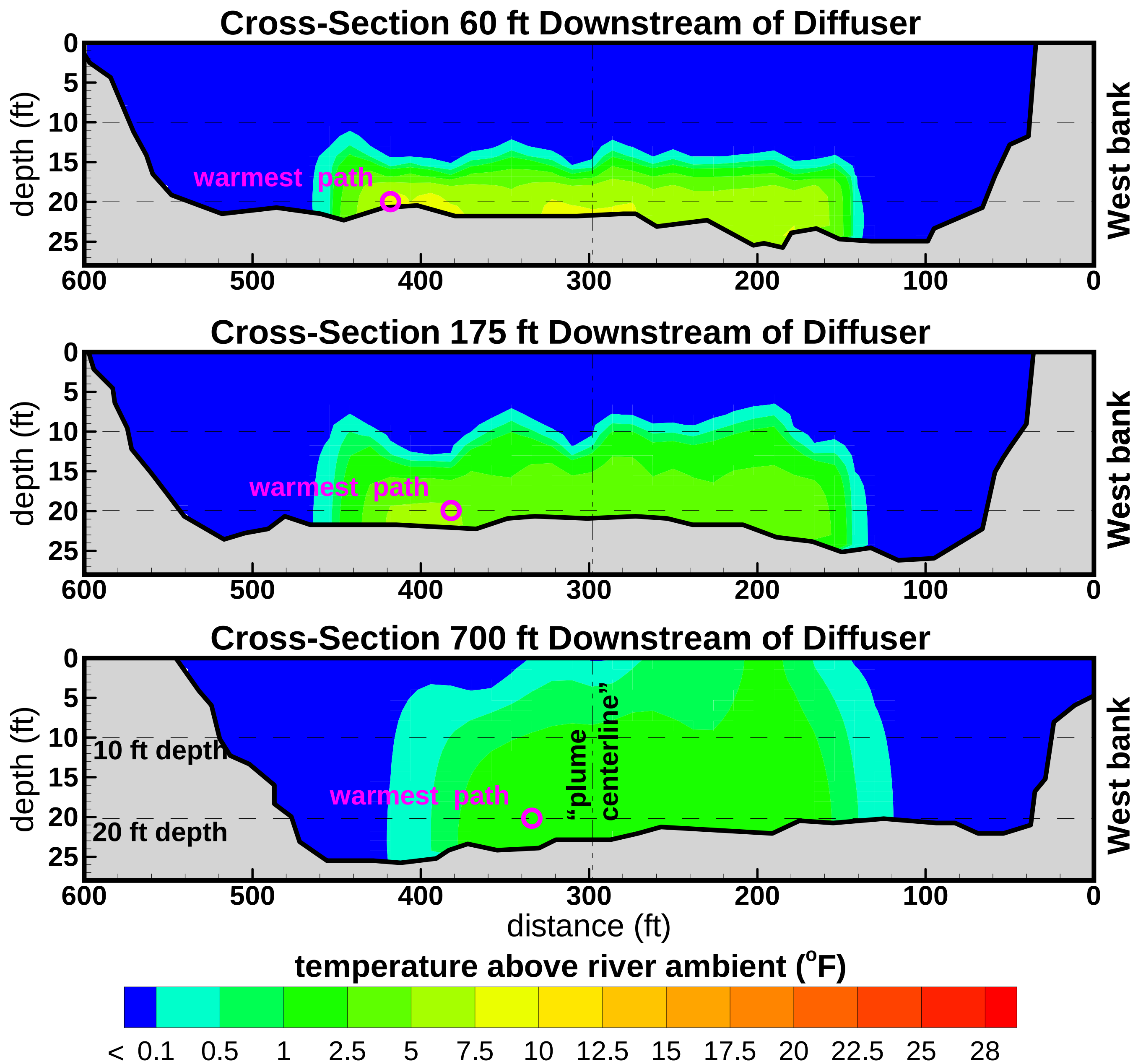
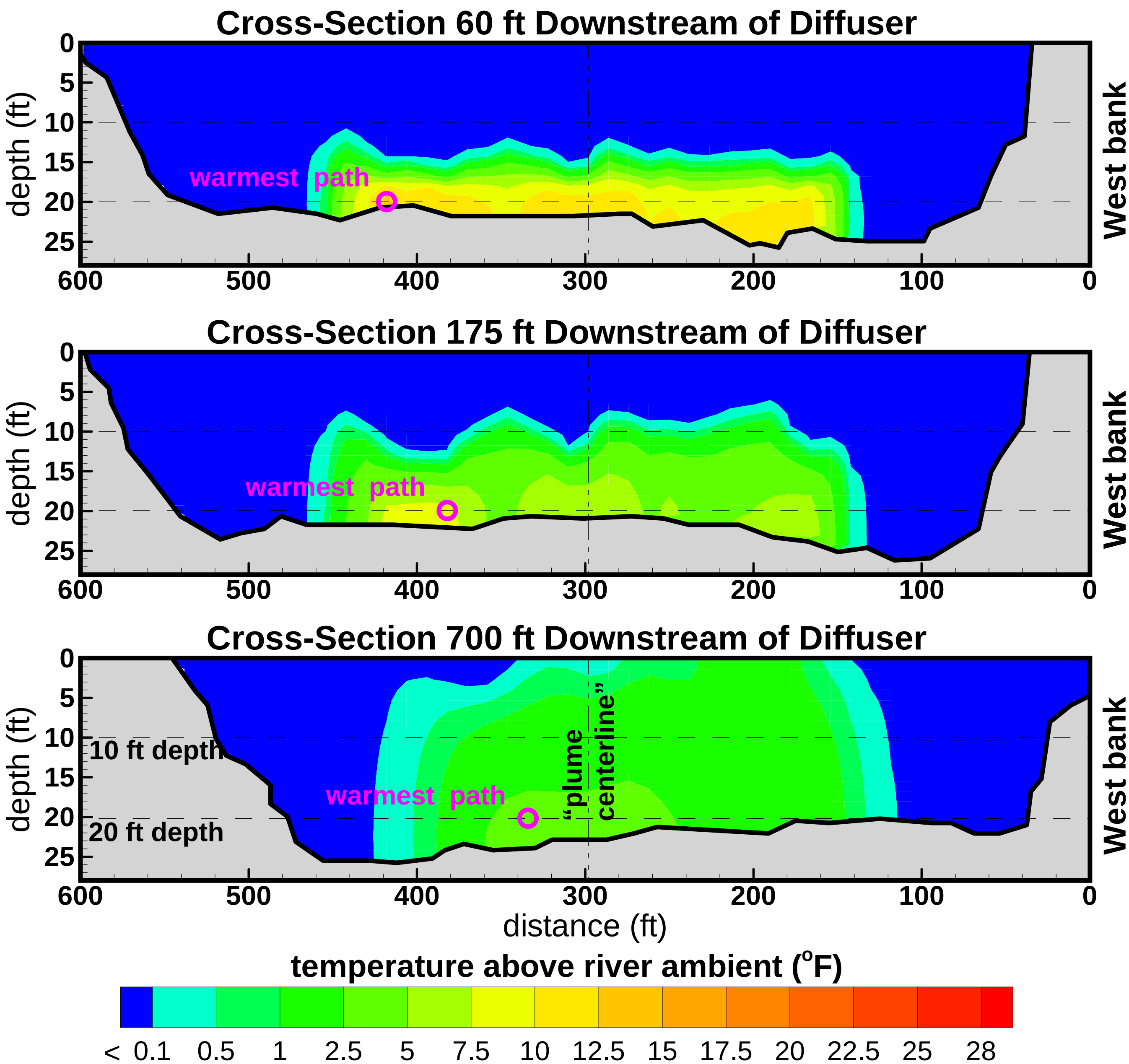
Figure 31 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **410 MGD**
14:1 DILUTION RATIO AND **10 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **410 MGD**
River Flowrate = **8880 CFS**
$T_{effluent} - T_{river}$ = **10 °F**

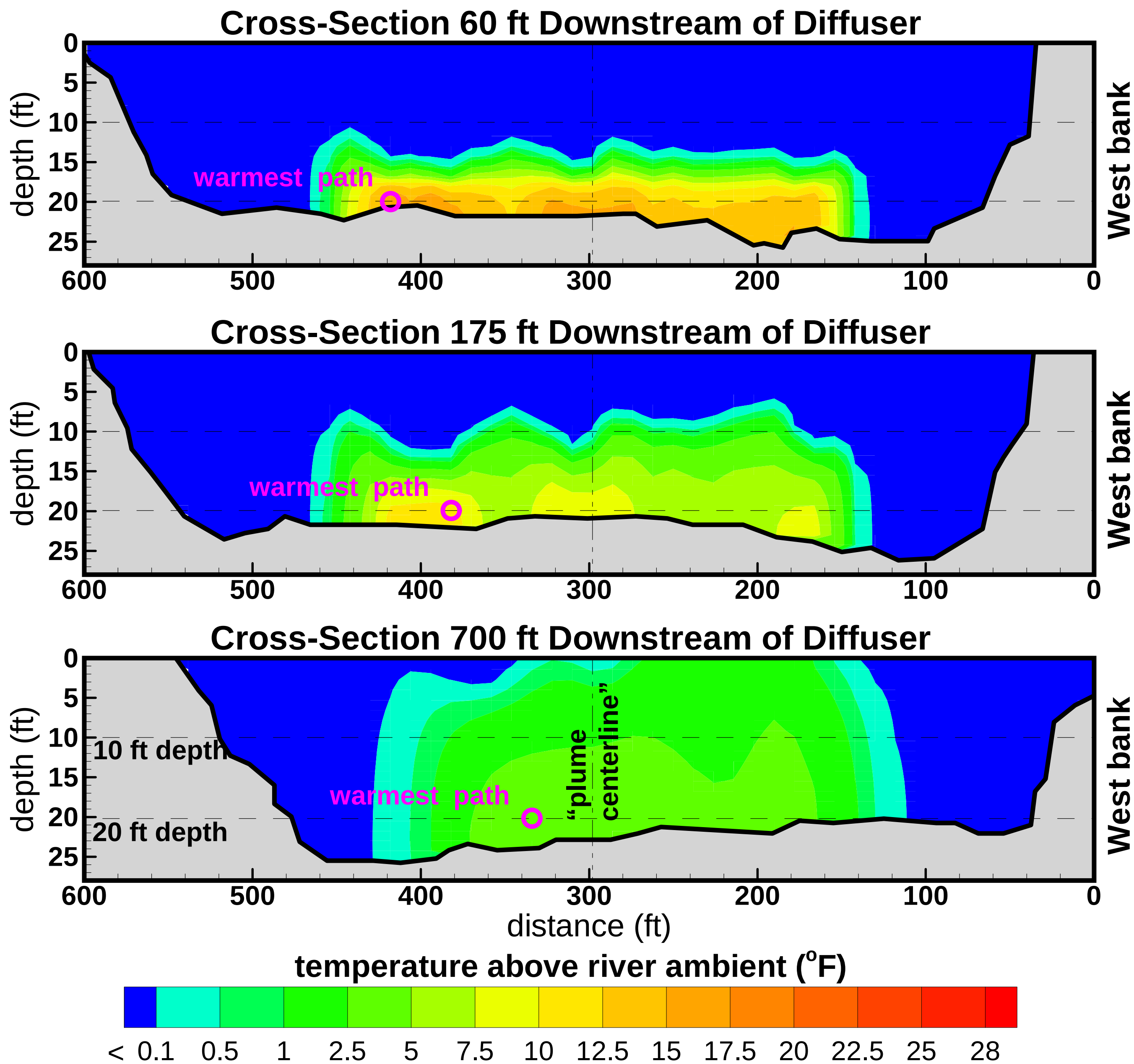
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **410 MGD**
14:1 DILUTION RATIO AND **15 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **410 MGD**
River Flowrate = **8880 CFS**
$T_{effluent} - T_{river}$ = **15 °F**

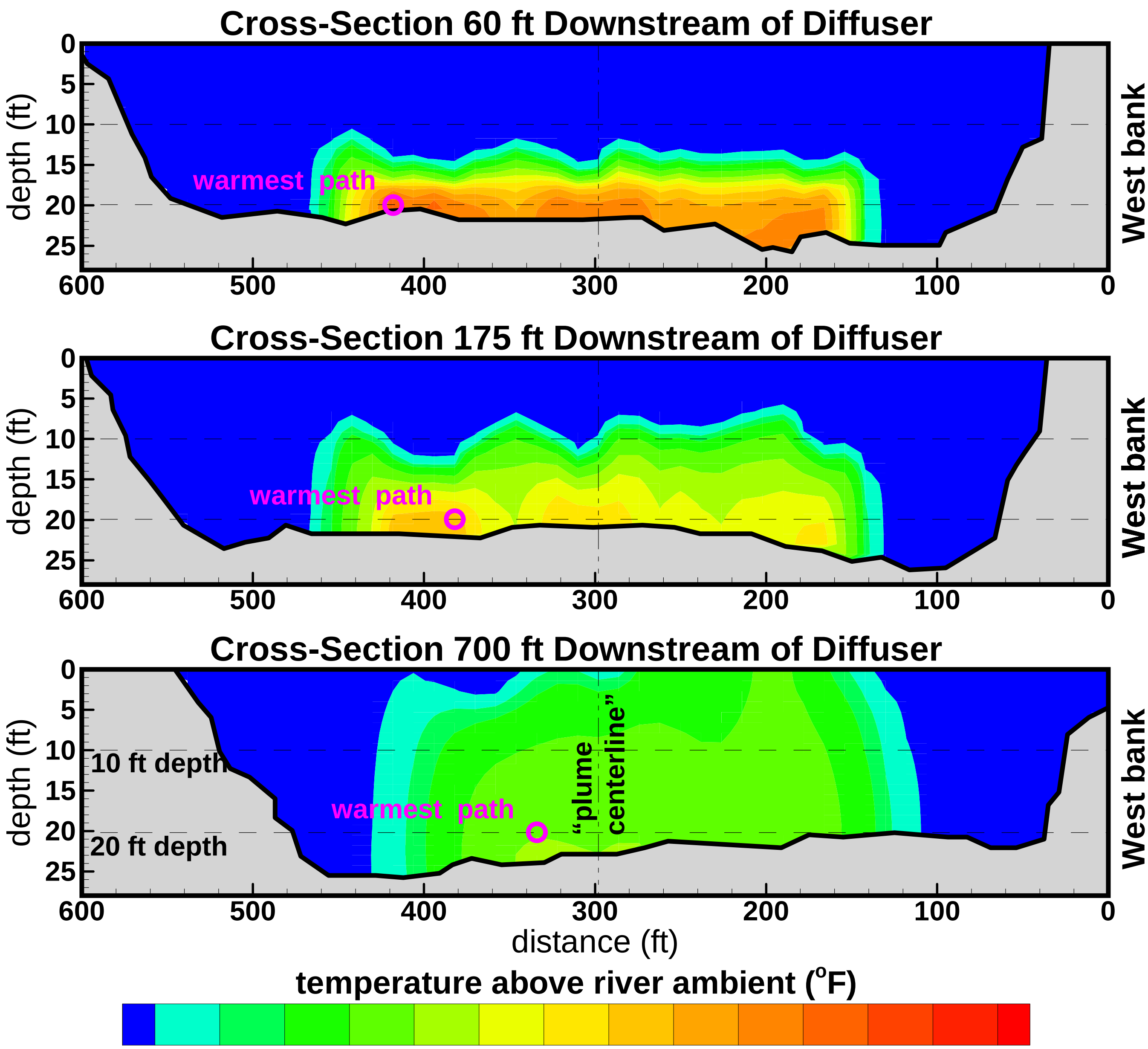
Figure 33 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **410 MGD**
14:1 DILUTION RATIO AND **20 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **410 MGD**
River Flowrate = **8880 CFS**
$T_{effluent} - T_{river}$ = **20 °F**

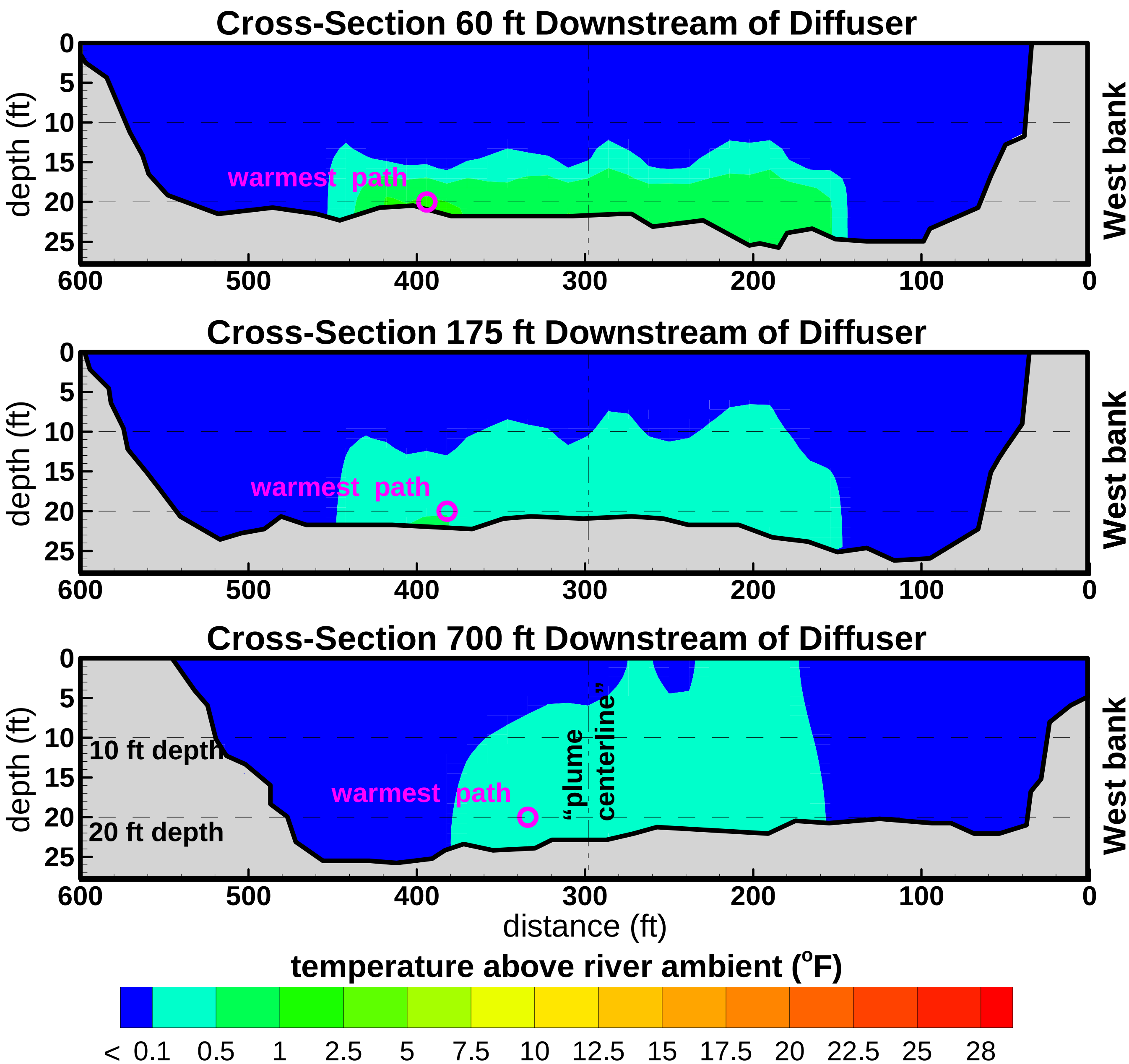
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **410 MGD**
14:1 DILUTION RATIO AND **25 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **410 MGD**
River Flowrate = **8880 CFS**
$T_{effluent} - T_{river}$ = **25 °F**

Figure 35 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **154 MGD**
67:1 DILUTION RATIO AND **5 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **154 MGD**
River Flowrate = **16000 CFS**
$T_{effluent} - T_{river}$ = **5 °F**

Figure 36 - DRAFT

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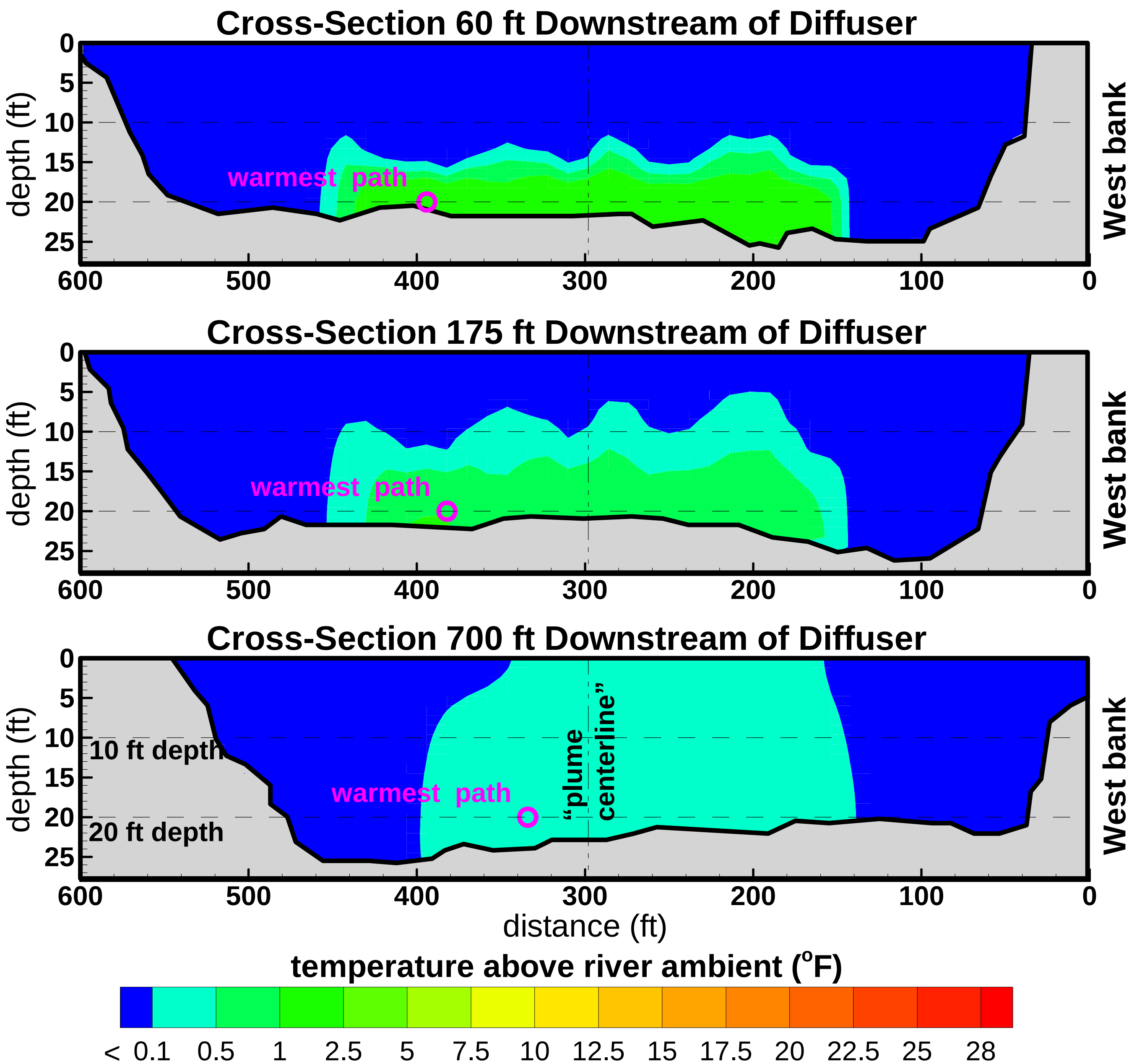
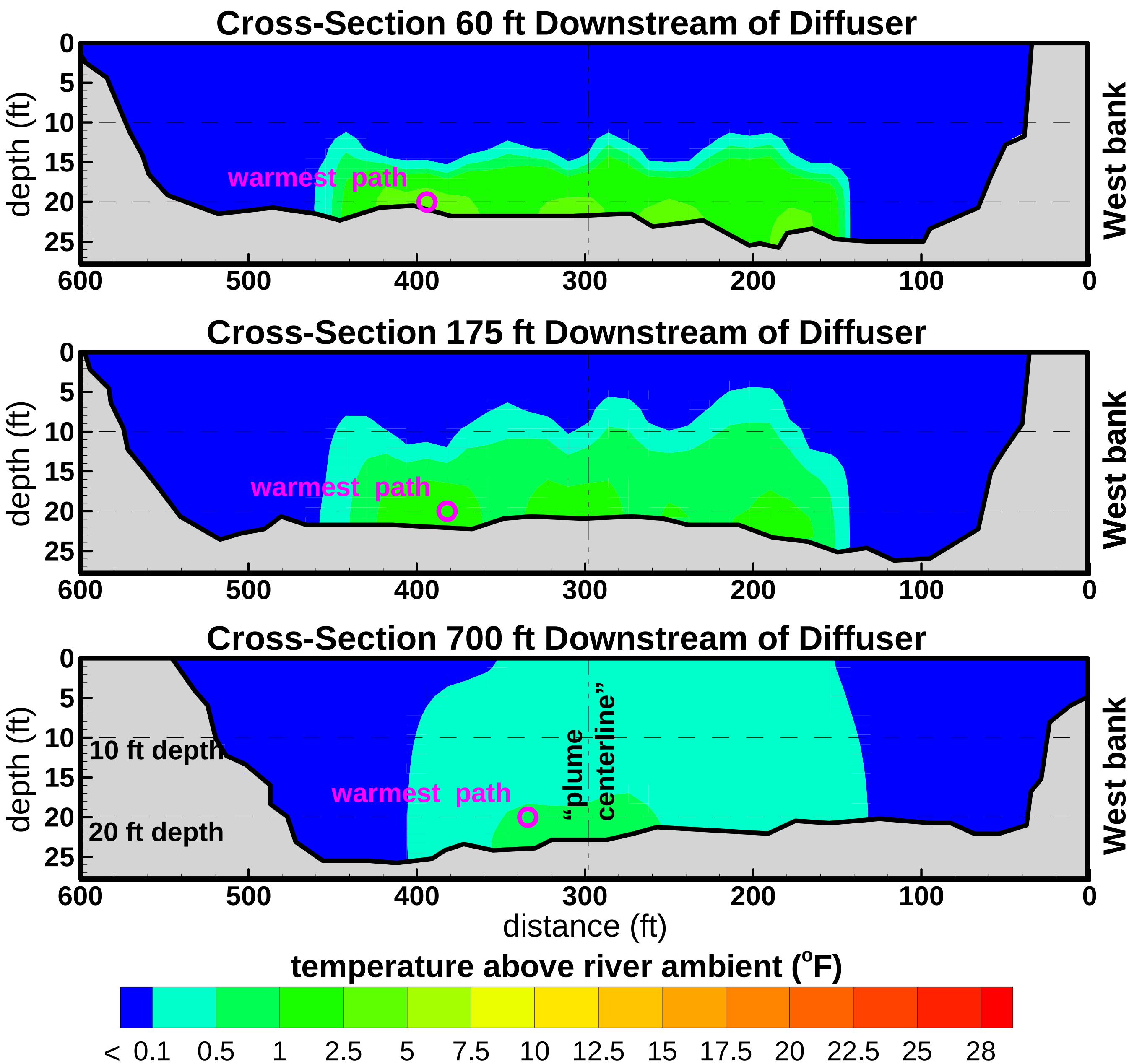
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **154 MGD**
67:1 DILUTION RATIO AND **10 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **154 MGD**
River Flowrate = **16000 CFS**
$T_{effluent} - T_{river}$ = **10 °F**

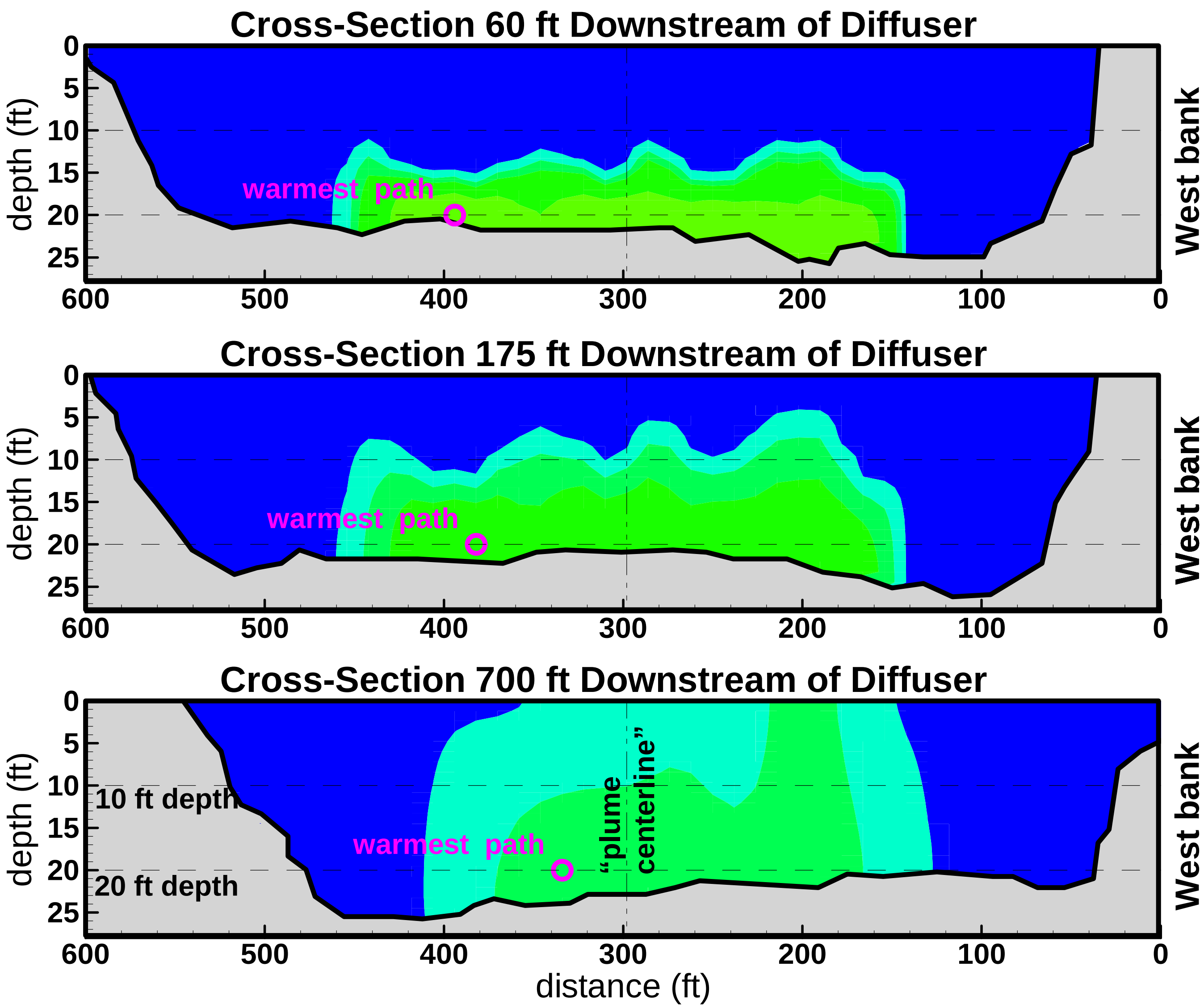
SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **154 MGD**
67:1 DILUTION RATIO AND **15 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **154 MGD**
River Flowrate = **16000 CFS**
$T_{effluent} - T_{river}$ = **15 °F**

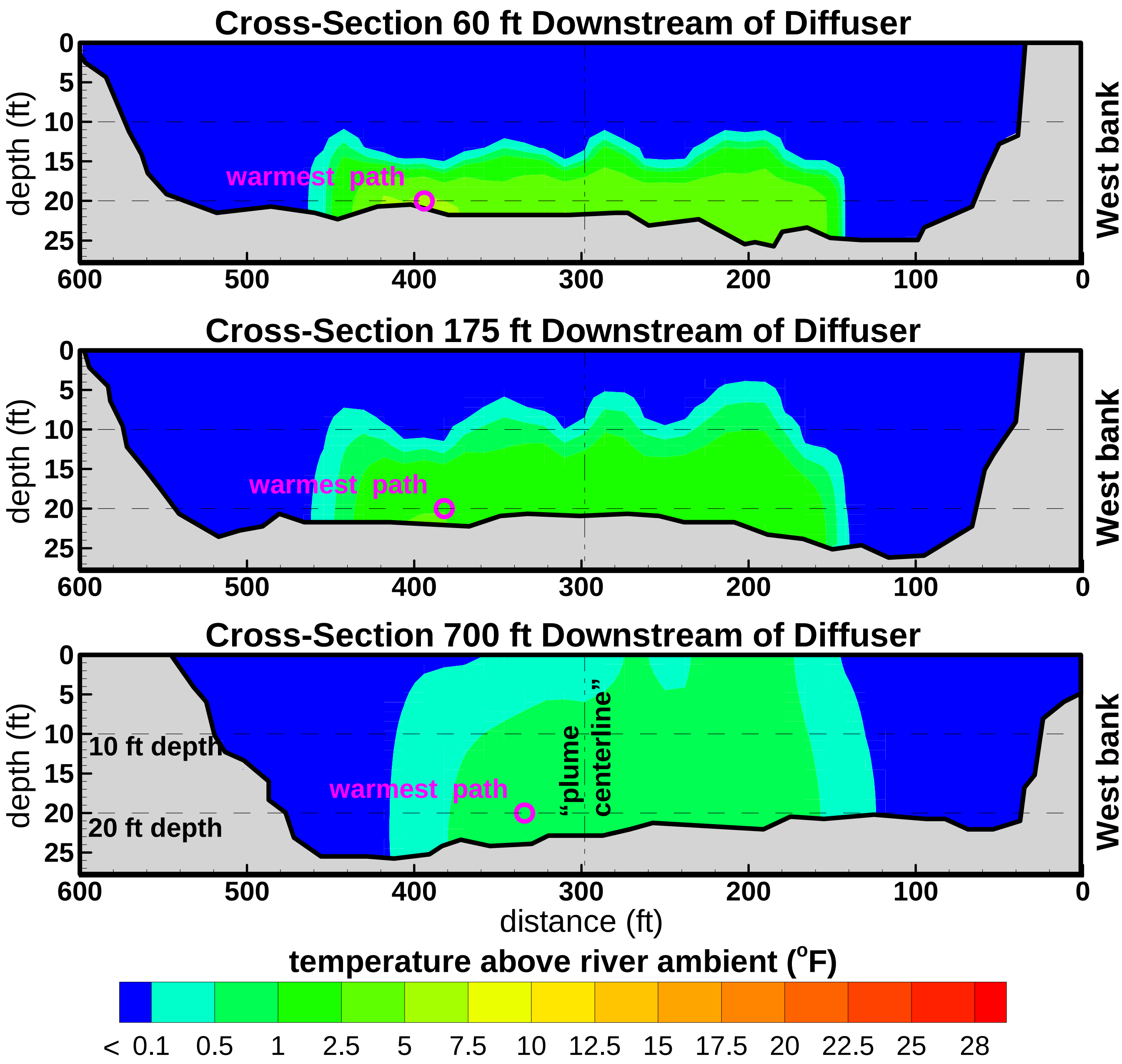
Figure 38 - DRAFT

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **154 MGD**
67:1 DILUTION RATIO AND **20 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **154 MGD**
River Flowrate = **16000 CFS**
$T_{effluent} - T_{river}$ = **20 °F**

SACRAMENTO RIVER DOWNSTREAM OF FREEPORT BRIDGE
SIMULATED TEMPERATURE CHANGES WITHIN PLUME
(DISCHARGE FROM 74-PORT DIFFUSER)
EFFLUENT FLOW RATE = **154 MGD**
67:1 DILUTION RATIO AND **25 °F** TEMPERATURE DIFFERENCE



Effluent Flowrate = **154 MGD**
River Flowrate = **16000 CFS**
$T_{effluent} - T_{river}$ = **25 °F**

ATTACHMENT B: TABLES

Table 1: Simulated drift velocity, drift time, and temperature differential downstream of diffuser along centerline at surface for 60 MGD effluent flow at 14:1 (river flow = 1300 cfs*) FLOWMOD has been validated for river flows exceeding 3,800 cfs. For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
0	0.46	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.46	13.0	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.45	26.2	0.0000	0.0000	0.0000	0.0000	0.0000
18	0.45	39.5	0.0000	0.0000	0.0000	0.0000	0.0000
24	0.45	52.9	0.0000	0.0000	0.0000	0.0000	0.0000
30	0.44	66.4	0.0000	0.0000	0.0000	0.0000	0.0000
36	0.44	80.0	0.0000	0.0000	0.0000	0.0000	0.0000
42	0.44	93.6	0.0000	0.0000	0.0000	0.0000	0.0000
48	0.44	107.3	0.0000	0.0000	0.0000	0.0000	0.0000
54	0.44	120.9	0.0000	0.0000	0.0000	0.0000	0.0000
60	0.44	134.5	0.0000	0.0000	0.0000	0.0000	0.0000
66	0.44	148.2	0.0000	0.0000	0.0000	0.0000	0.0000
72	0.44	161.7	0.0000	0.0000	0.0000	0.0000	0.0000
78	0.44	175.3	0.0000	0.0000	0.0000	0.0000	0.0000
84	0.45	188.7	0.0000	0.0000	0.0000	0.0000	0.0000
90	0.45	202.1	0.0000	0.0000	0.0000	0.0000	0.0000
96	0.45	215.5	0.0000	0.0000	0.0000	0.0000	0.0000
102	0.45	228.9	0.0000	0.0000	0.0000	0.0000	0.0000
108	0.45	242.2	0.0000	0.0000	0.0000	0.0000	0.0000
114	0.45	255.6	0.0000	0.0000	0.0000	0.0000	0.0000
120	0.45	268.9	0.0000	0.0000	0.0000	0.0000	0.0000
126	0.45	282.3	0.0000	0.0000	0.0000	0.0000	0.0000
132	0.45	295.7	0.0000	0.0000	0.0000	0.0000	0.0000
138	0.45	309.1	0.0000	0.0000	0.0000	0.0000	0.0000
144	0.45	322.4	0.0000	0.0000	0.0000	0.0000	0.0000
150	0.45	335.7	0.0000	0.0000	0.0000	0.0000	0.0000
156	0.45	349.1	0.0000	0.0000	0.0000	0.0000	0.0000
162	0.45	362.4	0.0000	0.0000	0.0000	0.0000	0.0000
168	0.45	375.8	0.0000	0.0000	0.0000	0.0000	0.0000
174	0.45	389.1	0.0000	0.0000	0.0000	0.0000	0.0000
180	0.45	402.4	0.0000	0.0000	0.0000	0.0000	0.0000
186	0.45	415.8	0.0000	0.0000	0.0000	0.0000	0.0000
192	0.45	429.1	0.0000	0.0000	0.0000	0.0000	0.0000
198	0.45	442.4	0.0000	0.0000	0.0000	0.0000	0.0000
204	0.45	455.8	0.0000	0.0000	0.0000	0.0000	0.0000
210	0.45	469.1	0.0000	0.0000	0.0000	0.0000	0.0000
216	0.45	482.4	0.0000	0.0000	0.0000	0.0000	0.0000
222	0.45	495.8	0.0000	0.0000	0.0000	0.0000	0.0000
228	0.45	509.1	0.0000	0.0000	0.0000	0.0000	0.0000
234	0.45	522.4	0.0000	0.0000	0.0000	0.0000	0.0000
240	0.45	535.6	0.0000	0.0000	0.0000	0.0000	0.0000
246	0.45	548.9	0.0000	0.0000	0.0000	0.0000	0.0000

Table 1 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
252	0.45	562.3	0.0000	0.0000	0.0000	0.0000	0.0000
258	0.45	575.6	0.0000	0.0000	0.0000	0.0000	0.0000
264	0.45	588.9	0.0000	0.0000	0.0000	0.0000	0.0000
270	0.45	602.3	0.0000	0.0000	0.0000	0.0000	0.0000
276	0.45	615.6	0.0000	0.0000	0.0000	0.0000	0.0000
282	0.45	628.9	0.0000	0.0000	0.0000	0.0000	0.0000
288	0.45	642.2	0.0000	0.0000	0.0000	0.0000	0.0000
294	0.45	655.5	0.0000	0.0000	0.0000	0.0000	0.0000
300	0.45	668.8	0.0000	0.0000	0.0000	0.0000	0.0000
306	0.45	682.1	0.0000	0.0000	0.0000	0.0000	0.0000
312	0.45	695.4	0.0000	0.0000	0.0000	0.0000	0.0000
318	0.45	708.8	0.0000	0.0000	0.0000	0.0000	0.0000
324	0.45	722.1	0.0000	0.0000	0.0000	0.0000	0.0000
330	0.45	735.5	0.0000	0.0000	0.0000	0.0000	0.0000
336	0.45	748.8	0.0000	0.0000	0.0000	0.0000	0.0000
342	0.45	762.1	0.0000	0.0000	0.0000	0.0000	0.0000
348	0.45	775.5	0.0000	0.0000	0.0000	0.0000	0.0000
354	0.45	788.9	0.0000	0.0000	0.0000	0.0000	0.0000
360	0.45	802.3	0.0000	0.0000	0.0000	0.0000	0.0000
366	0.45	815.6	0.0000	0.0000	0.0000	0.0000	0.0000
372	0.45	828.9	0.0000	0.0000	0.0000	0.0000	0.0000
378	0.45	842.1	0.0000	0.0000	0.0000	0.0000	0.0001
384	0.45	855.4	0.0000	0.0000	0.0000	0.0000	0.0001
390	0.46	868.5	0.0000	0.0000	0.0000	0.0001	0.0001
396	0.46	881.7	0.0000	0.0000	0.0000	0.0001	0.0001
402	0.46	894.9	0.0000	0.0000	0.0000	0.0001	0.0001
408	0.46	908.0	0.0000	0.0000	0.0000	0.0001	0.0001
414	0.46	921.2	0.0000	0.0000	0.0001	0.0001	0.0001
420	0.46	934.3	0.0000	0.0000	0.0001	0.0001	0.0001
426	0.46	947.5	0.0000	0.0000	0.0001	0.0001	0.0001
432	0.46	960.7	0.0000	0.0000	0.0001	0.0001	0.0001
438	0.46	973.8	0.0000	0.0000	0.0001	0.0001	0.0001
444	0.46	986.9	0.0000	0.0001	0.0001	0.0001	0.0001
450	0.46	1000.0	0.0000	0.0001	0.0001	0.0001	0.0001
456	0.46	1013.1	0.0000	0.0001	0.0001	0.0001	0.0002
462	0.46	1026.3	0.0000	0.0001	0.0001	0.0001	0.0002
468	0.46	1039.4	0.0000	0.0001	0.0001	0.0001	0.0002
474	0.46	1052.5	0.0000	0.0001	0.0001	0.0002	0.0002
480	0.46	1065.6	0.0000	0.0001	0.0001	0.0002	0.0002
486	0.46	1078.7	0.0000	0.0001	0.0001	0.0002	0.0002
492	0.46	1091.8	0.0000	0.0001	0.0001	0.0002	0.0002
498	0.46	1104.9	0.0001	0.0001	0.0002	0.0002	0.0003

Table 1 (continued)

distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
504	0.46	1118.0	0.0001	0.0001	0.0002	0.0002	0.0003
510	0.46	1131.0	0.0001	0.0001	0.0002	0.0002	0.0003
516	0.46	1144.1	0.0001	0.0001	0.0002	0.0003	0.0003
522	0.46	1157.2	0.0001	0.0001	0.0002	0.0003	0.0004
528	0.46	1170.3	0.0001	0.0002	0.0002	0.0003	0.0004
534	0.46	1183.3	0.0001	0.0002	0.0002	0.0003	0.0004
540	0.46	1196.3	0.0001	0.0002	0.0003	0.0003	0.0004
546	0.46	1209.3	0.0001	0.0002	0.0003	0.0004	0.0005
552	0.46	1222.4	0.0001	0.0002	0.0003	0.0004	0.0005
558	0.46	1235.4	0.0001	0.0002	0.0003	0.0004	0.0005
564	0.46	1248.4	0.0001	0.0002	0.0003	0.0005	0.0006
570	0.46	1261.4	0.0001	0.0002	0.0004	0.0005	0.0006
576	0.46	1274.5	0.0001	0.0003	0.0004	0.0005	0.0007
582	0.46	1287.5	0.0001	0.0003	0.0004	0.0006	0.0007
588	0.46	1300.5	0.0002	0.0003	0.0005	0.0006	0.0008
594	0.46	1313.5	0.0002	0.0003	0.0005	0.0007	0.0008
600	0.46	1326.5	0.0002	0.0003	0.0005	0.0007	0.0009
606	0.46	1339.5	0.0002	0.0004	0.0006	0.0007	0.0009
612	0.46	1352.5	0.0002	0.0004	0.0006	0.0008	0.0010
618	0.46	1365.5	0.0002	0.0004	0.0006	0.0008	0.0011
624	0.46	1378.6	0.0002	0.0005	0.0007	0.0009	0.0011
630	0.46	1391.6	0.0002	0.0005	0.0007	0.0010	0.0012
636	0.46	1404.6	0.0003	0.0005	0.0008	0.0010	0.0013
642	0.46	1417.5	0.0003	0.0005	0.0008	0.0011	0.0014
648	0.46	1430.5	0.0003	0.0006	0.0009	0.0011	0.0014
654	0.46	1443.4	0.0003	0.0006	0.0009	0.0012	0.0015
660	0.46	1456.4	0.0003	0.0006	0.0010	0.0013	0.0016
666	0.46	1469.3	0.0003	0.0007	0.0010	0.0014	0.0017
672	0.47	1482.2	0.0004	0.0007	0.0011	0.0014	0.0018
678	0.47	1495.1	0.0004	0.0008	0.0011	0.0015	0.0019
684	0.47	1508.0	0.0004	0.0008	0.0012	0.0016	0.0020
690	0.47	1520.8	0.0004	0.0009	0.0013	0.0017	0.0021
696	0.47	1533.6	0.0004	0.0009	0.0013	0.0018	0.0022
702	0.47	1546.4	0.0005	0.0009	0.0014	0.0019	0.0024
708	0.47	1559.2	0.0005	0.0010	0.0015	0.0020	0.0025
714	0.47	1572.0	0.0005	0.0011	0.0016	0.0021	0.0026
720	0.47	1584.8	0.0006	0.0011	0.0017	0.0022	0.0028
726	0.47	1597.5	0.0006	0.0012	0.0017	0.0023	0.0029
732	0.47	1610.3	0.0006	0.0012	0.0018	0.0024	0.0030
738	0.47	1622.9	0.0006	0.0013	0.0019	0.0025	0.0032
744	0.47	1635.7	0.0007	0.0013	0.0020	0.0027	0.0033
750	0.47	1648.4	0.0007	0.0014	0.0021	0.0028	0.0035

Table 1 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
756	0.47	1661.1	0.0007	0.0015	0.0022	0.0029	0.0036
762	0.47	1673.8	0.0008	0.0015	0.0023	0.0030	0.0038
768	0.47	1686.5	0.0008	0.0016	0.0024	0.0032	0.0040
774	0.47	1699.2	0.0008	0.0017	0.0025	0.0033	0.0041
780	0.47	1711.9	0.0009	0.0017	0.0026	0.0034	0.0043
786	0.47	1724.6	0.0009	0.0018	0.0027	0.0036	0.0045
792	0.47	1737.2	0.0009	0.0019	0.0028	0.0037	0.0047
798	0.47	1749.9	0.0010	0.0019	0.0029	0.0039	0.0048
804	0.47	1762.5	0.0010	0.0020	0.0030	0.0040	0.0050
810	0.47	1775.2	0.0010	0.0021	0.0031	0.0042	0.0052
816	0.48	1787.8	0.0011	0.0022	0.0032	0.0043	0.0054
822	0.48	1800.4	0.0011	0.0022	0.0034	0.0045	0.0056
828	0.48	1813.0	0.0012	0.0023	0.0035	0.0046	0.0058
834	0.48	1825.6	0.0012	0.0024	0.0036	0.0048	0.0060
840	0.48	1838.1	0.0012	0.0025	0.0037	0.0049	0.0062
846	0.48	1850.7	0.0013	0.0026	0.0038	0.0051	0.0064
852	0.48	1863.3	0.0013	0.0026	0.0039	0.0053	0.0066
858	0.48	1875.8	0.0014	0.0027	0.0041	0.0054	0.0068
864	0.48	1888.4	0.0014	0.0028	0.0042	0.0056	0.0070
870	0.48	1900.9	0.0014	0.0029	0.0043	0.0057	0.0072
876	0.48	1913.4	0.0015	0.0030	0.0044	0.0059	0.0074
882	0.48	1925.9	0.0015	0.0030	0.0046	0.0061	0.0076
888	0.48	1938.3	0.0016	0.0031	0.0047	0.0062	0.0078
894	0.48	1950.8	0.0016	0.0032	0.0048	0.0064	0.0080
900	0.48	1963.2	0.0016	0.0033	0.0049	0.0066	0.0082
906	0.48	1975.7	0.0017	0.0034	0.0051	0.0067	0.0084
912	0.48	1988.1	0.0017	0.0035	0.0052	0.0069	0.0086
918	0.48	2000.5	0.0018	0.0035	0.0053	0.0071	0.0088
924	0.48	2012.9	0.0018	0.0036	0.0054	0.0072	0.0091
930	0.49	2025.3	0.0019	0.0037	0.0056	0.0074	0.0093
936	0.49	2037.6	0.0019	0.0038	0.0057	0.0076	0.0095
942	0.49	2049.9	0.0019	0.0039	0.0058	0.0078	0.0097
948	0.49	2062.2	0.0020	0.0040	0.0060	0.0079	0.0099
954	0.49	2074.5	0.0020	0.0041	0.0061	0.0081	0.0101
960	0.49	2086.8	0.0021	0.0041	0.0062	0.0083	0.0104
966	0.49	2099.1	0.0021	0.0042	0.0063	0.0085	0.0106
972	0.49	2111.4	0.0022	0.0043	0.0065	0.0086	0.0108
978	0.49	2123.7	0.0022	0.0044	0.0066	0.0088	0.0110
984	0.49	2136.0	0.0022	0.0045	0.0067	0.0090	0.0112
990	0.49	2148.2	0.0023	0.0046	0.0069	0.0092	0.0115

Table 2: Simulated drift velocity, drift time, and temperature differential downstream of diffuser along centerline at 10 ft depth for 60 MGD effluent flow at 14:1 (river flow = 1300 cfs) FLOWMOD has been validated for river flows exceeding 3,800 cfs. For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
0	0.47	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.46	12.9	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.45	26.0	0.0000	0.0000	0.0000	0.0000	0.0000
18	0.45	39.3	0.0000	0.0000	0.0000	0.0000	0.0000
24	0.44	52.8	0.0000	0.0000	0.0000	0.0000	0.0000
30	0.44	66.5	0.0000	0.0000	0.0000	0.0000	0.0000
36	0.44	80.2	0.0000	0.0000	0.0000	0.0000	0.0000
42	0.44	93.8	0.0000	0.0000	0.0000	0.0000	0.0000
48	0.44	107.5	0.0000	0.0000	0.0001	0.0001	0.0001
54	0.44	121.2	0.0001	0.0001	0.0002	0.0003	0.0003
60	0.44	134.9	0.0001	0.0003	0.0004	0.0005	0.0007
66	0.44	148.6	0.0003	0.0005	0.0008	0.0011	0.0013
72	0.44	162.3	0.0006	0.0012	0.0018	0.0024	0.0030
78	0.44	175.9	0.0015	0.0029	0.0044	0.0059	0.0074
84	0.44	189.5	0.0026	0.0052	0.0079	0.0105	0.0131
90	0.45	202.9	0.0039	0.0078	0.0116	0.0155	0.0194
96	0.45	216.4	0.0051	0.0102	0.0153	0.0204	0.0255
102	0.45	229.8	0.0062	0.0124	0.0186	0.0248	0.0310
108	0.45	243.3	0.0073	0.0146	0.0219	0.0292	0.0365
114	0.45	256.7	0.0085	0.0169	0.0254	0.0338	0.0423
120	0.44	270.2	0.0096	0.0192	0.0288	0.0384	0.0479
126	0.44	283.7	0.0108	0.0215	0.0323	0.0430	0.0538
132	0.44	297.3	0.0120	0.0240	0.0360	0.0479	0.0599
138	0.44	310.8	0.0133	0.0266	0.0399	0.0532	0.0664
144	0.44	324.3	0.0147	0.0294	0.0440	0.0587	0.0734
150	0.44	337.8	0.0161	0.0323	0.0484	0.0646	0.0807
156	0.44	351.4	0.0177	0.0355	0.0532	0.0709	0.0886
162	0.44	364.9	0.0195	0.0391	0.0586	0.0781	0.0976
168	0.44	378.4	0.0213	0.0425	0.0638	0.0850	0.1063
174	0.44	391.9	0.0229	0.0459	0.0688	0.0917	0.1147
180	0.44	405.4	0.0245	0.0491	0.0736	0.0982	0.1227
186	0.44	418.9	0.0261	0.0523	0.0784	0.1045	0.1306
192	0.44	432.4	0.0278	0.0556	0.0834	0.1112	0.1390
198	0.44	446.0	0.0295	0.0591	0.0886	0.1181	0.1477
204	0.44	459.5	0.0314	0.0628	0.0942	0.1256	0.1570
210	0.44	473.1	0.0335	0.0669	0.1004	0.1339	0.1673
216	0.44	486.7	0.0357	0.0714	0.1071	0.1429	0.1786
222	0.44	500.2	0.0378	0.0756	0.1134	0.1512	0.1890
228	0.44	513.7	0.0397	0.0794	0.1191	0.1587	0.1984
234	0.44	527.2	0.0413	0.0825	0.1238	0.1651	0.2063
240	0.44	540.7	0.0426	0.0851	0.1277	0.1703	0.2128
246	0.44	554.2	0.0438	0.0875	0.1313	0.1750	0.2188

Table 2 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
252	0.44	567.8	0.0449	0.0898	0.1348	0.1797	0.2246
258	0.44	581.4	0.0463	0.0926	0.1390	0.1853	0.2316
264	0.44	595.0	0.0484	0.0968	0.1452	0.1936	0.2421
270	0.44	608.6	0.0503	0.1007	0.1510	0.2014	0.2517
276	0.44	622.2	0.0523	0.1046	0.1569	0.2092	0.2615
282	0.44	635.7	0.0538	0.1076	0.1615	0.2153	0.2691
288	0.44	649.3	0.0552	0.1103	0.1655	0.2206	0.2758
294	0.44	662.7	0.0564	0.1128	0.1692	0.2256	0.2820
300	0.44	676.3	0.0576	0.1153	0.1729	0.2306	0.2882
306	0.44	689.9	0.0589	0.1178	0.1767	0.2356	0.2945
312	0.44	703.4	0.0600	0.1200	0.1800	0.2400	0.3000
318	0.44	717.0	0.0609	0.1218	0.1827	0.2436	0.3045
324	0.44	730.6	0.0617	0.1234	0.1852	0.2469	0.3086
330	0.44	744.2	0.0625	0.1250	0.1874	0.2499	0.3124
336	0.44	757.8	0.0631	0.1262	0.1893	0.2524	0.3155
342	0.44	771.4	0.0637	0.1274	0.1911	0.2548	0.3185
348	0.44	785.0	0.0647	0.1295	0.1942	0.2590	0.3237
354	0.44	798.7	0.0664	0.1327	0.1991	0.2655	0.3319
360	0.44	812.4	0.0699	0.1398	0.2097	0.2796	0.3495
366	0.44	826.0	0.0762	0.1524	0.2285	0.3047	0.3809
372	0.44	839.5	0.0805	0.1610	0.2415	0.3219	0.4024
378	0.45	853.0	0.0832	0.1664	0.2495	0.3327	0.4159
384	0.45	866.5	0.0852	0.1705	0.2557	0.3410	0.4262
390	0.45	879.8	0.0872	0.1743	0.2615	0.3487	0.4358
396	0.45	893.3	0.0890	0.1780	0.2670	0.3561	0.4451
402	0.45	906.7	0.0907	0.1815	0.2722	0.3629	0.4536
408	0.45	920.1	0.0922	0.1844	0.2766	0.3688	0.4610
414	0.45	933.6	0.0935	0.1871	0.2806	0.3742	0.4677
420	0.45	947.0	0.0952	0.1904	0.2856	0.3807	0.4759
426	0.45	960.4	0.0971	0.1942	0.2913	0.3885	0.4856
432	0.45	973.8	0.0992	0.1985	0.2977	0.3970	0.4962
438	0.45	987.2	0.1016	0.2031	0.3047	0.4063	0.5078
444	0.45	1000.6	0.1041	0.2082	0.3122	0.4163	0.5204
450	0.45	1014.0	0.1068	0.2135	0.3203	0.4270	0.5338
456	0.45	1027.4	0.1096	0.2192	0.3288	0.4384	0.5479
462	0.45	1040.8	0.1124	0.2249	0.3373	0.4497	0.5622
468	0.45	1054.2	0.1153	0.2306	0.3460	0.4613	0.5766
474	0.45	1067.6	0.1184	0.2368	0.3553	0.4737	0.5921
480	0.45	1081.0	0.1216	0.2432	0.3648	0.4864	0.6080
486	0.45	1094.4	0.1249	0.2498	0.3747	0.4995	0.6244
492	0.45	1107.7	0.1284	0.2567	0.3851	0.5134	0.6418
498	0.45	1121.1	0.1318	0.2637	0.3955	0.5273	0.6592

Table 2 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
504	0.45	1134.4	0.1355	0.2710	0.4065	0.5420	0.6775
510	0.45	1147.8	0.1392	0.2784	0.4177	0.5569	0.6961
516	0.45	1161.2	0.1429	0.2858	0.4287	0.5716	0.7145
522	0.45	1174.6	0.1467	0.2933	0.4400	0.5866	0.7333
528	0.45	1187.9	0.1507	0.3013	0.4520	0.6026	0.7533
534	0.45	1201.3	0.1548	0.3097	0.4645	0.6194	0.7742
540	0.45	1214.6	0.1590	0.3180	0.4770	0.6359	0.7949
546	0.45	1227.9	0.1629	0.3257	0.4886	0.6514	0.8143
552	0.45	1241.2	0.1665	0.3331	0.4996	0.6662	0.8327
558	0.45	1254.6	0.1701	0.3402	0.5104	0.6805	0.8506
564	0.45	1267.9	0.1737	0.3473	0.5210	0.6946	0.8683
570	0.45	1281.3	0.1773	0.3546	0.5319	0.7092	0.8866
576	0.45	1294.7	0.1812	0.3625	0.5437	0.7250	0.9062
582	0.45	1308.0	0.1857	0.3714	0.5570	0.7427	0.9284
588	0.45	1321.3	0.1902	0.3804	0.5706	0.7609	0.9511
594	0.45	1334.7	0.1935	0.3870	0.5806	0.7741	0.9676
600	0.45	1348.0	0.1960	0.3920	0.5880	0.7841	0.9801
606	0.45	1361.4	0.1984	0.3968	0.5952	0.7936	0.9919
612	0.45	1374.7	0.2008	0.4016	0.6024	0.8032	1.0040
618	0.45	1388.1	0.2034	0.4068	0.6102	0.8136	1.0169
624	0.45	1401.5	0.2063	0.4126	0.6189	0.8252	1.0315
630	0.45	1414.9	0.2094	0.4189	0.6283	0.8377	1.0471
636	0.45	1428.2	0.2127	0.4254	0.6381	0.8507	1.0634
642	0.45	1441.5	0.2161	0.4321	0.6482	0.8643	1.0803
648	0.45	1454.9	0.2198	0.4396	0.6594	0.8792	1.0990
654	0.45	1468.2	0.2235	0.4470	0.6704	0.8939	1.1174
660	0.45	1481.5	0.2270	0.4540	0.6810	0.9079	1.1349
666	0.45	1494.8	0.2308	0.4616	0.6924	0.9232	1.1540
672	0.45	1508.1	0.2342	0.4684	0.7026	0.9368	1.1710
678	0.45	1521.4	0.2371	0.4742	0.7114	0.9485	1.1856
684	0.45	1534.6	0.2402	0.4805	0.7207	0.9609	1.2012
690	0.45	1547.8	0.2434	0.4867	0.7301	0.9735	1.2168
696	0.45	1561.0	0.2466	0.4932	0.7398	0.9864	1.2330
702	0.45	1574.2	0.2500	0.5000	0.7500	1.0000	1.2500
708	0.46	1587.4	0.2533	0.5065	0.7598	1.0130	1.2663
714	0.46	1600.6	0.2557	0.5114	0.7672	1.0229	1.2786
720	0.46	1613.7	0.2579	0.5157	0.7736	1.0314	1.2893
726	0.46	1626.9	0.2597	0.5194	0.7790	1.0387	1.2984
732	0.46	1640.0	0.2610	0.5220	0.7830	1.0440	1.3050
738	0.46	1653.1	0.2617	0.5235	0.7852	1.0470	1.3087
744	0.46	1666.2	0.2622	0.5245	0.7867	1.0489	1.3112
750	0.46	1679.3	0.2626	0.5252	0.7878	1.0504	1.3130

Table 2 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
756	0.46	1692.4	0.2630	0.5260	0.7890	1.0520	1.3150
762	0.46	1705.6	0.2636	0.5272	0.7909	1.0545	1.3181
768	0.46	1718.7	0.2643	0.5287	0.7930	1.0573	1.3216
774	0.46	1731.7	0.2645	0.5290	0.7935	1.0579	1.3224
780	0.46	1744.8	0.2645	0.5290	0.7936	1.0581	1.3226
786	0.46	1757.9	0.2643	0.5286	0.7929	1.0572	1.3215
792	0.46	1770.9	0.2641	0.5282	0.7923	1.0564	1.3205
798	0.46	1783.9	0.2641	0.5282	0.7923	1.0564	1.3204
804	0.46	1797.0	0.2642	0.5285	0.7927	1.0569	1.3211
810	0.46	1810.0	0.2644	0.5289	0.7933	1.0577	1.3221
816	0.46	1823.0	0.2647	0.5294	0.7940	1.0587	1.3234
822	0.46	1836.0	0.2650	0.5299	0.7949	1.0599	1.3248
828	0.46	1849.0	0.2651	0.5301	0.7952	1.0603	1.3253
834	0.46	1862.0	0.2649	0.5298	0.7948	1.0597	1.3246
840	0.46	1874.9	0.2645	0.5291	0.7936	1.0582	1.3227
846	0.46	1887.8	0.2640	0.5280	0.7920	1.0560	1.3200
852	0.46	1900.8	0.2634	0.5268	0.7903	1.0537	1.3171
858	0.46	1913.7	0.2629	0.5258	0.7888	1.0517	1.3146
864	0.46	1926.6	0.2626	0.5251	0.7877	1.0502	1.3128
870	0.47	1939.5	0.2624	0.5249	0.7873	1.0498	1.3122
876	0.47	1952.4	0.2627	0.5254	0.7881	1.0508	1.3134
882	0.47	1965.3	0.2632	0.5265	0.7897	1.0530	1.3162
888	0.47	1978.1	0.2635	0.5270	0.7905	1.0539	1.3174
894	0.47	1990.9	0.2634	0.5268	0.7902	1.0536	1.3170
900	0.47	2003.7	0.2632	0.5264	0.7896	1.0528	1.3160
906	0.47	2016.5	0.2630	0.5260	0.7890	1.0520	1.3150
912	0.47	2029.2	0.2630	0.5259	0.7889	1.0519	1.3148
918	0.47	2042.0	0.2633	0.5266	0.7898	1.0531	1.3164
924	0.47	2054.8	0.2641	0.5283	0.7924	1.0565	1.3206
930	0.47	2067.5	0.2655	0.5309	0.7964	1.0619	1.3273
936	0.47	2080.2	0.2665	0.5331	0.7996	1.0661	1.3327
942	0.47	2092.8	0.2673	0.5346	0.8019	1.0693	1.3366
948	0.47	2105.5	0.2679	0.5357	0.8036	1.0715	1.3394
954	0.47	2118.2	0.2682	0.5365	0.8047	1.0729	1.3411
960	0.47	2130.8	0.2684	0.5368	0.8052	1.0736	1.3419
966	0.47	2143.5	0.2683	0.5367	0.8050	1.0733	1.3417
972	0.47	2156.1	0.2681	0.5362	0.8043	1.0724	1.3406
978	0.47	2168.7	0.2678	0.5357	0.8035	1.0713	1.3391
984	0.47	2181.4	0.2675	0.5350	0.8025	1.0701	1.3376
990	0.47	2194.0	0.2671	0.5343	0.8014	1.0685	1.3357

Table 3: Simulated drift velocity, drift time, and temperature differential downstream of diffuser along warmest path at 20 ft depth for 60 MGD effluent flow at 14:1 (river flow = 1300 cfs) FLOWMOD has been validated for river flows exceeding 3,800 cfs. For lower river flows the effect of plume buoyancy may or may not result in more vertical mixing than indicated by FLOWMOD.							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
0	0.16	0.0	5.00	10.00	15.00	20.00	25.00
6	0.31	19.5	4.81	9.61	14.42	19.22	24.03
12	0.29	39.5	4.49	8.99	13.48	17.97	22.47
18	0.28	60.6	4.28	8.55	12.83	17.10	21.38
24	0.26	83.0	4.17	8.34	12.51	16.69	20.86
30	0.25	106.7	4.08	8.16	12.23	16.31	20.39
36	0.23	131.7	3.98	7.97	11.95	15.94	19.92
42	0.22	157.9	3.90	7.80	11.70	15.60	19.50
48	0.21	185.4	3.83	7.65	11.48	15.30	19.13
54	0.21	214.0	3.77	7.54	11.31	15.08	18.85
60	0.20	243.2	3.74	7.47	11.21	14.95	18.69
66	0.20	272.9	3.73	7.46	11.19	14.92	18.65
72	0.20	303.1	3.73	7.46	11.19	14.93	18.66
78	0.20	333.6	3.73	7.46	11.18	14.91	18.64
84	0.19	364.6	3.72	7.44	11.16	14.88	18.60
90	0.19	395.8	3.72	7.44	11.16	14.88	18.60
96	0.19	427.1	3.70	7.40	11.10	14.79	18.49
102	0.19	458.5	3.68	7.35	11.03	14.70	18.38
108	0.19	490.0	3.65	7.31	10.96	14.62	18.27
114	0.19	521.7	3.63	7.27	10.90	14.54	18.17
120	0.19	553.6	3.62	7.24	10.85	14.47	18.09
126	0.19	585.4	3.60	7.20	10.80	14.40	18.00
132	0.19	617.1	3.58	7.17	10.75	14.34	17.92
138	0.19	648.7	3.57	7.14	10.71	14.27	17.84
144	0.19	680.0	3.55	7.10	10.65	14.20	17.75
150	0.19	711.3	3.53	7.07	10.60	14.13	17.66
156	0.20	742.2	3.52	7.03	10.55	14.07	17.58
162	0.20	772.6	3.50	7.00	10.50	14.00	17.50
168	0.20	802.7	3.48	6.96	10.45	13.93	17.41
174	0.20	832.6	3.47	6.94	10.41	13.88	17.35
180	0.20	862.3	3.46	6.91	10.37	13.82	17.28
186	0.20	891.7	3.44	6.88	10.32	13.75	17.19
192	0.21	920.9	3.42	6.84	10.27	13.69	17.11
198	0.21	950.1	3.41	6.81	10.22	13.62	17.03
204	0.21	979.2	3.40	6.80	10.21	13.61	17.01
210	0.21	1007.9	3.39	6.78	10.18	13.57	16.96
216	0.21	1036.3	3.38	6.76	10.14	13.52	16.90
222	0.21	1064.7	3.37	6.74	10.11	13.48	16.85
228	0.21	1092.9	3.36	6.71	10.07	13.43	16.79
234	0.21	1121.0	3.35	6.69	10.04	13.38	16.73
240	0.22	1148.8	3.33	6.67	10.00	13.34	16.67
246	0.22	1176.6	3.32	6.65	9.97	13.29	16.61

Table 3 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
252	0.22	1204.3	3.31	6.62	9.93	13.24	16.55
258	0.22	1231.7	3.30	6.60	9.90	13.20	16.50
264	0.22	1259.3	3.29	6.58	9.87	13.16	16.45
270	0.22	1286.8	3.33	6.66	9.99	13.33	16.66
276	0.23	1313.4	3.33	6.66	9.98	13.31	16.64
282	0.23	1339.9	3.32	6.63	9.95	13.27	16.58
288	0.22	1366.6	3.30	6.59	9.89	13.19	16.49
294	0.23	1393.1	3.27	6.55	9.82	13.10	16.37
300	0.23	1419.5	3.26	6.52	9.78	13.04	16.29
306	0.23	1445.8	3.25	6.49	9.74	12.99	16.23
312	0.23	1471.9	3.24	6.47	9.71	12.94	16.18
318	0.23	1498.0	3.22	6.45	9.67	12.89	16.12
324	0.23	1524.1	3.21	6.42	9.64	12.85	16.06
330	0.23	1550.3	3.20	6.40	9.60	12.80	16.00
336	0.23	1576.5	3.19	6.38	9.57	12.76	15.95
342	0.23	1602.5	3.19	6.37	9.56	12.75	15.94
348	0.23	1628.5	3.18	6.37	9.55	12.73	15.91
354	0.23	1654.3	3.18	6.36	9.54	12.71	15.89
360	0.24	1679.9	3.17	6.34	9.51	12.67	15.84
366	0.23	1705.5	3.15	6.30	9.45	12.60	15.75
372	0.23	1731.2	3.13	6.26	9.39	12.52	15.65
378	0.23	1757.2	3.11	6.23	9.34	12.46	15.57
384	0.23	1783.4	3.10	6.19	9.29	12.39	15.48
390	0.23	1809.3	3.08	6.17	9.25	12.33	15.42
396	0.23	1835.3	3.07	6.14	9.21	12.28	15.35
402	0.23	1861.0	3.05	6.11	9.16	12.21	15.27
408	0.23	1886.6	3.04	6.07	9.11	12.15	15.19
414	0.23	1912.2	3.02	6.04	9.05	12.07	15.09
420	0.23	1938.1	3.00	5.99	8.99	11.98	14.98
426	0.24	1964.0	3.01	6.02	9.03	12.05	15.06
432	0.24	1989.3	3.00	6.00	8.99	11.99	14.99
438	0.23	2014.7	2.98	5.96	8.94	11.91	14.89
444	0.23	2040.4	2.96	5.91	8.87	11.83	14.79
450	0.23	2066.4	2.93	5.86	8.79	11.72	14.65
456	0.22	2093.0	2.91	5.82	8.73	11.64	14.55
462	0.22	2119.7	2.89	5.78	8.68	11.57	14.46
468	0.23	2146.4	2.87	5.74	8.61	11.48	14.35
474	0.22	2173.3	2.86	5.71	8.57	11.43	14.29
480	0.22	2200.3	2.86	5.72	8.58	11.44	14.30
486	0.22	2227.1	2.84	5.69	8.53	11.38	14.22
492	0.22	2253.9	2.82	5.64	8.46	11.28	14.10
498	0.22	2281.3	2.79	5.58	8.37	11.16	13.95

Table 3 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
504	0.21	2309.1	2.76	5.53	8.29	11.05	13.82
510	0.24	2335.2	2.74	5.48	8.23	10.97	13.71
516	0.24	2360.1	2.74	5.47	8.21	10.95	13.69
522	0.24	2385.4	2.75	5.50	8.25	11.00	13.74
528	0.24	2410.5	2.74	5.49	8.23	10.97	13.71
534	0.23	2436.0	2.73	5.46	8.19	10.92	13.64
540	0.23	2462.1	2.72	5.44	8.16	10.88	13.60
546	0.22	2489.0	2.71	5.42	8.14	10.85	13.56
552	0.22	2516.5	2.72	5.43	8.15	10.86	13.58
558	0.22	2543.9	2.71	5.41	8.12	10.83	13.53
564	0.22	2571.5	2.70	5.39	8.09	10.78	13.48
570	0.22	2599.4	2.68	5.36	8.04	10.72	13.40
576	0.21	2627.3	2.66	5.32	7.98	10.64	13.30
582	0.21	2655.5	2.64	5.29	7.93	10.58	13.22
588	0.21	2683.6	2.63	5.26	7.89	10.52	13.15
594	0.21	2712.2	2.62	5.23	7.85	10.46	13.08
600	0.21	2741.1	2.61	5.22	7.83	10.44	13.05
606	0.21	2769.5	2.59	5.19	7.78	10.37	12.97
612	0.21	2797.8	2.57	5.14	7.72	10.29	12.86
618	0.21	2826.0	2.55	5.11	7.66	10.21	12.77
624	0.22	2854.0	2.53	5.07	7.60	10.14	12.67
630	0.22	2881.8	2.52	5.03	7.55	10.07	12.59
636	0.22	2909.4	2.50	5.00	7.50	10.00	12.50
642	0.22	2936.7	2.48	4.97	7.45	9.94	12.42
648	0.22	2963.9	2.47	4.94	7.41	9.87	12.34
654	0.23	2990.8	2.45	4.90	7.36	9.81	12.26
660	0.23	3017.3	2.43	4.86	7.30	9.73	12.16
666	0.23	3043.5	2.41	4.82	7.24	9.65	12.06
672	0.23	3069.7	2.39	4.78	7.17	9.56	11.95
678	0.23	3095.9	2.37	4.74	7.11	9.48	11.86
684	0.23	3121.8	2.35	4.70	7.06	9.41	11.76
690	0.24	3147.4	2.33	4.67	7.00	9.33	11.67
696	0.25	3172.3	2.32	4.64	6.97	9.29	11.61
702	0.25	3196.4	2.32	4.64	6.96	9.28	11.60
708	0.25	3220.2	2.32	4.63	6.95	9.26	11.58
714	0.25	3244.0	2.31	4.62	6.93	9.24	11.55
720	0.26	3267.6	2.30	4.61	6.91	9.22	11.52
726	0.26	3291.1	2.30	4.60	6.89	9.19	11.49
732	0.26	3314.6	2.29	4.58	6.87	9.16	11.45
738	0.26	3337.8	2.28	4.56	6.84	9.12	11.40
744	0.26	3361.1	2.27	4.54	6.80	9.07	11.34
750	0.26	3384.5	2.26	4.51	6.77	9.02	11.28

Table 3 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
756	0.26	3408.0	2.25	4.49	6.74	8.99	11.23
762	0.26	3431.3	2.24	4.47	6.71	8.94	11.18
768	0.26	3454.6	2.22	4.45	6.67	8.90	11.12
774	0.26	3477.7	2.21	4.43	6.64	8.86	11.07
780	0.26	3500.9	2.20	4.41	6.61	8.81	11.02
786	0.26	3523.9	2.19	4.38	6.58	8.77	10.96
792	0.26	3547.0	2.18	4.36	6.54	8.73	10.91
798	0.26	3570.1	2.17	4.34	6.51	8.68	10.85
804	0.26	3593.2	2.16	4.31	6.47	8.62	10.78
810	0.26	3616.4	2.14	4.27	6.41	8.55	10.69
816	0.25	3639.9	2.12	4.24	6.36	8.48	10.61
822	0.26	3663.4	2.11	4.21	6.32	8.42	10.53
828	0.26	3686.7	2.09	4.18	6.27	8.37	10.46
834	0.25	3710.3	2.08	4.15	6.23	8.31	10.39
840	0.26	3733.8	2.07	4.14	6.21	8.27	10.34
846	0.26	3756.9	2.05	4.11	6.16	8.21	10.27
852	0.26	3779.8	2.03	4.07	6.10	8.14	10.17
858	0.26	3802.9	2.02	4.03	6.05	8.07	10.08
864	0.26	3825.8	2.00	4.00	6.00	8.00	10.00
870	0.33	3845.9	1.99	3.98	5.97	7.96	9.95
876	0.34	3863.8	1.99	3.97	5.96	7.94	9.93
882	0.34	3881.7	1.98	3.96	5.94	7.92	9.90
888	0.34	3899.3	1.98	3.95	5.93	7.90	9.88
894	0.34	3916.9	1.97	3.93	5.90	7.86	9.83
900	0.28	3936.1	1.96	3.91	5.87	7.83	9.79
906	0.28	3957.2	1.95	3.90	5.86	7.81	9.76
912	0.28	3978.4	1.95	3.89	5.84	7.79	9.74
918	0.28	3999.6	1.94	3.88	5.83	7.77	9.71
924	0.29	4020.6	1.94	3.87	5.81	7.75	9.68
930	0.29	4041.6	1.93	3.86	5.79	7.72	9.65
936	0.29	4062.6	1.92	3.85	5.77	7.69	9.62
942	0.29	4083.4	1.92	3.83	5.75	7.66	9.58
948	0.29	4104.1	1.91	3.82	5.73	7.64	9.54
954	0.29	4124.5	1.90	3.80	5.70	7.60	9.50
960	0.29	4145.0	1.89	3.77	5.66	7.55	9.43
966	0.35	4163.7	1.88	3.76	5.64	7.52	9.40
972	0.35	4180.8	1.87	3.75	5.62	7.49	9.37
978	0.35	4197.9	1.87	3.73	5.60	7.47	9.33
984	0.35	4215.0	1.86	3.72	5.58	7.44	9.30
990	0.35	4232.0	1.85	3.70	5.56	7.41	9.26

Table 4: Simulated drift velocity, drift time, and temperature differential downstream of diffuser along centerline at surface for 181 MGD effluent flow at 14:1 (river flow = 3921 cfs)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
0	1.40	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
6	1.40	4.3	0.0000	0.0000	0.0000	0.0000	0.0000
12	1.38	8.6	0.0000	0.0000	0.0000	0.0000	0.0000
18	1.37	13.0	0.0000	0.0000	0.0000	0.0000	0.0000
24	1.35	17.4	0.0000	0.0000	0.0000	0.0000	0.0000
30	1.34	21.8	0.0000	0.0000	0.0000	0.0000	0.0000
36	1.34	26.3	0.0000	0.0000	0.0000	0.0000	0.0000
42	1.34	30.8	0.0000	0.0000	0.0000	0.0000	0.0000
48	1.34	35.3	0.0000	0.0000	0.0000	0.0000	0.0000
54	1.34	39.7	0.0000	0.0000	0.0000	0.0000	0.0000
60	1.35	44.2	0.0000	0.0000	0.0000	0.0000	0.0000
66	1.35	48.7	0.0000	0.0000	0.0000	0.0000	0.0000
72	1.35	53.1	0.0000	0.0000	0.0000	0.0000	0.0000
78	1.36	57.5	0.0000	0.0000	0.0000	0.0000	0.0000
84	1.37	61.9	0.0000	0.0000	0.0000	0.0000	0.0000
90	1.38	66.3	0.0000	0.0000	0.0000	0.0000	0.0000
96	1.38	70.6	0.0000	0.0000	0.0000	0.0000	0.0000
102	1.38	75.0	0.0000	0.0000	0.0000	0.0000	0.0000
108	1.39	79.3	0.0000	0.0000	0.0000	0.0000	0.0000
114	1.39	83.6	0.0000	0.0000	0.0000	0.0000	0.0000
120	1.39	87.9	0.0000	0.0000	0.0000	0.0000	0.0000
126	1.39	92.2	0.0000	0.0000	0.0000	0.0000	0.0000
132	1.40	96.5	0.0000	0.0000	0.0000	0.0000	0.0000
138	1.40	100.8	0.0000	0.0000	0.0000	0.0000	0.0000
144	1.40	105.1	0.0000	0.0000	0.0000	0.0000	0.0000
150	1.41	109.4	0.0000	0.0000	0.0000	0.0000	0.0000
156	1.41	113.6	0.0000	0.0000	0.0000	0.0000	0.0000
162	1.42	117.9	0.0000	0.0000	0.0000	0.0000	0.0000
168	1.42	122.1	0.0000	0.0000	0.0000	0.0000	0.0000
174	1.42	126.3	0.0000	0.0000	0.0000	0.0000	0.0000
180	1.42	130.6	0.0000	0.0000	0.0000	0.0000	0.0000
186	1.42	134.8	0.0000	0.0000	0.0000	0.0000	0.0000
192	1.42	139.0	0.0000	0.0000	0.0000	0.0000	0.0000
198	1.42	143.2	0.0000	0.0000	0.0000	0.0000	0.0000
204	1.42	147.4	0.0000	0.0000	0.0000	0.0000	0.0000
210	1.43	151.6	0.0000	0.0000	0.0000	0.0000	0.0000
216	1.43	155.8	0.0000	0.0000	0.0000	0.0000	0.0000
222	1.43	160.0	0.0000	0.0000	0.0000	0.0000	0.0000
228	1.44	164.2	0.0000	0.0000	0.0000	0.0000	0.0000
234	1.44	168.4	0.0000	0.0000	0.0000	0.0000	0.0000
240	1.44	172.5	0.0000	0.0000	0.0000	0.0000	0.0000
246	1.44	176.7	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
252	1.44	180.9	0.0000	0.0000	0.0000	0.0000	0.0000
258	1.44	185.0	0.0000	0.0000	0.0000	0.0000	0.0000
264	1.45	189.2	0.0000	0.0000	0.0000	0.0000	0.0000
270	1.45	193.3	0.0000	0.0000	0.0000	0.0000	0.0000
276	1.45	197.5	0.0000	0.0000	0.0000	0.0000	0.0000
282	1.46	201.6	0.0000	0.0000	0.0000	0.0000	0.0000
288	1.46	205.7	0.0000	0.0000	0.0000	0.0000	0.0000
294	1.46	209.8	0.0000	0.0000	0.0000	0.0000	0.0000
300	1.46	213.9	0.0000	0.0000	0.0000	0.0000	0.0000
306	1.46	218.0	0.0000	0.0000	0.0000	0.0000	0.0000
312	1.47	222.1	0.0000	0.0000	0.0000	0.0000	0.0000
318	1.47	226.2	0.0000	0.0000	0.0000	0.0000	0.0000
324	1.47	230.3	0.0000	0.0000	0.0000	0.0000	0.0000
330	1.47	234.4	0.0000	0.0000	0.0000	0.0000	0.0000
336	1.47	238.5	0.0000	0.0000	0.0000	0.0000	0.0000
342	1.47	242.5	0.0000	0.0000	0.0000	0.0000	0.0000
348	1.47	246.6	0.0000	0.0000	0.0000	0.0000	0.0000
354	1.48	250.7	0.0000	0.0000	0.0000	0.0000	0.0000
360	1.48	254.8	0.0000	0.0000	0.0000	0.0000	0.0000
366	1.49	258.8	0.0000	0.0000	0.0000	0.0000	0.0000
372	1.50	262.8	0.0000	0.0000	0.0000	0.0000	0.0000
378	1.51	266.8	0.0000	0.0000	0.0000	0.0000	0.0000
384	1.51	270.8	0.0000	0.0000	0.0000	0.0000	0.0000
390	1.52	274.7	0.0000	0.0000	0.0000	0.0000	0.0000
396	1.52	278.7	0.0000	0.0000	0.0000	0.0000	0.0000
402	1.53	282.6	0.0000	0.0000	0.0000	0.0000	0.0000
408	1.53	286.5	0.0000	0.0000	0.0000	0.0000	0.0000
414	1.53	290.4	0.0000	0.0000	0.0000	0.0000	0.0000
420	1.53	294.4	0.0000	0.0000	0.0000	0.0000	0.0000
426	1.54	298.3	0.0000	0.0000	0.0000	0.0000	0.0000
432	1.54	302.2	0.0000	0.0000	0.0000	0.0000	0.0000
438	1.54	306.1	0.0000	0.0000	0.0000	0.0000	0.0000
444	1.55	309.9	0.0000	0.0000	0.0000	0.0000	0.0000
450	1.55	313.8	0.0000	0.0000	0.0000	0.0000	0.0000
456	1.55	317.7	0.0000	0.0000	0.0000	0.0000	0.0000
462	1.56	321.6	0.0000	0.0000	0.0000	0.0000	0.0000
468	1.56	325.4	0.0000	0.0000	0.0000	0.0000	0.0000
474	1.56	329.3	0.0000	0.0000	0.0000	0.0000	0.0000
480	1.56	333.1	0.0000	0.0000	0.0000	0.0000	0.0000
486	1.57	336.9	0.0000	0.0000	0.0000	0.0000	0.0000
492	1.57	340.7	0.0000	0.0000	0.0000	0.0000	0.0000
498	1.57	344.6	0.0000	0.0000	0.0000	0.0000	0.0001

Table 4 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
504	1.58	348.4	0.0000	0.0000	0.0000	0.0000	0.0001
510	1.58	352.2	0.0000	0.0000	0.0000	0.0001	0.0001
516	1.58	356.0	0.0000	0.0000	0.0001	0.0001	0.0001
522	1.59	359.8	0.0000	0.0000	0.0001	0.0001	0.0001
528	1.59	363.5	0.0000	0.0001	0.0001	0.0001	0.0001
534	1.59	367.3	0.0000	0.0001	0.0001	0.0001	0.0001
540	1.60	371.1	0.0000	0.0001	0.0001	0.0001	0.0002
546	1.60	374.8	0.0000	0.0001	0.0001	0.0002	0.0002
552	1.60	378.6	0.0000	0.0001	0.0001	0.0002	0.0002
558	1.61	382.3	0.0001	0.0001	0.0002	0.0002	0.0003
564	1.61	386.0	0.0001	0.0001	0.0002	0.0003	0.0003
570	1.61	389.8	0.0001	0.0001	0.0002	0.0003	0.0004
576	1.61	393.5	0.0001	0.0002	0.0003	0.0003	0.0004
582	1.61	397.2	0.0001	0.0002	0.0003	0.0004	0.0005
588	1.62	400.9	0.0001	0.0002	0.0003	0.0004	0.0006
594	1.62	404.6	0.0001	0.0003	0.0004	0.0005	0.0006
600	1.62	408.4	0.0001	0.0003	0.0004	0.0006	0.0007
606	1.62	412.1	0.0002	0.0003	0.0005	0.0006	0.0008
612	1.62	415.7	0.0002	0.0004	0.0005	0.0007	0.0009
618	1.63	419.4	0.0002	0.0004	0.0006	0.0008	0.0010
624	1.63	423.1	0.0002	0.0004	0.0007	0.0009	0.0011
630	1.63	426.8	0.0002	0.0005	0.0007	0.0010	0.0012
636	1.63	430.5	0.0003	0.0006	0.0008	0.0011	0.0014
642	1.64	434.1	0.0003	0.0006	0.0009	0.0012	0.0015
648	1.64	437.8	0.0003	0.0007	0.0010	0.0014	0.0017
654	1.65	441.5	0.0004	0.0008	0.0011	0.0015	0.0019
660	1.65	445.1	0.0004	0.0008	0.0012	0.0017	0.0021
666	1.66	448.7	0.0005	0.0009	0.0014	0.0018	0.0023
672	1.66	452.3	0.0005	0.0010	0.0015	0.0020	0.0025
678	1.67	456.0	0.0006	0.0011	0.0017	0.0022	0.0028
684	1.67	459.5	0.0006	0.0012	0.0018	0.0024	0.0030
690	1.67	463.1	0.0007	0.0013	0.0020	0.0026	0.0033
696	1.68	466.7	0.0007	0.0014	0.0022	0.0029	0.0036
702	1.68	470.3	0.0008	0.0016	0.0024	0.0031	0.0039
708	1.69	473.8	0.0009	0.0017	0.0026	0.0034	0.0043
714	1.69	477.4	0.0009	0.0019	0.0028	0.0037	0.0046
720	1.70	480.9	0.0010	0.0020	0.0030	0.0040	0.0050
726	1.70	484.5	0.0011	0.0022	0.0032	0.0043	0.0054
732	1.71	488.0	0.0012	0.0023	0.0035	0.0046	0.0058
738	1.71	491.5	0.0012	0.0025	0.0037	0.0049	0.0062
744	1.71	495.0	0.0013	0.0026	0.0039	0.0053	0.0066
750	1.71	498.5	0.0014	0.0028	0.0042	0.0056	0.0070

Table 4 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
756	1.72	502.0	0.0015	0.0030	0.0044	0.0059	0.0074
762	1.72	505.5	0.0016	0.0031	0.0047	0.0063	0.0079
768	1.73	509.0	0.0017	0.0033	0.0050	0.0067	0.0083
774	1.73	512.4	0.0018	0.0035	0.0053	0.0070	0.0088
780	1.73	515.9	0.0019	0.0037	0.0056	0.0074	0.0093
786	1.74	519.4	0.0019	0.0039	0.0058	0.0078	0.0097
792	1.74	522.8	0.0020	0.0041	0.0061	0.0082	0.0102
798	1.74	526.2	0.0021	0.0043	0.0064	0.0086	0.0107
804	1.75	529.7	0.0022	0.0045	0.0067	0.0090	0.0112
810	1.75	533.1	0.0024	0.0047	0.0071	0.0094	0.0118
816	1.76	536.5	0.0025	0.0049	0.0074	0.0098	0.0123
822	1.76	539.9	0.0026	0.0051	0.0077	0.0103	0.0128
828	1.77	543.3	0.0027	0.0054	0.0080	0.0107	0.0134
834	1.77	546.7	0.0028	0.0056	0.0084	0.0111	0.0139
840	1.78	550.1	0.0029	0.0058	0.0087	0.0115	0.0144
846	1.78	553.5	0.0030	0.0060	0.0090	0.0120	0.0149
852	1.78	556.8	0.0031	0.0062	0.0093	0.0124	0.0154
858	1.79	560.2	0.0032	0.0064	0.0096	0.0128	0.0160
864	1.79	563.6	0.0033	0.0066	0.0099	0.0132	0.0165
870	1.80	566.9	0.0034	0.0068	0.0102	0.0136	0.0170
876	1.80	570.2	0.0035	0.0070	0.0105	0.0140	0.0175
882	1.81	573.6	0.0036	0.0072	0.0108	0.0145	0.0181
888	1.82	576.9	0.0037	0.0074	0.0112	0.0149	0.0186
894	1.82	580.2	0.0038	0.0076	0.0114	0.0153	0.0191
900	1.83	583.4	0.0039	0.0078	0.0117	0.0156	0.0195
906	1.83	586.7	0.0040	0.0080	0.0120	0.0160	0.0200
912	1.84	590.0	0.0041	0.0082	0.0122	0.0163	0.0204
918	1.84	593.3	0.0042	0.0083	0.0125	0.0167	0.0208
924	1.85	596.5	0.0043	0.0085	0.0128	0.0170	0.0213
930	1.85	599.8	0.0044	0.0087	0.0131	0.0174	0.0218
936	1.86	603.0	0.0044	0.0089	0.0133	0.0177	0.0222
942	1.87	606.2	0.0045	0.0090	0.0135	0.0181	0.0226
948	1.87	609.4	0.0046	0.0092	0.0138	0.0184	0.0229
954	1.88	612.6	0.0047	0.0093	0.0140	0.0186	0.0233
960	1.88	615.8	0.0047	0.0095	0.0142	0.0189	0.0236
966	1.88	619.0	0.0048	0.0096	0.0144	0.0192	0.0240
972	1.89	622.2	0.0049	0.0097	0.0146	0.0194	0.0243
978	1.89	625.4	0.0049	0.0098	0.0148	0.0197	0.0246
984	1.89	628.5	0.0050	0.0100	0.0149	0.0199	0.0249
990	1.89	631.7	0.0050	0.0101	0.0151	0.0201	0.0252

Table 5: Simulated drift velocity, drift time, and temperature differential downstream of diffuser along centerline at 10 ft depth for 181 MGD effluent flow at 14:1 (river flow = 3921 cfs)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
0	1.42	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
6	1.41	4.2	0.0000	0.0000	0.0000	0.0000	0.0000
12	1.38	8.5	0.0000	0.0000	0.0000	0.0000	0.0000
18	1.36	12.9	0.0000	0.0000	0.0000	0.0000	0.0000
24	1.35	17.4	0.0000	0.0000	0.0000	0.0000	0.0000
30	1.34	21.8	0.0000	0.0000	0.0000	0.0000	0.0000
36	1.33	26.3	0.0000	0.0000	0.0000	0.0000	0.0000
42	1.33	30.8	0.0000	0.0000	0.0000	0.0000	0.0000
48	1.34	35.3	0.0000	0.0000	0.0000	0.0001	0.0001
54	1.34	39.8	0.0000	0.0001	0.0001	0.0002	0.0002
60	1.34	44.3	0.0001	0.0002	0.0003	0.0004	0.0005
66	1.34	48.7	0.0002	0.0004	0.0007	0.0009	0.0011
72	1.34	53.2	0.0006	0.0012	0.0018	0.0024	0.0030
78	1.36	57.7	0.0020	0.0040	0.0060	0.0080	0.0100
84	1.37	62.1	0.0038	0.0075	0.0113	0.0150	0.0188
90	1.37	66.4	0.0056	0.0111	0.0167	0.0223	0.0278
96	1.38	70.8	0.0073	0.0146	0.0219	0.0291	0.0364
102	1.38	75.2	0.0090	0.0179	0.0269	0.0359	0.0448
108	1.38	79.5	0.0110	0.0220	0.0330	0.0441	0.0551
114	1.38	83.9	0.0134	0.0268	0.0402	0.0536	0.0670
120	1.38	88.2	0.0160	0.0320	0.0481	0.0641	0.0801
126	1.38	92.6	0.0189	0.0378	0.0568	0.0757	0.0946
132	1.38	96.9	0.0220	0.0440	0.0660	0.0880	0.1100
138	1.39	101.2	0.0254	0.0508	0.0762	0.1016	0.1270
144	1.39	105.5	0.0292	0.0584	0.0876	0.1168	0.1460
150	1.39	109.9	0.0331	0.0662	0.0993	0.1323	0.1654
156	1.40	114.2	0.0372	0.0743	0.1115	0.1487	0.1858
162	1.40	118.5	0.0419	0.0837	0.1256	0.1674	0.2093
168	1.40	122.7	0.0466	0.0933	0.1399	0.1866	0.2332
174	1.40	127.0	0.0517	0.1035	0.1552	0.2070	0.2587
180	1.40	131.3	0.0573	0.1146	0.1720	0.2293	0.2866
186	1.40	135.6	0.0636	0.1272	0.1908	0.2544	0.3180
192	1.40	139.8	0.0712	0.1425	0.2137	0.2849	0.3562
198	1.40	144.1	0.0807	0.1614	0.2421	0.3229	0.4036
204	1.40	148.4	0.0927	0.1854	0.2782	0.3709	0.4636
210	1.40	152.7	0.1082	0.2164	0.3245	0.4327	0.5409
216	1.41	157.0	0.1276	0.2551	0.3827	0.5102	0.6378
222	1.41	161.2	0.1476	0.2951	0.4427	0.5903	0.7378
228	1.41	165.5	0.1681	0.3362	0.5043	0.6724	0.8404
234	1.41	169.8	0.1874	0.3747	0.5621	0.7495	0.9368
240	1.40	174.0	0.2063	0.4126	0.6188	0.8251	1.0314
246	1.40	178.3	0.2264	0.4529	0.6793	0.9057	1.1322

Table 5 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
252	1.40	182.6	0.2486	0.4972	0.7457	0.9943	1.2429
258	1.40	186.9	0.2737	0.5475	0.8212	1.0950	1.3687
264	1.40	191.2	0.3052	0.6104	0.9156	1.2208	1.5259
270	1.40	195.4	0.3356	0.6712	1.0068	1.3424	1.6780
276	1.40	199.7	0.3662	0.7324	1.0985	1.4647	1.8309
282	1.40	204.0	0.3913	0.7825	1.1738	1.5650	1.9563
288	1.40	208.3	0.4121	0.8243	1.2364	1.6486	2.0607
294	1.40	212.6	0.4303	0.8607	1.2910	1.7213	2.1517
300	1.40	216.9	0.4473	0.8946	1.3419	1.7893	2.2366
306	1.40	221.2	0.4635	0.9271	1.3906	1.8541	2.3176
312	1.40	225.5	0.4764	0.9528	1.4292	1.9056	2.3820
318	1.40	229.8	0.4850	0.9701	1.4551	1.9401	2.4252
324	1.40	234.1	0.4917	0.9834	1.4752	1.9669	2.4586
330	1.40	238.4	0.4970	0.9939	1.4909	1.9878	2.4848
336	1.40	242.7	0.5000	1.0000	1.5000	2.0000	2.5000
342	1.39	246.9	0.5028	1.0056	1.5083	2.0111	2.5139
348	1.39	251.2	0.5102	1.0204	1.5306	2.0408	2.5510
354	1.39	255.6	0.5227	1.0455	1.5682	2.0909	2.6136
360	1.39	259.9	0.5411	1.0822	1.6233	2.1643	2.7054
366	1.40	264.2	0.5670	1.1341	1.7011	2.2682	2.8352
372	1.42	268.4	0.5839	1.1677	1.7516	2.3355	2.9193
378	1.42	272.7	0.5945	1.1890	1.7834	2.3779	2.9724
384	1.42	276.9	0.6023	1.2045	1.8068	2.4090	3.0113
390	1.43	281.1	0.6081	1.2163	1.8244	2.4325	3.0406
396	1.43	285.3	0.6128	1.2256	1.8384	2.4512	3.0640
402	1.43	289.5	0.6161	1.2322	1.8483	2.4645	3.0806
408	1.43	293.7	0.6175	1.2350	1.8524	2.4699	3.0874
414	1.43	297.8	0.6177	1.2353	1.8530	2.4706	3.0883
420	1.44	302.0	0.6195	1.2390	1.8585	2.4780	3.0975
426	1.44	306.2	0.6225	1.2450	1.8675	2.4900	3.1126
432	1.44	310.4	0.6260	1.2521	1.8781	2.5042	3.1302
438	1.44	314.5	0.6301	1.2601	1.8902	2.5202	3.1503
444	1.44	318.7	0.6343	1.2686	1.9029	2.5372	3.1715
450	1.45	322.8	0.6387	1.2774	1.9161	2.5548	3.1935
456	1.45	327.0	0.6432	1.2865	1.9297	2.5729	3.2162
462	1.45	331.1	0.6472	1.2944	1.9416	2.5888	3.2361
468	1.45	335.3	0.6507	1.3013	1.9520	2.6026	3.2533
474	1.45	339.4	0.6543	1.3085	1.9628	2.6170	3.2713
480	1.46	343.5	0.6573	1.3147	1.9720	2.6293	3.2867
486	1.46	347.6	0.6602	1.3203	1.9805	2.6407	3.3008
492	1.46	351.7	0.6631	1.3262	1.9893	2.6524	3.3155
498	1.46	355.8	0.6656	1.3312	1.9967	2.6623	3.3279

Table 5 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
504	1.46	359.9	0.6683	1.3366	2.0049	2.6732	3.3415
510	1.47	364.0	0.6708	1.3416	2.0124	2.6832	3.3540
516	1.47	368.1	0.6728	1.3456	2.0185	2.6913	3.3641
522	1.47	372.2	0.6747	1.3495	2.0242	2.6990	3.3737
528	1.47	376.3	0.6770	1.3540	2.0310	2.7080	3.3850
534	1.47	380.4	0.6795	1.3591	2.0386	2.7182	3.3977
540	1.48	384.4	0.6818	1.3637	2.0455	2.7274	3.4092
546	1.48	388.5	0.6833	1.3666	2.0499	2.7332	3.4165
552	1.48	392.6	0.6843	1.3686	2.0528	2.7371	3.4214
558	1.48	396.6	0.6850	1.3700	2.0550	2.7400	3.4250
564	1.48	400.7	0.6856	1.3713	2.0569	2.7426	3.4282
570	1.48	404.7	0.6865	1.3730	2.0595	2.7460	3.4326
576	1.48	408.7	0.6879	1.3757	2.0636	2.7514	3.4393
582	1.49	412.8	0.6898	1.3795	2.0693	2.7590	3.4488
588	1.49	416.8	0.6918	1.3836	2.0754	2.7672	3.4590
594	1.50	420.8	0.6921	1.3842	2.0763	2.7684	3.4605
600	1.50	424.8	0.6911	1.3821	2.0732	2.7643	3.4553
606	1.49	428.9	0.6900	1.3800	2.0699	2.7599	3.4499
612	1.49	432.9	0.6891	1.3781	2.0672	2.7563	3.4454
618	1.50	436.9	0.6886	1.3772	2.0658	2.7544	3.4430
624	1.50	440.9	0.6887	1.3774	2.0661	2.7549	3.4436
630	1.50	444.9	0.6892	1.3785	2.0677	2.7570	3.4462
636	1.50	448.9	0.6900	1.3800	2.0700	2.7601	3.4501
642	1.51	452.9	0.6910	1.3819	2.0729	2.7639	3.4549
648	1.51	456.9	0.6922	1.3845	2.0767	2.7690	3.4612
654	1.52	460.8	0.6934	1.3868	2.0802	2.7737	3.4671
660	1.52	464.8	0.6944	1.3888	2.0832	2.7776	3.4720
666	1.53	468.7	0.6955	1.3910	2.0865	2.7820	3.4775
672	1.53	472.6	0.6964	1.3928	2.0891	2.7855	3.4819
678	1.53	476.6	0.6968	1.3937	2.0905	2.7874	3.4842
684	1.54	480.5	0.6975	1.3950	2.0926	2.7901	3.4876
690	1.54	484.4	0.6981	1.3963	2.0944	2.7926	3.4907
696	1.55	488.2	0.6988	1.3976	2.0963	2.7951	3.4939
702	1.55	492.1	0.6995	1.3989	2.0984	2.7979	3.4973
708	1.56	496.0	0.7001	1.4001	2.1002	2.8002	3.5003
714	1.56	499.8	0.7001	1.4002	2.1003	2.8005	3.5006
720	1.57	503.7	0.6999	1.3997	2.0996	2.7995	3.4994
726	1.57	507.5	0.6993	1.3987	2.0980	2.7974	3.4967
732	1.57	511.3	0.6983	1.3967	2.0950	2.7934	3.4917
738	1.58	515.1	0.6967	1.3934	2.0901	2.7868	3.4835
744	1.58	518.9	0.6948	1.3896	2.0844	2.7792	3.4740
750	1.58	522.7	0.6927	1.3855	2.0782	2.7709	3.4636

Table 5 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
756	1.59	526.5	0.6906	1.3813	2.0719	2.7625	3.4531
762	1.59	530.3	0.6888	1.3775	2.0663	2.7550	3.4438
768	1.60	534.0	0.6871	1.3741	2.0612	2.7483	3.4353
774	1.60	537.8	0.6848	1.3695	2.0543	2.7391	3.4239
780	1.61	541.5	0.6824	1.3648	2.0471	2.7295	3.4119
786	1.61	545.3	0.6797	1.3594	2.0391	2.7188	3.3985
792	1.61	549.0	0.6770	1.3541	2.0311	2.7081	3.3852
798	1.62	552.7	0.6745	1.3491	2.0236	2.6981	3.3726
804	1.62	556.4	0.6721	1.3443	2.0164	2.6885	3.3606
810	1.63	560.1	0.6697	1.3394	2.0091	2.6788	3.3485
816	1.63	563.8	0.6673	1.3345	2.0018	2.6691	3.3363
822	1.64	567.5	0.6648	1.3297	1.9945	2.6593	3.3241
828	1.64	571.1	0.6622	1.3243	1.9865	2.6486	3.3108
834	1.65	574.8	0.6592	1.3184	1.9776	2.6368	3.2960
840	1.65	578.4	0.6559	1.3119	1.9678	2.6238	3.2797
846	1.66	582.0	0.6524	1.3048	1.9572	2.6096	3.2620
852	1.66	585.6	0.6487	1.2974	1.9461	2.5948	3.2435
858	1.67	589.2	0.6450	1.2900	1.9350	2.5800	3.2250
864	1.67	592.8	0.6413	1.2825	1.9238	2.5651	3.2064
870	1.68	596.4	0.6377	1.2753	1.9130	2.5506	3.1883
876	1.69	600.0	0.6343	1.2686	1.9029	2.5372	3.1715
882	1.70	603.5	0.6312	1.2624	1.8935	2.5247	3.1559
888	1.71	607.0	0.6277	1.2553	1.8830	2.5106	3.1383
894	1.71	610.5	0.6237	1.2473	1.8710	2.4947	3.1184
900	1.72	614.0	0.6194	1.2388	1.8583	2.4777	3.0971
906	1.72	617.5	0.6150	1.2299	1.8449	2.4599	3.0749
912	1.73	621.0	0.6105	1.2211	1.8316	2.4421	3.0526
918	1.73	624.5	0.6063	1.2126	1.8189	2.4252	3.0315
924	1.74	627.9	0.6024	1.2049	1.8073	2.4098	3.0122
930	1.75	631.4	0.5989	1.1978	1.7968	2.3957	2.9946
936	1.76	634.8	0.5951	1.1903	1.7854	2.3805	2.9756
942	1.76	638.2	0.5909	1.1818	1.7728	2.3637	2.9546
948	1.77	641.6	0.5864	1.1727	1.7591	2.3454	2.9318
954	1.78	645.0	0.5815	1.1630	1.7445	2.3260	2.9075
960	1.78	648.3	0.5763	1.1527	1.7290	2.3054	2.8817
966	1.79	651.7	0.5709	1.1418	1.7127	2.2836	2.8546
972	1.79	655.1	0.5652	1.1304	1.6957	2.2609	2.8261
978	1.79	658.4	0.5594	1.1187	1.6781	2.2374	2.7968
984	1.80	661.8	0.5534	1.1067	1.6601	2.2134	2.7668
990	1.80	665.1	0.5472	1.0943	1.6415	2.1886	2.7358

Table 6: Simulated drift velocity, drift time, and temperature differential downstream of diffuser along warmest path at 20 ft depth for 181 MGD effluent flow at 14:1 (river flow = 3921 cfs)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
0	0.47	0.0	5.00	10.00	15.00	20.00	25.00
6	0.90	8.8	5.00	9.99	14.99	19.98	24.98
12	0.88	15.5	4.98	9.96	14.94	19.92	24.90
18	0.95	22.1	4.96	9.92	14.87	19.83	24.79
24	1.05	28.1	4.76	9.51	14.27	19.03	23.79
30	1.03	33.9	4.63	9.27	13.90	18.53	23.17
36	1.03	39.8	4.53	9.05	13.58	18.10	22.63
42	1.04	45.5	4.41	8.83	13.24	17.66	22.07
48	1.03	51.3	4.21	8.42	12.63	16.85	21.06
54	1.03	57.2	4.16	8.31	12.47	16.63	20.78
60	1.05	62.9	4.00	8.00	12.00	15.99	19.99
66	1.03	68.7	3.82	7.63	11.45	15.27	19.08
72	1.03	74.5	3.71	7.42	11.13	14.83	18.54
78	1.06	80.2	3.57	7.15	10.72	14.29	17.86
84	1.06	85.9	3.39	6.78	10.17	13.55	16.94
90	1.03	91.6	3.22	6.45	9.67	12.89	16.12
96	1.02	97.5	3.11	6.23	9.34	12.46	15.57
102	1.02	103.4	3.03	6.07	9.10	12.14	15.17
108	1.02	109.2	2.96	5.91	8.87	11.82	14.78
114	1.02	115.1	2.88	5.75	8.63	11.51	14.38
120	1.02	121.0	2.83	5.66	8.48	11.31	14.14
126	1.02	126.9	2.77	5.55	8.32	11.10	13.87
132	1.02	132.7	2.72	5.43	8.15	10.87	13.58
138	1.03	138.6	2.67	5.34	8.01	10.68	13.35
144	1.04	144.3	2.64	5.28	7.92	10.56	13.20
150	1.05	150.1	2.60	5.20	7.80	10.40	13.00
156	1.05	155.8	2.56	5.12	7.68	10.25	12.81
162	1.05	161.5	2.53	5.06	7.59	10.13	12.66
168	1.06	167.2	2.50	5.01	7.51	10.01	12.52
174	1.07	172.9	2.48	4.96	7.44	9.92	12.40
180	1.08	178.5	2.45	4.90	7.35	9.80	12.25
186	1.08	184.0	2.42	4.85	7.27	9.69	12.11
192	1.09	189.5	2.39	4.79	7.18	9.58	11.97
198	1.09	195.0	2.37	4.74	7.10	9.47	11.84
204	1.10	200.5	2.34	4.68	7.02	9.36	11.69
210	1.10	206.0	2.31	4.62	6.94	9.25	11.56
216	1.10	211.5	2.29	4.58	6.87	9.16	11.45
222	1.11	216.9	2.26	4.53	6.79	9.06	11.32
228	1.11	222.4	2.24	4.48	6.71	8.95	11.19
234	1.11	227.8	2.22	4.43	6.65	8.87	11.09
240	1.12	233.1	2.20	4.40	6.60	8.80	11.00
246	1.13	238.5	2.18	4.36	6.54	8.72	10.90

Table 6 (continued)

distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
252	1.13	243.8	2.16	4.32	6.47	8.63	10.79
258	1.14	249.1	2.13	4.27	6.40	8.54	10.67
264	1.14	254.4	2.11	4.22	6.33	8.44	10.54
270	1.14	259.7	2.09	4.17	6.26	8.35	10.43
276	1.14	265.0	2.07	4.14	6.21	8.29	10.36
282	1.15	270.2	2.05	4.10	6.16	8.21	10.26
288	1.15	275.4	2.03	4.06	6.08	8.11	10.14
294	1.15	280.6	2.01	4.02	6.02	8.03	10.04
300	1.15	285.9	1.99	3.97	5.96	7.95	9.93
306	1.15	291.1	1.97	3.94	5.90	7.87	9.84
312	1.16	296.3	1.96	3.92	5.88	7.84	9.80
318	1.17	301.4	1.94	3.88	5.82	7.76	9.69
324	1.17	306.5	1.92	3.84	5.76	7.68	9.60
330	1.18	311.7	1.90	3.81	5.71	7.61	9.51
336	1.18	316.8	1.88	3.76	5.65	7.53	9.41
342	1.18	321.8	1.87	3.73	5.60	7.46	9.33
348	1.18	326.9	1.85	3.70	5.55	7.40	9.25
354	1.18	332.0	1.84	3.67	5.51	7.34	9.18
360	1.19	337.1	1.83	3.67	5.50	7.33	9.17
366	1.21	342.1	1.82	3.64	5.46	7.27	9.09
372	1.21	347.0	1.80	3.60	5.40	7.20	9.00
378	1.21	352.0	1.78	3.56	5.34	7.12	8.90
384	1.22	357.0	1.75	3.51	5.26	7.02	8.77
390	1.21	361.9	1.72	3.44	5.16	6.88	8.61
396	1.20	366.9	1.70	3.39	5.09	6.79	8.48
402	1.21	371.8	1.67	3.35	5.02	6.70	8.37
408	1.21	376.8	1.65	3.31	4.96	6.62	8.27
414	1.23	381.7	1.64	3.27	4.91	6.55	8.18
420	1.23	386.6	1.62	3.23	4.85	6.46	8.08
426	1.24	391.5	1.59	3.19	4.78	6.37	7.97
432	1.24	396.3	1.57	3.14	4.71	6.28	7.85
438	1.24	401.2	1.55	3.09	4.64	6.18	7.73
444	1.22	406.0	1.52	3.05	4.57	6.10	7.62
450	1.23	410.9	1.52	3.03	4.55	6.07	7.58
456	1.23	415.8	1.51	3.02	4.52	6.03	7.54
462	1.23	420.7	1.50	3.00	4.49	5.99	7.49
468	1.24	425.5	1.49	2.98	4.46	5.95	7.44
474	1.24	430.4	1.48	2.95	4.43	5.91	7.38
480	1.25	435.2	1.46	2.93	4.39	5.86	7.32
486	1.25	440.0	1.45	2.90	4.36	5.81	7.26
492	1.26	444.8	1.44	2.88	4.32	5.75	7.19
498	1.26	449.5	1.43	2.85	4.28	5.70	7.13

Table 6 (continued)

distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
504	1.27	454.3	1.41	2.82	4.23	5.64	7.05
510	1.27	459.0	1.39	2.79	4.18	5.57	6.97
516	1.28	463.7	1.38	2.75	4.13	5.51	6.88
522	1.28	468.4	1.36	2.72	4.08	5.44	6.80
528	1.29	473.1	1.34	2.68	4.03	5.37	6.71
534	1.30	477.7	1.32	2.65	3.97	5.30	6.62
540	1.29	482.3	1.31	2.62	3.94	5.25	6.56
546	1.29	487.0	1.31	2.61	3.92	5.23	6.53
552	1.30	491.6	1.30	2.60	3.90	5.20	6.50
558	1.30	496.2	1.29	2.59	3.88	5.17	6.47
564	1.31	500.8	1.29	2.57	3.86	5.14	6.43
570	1.31	505.4	1.28	2.55	3.83	5.10	6.38
576	1.32	510.0	1.27	2.53	3.80	5.07	6.33
582	1.32	514.5	1.26	2.51	3.77	5.03	6.28
588	1.33	519.0	1.25	2.49	3.74	4.99	6.23
594	1.33	523.6	1.24	2.47	3.71	4.95	6.19
600	1.34	528.0	1.23	2.45	3.68	4.91	6.13
606	1.35	532.5	1.21	2.43	3.64	4.86	6.07
612	1.35	537.0	1.20	2.40	3.61	4.81	6.01
618	1.35	541.4	1.19	2.38	3.57	4.75	5.94
624	1.35	545.9	1.18	2.36	3.54	4.73	5.91
630	1.35	550.3	1.18	2.36	3.53	4.71	5.89
636	1.36	554.8	1.17	2.35	3.52	4.70	5.87
642	1.37	559.2	1.17	2.34	3.50	4.67	5.84
648	1.36	563.6	1.16	2.32	3.48	4.64	5.80
654	1.36	568.0	1.15	2.31	3.46	4.62	5.77
660	1.37	572.4	1.15	2.30	3.44	4.59	5.74
666	1.38	576.7	1.14	2.28	3.43	4.57	5.71
672	1.38	581.1	1.14	2.27	3.41	4.54	5.68
678	1.39	585.4	1.13	2.26	3.38	4.51	5.64
684	1.40	589.7	1.12	2.24	3.36	4.48	5.60
690	1.40	594.0	1.11	2.22	3.33	4.45	5.56
696	1.38	598.3	1.11	2.22	3.33	4.44	5.55
702	1.37	602.7	1.11	2.22	3.33	4.44	5.55
708	1.40	607.0	1.12	2.23	3.35	4.47	5.59
714	1.43	611.3	1.12	2.23	3.35	4.46	5.58
720	1.41	615.5	1.11	2.22	3.34	4.45	5.56
726	1.39	619.8	1.11	2.22	3.32	4.43	5.54
732	1.40	624.1	1.11	2.21	3.32	4.42	5.53
738	1.43	628.3	1.10	2.20	3.30	4.40	5.50
744	1.42	632.5	1.09	2.18	3.27	4.37	5.46
750	1.41	636.8	1.08	2.16	3.24	4.32	5.40

Table 6 (continued)

distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
756	1.44	641.0	1.08	2.15	3.23	4.30	5.38
762	1.44	645.2	1.07	2.15	3.22	4.29	5.37
768	1.43	649.3	1.07	2.14	3.21	4.28	5.35
774	1.43	653.5	1.07	2.13	3.20	4.27	5.33
780	1.44	657.7	1.06	2.13	3.19	4.26	5.32
786	1.44	661.9	1.06	2.12	3.18	4.24	5.31
792	1.44	666.0	1.06	2.11	3.17	4.23	5.29
798	1.45	670.2	1.05	2.11	3.16	4.21	5.27
804	1.47	674.3	1.05	2.10	3.15	4.20	5.24
810	1.47	678.4	1.05	2.10	3.15	4.20	5.24
816	1.47	682.5	1.05	2.10	3.15	4.19	5.24
822	1.48	686.6	1.05	2.10	3.15	4.19	5.24
828	1.49	690.6	1.05	2.09	3.14	4.19	5.23
834	1.49	694.6	1.04	2.09	3.13	4.18	5.22
840	1.50	698.6	1.04	2.08	3.12	4.16	5.20
846	1.50	702.7	1.04	2.07	3.11	4.15	5.18
852	1.51	706.6	1.03	2.07	3.10	4.13	5.17
858	1.51	710.6	1.03	2.07	3.10	4.13	5.16
864	1.52	714.6	1.03	2.06	3.10	4.13	5.16
870	1.52	718.5	1.03	2.06	3.09	4.12	5.16
876	1.52	722.5	1.03	2.06	3.09	4.12	5.15
882	1.54	726.4	1.03	2.06	3.09	4.11	5.14
888	1.55	730.3	1.03	2.05	3.08	4.11	5.13
894	1.56	734.1	1.03	2.05	3.08	4.10	5.13
900	1.57	738.0	1.03	2.05	3.08	4.10	5.13
906	1.57	741.8	1.02	2.05	3.07	4.10	5.12
912	1.57	745.6	1.02	2.05	3.07	4.09	5.12
918	1.56	749.5	1.02	2.05	3.07	4.09	5.11
924	1.57	753.3	1.02	2.04	3.07	4.09	5.11
930	1.58	757.1	1.02	2.04	3.06	4.08	5.10
936	1.59	760.9	1.02	2.04	3.06	4.08	5.10
942	1.59	764.6	1.02	2.03	3.05	4.07	5.09
948	1.60	768.4	1.02	2.03	3.05	4.07	5.08
954	1.61	772.1	1.02	2.03	3.05	4.06	5.08
960	1.61	775.9	1.02	2.03	3.05	4.06	5.08
966	1.62	779.6	1.01	2.03	3.04	4.06	5.07
972	1.62	783.3	1.01	2.03	3.04	4.06	5.07
978	1.62	787.0	1.01	2.03	3.04	4.05	5.06
984	1.62	790.7	1.01	2.02	3.04	4.05	5.06
990	1.63	794.4	1.01	2.02	3.03	4.05	5.06

Table 7: Simulated drift velocity, drift time, and temperature differential downstream of diffuser along centerline at surface for 410 MGD effluent flow at 14:1 (river flow = 8880 cfs)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
0	3.19	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
6	3.18	1.9	0.0000	0.0000	0.0000	0.0000	0.0000
12	3.15	3.8	0.0000	0.0000	0.0000	0.0000	0.0000
18	3.11	5.7	0.0000	0.0000	0.0000	0.0000	0.0000
24	3.08	7.6	0.0000	0.0000	0.0000	0.0000	0.0000
30	3.06	9.6	0.0000	0.0000	0.0000	0.0000	0.0000
36	3.05	11.6	0.0000	0.0000	0.0000	0.0000	0.0000
42	3.05	13.5	0.0000	0.0000	0.0000	0.0000	0.0000
48	3.05	15.5	0.0000	0.0000	0.0000	0.0000	0.0000
54	3.05	17.5	0.0000	0.0000	0.0000	0.0000	0.0000
60	3.06	19.4	0.0000	0.0000	0.0000	0.0000	0.0000
66	3.07	21.4	0.0000	0.0000	0.0000	0.0000	0.0000
72	3.08	23.3	0.0000	0.0000	0.0000	0.0000	0.0000
78	3.09	25.3	0.0000	0.0000	0.0000	0.0000	0.0000
84	3.11	27.2	0.0000	0.0000	0.0000	0.0000	0.0000
90	3.13	29.1	0.0000	0.0000	0.0000	0.0000	0.0000
96	3.14	31.0	0.0000	0.0000	0.0000	0.0000	0.0000
102	3.14	33.0	0.0000	0.0000	0.0000	0.0000	0.0000
108	3.15	34.9	0.0000	0.0000	0.0000	0.0000	0.0000
114	3.15	36.8	0.0000	0.0000	0.0000	0.0000	0.0000
120	3.16	38.7	0.0000	0.0000	0.0000	0.0000	0.0000
126	3.16	40.6	0.0000	0.0000	0.0000	0.0000	0.0000
132	3.17	42.5	0.0000	0.0000	0.0000	0.0000	0.0000
138	3.18	44.4	0.0000	0.0000	0.0000	0.0000	0.0000
144	3.19	46.2	0.0000	0.0000	0.0000	0.0000	0.0000
150	3.20	48.1	0.0000	0.0000	0.0000	0.0000	0.0000
156	3.20	50.0	0.0000	0.0000	0.0000	0.0000	0.0000
162	3.21	51.9	0.0000	0.0000	0.0000	0.0000	0.0000
168	3.22	53.7	0.0000	0.0000	0.0000	0.0000	0.0000
174	3.22	55.6	0.0000	0.0000	0.0000	0.0000	0.0000
180	3.22	57.5	0.0000	0.0000	0.0000	0.0000	0.0000
186	3.22	59.3	0.0000	0.0000	0.0000	0.0000	0.0000
192	3.22	61.2	0.0000	0.0000	0.0000	0.0000	0.0000
198	3.23	63.0	0.0000	0.0000	0.0000	0.0000	0.0000
204	3.23	64.9	0.0000	0.0000	0.0000	0.0000	0.0000
210	3.24	66.8	0.0000	0.0000	0.0000	0.0000	0.0000
216	3.24	68.6	0.0000	0.0000	0.0000	0.0000	0.0000
222	3.25	70.5	0.0000	0.0000	0.0000	0.0000	0.0000
228	3.26	72.3	0.0000	0.0000	0.0000	0.0000	0.0000
234	3.26	74.2	0.0000	0.0000	0.0000	0.0000	0.0000
240	3.26	76.0	0.0000	0.0000	0.0000	0.0000	0.0000
246	3.26	77.8	0.0000	0.0000	0.0000	0.0000	0.0000

Table 7 (continued)

distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
252	3.26	79.7	0.0000	0.0000	0.0000	0.0000	0.0000
258	3.27	81.5	0.0000	0.0000	0.0000	0.0000	0.0000
264	3.27	83.3	0.0000	0.0000	0.0000	0.0000	0.0000
270	3.28	85.2	0.0000	0.0000	0.0000	0.0000	0.0000
276	3.29	87.0	0.0000	0.0000	0.0000	0.0000	0.0000
282	3.30	88.8	0.0000	0.0000	0.0000	0.0000	0.0000
288	3.30	90.6	0.0000	0.0000	0.0000	0.0000	0.0000
294	3.31	92.4	0.0000	0.0000	0.0000	0.0000	0.0000
300	3.31	94.3	0.0000	0.0000	0.0000	0.0000	0.0000
306	3.32	96.1	0.0000	0.0000	0.0000	0.0000	0.0000
312	3.32	97.9	0.0000	0.0000	0.0000	0.0000	0.0000
318	3.32	99.7	0.0000	0.0000	0.0000	0.0000	0.0000
324	3.32	101.5	0.0000	0.0000	0.0000	0.0000	0.0000
330	3.33	103.3	0.0000	0.0000	0.0000	0.0000	0.0000
336	3.32	105.1	0.0000	0.0000	0.0000	0.0000	0.0000
342	3.32	106.9	0.0000	0.0000	0.0000	0.0000	0.0000
348	3.33	108.7	0.0000	0.0000	0.0000	0.0000	0.0000
354	3.33	110.5	0.0000	0.0000	0.0000	0.0000	0.0000
360	3.35	112.3	0.0000	0.0000	0.0000	0.0000	0.0000
366	3.37	114.1	0.0000	0.0000	0.0000	0.0000	0.0000
372	3.39	115.9	0.0000	0.0000	0.0000	0.0000	0.0000
378	3.41	117.6	0.0000	0.0000	0.0000	0.0000	0.0000
384	3.42	119.4	0.0000	0.0000	0.0000	0.0000	0.0000
390	3.43	121.1	0.0000	0.0000	0.0000	0.0000	0.0000
396	3.44	122.9	0.0000	0.0000	0.0000	0.0000	0.0000
402	3.44	124.6	0.0000	0.0000	0.0000	0.0000	0.0000
408	3.45	126.4	0.0000	0.0000	0.0000	0.0000	0.0000
414	3.45	128.1	0.0000	0.0000	0.0000	0.0000	0.0000
420	3.46	129.9	0.0000	0.0000	0.0000	0.0000	0.0000
426	3.46	131.6	0.0000	0.0000	0.0000	0.0000	0.0000
432	3.47	133.3	0.0000	0.0000	0.0000	0.0000	0.0000
438	3.48	135.0	0.0000	0.0000	0.0000	0.0000	0.0000
444	3.48	136.8	0.0000	0.0000	0.0000	0.0000	0.0000
450	3.49	138.5	0.0000	0.0000	0.0000	0.0000	0.0000
456	3.50	140.2	0.0000	0.0000	0.0000	0.0000	0.0000
462	3.50	141.9	0.0000	0.0000	0.0000	0.0000	0.0000
468	3.51	143.6	0.0000	0.0000	0.0000	0.0000	0.0001
474	3.52	145.3	0.0000	0.0000	0.0000	0.0001	0.0001
480	3.52	147.0	0.0000	0.0000	0.0001	0.0001	0.0001
486	3.53	148.7	0.0000	0.0001	0.0001	0.0001	0.0001
492	3.53	150.4	0.0000	0.0001	0.0001	0.0002	0.0002
498	3.54	152.1	0.0001	0.0001	0.0002	0.0002	0.0003

Table 7 (continued)

distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
504	3.54	153.8	0.0001	0.0001	0.0002	0.0003	0.0003
510	3.55	155.5	0.0001	0.0002	0.0003	0.0004	0.0005
516	3.56	157.2	0.0001	0.0002	0.0004	0.0005	0.0006
522	3.56	158.9	0.0002	0.0003	0.0005	0.0006	0.0008
528	3.57	160.6	0.0002	0.0004	0.0006	0.0008	0.0010
534	3.58	162.3	0.0003	0.0005	0.0008	0.0010	0.0013
540	3.58	163.9	0.0003	0.0006	0.0010	0.0013	0.0016
546	3.59	165.6	0.0004	0.0008	0.0012	0.0016	0.0020
552	3.59	167.3	0.0005	0.0010	0.0015	0.0021	0.0026
558	3.60	169.0	0.0006	0.0013	0.0019	0.0026	0.0032
564	3.60	170.6	0.0008	0.0016	0.0024	0.0032	0.0040
570	3.60	172.3	0.0010	0.0020	0.0030	0.0040	0.0049
576	3.61	174.0	0.0012	0.0024	0.0036	0.0048	0.0061
582	3.61	175.6	0.0015	0.0030	0.0044	0.0059	0.0074
588	3.62	177.3	0.0018	0.0036	0.0054	0.0072	0.0090
594	3.62	178.9	0.0022	0.0043	0.0065	0.0087	0.0108
600	3.63	180.6	0.0026	0.0052	0.0078	0.0104	0.0130
606	3.63	182.2	0.0031	0.0062	0.0093	0.0124	0.0155
612	3.63	183.9	0.0037	0.0074	0.0111	0.0148	0.0185
618	3.63	185.5	0.0044	0.0087	0.0131	0.0175	0.0218
624	3.63	187.2	0.0051	0.0103	0.0154	0.0205	0.0257
630	3.64	188.9	0.0060	0.0120	0.0180	0.0240	0.0301
636	3.65	190.5	0.0070	0.0140	0.0210	0.0280	0.0350
642	3.65	192.1	0.0081	0.0163	0.0244	0.0326	0.0407
648	3.66	193.8	0.0095	0.0189	0.0284	0.0378	0.0473
654	3.67	195.4	0.0109	0.0219	0.0328	0.0438	0.0547
660	3.68	197.0	0.0126	0.0252	0.0378	0.0505	0.0631
666	3.69	198.7	0.0145	0.0290	0.0435	0.0581	0.0726
672	3.70	200.3	0.0166	0.0333	0.0499	0.0666	0.0832
678	3.71	201.9	0.0190	0.0381	0.0571	0.0761	0.0952
684	3.71	203.5	0.0217	0.0434	0.0651	0.0868	0.1086
690	3.72	205.1	0.0247	0.0494	0.0741	0.0988	0.1235
696	3.73	206.8	0.0280	0.0561	0.0841	0.1122	0.1402
702	3.74	208.4	0.0317	0.0634	0.0952	0.1269	0.1586
708	3.75	210.0	0.0357	0.0715	0.1072	0.1430	0.1787
714	3.75	211.6	0.0401	0.0802	0.1202	0.1603	0.2004
720	3.76	213.2	0.0447	0.0894	0.1341	0.1788	0.2235
726	3.77	214.8	0.0496	0.0992	0.1488	0.1985	0.2481
732	3.77	216.4	0.0548	0.1096	0.1644	0.2192	0.2740
738	3.78	217.9	0.0602	0.1204	0.1807	0.2409	0.3011
744	3.78	219.5	0.0659	0.1317	0.1976	0.2634	0.3293
750	3.79	221.1	0.0717	0.1433	0.2150	0.2867	0.3583

Table 7 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
756	3.79	222.7	0.0776	0.1553	0.2329	0.3105	0.3881
762	3.79	224.3	0.0837	0.1674	0.2511	0.3348	0.4186
768	3.80	225.9	0.0899	0.1798	0.2697	0.3595	0.4494
774	3.81	227.4	0.0961	0.1923	0.2884	0.3845	0.4806
780	3.81	229.0	0.1024	0.2048	0.3072	0.4096	0.5120
786	3.81	230.6	0.1087	0.2173	0.3260	0.4347	0.5433
792	3.82	232.2	0.1149	0.2298	0.3447	0.4596	0.5745
798	3.82	233.7	0.1211	0.2422	0.3632	0.4843	0.6054
804	3.83	235.3	0.1272	0.2543	0.3815	0.5087	0.6358
810	3.83	236.9	0.1331	0.2663	0.3994	0.5325	0.6657
816	3.84	238.4	0.1390	0.2779	0.4169	0.5558	0.6948
822	3.85	240.0	0.1446	0.2892	0.4339	0.5785	0.7231
828	3.85	241.6	0.1501	0.3002	0.4503	0.6004	0.7505
834	3.86	243.1	0.1554	0.3108	0.4661	0.6215	0.7769
840	3.87	244.7	0.1604	0.3209	0.4813	0.6417	0.8022
846	3.87	246.2	0.1653	0.3305	0.4958	0.6611	0.8264
852	3.88	247.8	0.1699	0.3397	0.5096	0.6795	0.8493
858	3.88	249.3	0.1742	0.3485	0.5227	0.6969	0.8711
864	3.89	250.8	0.1783	0.3567	0.5350	0.7134	0.8917
870	3.90	252.4	0.1822	0.3644	0.5466	0.7289	0.9111
876	3.91	253.9	0.1859	0.3717	0.5576	0.7435	0.9293
882	3.92	255.5	0.1893	0.3786	0.5679	0.7572	0.9464
888	3.93	257.0	0.1925	0.3849	0.5774	0.7698	0.9623
894	3.94	258.5	0.1954	0.3907	0.5861	0.7814	0.9768
900	3.94	260.0	0.1980	0.3960	0.5941	0.7921	0.9901
906	3.95	261.6	0.2005	0.4009	0.6014	0.8018	1.0023
912	3.96	263.1	0.2027	0.4053	0.6080	0.8107	1.0133
918	3.97	264.6	0.2047	0.4093	0.6140	0.8187	1.0234
924	3.98	266.1	0.2065	0.4130	0.6195	0.8260	1.0325
930	3.99	267.6	0.2082	0.4163	0.6245	0.8327	1.0408
936	4.00	269.1	0.2096	0.4193	0.6289	0.8386	1.0482
942	4.01	270.6	0.2109	0.4219	0.6328	0.8438	1.0547
948	4.02	272.1	0.2121	0.4242	0.6363	0.8484	1.0605
954	4.03	273.6	0.2131	0.4262	0.6393	0.8524	1.0655
960	4.03	275.1	0.2140	0.4279	0.6419	0.8558	1.0698
966	4.04	276.6	0.2147	0.4294	0.6441	0.8588	1.0735
972	4.04	278.1	0.2153	0.4306	0.6459	0.8612	1.0765
978	4.04	279.5	0.2158	0.4316	0.6474	0.8632	1.0790
984	4.05	281.0	0.2162	0.4324	0.6485	0.8647	1.0809
990	4.05	282.5	0.2164	0.4329	0.6493	0.8658	1.0822

Table 8: Simulated drift velocity, drift time, and temperature differential downstream of diffuser along centerline at 10 ft depth for 410 MGD effluent flow at 14:1 (river flow = 8880 cfs)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
0	3.24	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
6	3.21	1.9	0.0000	0.0000	0.0000	0.0000	0.0000
12	3.15	3.8	0.0000	0.0000	0.0000	0.0000	0.0000
18	3.10	5.7	0.0000	0.0000	0.0000	0.0000	0.0000
24	3.07	7.6	0.0000	0.0000	0.0000	0.0000	0.0000
30	3.05	9.6	0.0000	0.0000	0.0000	0.0000	0.0000
36	3.04	11.6	0.0000	0.0000	0.0000	0.0000	0.0000
42	3.04	13.5	0.0000	0.0000	0.0000	0.0000	0.0000
48	3.04	15.5	0.0000	0.0000	0.0000	0.0000	0.0000
54	3.05	17.5	0.0000	0.0000	0.0001	0.0001	0.0001
60	3.05	19.4	0.0000	0.0001	0.0001	0.0002	0.0002
66	3.05	21.4	0.0001	0.0002	0.0003	0.0004	0.0005
72	3.06	23.4	0.0003	0.0006	0.0009	0.0012	0.0015
78	3.08	25.3	0.0011	0.0022	0.0033	0.0045	0.0056
84	3.11	27.3	0.0022	0.0043	0.0065	0.0086	0.0108
90	3.12	29.2	0.0033	0.0066	0.0098	0.0131	0.0164
96	3.13	31.1	0.0044	0.0087	0.0131	0.0175	0.0219
102	3.13	33.0	0.0055	0.0110	0.0165	0.0220	0.0275
108	3.14	34.9	0.0069	0.0139	0.0208	0.0278	0.0347
114	3.14	36.9	0.0087	0.0174	0.0260	0.0347	0.0434
120	3.14	38.8	0.0107	0.0213	0.0320	0.0427	0.0534
126	3.14	40.7	0.0129	0.0258	0.0388	0.0517	0.0646
132	3.14	42.6	0.0154	0.0307	0.0461	0.0614	0.0768
138	3.15	44.5	0.0181	0.0363	0.0544	0.0726	0.0907
144	3.16	46.4	0.0214	0.0429	0.0643	0.0857	0.1071
150	3.17	48.3	0.0250	0.0500	0.0750	0.1000	0.1251
156	3.17	50.2	0.0291	0.0581	0.0872	0.1163	0.1453
162	3.18	52.1	0.0339	0.0679	0.1018	0.1358	0.1697
168	3.19	54.0	0.0396	0.0792	0.1188	0.1584	0.1980
174	3.19	55.9	0.0461	0.0922	0.1383	0.1844	0.2305
180	3.19	57.7	0.0536	0.1072	0.1608	0.2143	0.2679
186	3.18	59.6	0.0622	0.1244	0.1865	0.2487	0.3109
192	3.18	61.5	0.0725	0.1451	0.2176	0.2901	0.3627
198	3.18	63.4	0.0849	0.1698	0.2547	0.3396	0.4245
204	3.18	65.3	0.0999	0.1997	0.2996	0.3995	0.4994
210	3.18	67.2	0.1178	0.2355	0.3533	0.4711	0.5889
216	3.19	69.1	0.1389	0.2779	0.4168	0.5558	0.6947
222	3.19	70.9	0.1607	0.3215	0.4822	0.6430	0.8037
228	3.19	72.8	0.1825	0.3649	0.5474	0.7298	0.9123
234	3.19	74.7	0.2025	0.4050	0.6075	0.8100	1.0125
240	3.18	76.6	0.2220	0.4439	0.6659	0.8879	1.1098
246	3.17	78.5	0.2421	0.4843	0.7264	0.9686	1.2107

Table 8 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
252	3.17	80.4	0.2635	0.5270	0.7905	1.0540	1.3175
258	3.16	82.3	0.2866	0.5733	0.8599	1.1466	1.4332
264	3.16	84.2	0.3133	0.6266	0.9398	1.2531	1.5664
270	3.17	86.0	0.3381	0.6762	1.0143	1.3524	1.6905
276	3.17	87.9	0.3621	0.7242	1.0863	1.4484	1.8105
282	3.18	89.8	0.3814	0.7627	1.1441	1.5254	1.9068
288	3.17	91.7	0.3970	0.7940	1.1910	1.5880	1.9850
294	3.17	93.6	0.4106	0.8212	1.2318	1.6424	2.0530
300	3.17	95.5	0.4233	0.8466	1.2699	1.6932	2.1165
306	3.17	97.4	0.4355	0.8709	1.3064	1.7419	2.1773
312	3.17	99.3	0.4455	0.8910	1.3364	1.7819	2.2274
318	3.17	101.2	0.4529	0.9058	1.3586	1.8115	2.2644
324	3.17	103.1	0.4591	0.9181	1.3772	1.8363	2.2954
330	3.17	105.0	0.4643	0.9287	1.3930	1.8573	2.3216
336	3.17	106.9	0.4682	0.9363	1.4045	1.8727	2.3408
342	3.16	108.8	0.4717	0.9434	1.4151	1.8868	2.3585
348	3.15	110.7	0.4778	0.9556	1.4333	1.9111	2.3889
354	3.15	112.6	0.4869	0.9739	1.4608	1.9478	2.4347
360	3.16	114.5	0.5010	1.0021	1.5031	2.0041	2.5051
366	3.19	116.4	0.5218	1.0436	1.5653	2.0871	2.6089
372	3.22	118.2	0.5349	1.0698	1.6048	2.1397	2.6746
378	3.23	120.1	0.5428	1.0856	1.6284	2.1711	2.7139
384	3.23	121.9	0.5482	1.0964	1.6447	2.1929	2.7411
390	3.24	123.8	0.5524	1.1048	1.6572	2.2096	2.7620
396	3.24	125.6	0.5557	1.1115	1.6672	2.2230	2.7787
402	3.25	127.5	0.5581	1.1163	1.6744	2.2325	2.7907
408	3.26	129.3	0.5592	1.1184	1.6776	2.2368	2.7960
414	3.26	131.2	0.5594	1.1189	1.6783	2.2377	2.7971
420	3.26	133.0	0.5606	1.1212	1.6818	2.2424	2.8030
426	3.26	134.9	0.5625	1.1249	1.6874	2.2499	2.8123
432	3.26	136.7	0.5646	1.1292	1.6939	2.2585	2.8231
438	3.27	138.5	0.5670	1.1341	1.7011	2.2682	2.8352
444	3.27	140.4	0.5696	1.1392	1.7088	2.2784	2.8480
450	3.28	142.2	0.5722	1.1444	1.7167	2.2889	2.8611
456	3.28	144.0	0.5749	1.1499	1.7248	2.2997	2.8746
462	3.29	145.9	0.5773	1.1545	1.7318	2.3090	2.8863
468	3.29	147.7	0.5792	1.1585	1.7377	2.3170	2.8962
474	3.29	149.5	0.5813	1.1627	1.7440	2.3253	2.9067
480	3.30	151.3	0.5831	1.1662	1.7493	2.3324	2.9155
486	3.30	153.1	0.5847	1.1694	1.7542	2.3389	2.9236
492	3.30	155.0	0.5864	1.1728	1.7592	2.3456	2.9320
498	3.31	156.8	0.5878	1.1756	1.7634	2.3512	2.9390

Table 8 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
504	3.31	158.6	0.5894	1.1787	1.7681	2.3574	2.9468
510	3.32	160.4	0.5907	1.1815	1.7722	2.3630	2.9537
516	3.32	162.2	0.5918	1.1836	1.7754	2.3672	2.9590
522	3.32	164.0	0.5928	1.1856	1.7784	2.3712	2.9640
528	3.33	165.8	0.5940	1.1880	1.7819	2.3759	2.9699
534	3.33	167.6	0.5953	1.1907	1.7860	2.3813	2.9767
540	3.34	169.4	0.5965	1.1930	1.7895	2.3859	2.9824
546	3.34	171.2	0.5971	1.1942	1.7914	2.3885	2.9856
552	3.35	173.0	0.5974	1.1949	1.7923	2.3898	2.9872
558	3.35	174.8	0.5976	1.1952	1.7928	2.3904	2.9879
564	3.35	176.6	0.5977	1.1953	1.7930	2.3907	2.9883
570	3.35	178.4	0.5978	1.1957	1.7935	2.3914	2.9892
576	3.35	180.2	0.5983	1.1966	1.7949	2.3932	2.9915
582	3.35	182.0	0.5991	1.1982	1.7974	2.3965	2.9956
588	3.36	183.8	0.6000	1.2000	1.8000	2.4000	3.0000
594	3.37	185.5	0.5997	1.1995	1.7992	2.3990	2.9987
600	3.37	187.3	0.5986	1.1971	1.7957	2.3943	2.9929
606	3.37	189.1	0.5973	1.1947	1.7920	2.3893	2.9867
612	3.37	190.9	0.5962	1.1924	1.7885	2.3847	2.9809
618	3.37	192.7	0.5953	1.1905	1.7858	2.3811	2.9763
624	3.37	194.5	0.5947	1.1894	1.7841	2.3788	2.9734
630	3.37	196.2	0.5943	1.1887	1.7830	2.3773	2.9717
636	3.38	198.0	0.5941	1.1882	1.7823	2.3764	2.9705
642	3.39	199.8	0.5940	1.1879	1.7819	2.3759	2.9698
648	3.40	201.5	0.5940	1.1881	1.7821	2.3761	2.9701
654	3.41	203.3	0.5940	1.1881	1.7821	2.3761	2.9701
660	3.42	205.1	0.5939	1.1878	1.7817	2.3756	2.9695
666	3.43	206.8	0.5939	1.1878	1.7817	2.3756	2.9695
672	3.44	208.6	0.5937	1.1874	1.7811	2.3748	2.9685
678	3.44	210.3	0.5932	1.1865	1.7797	2.3729	2.9661
684	3.45	212.1	0.5930	1.1859	1.7789	2.3718	2.9648
690	3.46	213.8	0.5927	1.1854	1.7781	2.3708	2.9635
696	3.47	215.5	0.5925	1.1851	1.7776	2.3701	2.9626
702	3.47	217.3	0.5925	1.1849	1.7774	2.3699	2.9624
708	3.49	219.0	0.5924	1.1848	1.7772	2.3697	2.9621
714	3.50	220.7	0.5921	1.1841	1.7762	2.3682	2.9603
720	3.50	222.4	0.5916	1.1832	1.7747	2.3663	2.9579
726	3.51	224.1	0.5910	1.1820	1.7730	2.3640	2.9550
732	3.52	225.8	0.5902	1.1805	1.7707	2.3609	2.9512
738	3.52	227.5	0.5892	1.1784	1.7676	2.3568	2.9460
744	3.53	229.2	0.5881	1.1762	1.7643	2.3524	2.9404
750	3.53	230.9	0.5870	1.1740	1.7610	2.3480	2.9350

Table 8 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
756	3.54	232.6	0.5860	1.1720	1.7579	2.3439	2.9299
762	3.54	234.3	0.5852	1.1704	1.7555	2.3407	2.9259
768	3.55	236.0	0.5845	1.1690	1.7535	2.3380	2.9225
774	3.56	237.7	0.5835	1.1671	1.7506	2.3341	2.9177
780	3.57	239.4	0.5825	1.1651	1.7476	2.3302	2.9127
786	3.57	241.1	0.5814	1.1629	1.7443	2.3257	2.9071
792	3.58	242.7	0.5804	1.1607	1.7411	2.3214	2.9018
798	3.58	244.4	0.5794	1.1588	1.7383	2.3177	2.8971
804	3.59	246.1	0.5786	1.1571	1.7357	2.3143	2.8928
810	3.60	247.8	0.5778	1.1555	1.7333	2.3110	2.8888
816	3.61	249.4	0.5770	1.1539	1.7309	2.3079	2.8848
822	3.62	251.1	0.5762	1.1524	1.7286	2.3048	2.8810
828	3.63	252.8	0.5753	1.1506	1.7259	2.3012	2.8765
834	3.64	254.4	0.5742	1.1485	1.7227	2.2969	2.8712
840	3.65	256.0	0.5730	1.1460	1.7190	2.2920	2.8650
846	3.65	257.7	0.5716	1.1432	1.7149	2.2865	2.8581
852	3.66	259.3	0.5702	1.1403	1.7105	2.2807	2.8509
858	3.67	261.0	0.5687	1.1374	1.7061	2.2749	2.8436
864	3.67	262.6	0.5673	1.1345	1.7018	2.2691	2.8364
870	3.68	264.2	0.5659	1.1318	1.6977	2.2636	2.8295
876	3.70	265.9	0.5647	1.1294	1.6941	2.2588	2.8235
882	3.71	267.5	0.5636	1.1273	1.6909	2.2545	2.8181
888	3.73	269.1	0.5623	1.1246	1.6868	2.2491	2.8114
894	3.74	270.7	0.5606	1.1213	1.6819	2.2425	2.8032
900	3.75	272.3	0.5588	1.1177	1.6765	2.2353	2.7941
906	3.75	273.9	0.5569	1.1138	1.6707	2.2277	2.7846
912	3.76	275.5	0.5550	1.1099	1.6649	2.2199	2.7749
918	3.77	277.1	0.5531	1.1062	1.6594	2.2125	2.7656
924	3.78	278.7	0.5514	1.1029	1.6543	2.2057	2.7572
930	3.80	280.3	0.5499	1.0998	1.6496	2.1995	2.7494
936	3.81	281.8	0.5481	1.0963	1.6444	2.1925	2.7406
942	3.83	283.4	0.5461	1.0922	1.6383	2.1844	2.7305
948	3.84	285.0	0.5439	1.0877	1.6316	2.1755	2.7193
954	3.84	286.5	0.5414	1.0829	1.6243	2.1658	2.7072
960	3.85	288.1	0.5388	1.0777	1.6165	2.1554	2.6942
966	3.86	289.7	0.5361	1.0721	1.6082	2.1442	2.6803
972	3.86	291.2	0.5331	1.0662	1.5993	2.1324	2.6656
978	3.87	292.8	0.5301	1.0601	1.5902	2.1202	2.6503
984	3.87	294.3	0.5269	1.0538	1.5807	2.1076	2.6345
990	3.88	295.9	0.5237	1.0473	1.5710	2.0947	2.6183

Table 9: Simulated drift velocity, drift time, and temperature differential downstream of diffuser along warmest path at 20 ft depth for 410 MGD effluent flow at 14:1 (river flow = 8880 cfs)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
0	1.05	0.0	5.00	10.00	15.00	20.00	25.00
6	2.04	2.9	5.00	10.00	15.00	20.00	25.00
12	1.94	6.0	5.00	9.99	14.99	19.99	24.98
18	2.09	8.9	4.99	9.98	14.97	19.96	24.95
24	2.32	11.7	4.85	9.70	14.55	19.40	24.25
30	2.31	14.3	4.76	9.52	14.27	19.03	23.79
36	2.32	16.9	4.68	9.36	14.03	18.71	23.39
42	2.36	19.4	4.59	9.17	13.76	18.35	22.93
48	2.34	22.0	4.41	8.81	13.22	17.62	22.03
54	2.34	24.5	4.37	8.74	13.11	17.48	21.85
60	2.39	27.1	4.22	8.44	12.66	16.87	21.09
66	2.36	29.6	4.04	8.08	12.12	16.15	20.19
72	2.36	32.2	3.94	7.87	11.81	15.74	19.68
78	2.41	34.7	3.80	7.59	11.39	15.18	18.98
84	2.41	37.2	3.59	7.19	10.78	14.38	17.97
90	2.36	39.7	3.41	6.82	10.24	13.65	17.06
96	2.34	42.2	3.29	6.59	9.88	13.17	16.47
102	2.34	44.8	3.21	6.41	9.62	12.82	16.03
108	2.34	47.3	3.12	6.24	9.36	12.48	15.60
114	2.32	49.9	3.03	6.06	9.10	12.13	15.16
120	2.32	52.5	2.98	5.96	8.93	11.91	14.89
126	2.36	55.1	2.93	5.85	8.78	11.70	14.63
132	2.39	57.6	2.88	5.77	8.65	11.53	14.42
138	2.41	60.1	2.84	5.68	8.52	11.36	14.21
144	2.41	62.6	2.80	5.59	8.39	11.18	13.98
150	2.41	65.1	2.75	5.50	8.25	11.00	13.75
156	2.41	67.6	2.71	5.41	8.12	10.83	13.54
162	2.42	70.0	2.66	5.33	7.99	10.66	13.32
168	2.41	72.5	2.63	5.26	7.90	10.53	13.16
174	2.42	75.0	2.60	5.21	7.81	10.42	13.02
180	2.44	77.5	2.57	5.14	7.71	10.28	12.86
186	2.45	79.9	2.54	5.08	7.61	10.15	12.69
192	2.46	82.4	2.50	5.01	7.51	10.02	12.52
198	2.48	84.8	2.47	4.94	7.41	9.89	12.36
204	2.48	87.2	2.44	4.87	7.31	9.74	12.18
210	2.48	89.6	2.40	4.80	7.20	9.61	12.01
216	2.50	92.0	2.37	4.75	7.12	9.49	11.87
222	2.52	94.4	2.34	4.69	7.03	9.37	11.72
228	2.52	96.8	2.32	4.63	6.95	9.26	11.58
234	2.53	99.2	2.29	4.58	6.87	9.16	11.45
240	2.53	101.6	2.26	4.52	6.78	9.05	11.31
246	2.54	103.9	2.23	4.47	6.70	8.94	11.17

Table 9 (continued)

distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
252	2.55	106.3	2.21	4.41	6.62	8.83	11.03
258	2.56	108.6	2.18	4.36	6.54	8.72	10.90
264	2.58	111.0	2.15	4.30	6.45	8.61	10.76
270	2.58	113.3	2.12	4.24	6.36	8.48	10.60
276	2.58	115.6	2.10	4.19	6.29	8.39	10.49
282	2.61	117.9	2.07	4.14	6.21	8.28	10.34
288	2.61	120.2	2.03	4.07	6.10	8.14	10.17
294	2.61	122.5	2.00	4.01	6.01	8.02	10.02
300	2.62	124.8	1.97	3.95	5.92	7.89	9.86
306	2.62	127.1	1.94	3.89	5.83	7.77	9.72
312	2.65	129.4	1.93	3.86	5.78	7.71	9.64
318	2.67	131.7	1.90	3.79	5.69	7.59	9.48
324	2.66	133.9	1.87	3.73	5.60	7.47	9.33
330	2.68	136.2	1.84	3.68	5.52	7.36	9.20
336	2.69	138.4	1.81	3.62	5.43	7.24	9.05
342	2.69	140.6	1.78	3.57	5.35	7.13	8.92
348	2.69	142.8	1.76	3.52	5.27	7.03	8.79
354	2.69	145.1	1.73	3.47	5.20	6.94	8.67
360	2.72	147.3	1.73	3.45	5.18	6.91	8.63
366	2.75	149.5	1.71	3.41	5.12	6.82	8.53
372	2.75	151.7	1.68	3.36	5.04	6.72	8.40
378	2.76	153.9	1.65	3.31	4.96	6.62	8.27
384	2.78	156.0	1.62	3.24	4.86	6.48	8.10
390	2.76	158.2	1.58	3.16	4.74	6.32	7.90
396	2.75	160.4	1.55	3.10	4.65	6.20	7.75
402	2.76	162.5	1.52	3.05	4.57	6.09	7.62
408	2.77	164.7	1.50	3.00	4.50	6.01	7.51
414	2.80	166.9	1.48	2.97	4.45	5.93	7.41
420	2.78	169.0	1.47	2.95	4.42	5.89	7.36
426	2.79	171.2	1.46	2.91	4.37	5.82	7.28
432	2.77	173.3	1.43	2.87	4.30	5.73	7.17
438	2.76	175.5	1.42	2.84	4.26	5.68	7.10
444	2.78	177.7	1.41	2.81	4.22	5.63	7.03
450	2.79	179.8	1.39	2.79	4.18	5.58	6.97
456	2.80	182.0	1.38	2.76	4.14	5.52	6.91
462	2.81	184.1	1.37	2.73	4.10	5.47	6.83
468	2.82	186.2	1.35	2.70	4.05	5.40	6.76
474	2.83	188.4	1.34	2.67	4.01	5.34	6.68
480	2.84	190.5	1.32	2.64	3.96	5.28	6.60
486	2.85	192.6	1.30	2.61	3.91	5.21	6.52
492	2.87	194.7	1.29	2.57	3.86	5.15	6.43
498	2.88	196.8	1.27	2.54	3.81	5.08	6.35

Table 9 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
504	2.90	198.8	1.25	2.50	3.75	5.00	6.26
510	2.91	200.9	1.23	2.46	3.69	4.92	6.16
516	2.87	203.0	1.21	2.43	3.64	4.85	6.06
522	2.87	205.1	1.20	2.41	3.61	4.81	6.02
528	2.89	207.2	1.20	2.39	3.59	4.79	5.98
534	2.91	209.2	1.19	2.37	3.56	4.75	5.94
540	2.92	211.3	1.18	2.36	3.54	4.72	5.89
546	2.94	213.3	1.17	2.34	3.51	4.68	5.84
552	2.95	215.4	1.16	2.31	3.47	4.63	5.78
558	2.97	217.4	1.15	2.29	3.44	4.58	5.73
564	2.98	219.4	1.13	2.26	3.40	4.53	5.66
570	2.99	221.4	1.12	2.23	3.35	4.47	5.59
576	2.99	223.4	1.10	2.21	3.31	4.42	5.52
582	3.01	225.4	1.09	2.18	3.27	4.36	5.45
588	3.02	227.4	1.08	2.15	3.23	4.30	5.38
594	3.01	229.4	1.07	2.14	3.21	4.28	5.35
600	3.03	231.4	1.06	2.12	3.19	4.25	5.31
606	3.03	233.4	1.05	2.11	3.16	4.22	5.27
612	3.04	235.3	1.05	2.09	3.14	4.18	5.23
618	3.05	237.3	1.04	2.07	3.11	4.15	5.18
624	3.06	239.3	1.03	2.06	3.08	4.11	5.14
630	3.07	241.2	1.02	2.04	3.06	4.07	5.09
636	3.08	243.2	1.01	2.02	3.03	4.04	5.05
642	3.10	245.1	1.00	2.00	2.99	3.99	4.99
648	2.95	247.1	0.99	1.98	2.97	3.96	4.95
654	3.03	249.1	0.99	1.98	2.96	3.95	4.94
660	2.99	251.1	0.98	1.97	2.95	3.94	4.92
666	2.97	253.1	0.98	1.96	2.94	3.92	4.90
672	2.97	255.1	0.98	1.95	2.93	3.91	4.88
678	2.98	257.2	0.97	1.95	2.92	3.89	4.86
684	2.99	259.2	0.97	1.94	2.91	3.87	4.84
690	3.00	261.2	0.96	1.93	2.89	3.86	4.82
696	3.02	263.2	0.96	1.92	2.88	3.84	4.80
702	3.04	265.1	0.96	1.91	2.87	3.83	4.78
708	3.06	267.1	0.95	1.90	2.86	3.81	4.76
714	3.09	269.1	0.95	1.89	2.84	3.79	4.73
720	3.08	271.0	0.94	1.88	2.82	3.76	4.70
726	3.07	273.0	0.93	1.87	2.80	3.74	4.67
732	3.16	274.9	0.93	1.86	2.80	3.73	4.66
738	3.11	276.8	0.93	1.85	2.78	3.70	4.63
744	3.12	278.7	0.92	1.85	2.77	3.69	4.61
750	3.13	280.6	0.92	1.84	2.76	3.68	4.60

Table 9 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
756	3.14	282.6	0.92	1.83	2.75	3.67	4.58
762	3.17	284.5	0.91	1.83	2.74	3.66	4.57
768	3.20	286.3	0.91	1.83	2.74	3.65	4.56
774	3.21	288.2	0.91	1.82	2.73	3.64	4.55
780	3.22	290.1	0.91	1.82	2.72	3.63	4.54
786	3.23	291.9	0.91	1.81	2.72	3.62	4.53
792	3.24	293.8	0.90	1.81	2.71	3.61	4.52
798	3.25	295.6	0.90	1.80	2.70	3.60	4.50
804	3.26	297.5	0.90	1.79	2.69	3.59	4.49
810	3.26	299.3	0.89	1.79	2.68	3.57	4.47
816	3.26	301.2	0.89	1.78	2.67	3.56	4.45
822	3.28	303.0	0.89	1.78	2.67	3.56	4.45
828	3.30	304.8	0.89	1.77	2.66	3.55	4.43
834	3.31	306.6	0.88	1.77	2.65	3.53	4.42
840	3.32	308.4	0.88	1.76	2.64	3.52	4.40
846	3.33	310.2	0.88	1.76	2.64	3.51	4.39
852	3.35	312.0	0.88	1.75	2.63	3.51	4.38
858	3.37	313.8	0.87	1.75	2.62	3.49	4.37
864	3.38	315.6	0.87	1.74	2.61	3.48	4.35
870	3.28	317.4	0.87	1.74	2.60	3.47	4.34
876	3.32	319.2	0.87	1.73	2.60	3.47	4.33
882	3.41	321.0	0.87	1.73	2.60	3.46	4.33
888	3.46	322.8	0.86	1.73	2.59	3.46	4.32
894	3.37	324.5	0.86	1.72	2.58	3.45	4.31
900	3.39	326.3	0.86	1.72	2.58	3.44	4.30
906	3.40	328.1	0.86	1.72	2.57	3.43	4.29
912	3.43	329.8	0.85	1.71	2.56	3.42	4.27
918	3.42	331.6	0.85	1.70	2.55	3.40	4.25
924	3.41	333.3	0.85	1.70	2.55	3.40	4.24
930	3.44	335.1	0.85	1.69	2.54	3.39	4.23
936	3.45	336.8	0.85	1.69	2.54	3.38	4.23
942	3.49	338.5	0.84	1.69	2.53	3.38	4.22
948	3.51	340.3	0.84	1.68	2.53	3.37	4.21
954	3.50	342.0	0.84	1.68	2.52	3.36	4.20
960	3.53	343.7	0.84	1.68	2.51	3.35	4.19
966	3.54	345.4	0.83	1.67	2.50	3.34	4.17
972	3.51	347.1	0.83	1.66	2.49	3.32	4.15
978	3.52	348.8	0.83	1.66	2.49	3.32	4.15
984	3.55	350.5	0.83	1.66	2.49	3.31	4.14
990	3.54	352.2	0.83	1.66	2.49	3.32	4.15

Table 10: Simulated drift velocity, drift time, and temperature differential downstream of diffuser along centerline at surface for 154 MGD effluent flow at 67:1 (river flow = 16000 cfs)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
0	5.66	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
6	5.66	1.1	0.0000	0.0000	0.0000	0.0000	0.0000
12	5.63	2.1	0.0000	0.0000	0.0000	0.0000	0.0000
18	5.57	3.2	0.0000	0.0000	0.0000	0.0000	0.0000
24	5.51	4.3	0.0000	0.0000	0.0000	0.0000	0.0000
30	5.45	5.4	0.0000	0.0000	0.0000	0.0000	0.0000
36	5.40	6.5	0.0000	0.0000	0.0000	0.0000	0.0000
42	5.36	7.6	0.0000	0.0000	0.0000	0.0000	0.0000
48	5.33	8.7	0.0000	0.0000	0.0000	0.0000	0.0000
54	5.31	9.8	0.0000	0.0000	0.0000	0.0000	0.0000
60	5.29	11.0	0.0000	0.0000	0.0000	0.0000	0.0000
66	5.28	12.1	0.0000	0.0000	0.0000	0.0000	0.0000
72	5.28	13.3	0.0000	0.0000	0.0000	0.0000	0.0000
78	5.29	14.4	0.0000	0.0000	0.0000	0.0000	0.0000
84	5.30	15.5	0.0000	0.0000	0.0000	0.0000	0.0000
90	5.32	16.6	0.0000	0.0000	0.0000	0.0000	0.0000
96	5.32	17.8	0.0000	0.0000	0.0000	0.0000	0.0000
102	5.33	18.9	0.0000	0.0000	0.0000	0.0000	0.0000
108	5.34	20.0	0.0000	0.0000	0.0000	0.0000	0.0000
114	5.34	21.2	0.0000	0.0000	0.0000	0.0000	0.0000
120	5.35	22.3	0.0000	0.0000	0.0000	0.0000	0.0000
126	5.36	23.4	0.0000	0.0000	0.0000	0.0000	0.0000
132	5.37	24.5	0.0000	0.0000	0.0000	0.0000	0.0000
138	5.38	25.6	0.0000	0.0000	0.0000	0.0000	0.0000
144	5.40	26.7	0.0000	0.0000	0.0000	0.0000	0.0000
150	5.42	27.8	0.0000	0.0000	0.0000	0.0000	0.0000
156	5.43	29.0	0.0000	0.0000	0.0000	0.0000	0.0000
162	5.44	30.1	0.0000	0.0000	0.0000	0.0000	0.0000
168	5.45	31.2	0.0000	0.0000	0.0000	0.0000	0.0000
174	5.45	32.3	0.0000	0.0000	0.0000	0.0000	0.0000
180	5.45	33.4	0.0000	0.0000	0.0000	0.0000	0.0000
186	5.45	34.5	0.0000	0.0000	0.0000	0.0000	0.0000
192	5.45	35.6	0.0000	0.0000	0.0000	0.0000	0.0000
198	5.46	36.7	0.0000	0.0000	0.0000	0.0000	0.0000
204	5.46	37.8	0.0000	0.0000	0.0000	0.0000	0.0000
210	5.47	38.9	0.0000	0.0000	0.0000	0.0000	0.0000
216	5.48	40.0	0.0000	0.0000	0.0000	0.0000	0.0000
222	5.49	41.1	0.0000	0.0000	0.0000	0.0000	0.0000
228	5.50	42.1	0.0000	0.0000	0.0000	0.0000	0.0000
234	5.51	43.2	0.0000	0.0000	0.0000	0.0000	0.0000
240	5.51	44.3	0.0000	0.0000	0.0000	0.0000	0.0000
246	5.51	45.4	0.0000	0.0000	0.0000	0.0000	0.0000

Table 10 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
252	5.51	46.5	0.0000	0.0000	0.0000	0.0000	0.0000
258	5.52	47.6	0.0000	0.0000	0.0000	0.0000	0.0000
264	5.53	48.7	0.0000	0.0000	0.0000	0.0000	0.0000
270	5.54	49.8	0.0000	0.0000	0.0000	0.0000	0.0000
276	5.55	50.8	0.0000	0.0000	0.0000	0.0000	0.0000
282	5.56	51.9	0.0000	0.0000	0.0000	0.0000	0.0000
288	5.57	53.0	0.0000	0.0000	0.0000	0.0000	0.0000
294	5.58	54.1	0.0000	0.0000	0.0000	0.0000	0.0000
300	5.58	55.1	0.0000	0.0000	0.0000	0.0000	0.0000
306	5.59	56.2	0.0000	0.0000	0.0000	0.0000	0.0000
312	5.60	57.3	0.0000	0.0000	0.0000	0.0000	0.0000
318	5.60	58.4	0.0000	0.0000	0.0000	0.0000	0.0000
324	5.60	59.4	0.0000	0.0000	0.0000	0.0000	0.0000
330	5.60	60.5	0.0000	0.0000	0.0000	0.0000	0.0001
336	5.60	61.6	0.0000	0.0000	0.0000	0.0001	0.0001
342	5.60	62.7	0.0000	0.0000	0.0001	0.0001	0.0001
348	5.60	63.7	0.0000	0.0001	0.0001	0.0001	0.0002
354	5.61	64.8	0.0001	0.0001	0.0002	0.0002	0.0003
360	5.63	65.9	0.0001	0.0002	0.0002	0.0003	0.0004
366	5.67	66.9	0.0001	0.0002	0.0003	0.0004	0.0005
372	5.70	68.0	0.0001	0.0003	0.0004	0.0005	0.0007
378	5.73	69.0	0.0002	0.0004	0.0005	0.0007	0.0009
384	5.74	70.1	0.0002	0.0004	0.0007	0.0009	0.0011
390	5.76	71.1	0.0003	0.0005	0.0008	0.0011	0.0014
396	5.77	72.2	0.0003	0.0007	0.0010	0.0013	0.0017
402	5.78	73.2	0.0004	0.0008	0.0012	0.0016	0.0020
408	5.79	74.2	0.0005	0.0010	0.0014	0.0019	0.0024
414	5.79	75.3	0.0006	0.0011	0.0017	0.0023	0.0028
420	5.80	76.3	0.0007	0.0014	0.0020	0.0027	0.0034
426	5.81	77.3	0.0008	0.0016	0.0024	0.0032	0.0040
432	5.81	78.4	0.0010	0.0019	0.0029	0.0038	0.0048
438	5.82	79.4	0.0011	0.0023	0.0034	0.0045	0.0057
444	5.83	80.4	0.0014	0.0027	0.0041	0.0054	0.0068
450	5.84	81.5	0.0016	0.0033	0.0049	0.0065	0.0081
456	5.85	82.5	0.0020	0.0039	0.0059	0.0079	0.0098
462	5.86	83.5	0.0024	0.0048	0.0072	0.0096	0.0120
468	5.87	84.5	0.0029	0.0058	0.0087	0.0116	0.0146
474	5.87	85.6	0.0035	0.0071	0.0106	0.0142	0.0177
480	5.88	86.6	0.0043	0.0086	0.0129	0.0173	0.0216
486	5.89	87.6	0.0052	0.0105	0.0157	0.0209	0.0261
492	5.89	88.6	0.0063	0.0126	0.0189	0.0252	0.0315
498	5.90	89.6	0.0075	0.0150	0.0226	0.0301	0.0376

Table 10 (continued)

distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
504	5.90	90.7	0.0089	0.0178	0.0267	0.0356	0.0445
510	5.91	91.7	0.0105	0.0209	0.0314	0.0418	0.0523
516	5.91	92.7	0.0122	0.0243	0.0365	0.0486	0.0608
522	5.92	93.7	0.0140	0.0280	0.0420	0.0560	0.0700
528	5.92	94.7	0.0160	0.0320	0.0479	0.0639	0.0799
534	5.93	95.7	0.0181	0.0361	0.0542	0.0722	0.0903
540	5.94	96.7	0.0202	0.0405	0.0607	0.0809	0.1011
546	5.94	97.7	0.0225	0.0449	0.0674	0.0899	0.1124
552	5.94	98.8	0.0248	0.0495	0.0743	0.0991	0.1238
558	5.94	99.8	0.0271	0.0542	0.0813	0.1084	0.1354
564	5.94	100.8	0.0294	0.0589	0.0883	0.1177	0.1471
570	5.93	101.8	0.0318	0.0635	0.0953	0.1271	0.1589
576	5.93	102.8	0.0341	0.0682	0.1023	0.1364	0.1706
582	5.93	103.8	0.0364	0.0729	0.1093	0.1457	0.1821
588	5.94	104.8	0.0387	0.0774	0.1162	0.1549	0.1936
594	5.94	105.8	0.0410	0.0819	0.1229	0.1639	0.2049
600	5.93	106.8	0.0432	0.0864	0.1295	0.1727	0.2159
606	5.93	107.9	0.0453	0.0907	0.1360	0.1814	0.2267
612	5.92	108.9	0.0475	0.0949	0.1424	0.1898	0.2373
618	5.92	109.9	0.0495	0.0990	0.1485	0.1980	0.2475
624	5.92	110.9	0.0515	0.1030	0.1545	0.2060	0.2575
630	5.92	111.9	0.0535	0.1069	0.1604	0.2138	0.2673
636	5.92	112.9	0.0553	0.1107	0.1660	0.2214	0.2767
642	5.92	113.9	0.0572	0.1143	0.1715	0.2287	0.2859
648	5.93	114.9	0.0589	0.1179	0.1768	0.2358	0.2947
654	5.94	116.0	0.0607	0.1213	0.1820	0.2427	0.3034
660	5.95	117.0	0.0623	0.1247	0.1870	0.2494	0.3117
666	5.95	118.0	0.0640	0.1279	0.1919	0.2559	0.3199
672	5.96	119.0	0.0655	0.1311	0.1966	0.2622	0.3277
678	5.96	120.0	0.0671	0.1341	0.2012	0.2683	0.3353
684	5.97	121.0	0.0685	0.1371	0.2056	0.2742	0.3427
690	5.98	122.0	0.0700	0.1399	0.2099	0.2798	0.3498
696	5.98	123.0	0.0713	0.1427	0.2140	0.2853	0.3567
702	5.99	124.0	0.0727	0.1453	0.2180	0.2906	0.3633
708	6.00	125.0	0.0739	0.1479	0.2218	0.2957	0.3697
714	6.01	126.0	0.0752	0.1503	0.2255	0.3006	0.3758
720	6.01	127.0	0.0763	0.1527	0.2290	0.3053	0.3817
726	6.02	128.0	0.0775	0.1549	0.2324	0.3098	0.3873
732	6.02	129.0	0.0785	0.1571	0.2356	0.3142	0.3927
738	6.02	130.0	0.0796	0.1591	0.2387	0.3183	0.3978
744	6.03	131.0	0.0806	0.1611	0.2417	0.3222	0.4028
750	6.03	132.0	0.0815	0.1630	0.2445	0.3259	0.4074

Table 10 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F)				
			$T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
756	6.03	133.0	0.0824	0.1648	0.2471	0.3295	0.4119
762	6.04	134.0	0.0832	0.1665	0.2497	0.3329	0.4161
768	6.04	135.0	0.0840	0.1681	0.2521	0.3361	0.4202
774	6.05	136.0	0.0848	0.1696	0.2544	0.3392	0.4240
780	6.06	137.0	0.0855	0.1711	0.2566	0.3421	0.4276
786	6.06	137.9	0.0862	0.1724	0.2586	0.3449	0.4311
792	6.06	138.9	0.0869	0.1737	0.2606	0.3475	0.4343
798	6.07	139.9	0.0875	0.1750	0.2624	0.3499	0.4374
804	6.08	140.9	0.0881	0.1761	0.2642	0.3522	0.4403
810	6.08	141.9	0.0886	0.1772	0.2658	0.3544	0.4430
816	6.09	142.9	0.0891	0.1782	0.2673	0.3564	0.4455
822	6.10	143.9	0.0896	0.1791	0.2687	0.3583	0.4478
828	6.11	144.9	0.0900	0.1800	0.2700	0.3600	0.4500
834	6.12	145.8	0.0904	0.1808	0.2712	0.3616	0.4520
840	6.13	146.8	0.0908	0.1816	0.2723	0.3631	0.4539
846	6.14	147.8	0.0911	0.1822	0.2734	0.3645	0.4556
852	6.14	148.8	0.0914	0.1829	0.2743	0.3657	0.4572
858	6.15	149.7	0.0917	0.1834	0.2751	0.3668	0.4586
864	6.16	150.7	0.0920	0.1839	0.2759	0.3678	0.4598
870	6.17	151.7	0.0922	0.1844	0.2765	0.3687	0.4609
876	6.19	152.7	0.0924	0.1848	0.2771	0.3695	0.4619
882	6.20	153.6	0.0925	0.1851	0.2776	0.3702	0.4627
888	6.22	154.6	0.0927	0.1854	0.2781	0.3707	0.4634
894	6.23	155.6	0.0928	0.1856	0.2784	0.3712	0.4640
900	6.25	156.5	0.0929	0.1858	0.2787	0.3716	0.4645
906	6.26	157.5	0.0930	0.1859	0.2789	0.3718	0.4648
912	6.27	158.4	0.0930	0.1860	0.2790	0.3720	0.4650
918	6.28	159.4	0.0930	0.1860	0.2791	0.3721	0.4651
924	6.29	160.4	0.0930	0.1860	0.2791	0.3721	0.4651
930	6.31	161.3	0.0930	0.1860	0.2790	0.3720	0.4650
936	6.33	162.3	0.0930	0.1859	0.2789	0.3719	0.4648
942	6.35	163.2	0.0929	0.1858	0.2787	0.3717	0.4646
948	6.36	164.1	0.0928	0.1857	0.2785	0.3714	0.4642
954	6.37	165.1	0.0928	0.1855	0.2783	0.3710	0.4638
960	6.38	166.0	0.0927	0.1853	0.2780	0.3706	0.4633
966	6.39	167.0	0.0925	0.1851	0.2776	0.3702	0.4627
972	6.39	167.9	0.0924	0.1848	0.2772	0.3697	0.4621
978	6.40	168.8	0.0923	0.1845	0.2768	0.3691	0.4613
984	6.40	169.8	0.0921	0.1842	0.2763	0.3684	0.4605
990	6.40	170.7	0.0919	0.1839	0.2758	0.3677	0.4596

Table 11: Simulated drift velocity, drift time, and temperature differential downstream of diffuser <u>along centerline at 10 ft depth</u> for 154 MGD effluent flow at 67:1 (river flow = 16000 cfs)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
0	5.75	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
6	5.72	1.0	0.0000	0.0000	0.0000	0.0000	0.0000
12	5.66	2.1	0.0000	0.0000	0.0000	0.0000	0.0000
18	5.58	3.2	0.0000	0.0000	0.0000	0.0000	0.0000
24	5.51	4.3	0.0000	0.0000	0.0000	0.0000	0.0000
30	5.44	5.4	0.0000	0.0000	0.0000	0.0000	0.0000
36	5.39	6.5	0.0000	0.0000	0.0000	0.0000	0.0000
42	5.35	7.6	0.0000	0.0000	0.0000	0.0000	0.0000
48	5.32	8.7	0.0000	0.0000	0.0000	0.0000	0.0000
54	5.30	9.8	0.0000	0.0000	0.0000	0.0000	0.0000
60	5.28	11.0	0.0000	0.0000	0.0000	0.0000	0.0000
66	5.26	12.1	0.0000	0.0000	0.0000	0.0001	0.0001
72	5.26	13.2	0.0001	0.0002	0.0002	0.0003	0.0004
78	5.29	14.4	0.0003	0.0006	0.0008	0.0011	0.0014
84	5.31	15.5	0.0006	0.0012	0.0017	0.0023	0.0029
90	5.33	16.6	0.0010	0.0019	0.0029	0.0039	0.0048
96	5.33	17.8	0.0015	0.0030	0.0045	0.0060	0.0075
102	5.33	18.9	0.0023	0.0046	0.0069	0.0092	0.0115
108	5.33	20.0	0.0034	0.0068	0.0102	0.0136	0.0170
114	5.33	21.1	0.0048	0.0096	0.0144	0.0192	0.0240
120	5.33	22.3	0.0066	0.0132	0.0198	0.0264	0.0330
126	5.33	23.4	0.0089	0.0179	0.0268	0.0357	0.0447
132	5.33	24.5	0.0120	0.0240	0.0360	0.0481	0.0601
138	5.34	25.6	0.0161	0.0322	0.0484	0.0645	0.0806
144	5.35	26.8	0.0214	0.0427	0.0641	0.0855	0.1069
150	5.35	27.9	0.0277	0.0554	0.0830	0.1107	0.1384
156	5.34	29.0	0.0349	0.0699	0.1048	0.1398	0.1747
162	5.34	30.1	0.0430	0.0860	0.1290	0.1719	0.2149
168	5.33	31.3	0.0512	0.1025	0.1537	0.2049	0.2562
174	5.32	32.4	0.0590	0.1181	0.1771	0.2362	0.2952
180	5.30	33.5	0.0662	0.1324	0.1985	0.2647	0.3309
186	5.27	34.7	0.0727	0.1454	0.2181	0.2908	0.3636
192	5.25	35.8	0.0790	0.1579	0.2369	0.3159	0.3949
198	5.24	36.9	0.0849	0.1698	0.2547	0.3396	0.4245
204	5.22	38.1	0.0906	0.1812	0.2718	0.3624	0.4530
210	5.22	39.2	0.0960	0.1920	0.2879	0.3839	0.4799
216	5.21	40.4	0.1010	0.2020	0.3029	0.4039	0.5049
222	5.21	41.5	0.1053	0.2107	0.3160	0.4213	0.5267
228	5.21	42.7	0.1090	0.2179	0.3269	0.4358	0.5448
234	5.20	43.8	0.1118	0.2236	0.3354	0.4472	0.5590
240	5.18	45.0	0.1142	0.2285	0.3427	0.4570	0.5712
246	5.17	46.1	0.1166	0.2333	0.3499	0.4666	0.5832

Table 11 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
252	5.16	47.3	0.1191	0.2381	0.3572	0.4763	0.5954
258	5.15	48.5	0.1217	0.2433	0.3650	0.4867	0.6083
264	5.15	49.6	0.1246	0.2491	0.3737	0.4982	0.6228
270	5.16	50.8	0.1271	0.2542	0.3813	0.5084	0.6355
276	5.16	52.0	0.1294	0.2588	0.3881	0.5175	0.6469
282	5.17	53.1	0.1310	0.2620	0.3930	0.5240	0.6550
288	5.17	54.3	0.1321	0.2642	0.3963	0.5284	0.6606
294	5.16	55.4	0.1329	0.2658	0.3988	0.5317	0.6646
300	5.16	56.6	0.1336	0.2672	0.4008	0.5344	0.6679
306	5.17	57.8	0.1342	0.2684	0.4025	0.5367	0.6709
312	5.17	58.9	0.1345	0.2690	0.4036	0.5381	0.6726
318	5.17	60.1	0.1346	0.2691	0.4037	0.5382	0.6728
324	5.17	61.3	0.1345	0.2689	0.4034	0.5378	0.6723
330	5.17	62.4	0.1342	0.2685	0.4027	0.5370	0.6712
336	5.16	63.6	0.1339	0.2678	0.4017	0.5356	0.6695
342	5.15	64.7	0.1336	0.2671	0.4007	0.5343	0.6679
348	5.14	65.9	0.1335	0.2671	0.4006	0.5342	0.6677
354	5.14	67.1	0.1339	0.2678	0.4017	0.5356	0.6695
360	5.16	68.2	0.1349	0.2697	0.4046	0.5395	0.6743
366	5.20	69.4	0.1365	0.2730	0.4095	0.5459	0.6824
372	5.25	70.5	0.1373	0.2747	0.4120	0.5493	0.6866
378	5.27	71.7	0.1376	0.2751	0.4127	0.5503	0.6878
384	5.28	72.8	0.1375	0.2750	0.4125	0.5500	0.6875
390	5.29	74.0	0.1373	0.2746	0.4119	0.5492	0.6865
396	5.30	75.1	0.1370	0.2740	0.4110	0.5480	0.6850
402	5.31	76.2	0.1366	0.2732	0.4098	0.5464	0.6830
408	5.31	77.3	0.1361	0.2722	0.4082	0.5443	0.6804
414	5.32	78.5	0.1355	0.2710	0.4064	0.5419	0.6774
420	5.32	79.6	0.1350	0.2700	0.4050	0.5400	0.6749
426	5.32	80.7	0.1346	0.2692	0.4037	0.5383	0.6729
432	5.33	81.9	0.1342	0.2684	0.4026	0.5369	0.6711
438	5.34	83.0	0.1339	0.2678	0.4017	0.5356	0.6695
444	5.34	84.1	0.1336	0.2672	0.4008	0.5344	0.6680
450	5.35	85.2	0.1333	0.2667	0.4000	0.5333	0.6667
456	5.36	86.4	0.1331	0.2662	0.3992	0.5323	0.6654
462	5.37	87.5	0.1328	0.2656	0.3984	0.5312	0.6640
468	5.37	88.6	0.1325	0.2650	0.3975	0.5300	0.6625
474	5.38	89.7	0.1322	0.2644	0.3966	0.5288	0.6610
480	5.38	90.8	0.1319	0.2638	0.3956	0.5275	0.6594
486	5.39	91.9	0.1316	0.2631	0.3947	0.5262	0.6578
492	5.39	93.0	0.1313	0.2625	0.3938	0.5250	0.6563
498	5.40	94.2	0.1309	0.2619	0.3928	0.5237	0.6547

Table 11 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent}$ - T_{river}				
			5°F	10°F	15°F	20°F	25°F
504	5.41	95.3	0.1306	0.2613	0.3919	0.5225	0.6532
510	5.41	96.4	0.1303	0.2607	0.3910	0.5213	0.6517
516	5.42	97.5	0.1300	0.2600	0.3901	0.5201	0.6501
522	5.43	98.6	0.1297	0.2594	0.3891	0.5188	0.6485
528	5.43	99.7	0.1294	0.2588	0.3883	0.5177	0.6471
534	5.44	100.8	0.1292	0.2583	0.3875	0.5167	0.6459
540	5.45	101.9	0.1289	0.2578	0.3867	0.5156	0.6446
546	5.46	103.0	0.1286	0.2572	0.3858	0.5144	0.6430
552	5.47	104.1	0.1283	0.2566	0.3848	0.5131	0.6414
558	5.47	105.2	0.1279	0.2559	0.3838	0.5117	0.6397
564	5.47	106.3	0.1276	0.2552	0.3828	0.5104	0.6380
570	5.47	107.4	0.1273	0.2546	0.3819	0.5091	0.6364
576	5.47	108.5	0.1270	0.2540	0.3811	0.5081	0.6351
582	5.48	109.6	0.1268	0.2536	0.3804	0.5072	0.6340
588	5.49	110.7	0.1266	0.2532	0.3798	0.5064	0.6330
594	5.50	111.8	0.1263	0.2526	0.3789	0.5052	0.6315
600	5.50	112.9	0.1259	0.2518	0.3777	0.5035	0.6294
606	5.50	113.9	0.1255	0.2509	0.3764	0.5019	0.6274
612	5.50	115.0	0.1251	0.2502	0.3752	0.5003	0.6254
618	5.50	116.1	0.1247	0.2495	0.3742	0.4989	0.6237
624	5.50	117.2	0.1244	0.2489	0.3733	0.4977	0.6222
630	5.51	118.3	0.1242	0.2483	0.3725	0.4967	0.6209
636	5.52	119.4	0.1239	0.2479	0.3718	0.4958	0.6197
642	5.53	120.5	0.1237	0.2475	0.3712	0.4949	0.6187
648	5.55	121.6	0.1236	0.2471	0.3707	0.4942	0.6178
654	5.56	122.6	0.1234	0.2468	0.3702	0.4935	0.6169
660	5.58	123.7	0.1232	0.2464	0.3696	0.4929	0.6161
666	5.59	124.8	0.1231	0.2461	0.3692	0.4922	0.6153
672	5.61	125.9	0.1229	0.2458	0.3687	0.4916	0.6145
678	5.62	126.9	0.1227	0.2454	0.3681	0.4909	0.6136
684	5.63	128.0	0.1226	0.2451	0.3677	0.4903	0.6128
690	5.64	129.1	0.1224	0.2449	0.3673	0.4897	0.6122
696	5.65	130.1	0.1223	0.2446	0.3669	0.4893	0.6116
702	5.67	131.2	0.1222	0.2445	0.3667	0.4889	0.6111
708	5.68	132.3	0.1221	0.2443	0.3664	0.4886	0.6107
714	5.70	133.3	0.1220	0.2441	0.3661	0.4881	0.6102
720	5.71	134.4	0.1219	0.2438	0.3658	0.4877	0.6096
726	5.72	135.4	0.1218	0.2436	0.3654	0.4872	0.6090
732	5.73	136.5	0.1217	0.2433	0.3650	0.4867	0.6084
738	5.74	137.5	0.1215	0.2430	0.3646	0.4861	0.6076
744	5.75	138.5	0.1214	0.2427	0.3641	0.4855	0.6068
750	5.75	139.6	0.1212	0.2424	0.3637	0.4849	0.6061

Table 11 (continued)

distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
756	5.76	140.6	0.1211	0.2422	0.3633	0.4844	0.6055
762	5.77	141.7	0.1210	0.2420	0.3630	0.4840	0.6050
768	5.78	142.7	0.1209	0.2418	0.3627	0.4836	0.6045
774	5.80	143.8	0.1208	0.2416	0.3624	0.4832	0.6040
780	5.80	144.8	0.1207	0.2414	0.3621	0.4828	0.6034
786	5.81	145.8	0.1206	0.2411	0.3617	0.4823	0.6029
792	5.82	146.8	0.1205	0.2409	0.3614	0.4818	0.6023
798	5.83	147.9	0.1204	0.2407	0.3611	0.4814	0.6018
804	5.84	148.9	0.1203	0.2405	0.3608	0.4811	0.6014
810	5.85	149.9	0.1202	0.2404	0.3606	0.4807	0.6009
816	5.86	151.0	0.1201	0.2402	0.3603	0.4804	0.6005
822	5.88	152.0	0.1200	0.2400	0.3601	0.4801	0.6001
828	5.89	153.0	0.1199	0.2398	0.3598	0.4797	0.5996
834	5.90	154.0	0.1198	0.2396	0.3594	0.4792	0.5990
840	5.91	155.0	0.1197	0.2393	0.3590	0.4787	0.5983
846	5.92	156.0	0.1195	0.2390	0.3585	0.4780	0.5975
852	5.93	157.1	0.1193	0.2387	0.3580	0.4774	0.5967
858	5.94	158.1	0.1192	0.2383	0.3575	0.4767	0.5958
864	5.95	159.1	0.1190	0.2380	0.3570	0.4760	0.5949
870	5.96	160.1	0.1188	0.2376	0.3564	0.4753	0.5941
876	5.98	161.1	0.1187	0.2373	0.3560	0.4746	0.5933
882	6.01	162.1	0.1185	0.2370	0.3555	0.4740	0.5925
888	6.03	163.1	0.1183	0.2366	0.3549	0.4732	0.5915
894	6.04	164.1	0.1181	0.2362	0.3542	0.4723	0.5904
900	6.06	165.1	0.1178	0.2357	0.3535	0.4713	0.5892
906	6.07	166.1	0.1176	0.2351	0.3527	0.4703	0.5878
912	6.07	167.1	0.1173	0.2346	0.3519	0.4691	0.5864
918	6.09	168.0	0.1170	0.2340	0.3510	0.4681	0.5851
924	6.10	169.0	0.1168	0.2335	0.3503	0.4670	0.5838
930	6.13	170.0	0.1165	0.2330	0.3495	0.4660	0.5825
936	6.15	171.0	0.1162	0.2324	0.3486	0.4648	0.5811
942	6.17	172.0	0.1159	0.2318	0.3477	0.4636	0.5795
948	6.18	172.9	0.1156	0.2311	0.3467	0.4622	0.5778
954	6.20	173.9	0.1152	0.2304	0.3456	0.4607	0.5759
960	6.21	174.9	0.1148	0.2296	0.3444	0.4592	0.5740
966	6.21	175.8	0.1144	0.2288	0.3431	0.4575	0.5719
972	6.22	176.8	0.1139	0.2279	0.3418	0.4558	0.5697
978	6.23	177.8	0.1135	0.2270	0.3405	0.4539	0.5674
984	6.23	178.7	0.1130	0.2260	0.3390	0.4521	0.5651
990	6.24	179.7	0.1125	0.2251	0.3376	0.4501	0.5627

Table 12: Simulated drift velocity, drift time, and temperature differential downstream of diffuser along warmest path at 20 ft depth for 154 MGD effluent flow at 67:1 (river flow = 16000 cfs)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
0	0.39	0.0	5.00	10.00	15.00	20.00	25.00
6	0.73	10.7	4.79	9.58	14.37	19.16	23.95
12	0.87	18.2	3.71	7.42	11.13	14.85	18.56
18	1.31	23.7	2.90	5.80	8.70	11.60	14.49
24	1.59	27.8	2.29	4.59	6.88	9.18	11.47
30	1.70	31.5	1.92	3.84	5.76	7.69	9.61
36	1.87	34.9	1.66	3.32	4.99	6.65	8.31
42	2.08	37.9	1.45	2.91	4.36	5.81	7.26
48	2.22	40.7	1.26	2.52	3.78	5.05	6.31
54	2.38	43.3	1.15	2.30	3.45	4.60	5.75
60	2.53	45.7	1.03	2.07	3.10	4.14	5.17
66	2.67	48.0	0.94	1.88	2.82	3.76	4.69
72	2.78	50.2	0.85	1.71	2.56	3.42	4.27
78	3.01	52.3	0.80	1.61	2.41	3.21	4.02
84	3.05	54.3	0.77	1.54	2.31	3.08	3.85
90	3.09	56.2	0.74	1.47	2.21	2.95	3.68
96	3.15	58.1	0.71	1.42	2.14	2.85	3.56
102	3.21	60.0	0.69	1.37	2.06	2.74	3.43
108	3.27	61.9	0.66	1.32	1.98	2.64	3.30
114	3.33	63.7	0.64	1.27	1.91	2.55	3.18
120	3.39	65.5	0.62	1.23	1.85	2.46	3.08
126	3.45	67.2	0.60	1.19	1.79	2.38	2.98
132	3.53	69.0	0.58	1.16	1.74	2.31	2.89
138	3.60	70.7	0.56	1.12	1.68	2.25	2.81
144	3.63	72.3	0.54	1.09	1.63	2.18	2.72
150	3.65	74.0	0.53	1.06	1.59	2.12	2.65
156	3.68	75.6	0.51	1.03	1.54	2.06	2.57
162	3.71	77.2	0.50	1.00	1.50	2.00	2.50
168	3.74	78.8	0.49	0.98	1.47	1.95	2.44
174	3.78	80.4	0.48	0.95	1.43	1.91	2.39
180	3.85	82.0	0.47	0.93	1.40	1.87	2.33
186	3.88	83.6	0.46	0.92	1.37	1.83	2.29
192	3.92	85.1	0.45	0.90	1.35	1.79	2.24
198	3.95	86.6	0.44	0.88	1.32	1.76	2.20
204	3.98	88.1	0.43	0.86	1.29	1.73	2.16
210	3.99	89.6	0.42	0.85	1.27	1.69	2.12
216	4.02	91.1	0.42	0.83	1.25	1.66	2.08
222	4.05	92.6	0.41	0.82	1.22	1.63	2.04
228	4.06	94.1	0.40	0.80	1.20	1.60	2.00
234	4.07	95.6	0.39	0.79	1.18	1.57	1.96
240	4.12	97.0	0.39	0.77	1.16	1.55	1.93
246	4.16	98.5	0.38	0.76	1.14	1.52	1.90

Table 12 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
252	4.14	99.9	0.37	0.75	1.12	1.49	1.87
258	4.17	101.4	0.37	0.73	1.10	1.47	1.84
264	4.19	102.8	0.36	0.72	1.08	1.45	1.81
270	4.20	104.2	0.36	0.71	1.07	1.42	1.78
276	4.22	105.7	0.35	0.70	1.05	1.40	1.75
282	4.26	107.1	0.34	0.69	1.03	1.38	1.72
288	4.26	108.5	0.34	0.68	1.02	1.36	1.70
294	4.27	109.9	0.33	0.67	1.00	1.34	1.67
300	4.29	111.3	0.33	0.66	0.99	1.31	1.64
306	4.29	112.7	0.32	0.65	0.97	1.29	1.62
312	4.35	114.1	0.32	0.64	0.96	1.28	1.60
318	4.39	115.5	0.31	0.63	0.94	1.26	1.57
324	4.38	116.8	0.31	0.62	0.93	1.24	1.55
330	4.41	118.2	0.31	0.61	0.92	1.22	1.53
336	4.43	119.6	0.30	0.60	0.90	1.20	1.50
342	4.43	120.9	0.30	0.59	0.89	1.19	1.48
348	4.44	122.3	0.29	0.59	0.88	1.17	1.46
354	4.43	123.6	0.29	0.58	0.87	1.16	1.44
360	4.48	125.0	0.29	0.57	0.86	1.15	1.43
366	4.53	126.3	0.28	0.57	0.85	1.13	1.42
372	4.52	127.6	0.28	0.56	0.84	1.12	1.40
378	4.53	128.9	0.28	0.55	0.83	1.10	1.38
384	4.55	130.3	0.27	0.54	0.81	1.09	1.36
390	4.53	131.6	0.27	0.53	0.80	1.07	1.33
396	4.51	132.9	0.26	0.53	0.79	1.05	1.31
402	4.52	134.2	0.26	0.52	0.78	1.04	1.29
408	4.55	135.6	0.26	0.51	0.77	1.02	1.28
414	4.59	136.9	0.25	0.51	0.76	1.01	1.26
420	4.54	138.2	0.25	0.50	0.75	1.00	1.25
426	4.54	139.5	0.25	0.50	0.74	0.99	1.24
432	4.50	140.8	0.25	0.49	0.74	0.98	1.23
438	4.48	142.2	0.24	0.49	0.73	0.97	1.21
444	4.52	143.5	0.24	0.48	0.72	0.96	1.21
450	4.54	144.8	0.24	0.48	0.72	0.96	1.20
456	4.56	146.1	0.24	0.47	0.71	0.95	1.19
462	4.57	147.5	0.24	0.47	0.71	0.94	1.18
468	4.58	148.8	0.23	0.47	0.70	0.93	1.17
474	4.61	150.1	0.23	0.46	0.69	0.92	1.15
480	4.63	151.4	0.23	0.46	0.69	0.91	1.14
486	4.66	152.7	0.23	0.45	0.68	0.91	1.13
492	4.68	153.9	0.22	0.45	0.67	0.90	1.12
498	4.71	155.2	0.22	0.44	0.67	0.89	1.11

Table 12 (continued)

distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
504	4.74	156.5	0.22	0.44	0.66	0.88	1.10
510	4.75	157.8	0.22	0.43	0.65	0.87	1.08
516	4.77	159.0	0.21	0.43	0.64	0.86	1.07
522	4.68	160.3	0.21	0.42	0.64	0.85	1.06
528	4.71	161.6	0.21	0.42	0.63	0.84	1.05
534	4.74	162.8	0.21	0.42	0.63	0.84	1.05
540	4.77	164.1	0.21	0.42	0.62	0.83	1.04
546	4.80	165.4	0.21	0.41	0.62	0.83	1.03
552	4.82	166.6	0.21	0.41	0.62	0.82	1.03
558	4.84	167.8	0.20	0.41	0.61	0.81	1.02
564	4.86	169.1	0.20	0.40	0.61	0.81	1.01
570	4.87	170.3	0.20	0.40	0.60	0.80	1.00
576	4.89	171.5	0.20	0.40	0.59	0.79	0.99
582	4.91	172.8	0.20	0.39	0.59	0.78	0.98
588	4.93	174.0	0.19	0.39	0.58	0.78	0.97
594	4.91	175.2	0.19	0.38	0.58	0.77	0.96
600	4.95	176.4	0.19	0.38	0.57	0.77	0.96
606	4.95	177.6	0.19	0.38	0.57	0.76	0.95
612	4.95	178.9	0.19	0.38	0.57	0.76	0.94
618	4.97	180.1	0.19	0.38	0.56	0.75	0.94
624	4.98	181.3	0.19	0.37	0.56	0.75	0.93
630	5.00	182.5	0.19	0.37	0.56	0.74	0.93
636	4.91	183.7	0.18	0.37	0.55	0.74	0.92
642	4.92	184.9	0.18	0.37	0.55	0.73	0.92
648	4.96	186.1	0.18	0.37	0.55	0.73	0.91
654	4.95	187.3	0.18	0.36	0.55	0.73	0.91
660	4.87	188.5	0.18	0.36	0.55	0.73	0.91
666	4.84	189.8	0.18	0.36	0.54	0.73	0.91
672	4.84	191.0	0.18	0.36	0.54	0.72	0.90
678	4.84	192.3	0.18	0.36	0.54	0.72	0.90
684	4.86	193.5	0.18	0.36	0.54	0.72	0.90
690	4.88	194.7	0.18	0.36	0.54	0.72	0.90
696	4.90	196.0	0.18	0.36	0.54	0.71	0.89
702	4.94	197.2	0.18	0.36	0.53	0.71	0.89
708	4.98	198.4	0.18	0.35	0.53	0.71	0.89
714	5.03	199.6	0.18	0.35	0.53	0.71	0.88
720	5.14	200.8	0.18	0.35	0.53	0.70	0.88
726	5.15	201.9	0.18	0.35	0.53	0.70	0.88
732	5.17	203.1	0.17	0.35	0.52	0.70	0.87
738	5.18	204.2	0.17	0.35	0.52	0.70	0.87
744	5.19	205.4	0.17	0.35	0.52	0.69	0.87
750	5.21	206.6	0.17	0.34	0.52	0.69	0.86

Table 12 (continued)							
distance downstream of diffuser (ft)	velocity (fps)	drift time (s)	temperature differential (°F) $T_{effluent} - T_{river}$				
			5°F	10°F	15°F	20°F	25°F
756	5.11	207.7	0.17	0.34	0.52	0.69	0.86
762	5.15	208.9	0.17	0.34	0.51	0.69	0.86
768	5.19	210.1	0.17	0.34	0.51	0.69	0.86
774	5.21	211.2	0.17	0.34	0.51	0.68	0.85
780	5.23	212.4	0.17	0.34	0.51	0.68	0.85
786	5.24	213.5	0.17	0.34	0.51	0.68	0.85
792	5.26	214.6	0.17	0.34	0.51	0.68	0.85
798	5.28	215.8	0.17	0.34	0.51	0.68	0.85
804	5.29	216.9	0.17	0.34	0.51	0.67	0.84
810	5.29	218.1	0.17	0.34	0.50	0.67	0.84
816	5.28	219.2	0.17	0.34	0.50	0.67	0.84
822	5.32	220.3	0.17	0.33	0.50	0.67	0.84
828	5.36	221.5	0.17	0.33	0.50	0.67	0.83
834	5.36	222.6	0.17	0.33	0.50	0.67	0.83
840	5.37	223.7	0.17	0.33	0.50	0.66	0.83
846	5.40	224.8	0.17	0.33	0.50	0.66	0.83
852	5.43	225.9	0.17	0.33	0.50	0.66	0.83
858	5.46	227.0	0.16	0.33	0.49	0.66	0.82
864	5.47	228.1	0.16	0.33	0.49	0.66	0.82
870	5.45	229.2	0.16	0.33	0.49	0.65	0.82
876	5.46	230.3	0.16	0.33	0.49	0.65	0.82
882	5.52	231.4	0.16	0.33	0.49	0.65	0.82
888	5.59	232.5	0.16	0.33	0.49	0.65	0.81
894	5.45	233.6	0.16	0.32	0.49	0.65	0.81
900	5.47	234.7	0.16	0.32	0.49	0.65	0.81
906	5.49	235.8	0.16	0.32	0.49	0.65	0.81
912	5.54	236.9	0.16	0.32	0.48	0.65	0.81
918	5.51	237.9	0.16	0.32	0.48	0.64	0.80
924	5.50	239.0	0.16	0.32	0.48	0.64	0.80
930	5.54	240.1	0.16	0.32	0.48	0.64	0.80
936	5.56	241.2	0.16	0.32	0.48	0.64	0.80
942	5.63	242.3	0.16	0.32	0.48	0.64	0.80
948	5.65	243.3	0.16	0.32	0.48	0.64	0.80
954	5.64	244.4	0.16	0.32	0.48	0.64	0.79
960	5.69	245.5	0.16	0.32	0.48	0.63	0.79
966	5.69	246.5	0.16	0.32	0.47	0.63	0.79
972	5.64	247.6	0.16	0.32	0.47	0.63	0.79
978	5.66	248.6	0.16	0.31	0.47	0.63	0.79
984	5.72	249.7	0.16	0.31	0.47	0.63	0.79
990	5.76	250.7	0.16	0.31	0.47	0.63	0.79

Appendix E

MEDIAN-CASE SRWTP THERMAL PLUME EXPOSURE SCENARIOS

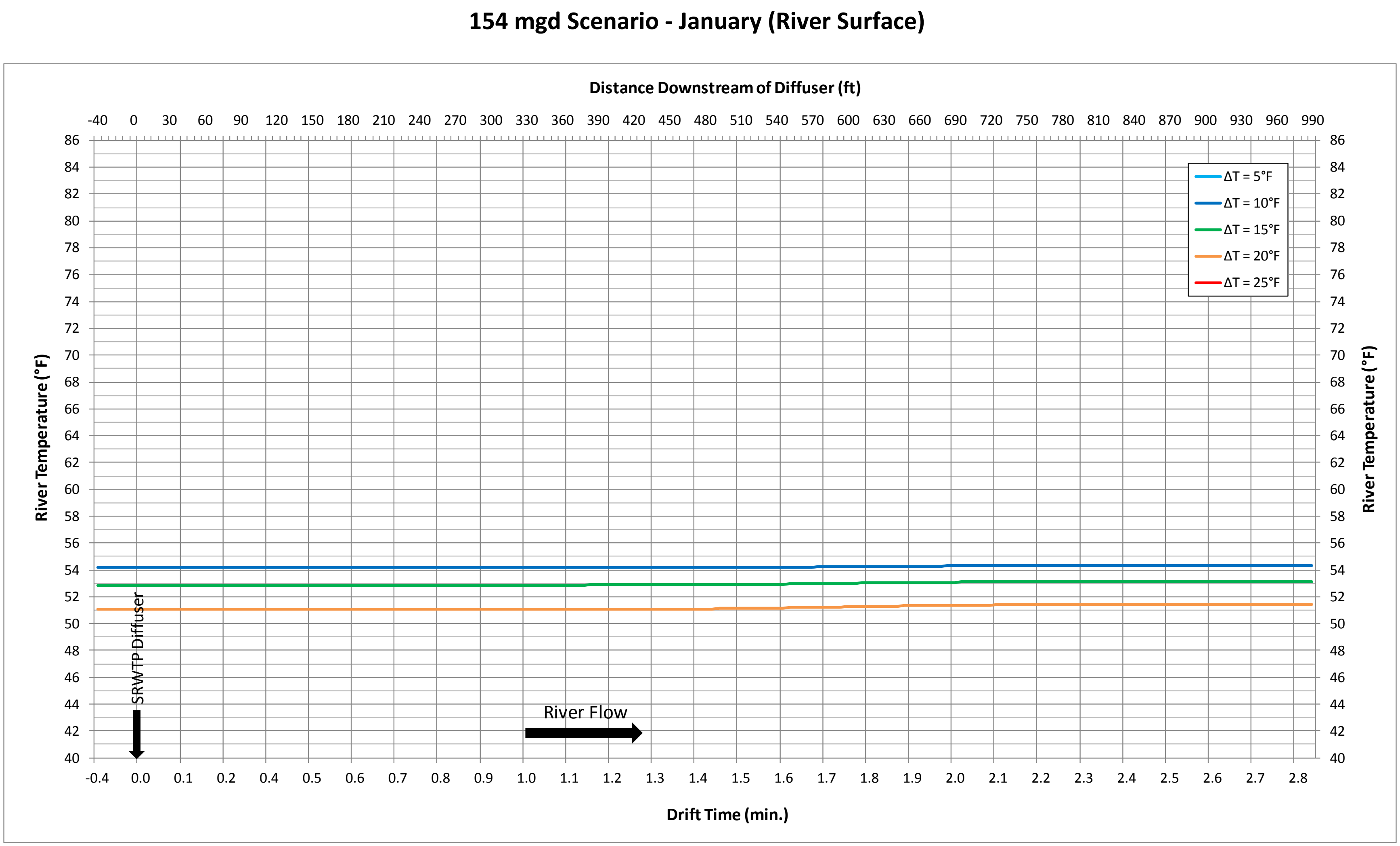


Figure E-1. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of January at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in January at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

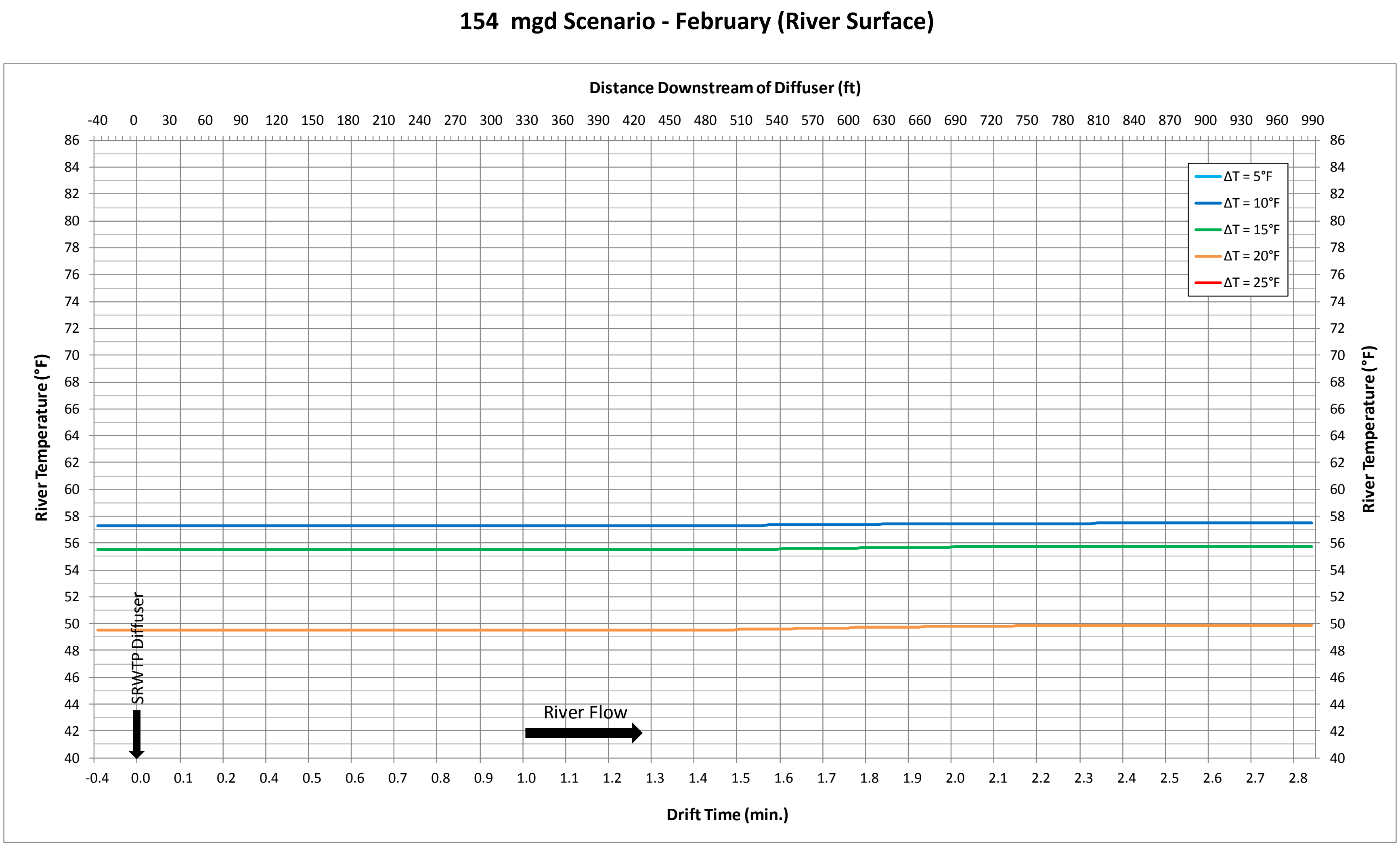


Figure E-2. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of February at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in February at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - March (River Surface)

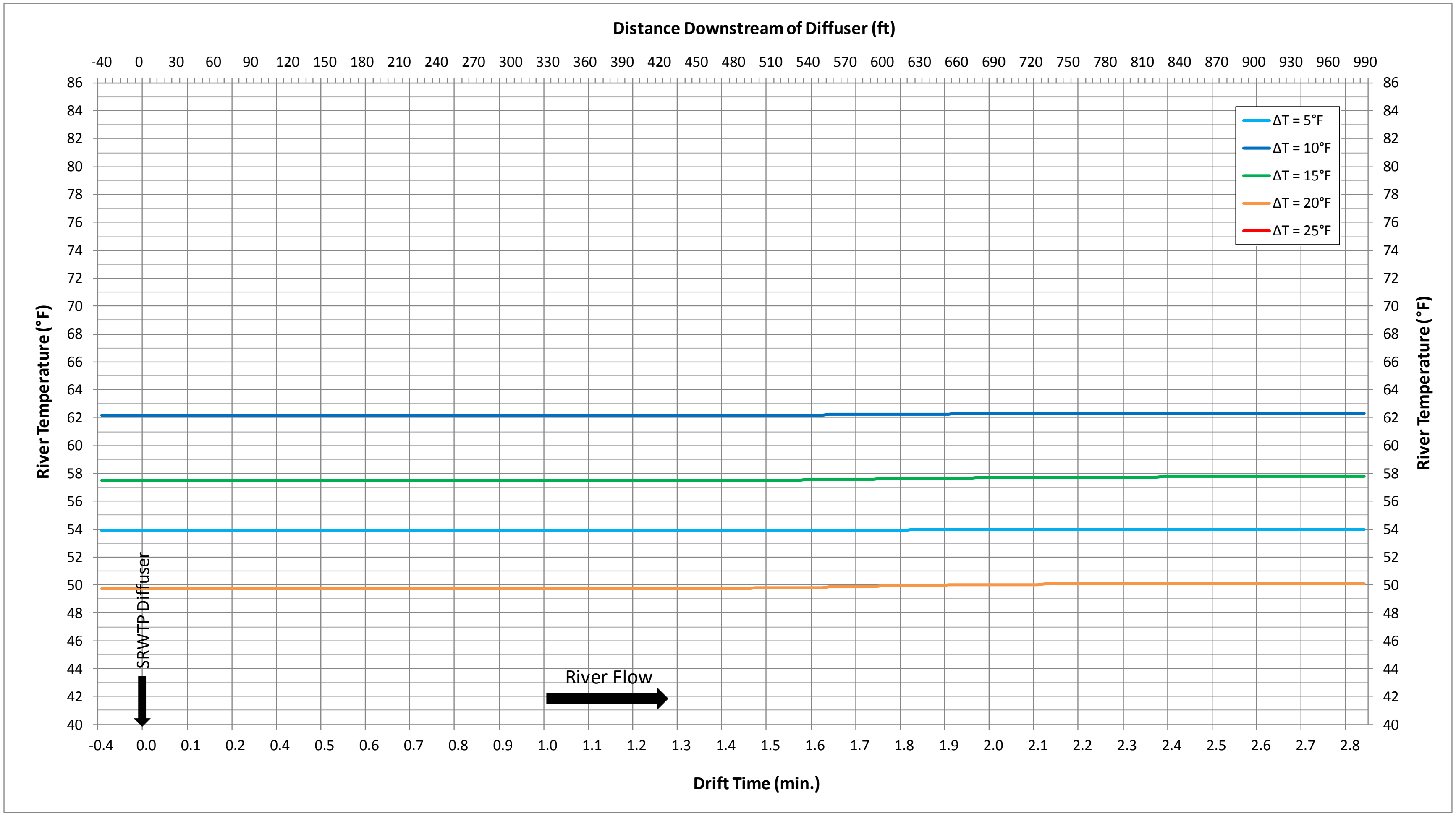


Figure E-3. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of March at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, 15°F, and 20°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in March at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

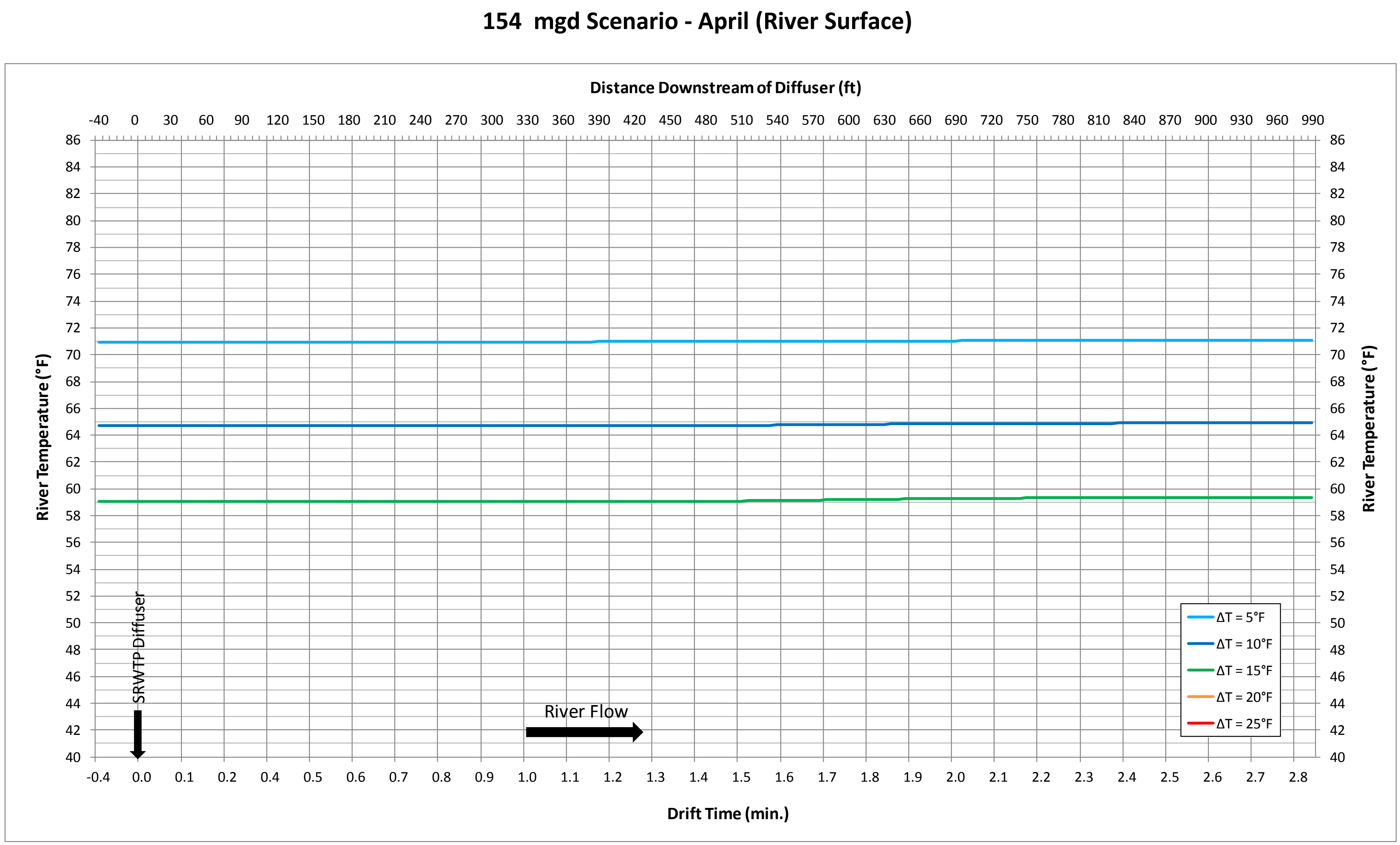


Figure E-4. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of April at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in April at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - May (River Surface)

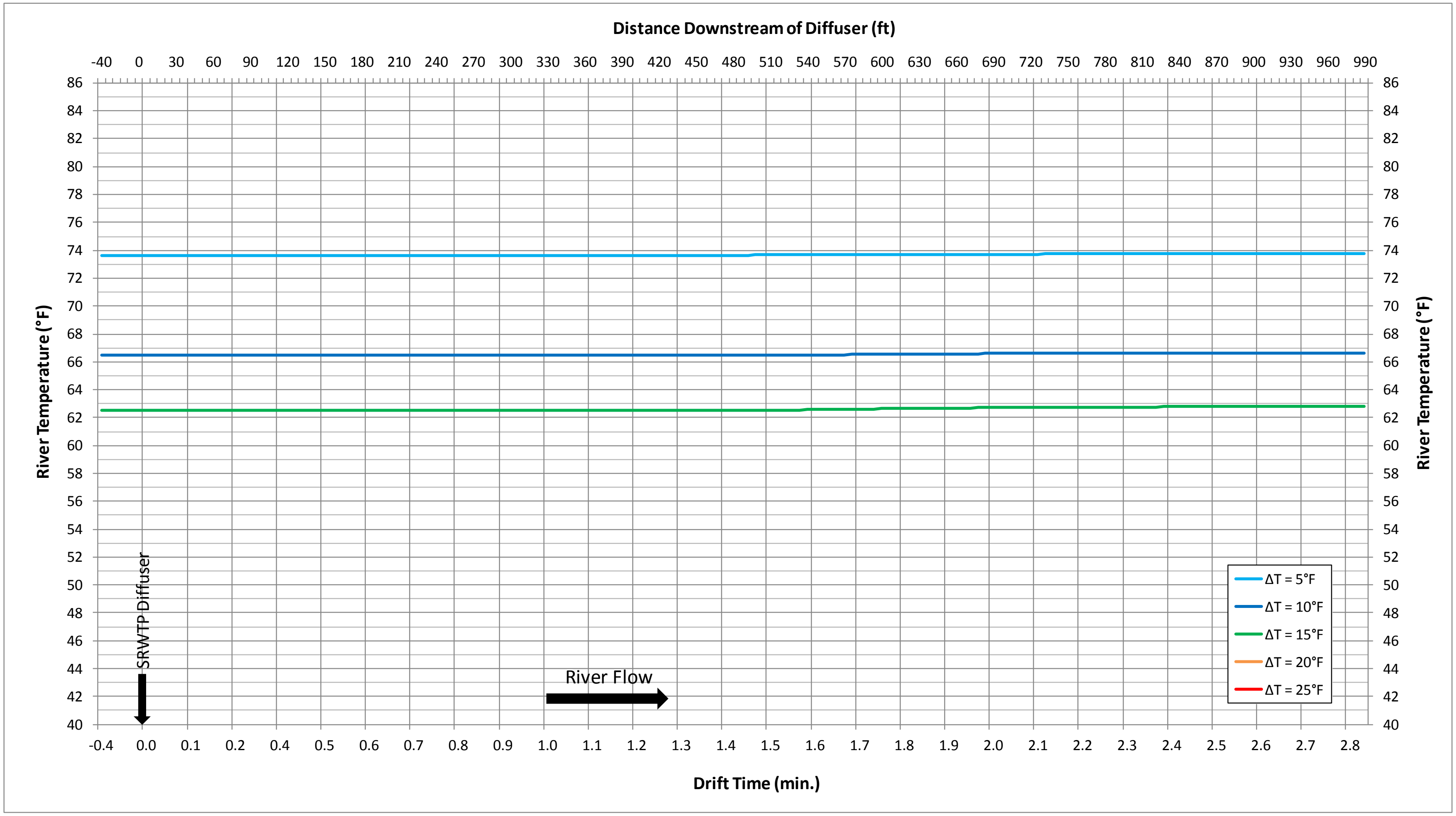


Figure E-5. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of May at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in May at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

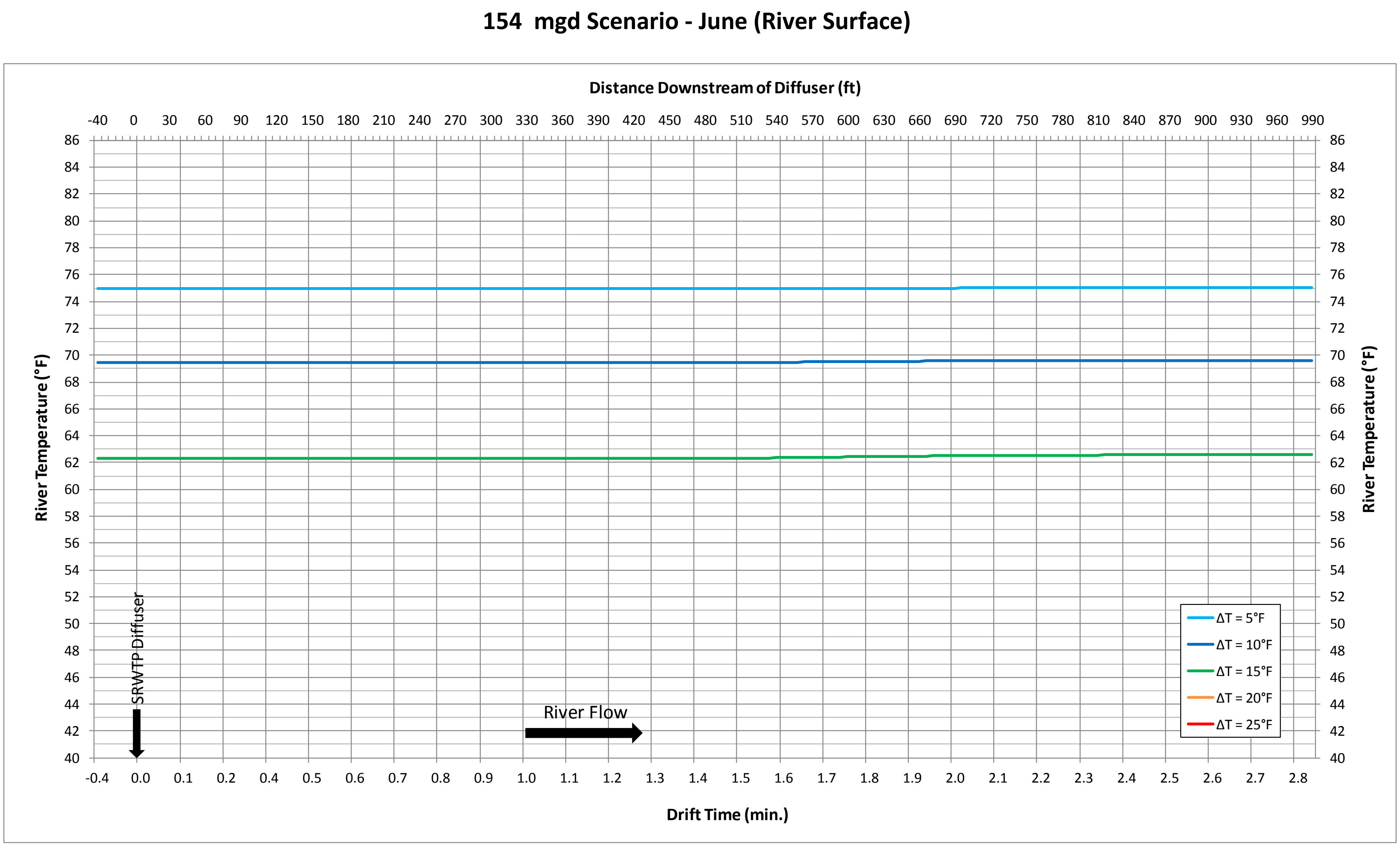


Figure E-6. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of June at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in June at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

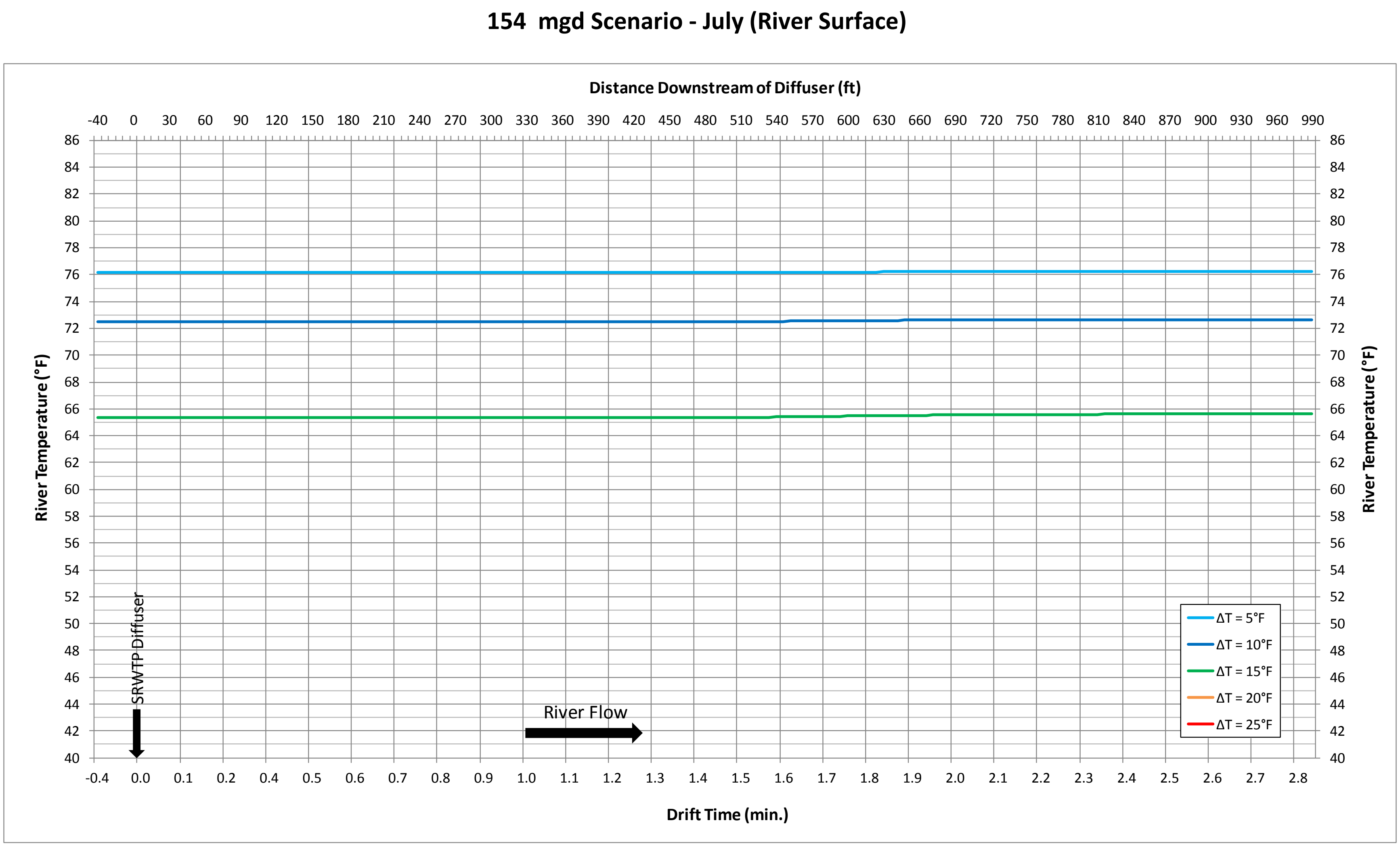


Figure E-7. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of July at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in July at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

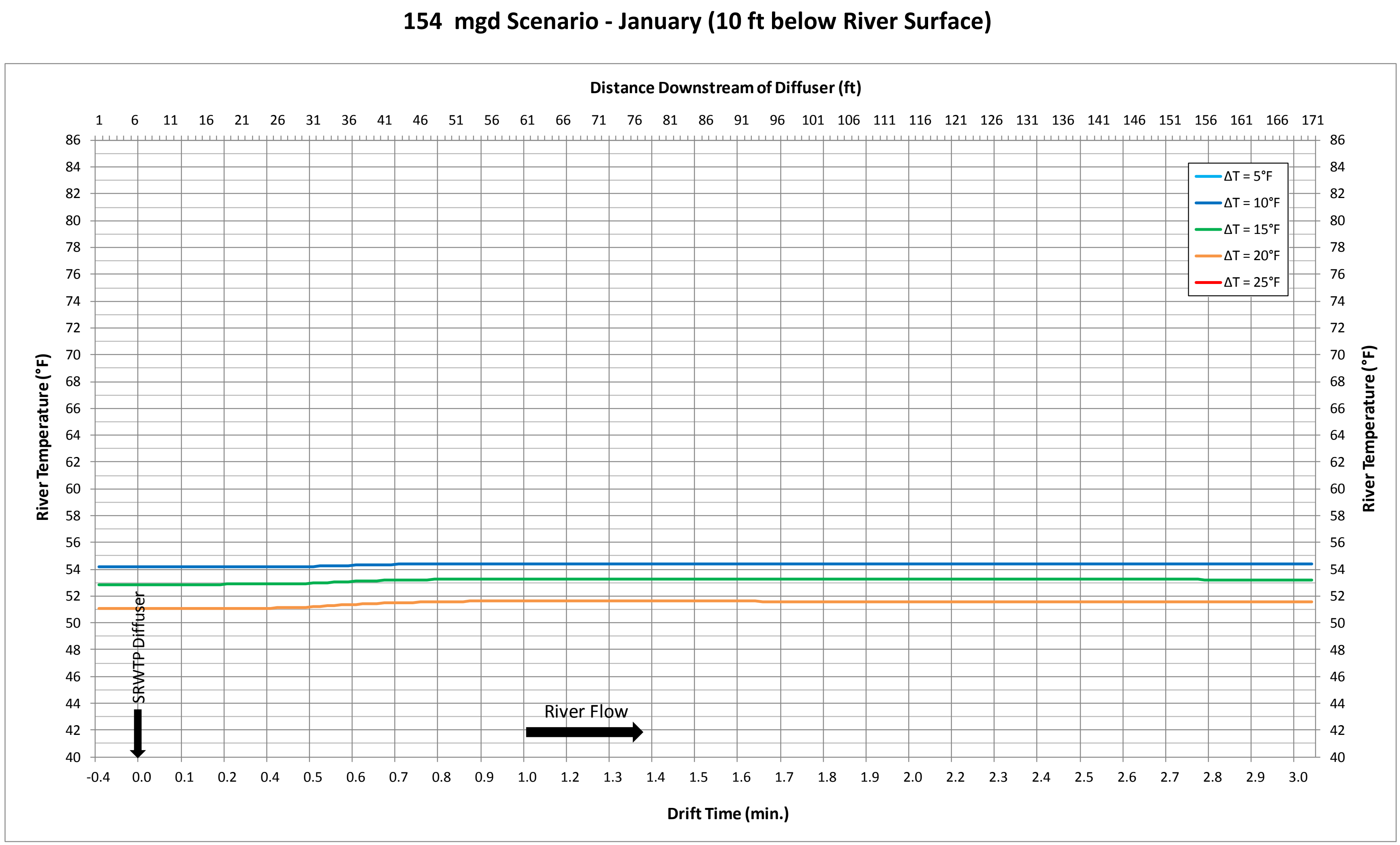


Figure E-8. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of January at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in January at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

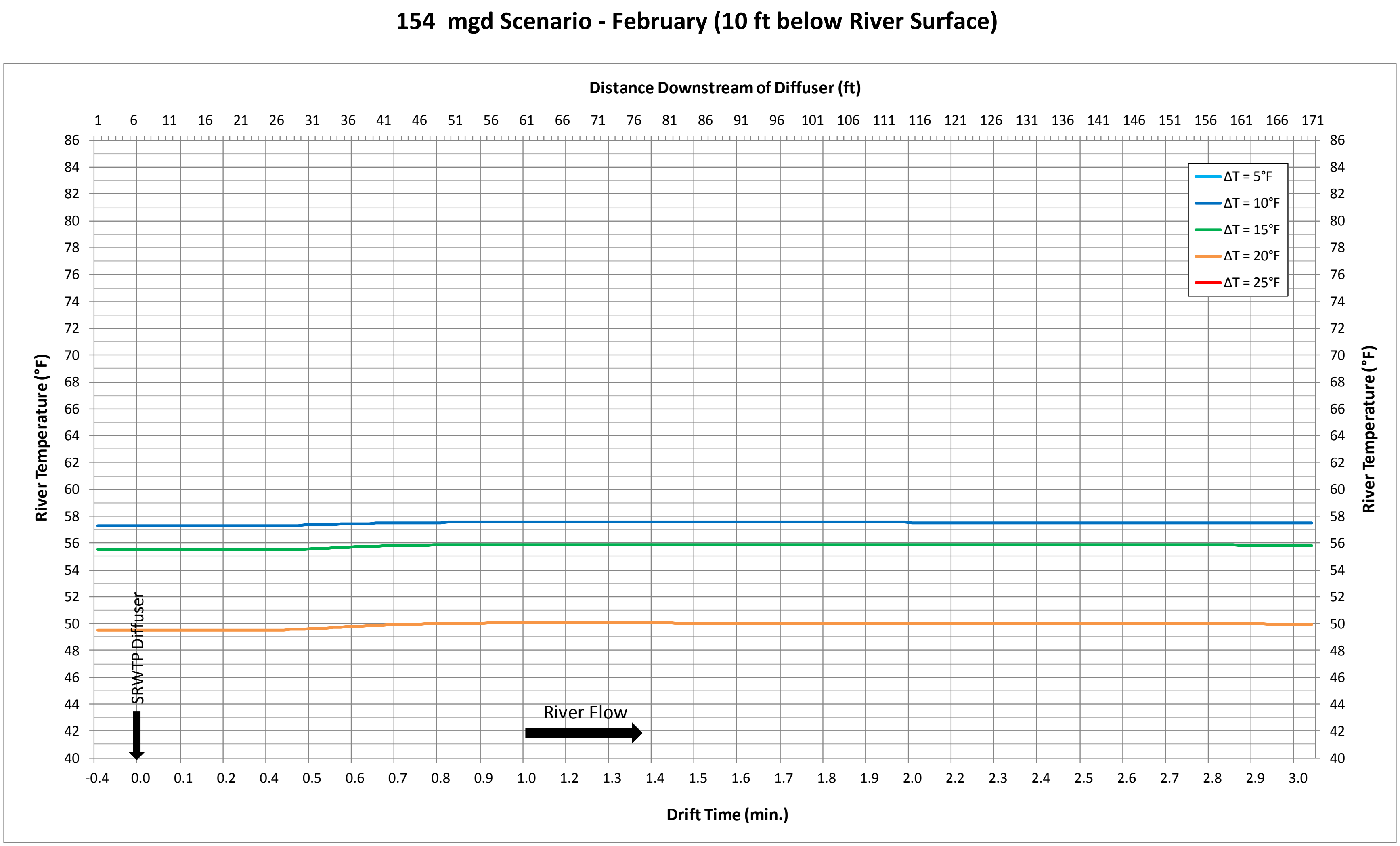


Figure E-9. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of February at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in February at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - March (10 ft below River Surface)

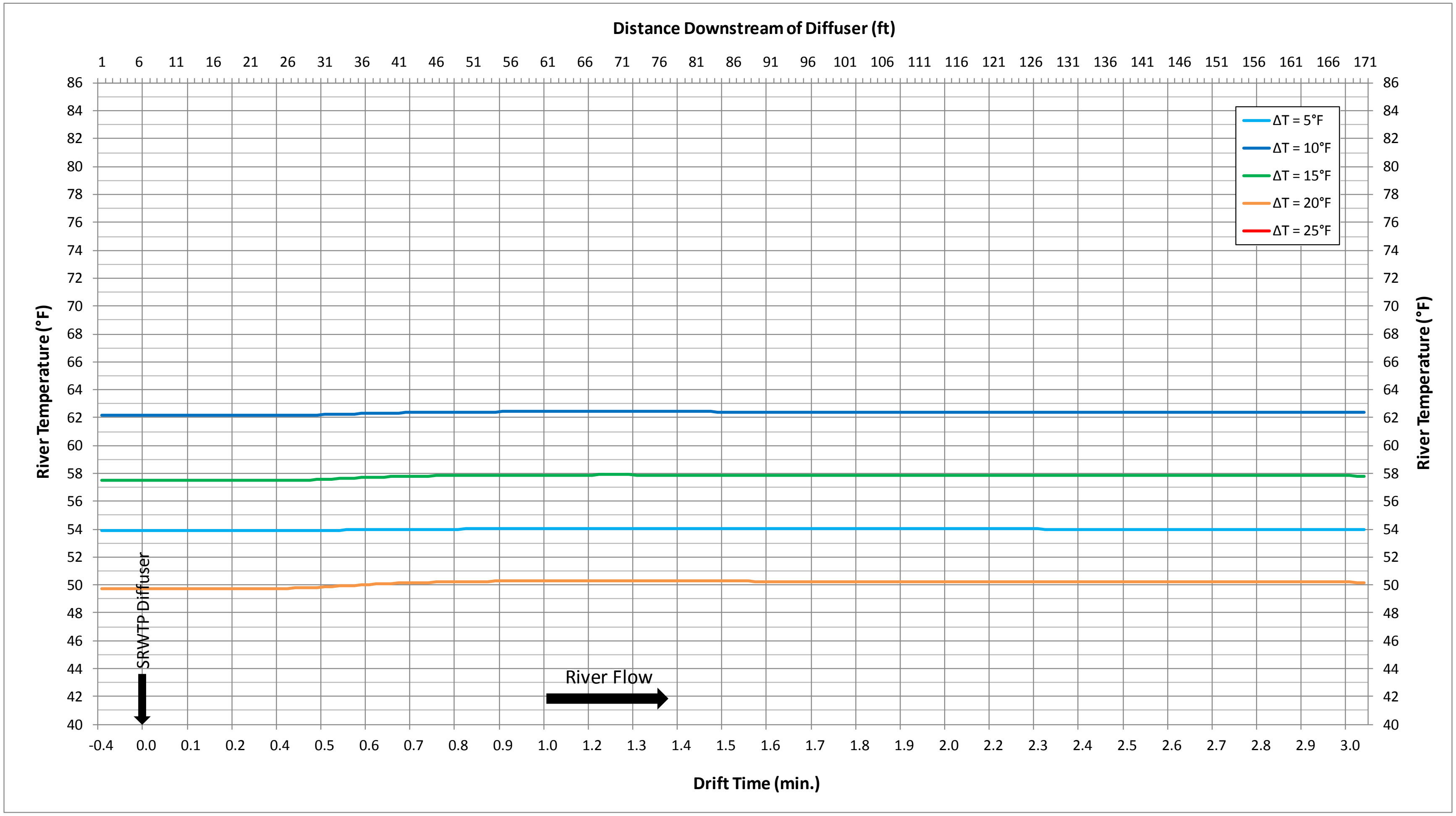


Figure E-10. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of March at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, 15°F, and 20°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in March at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - April (10 ft below River Surface)

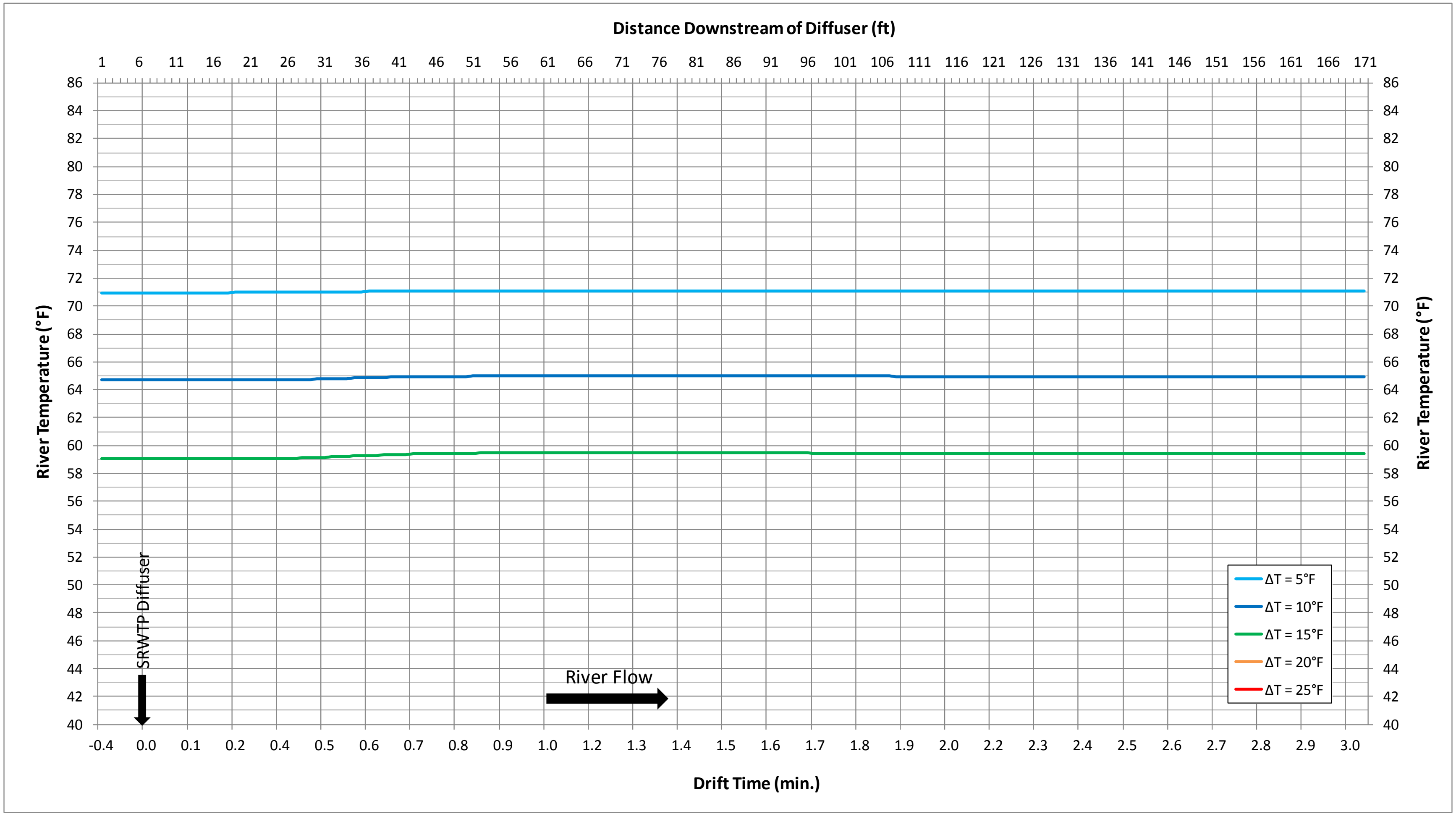


Figure E-11. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of April at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in April at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - May (10 ft below River Surface)

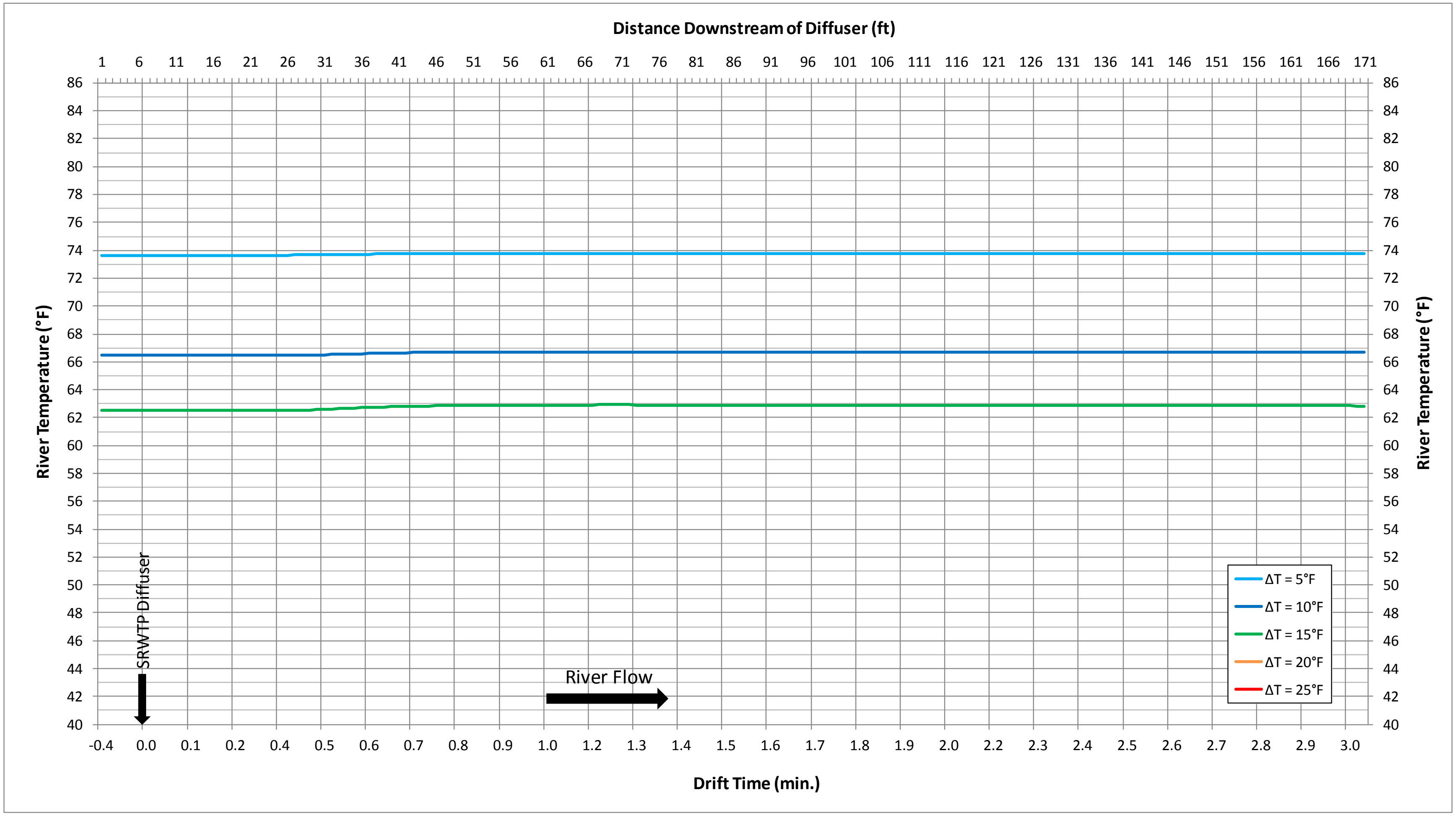


Figure E-12. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of May at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in May at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

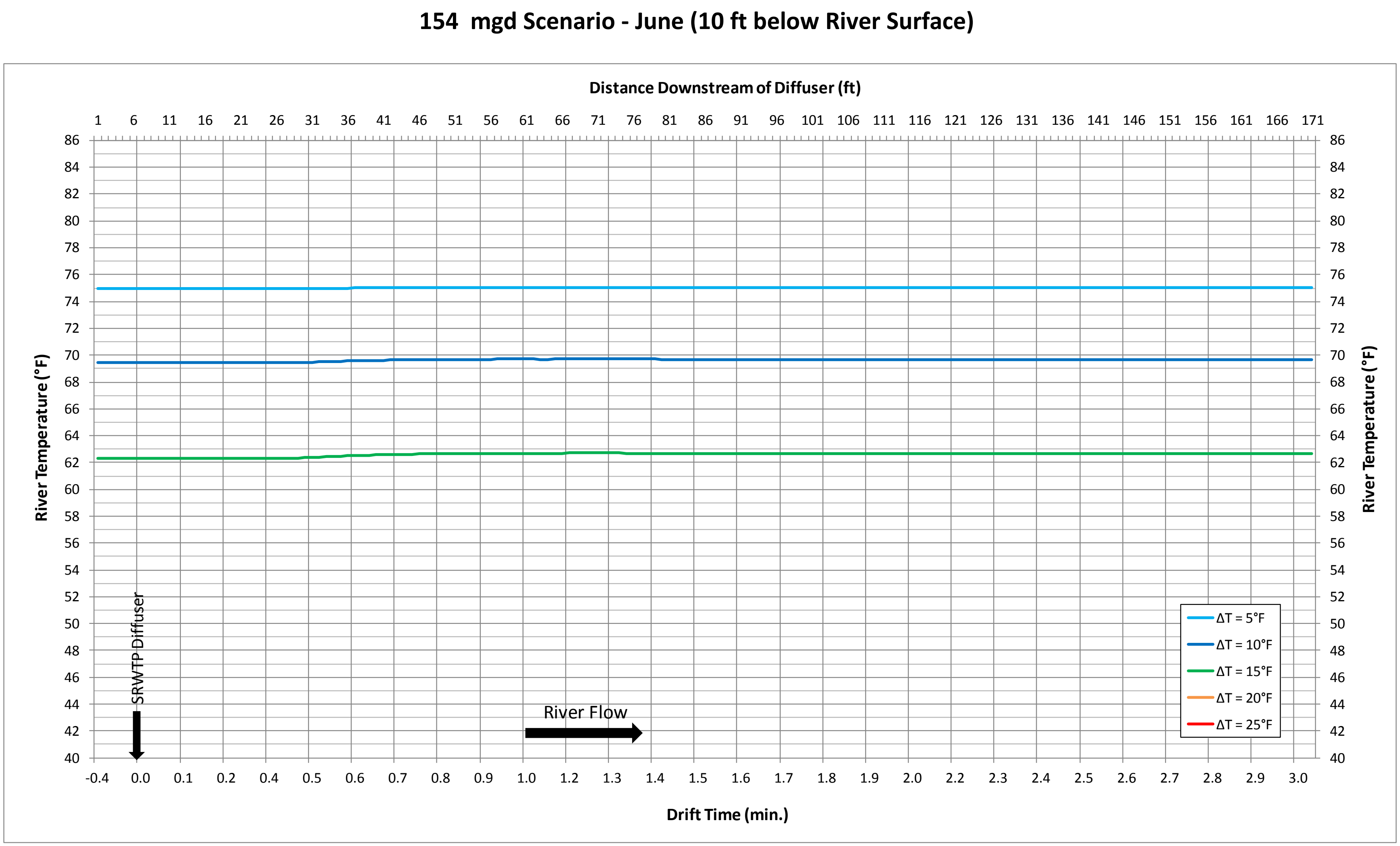


Figure E-13. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of June at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in June at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - July (10 ft below River Surface)

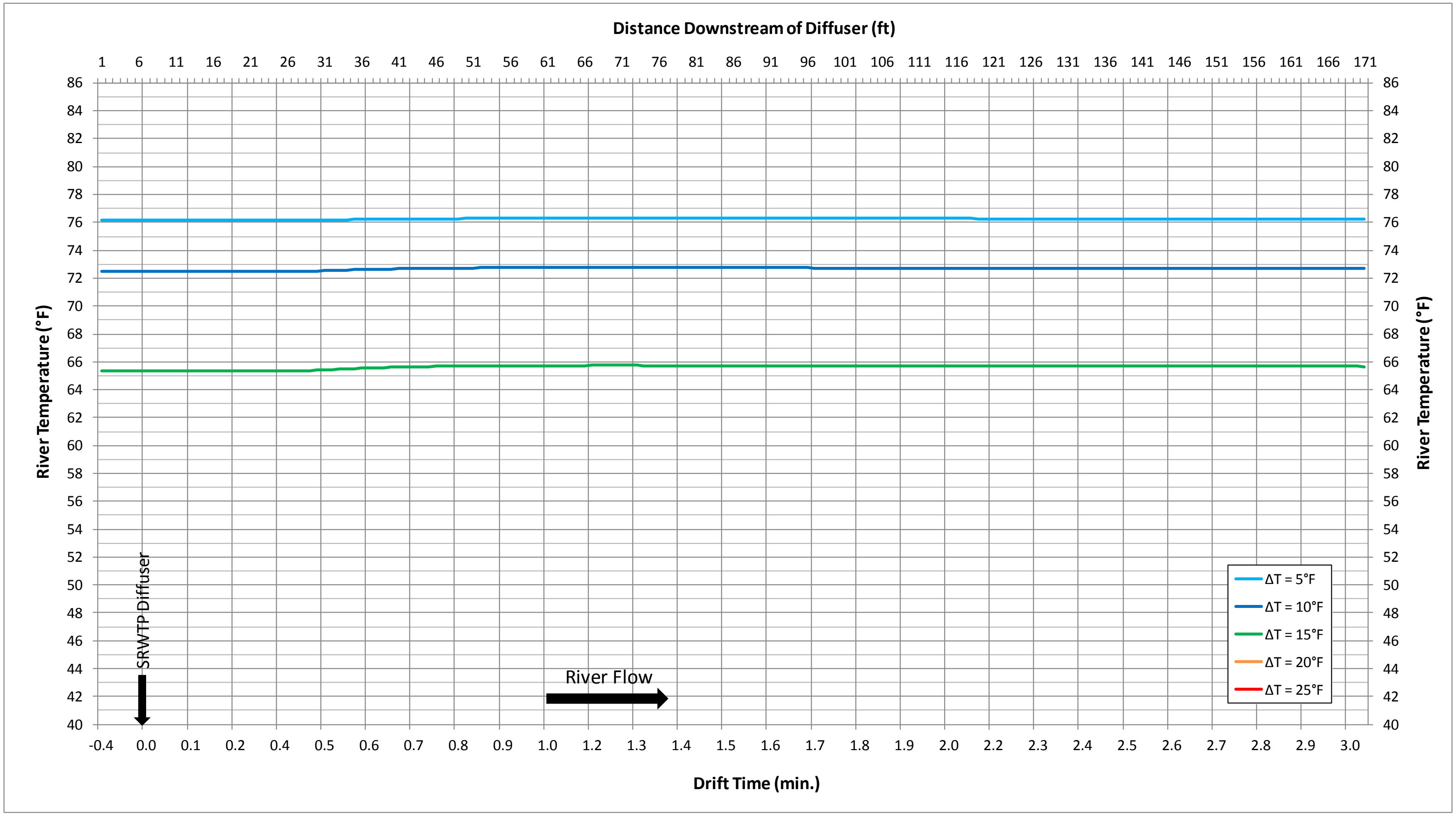
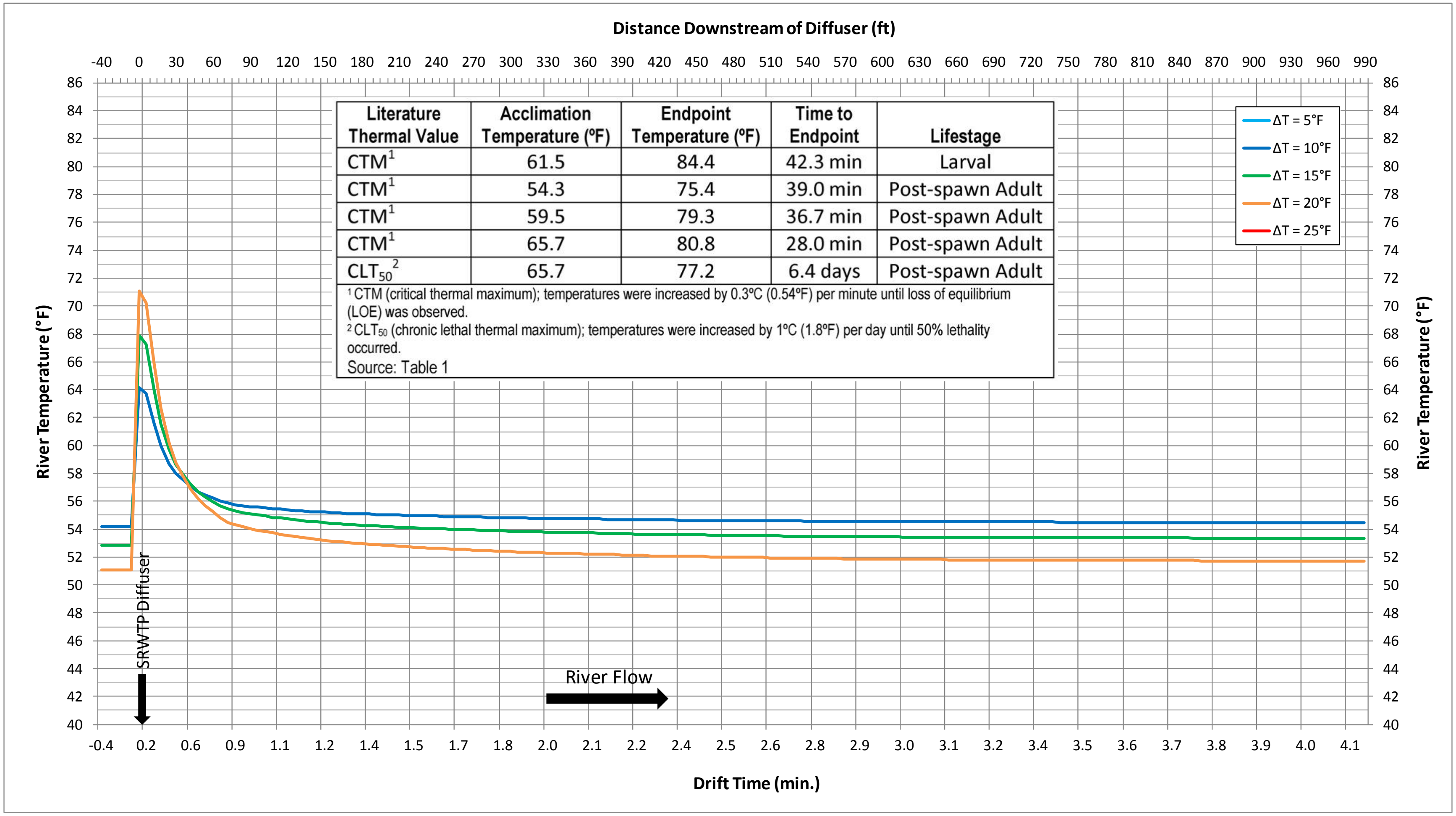


Figure E-14. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of July at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in July at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - January (River Bottom)

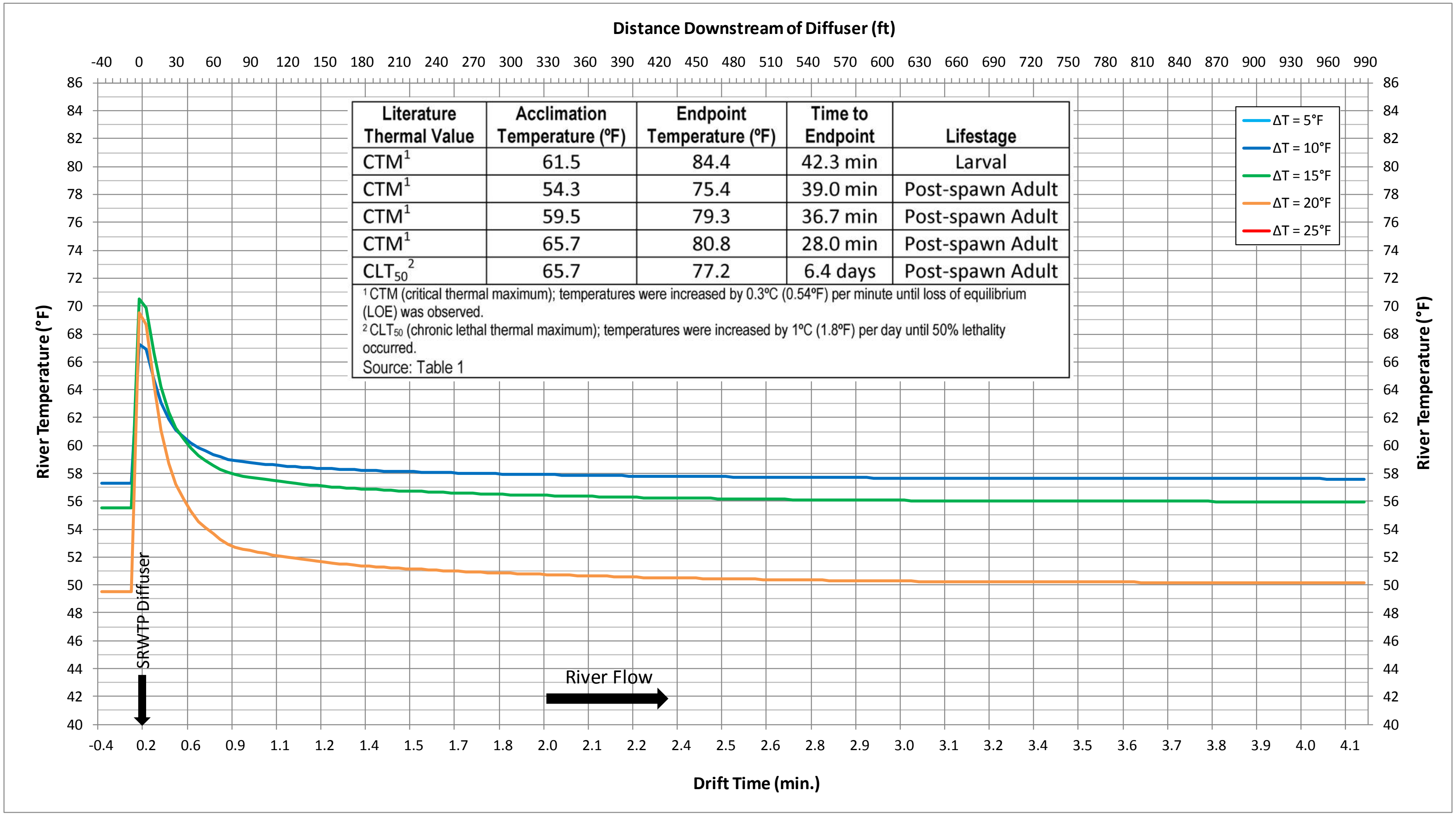


Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure E-15. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of January at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in January at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - February (River Bottom)

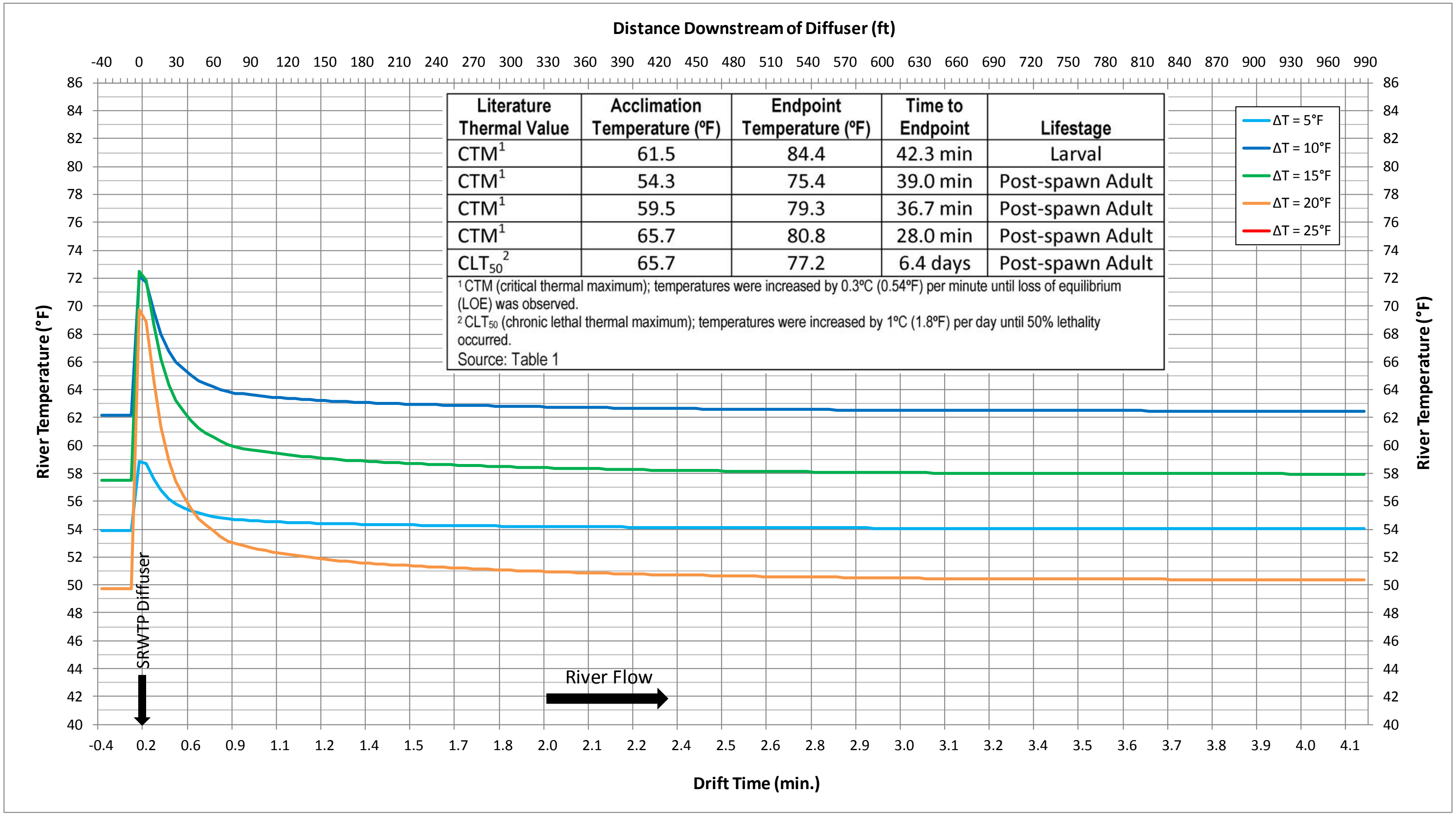


Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure E-16. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of February at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in February at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - March (River Bottom)

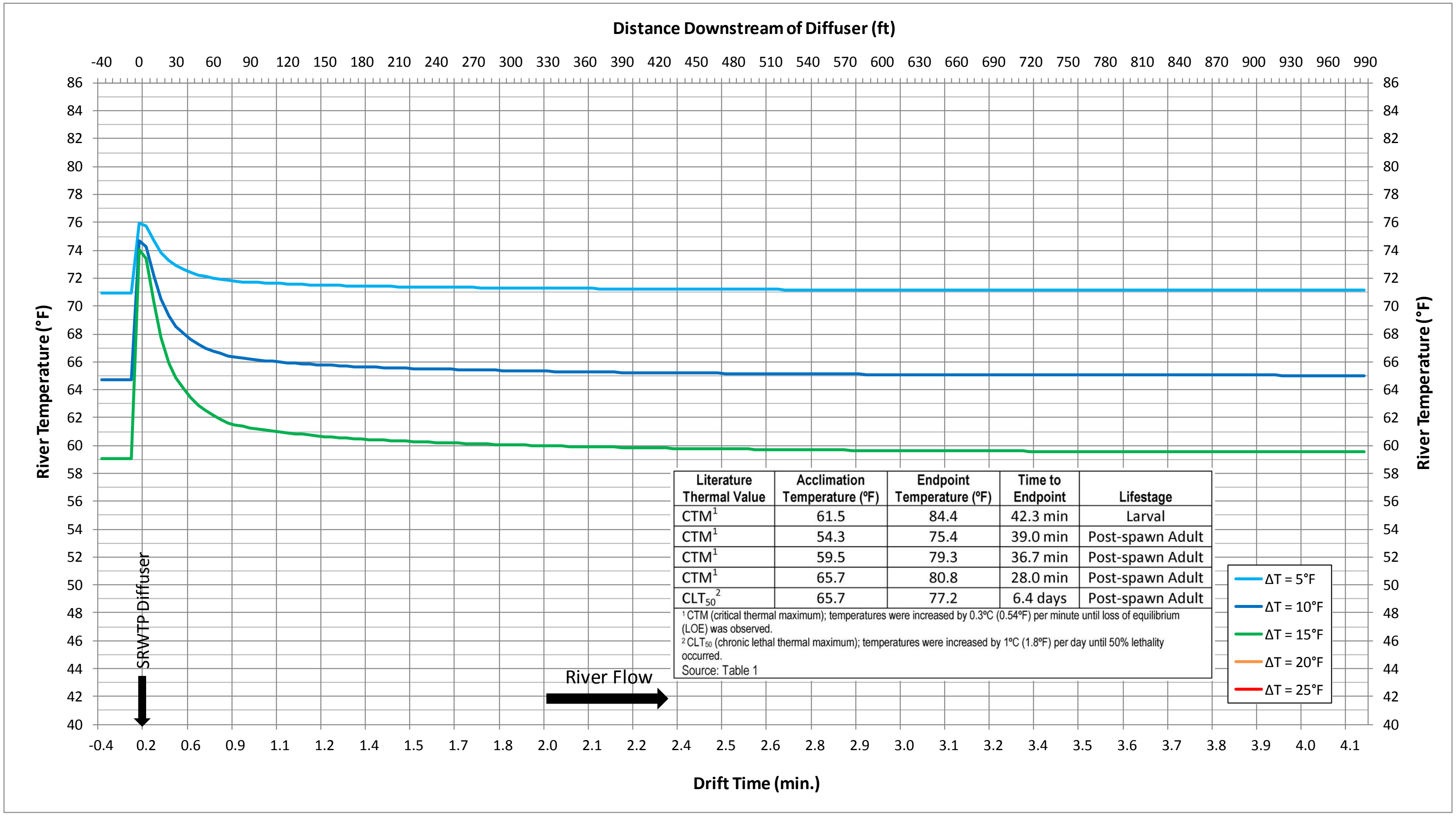


Literature Thermal Value	Acclimation Temperature (°F)	Endpoint Temperature (°F)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3°C (0.54°F) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1°C (1.8°F) per day until 50% lethality occurred.
Source: Table 1

Figure E-17. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of March at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, 15°F, and 20°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in March at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - April (River Bottom)

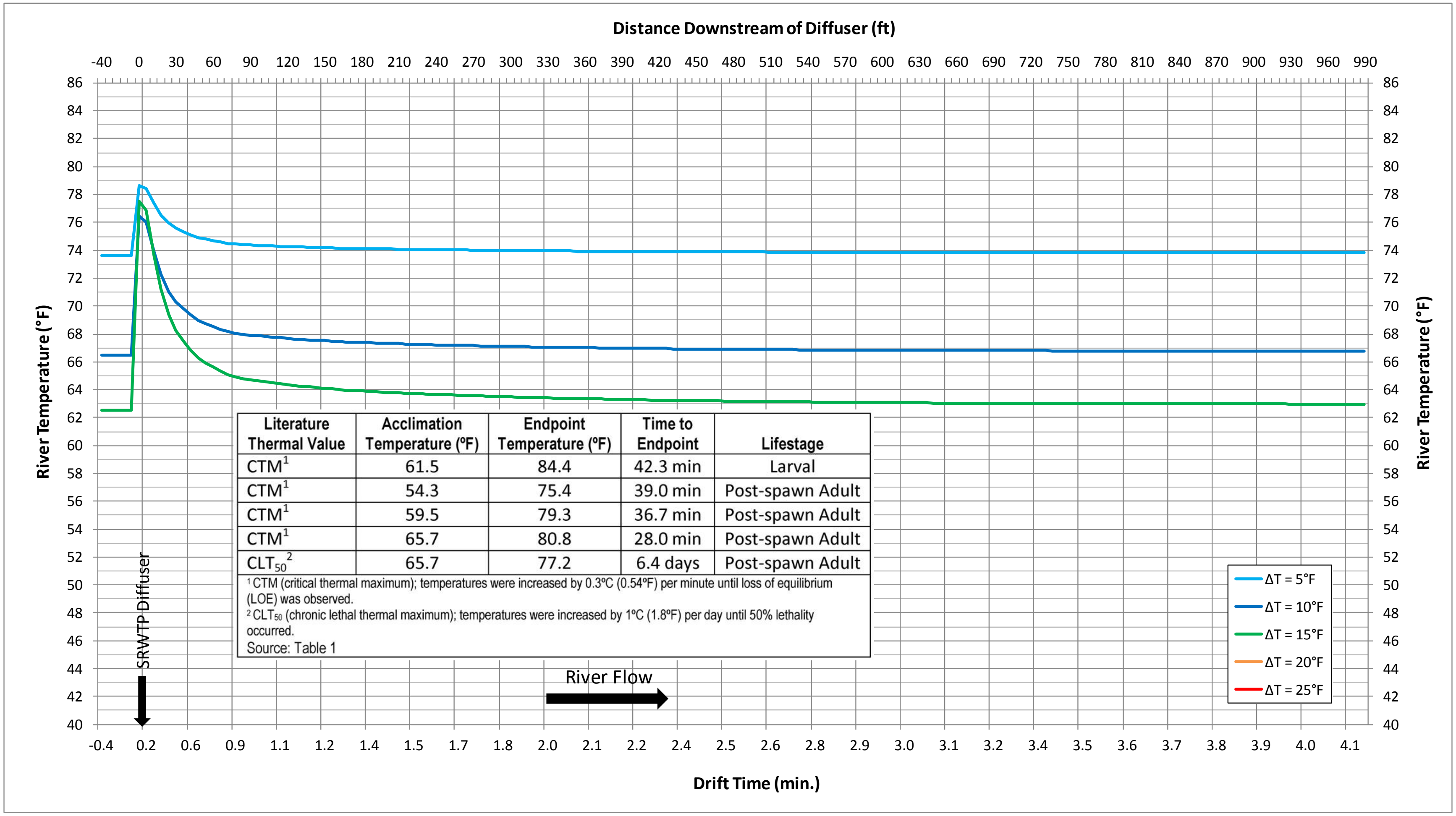


Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure E-18. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of April at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in April at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - May (River Bottom)



Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.

[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.

Source: Table 1

Figure E-19. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of May at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in May at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - June (River Bottom)

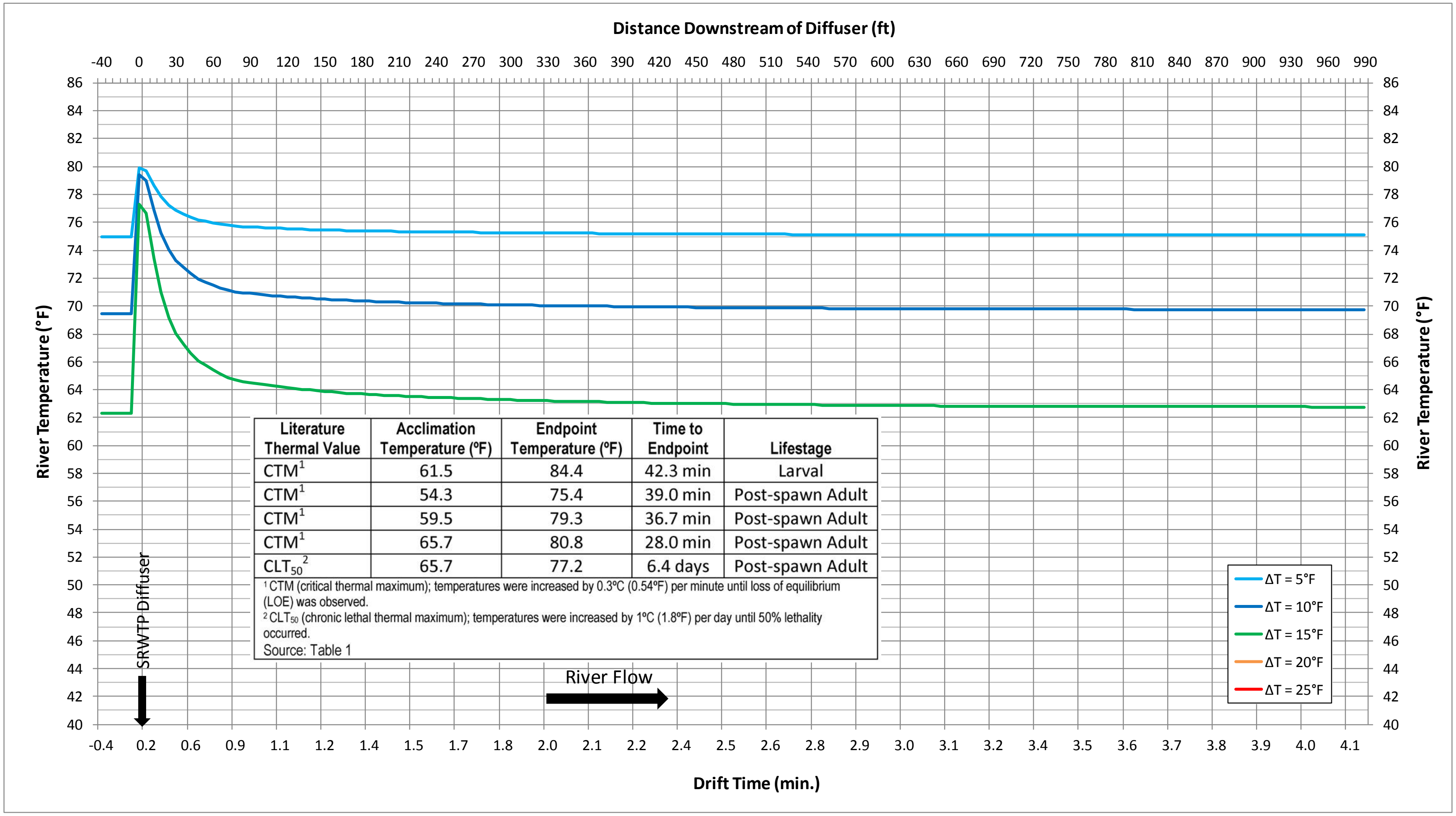
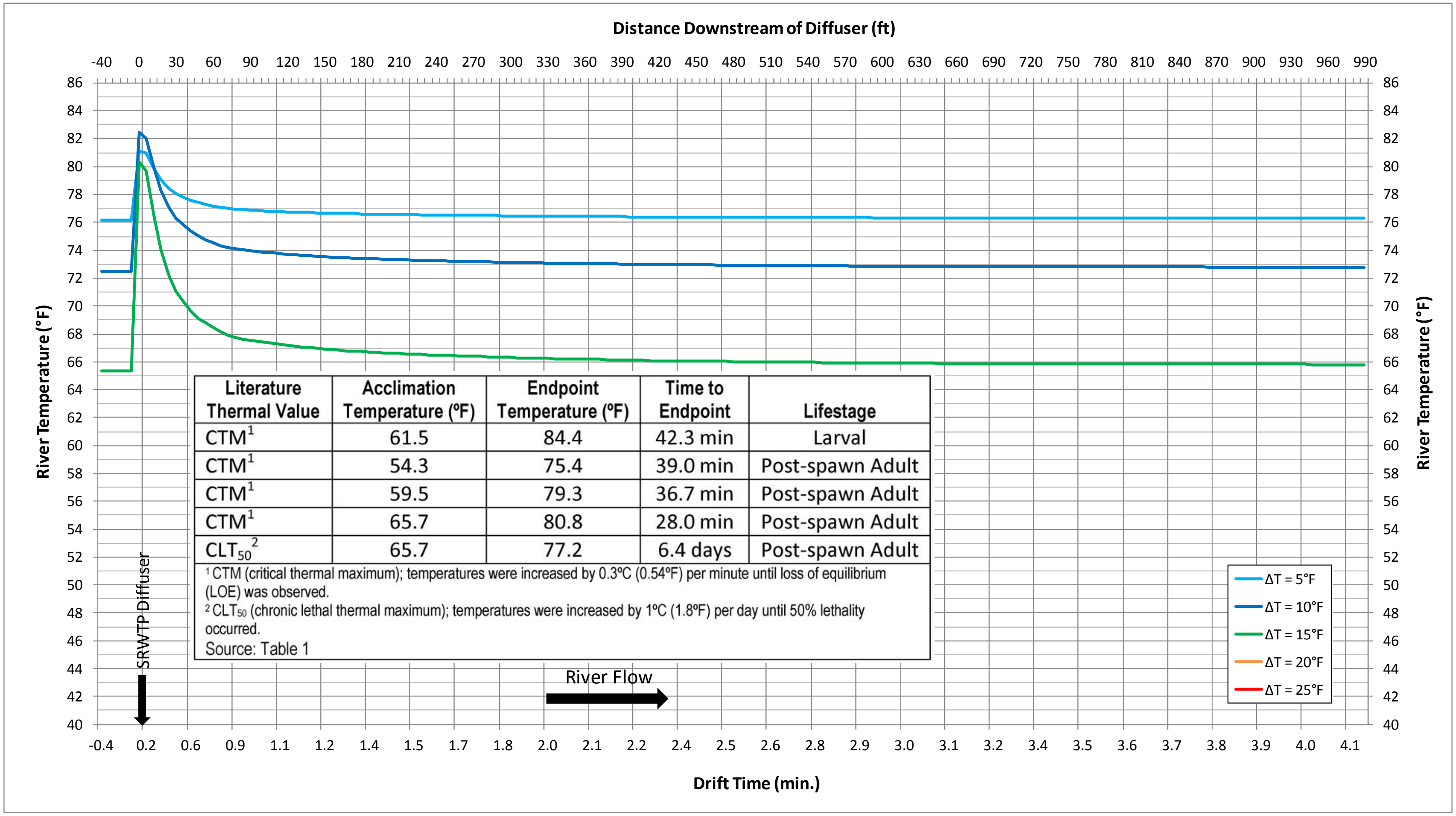


Figure E-20. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of June at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in June at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

154 mgd Scenario - July (River Bottom)



Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure E-21. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of July at a SRWTP discharge rate of 154 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Median-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in July at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

Appendix F

WORST-CASE SRWTP THERMAL PLUME EXPOSURE SCENARIOS

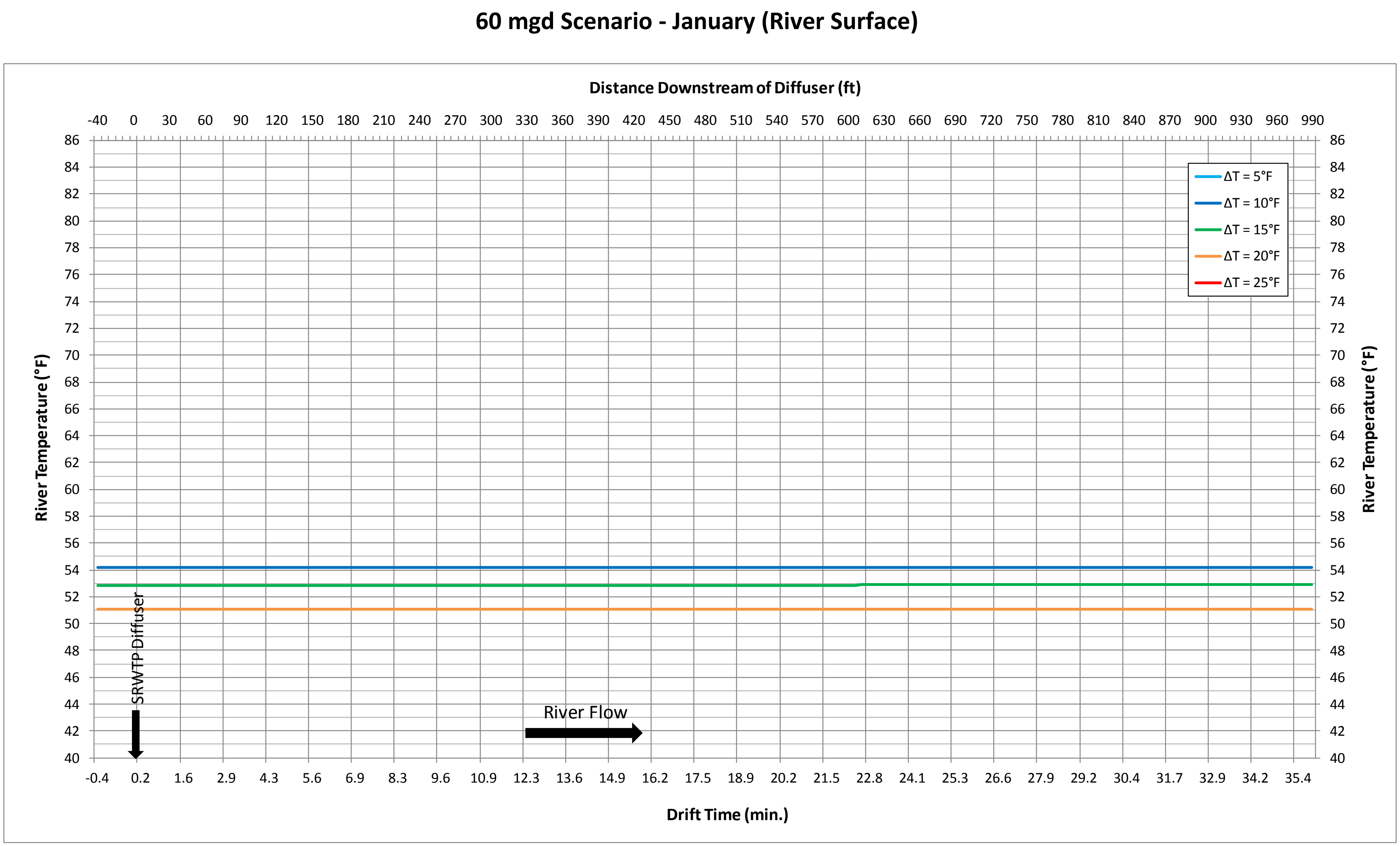


Figure F-1. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of January at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in January at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

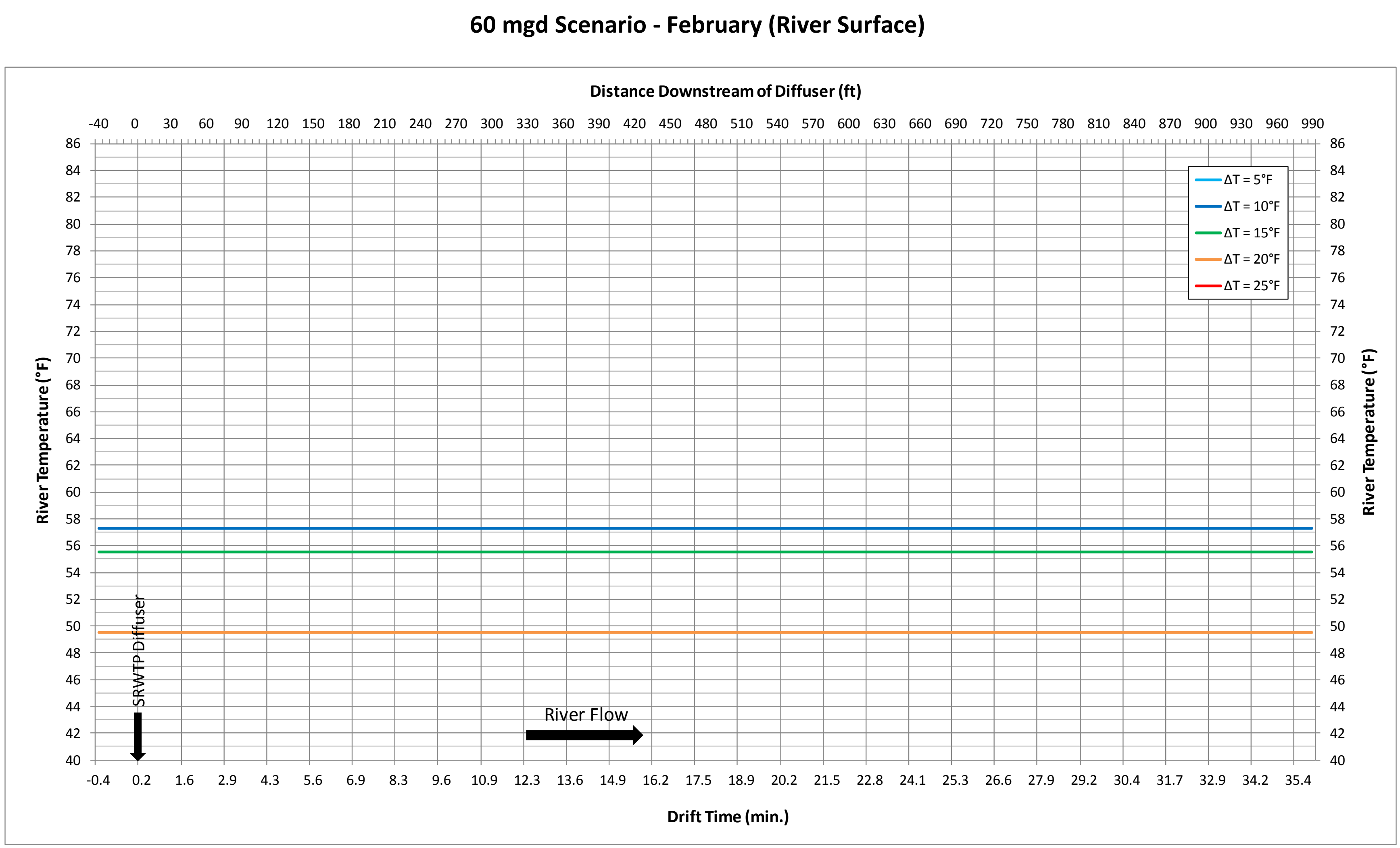


Figure F-2. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of February at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in February at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - March (River Surface)

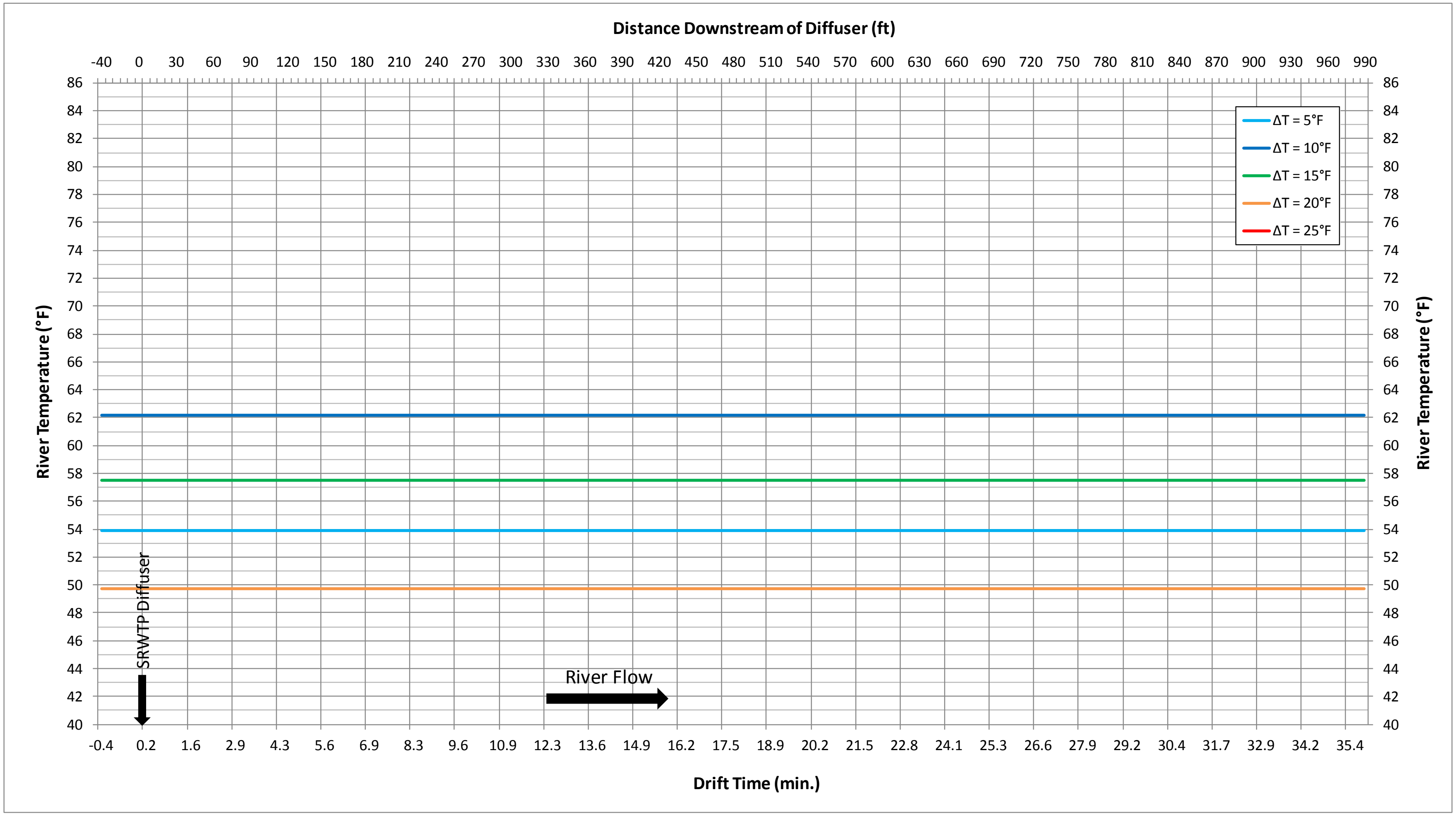


Figure F-3. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of March at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in March at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - April (River Surface)

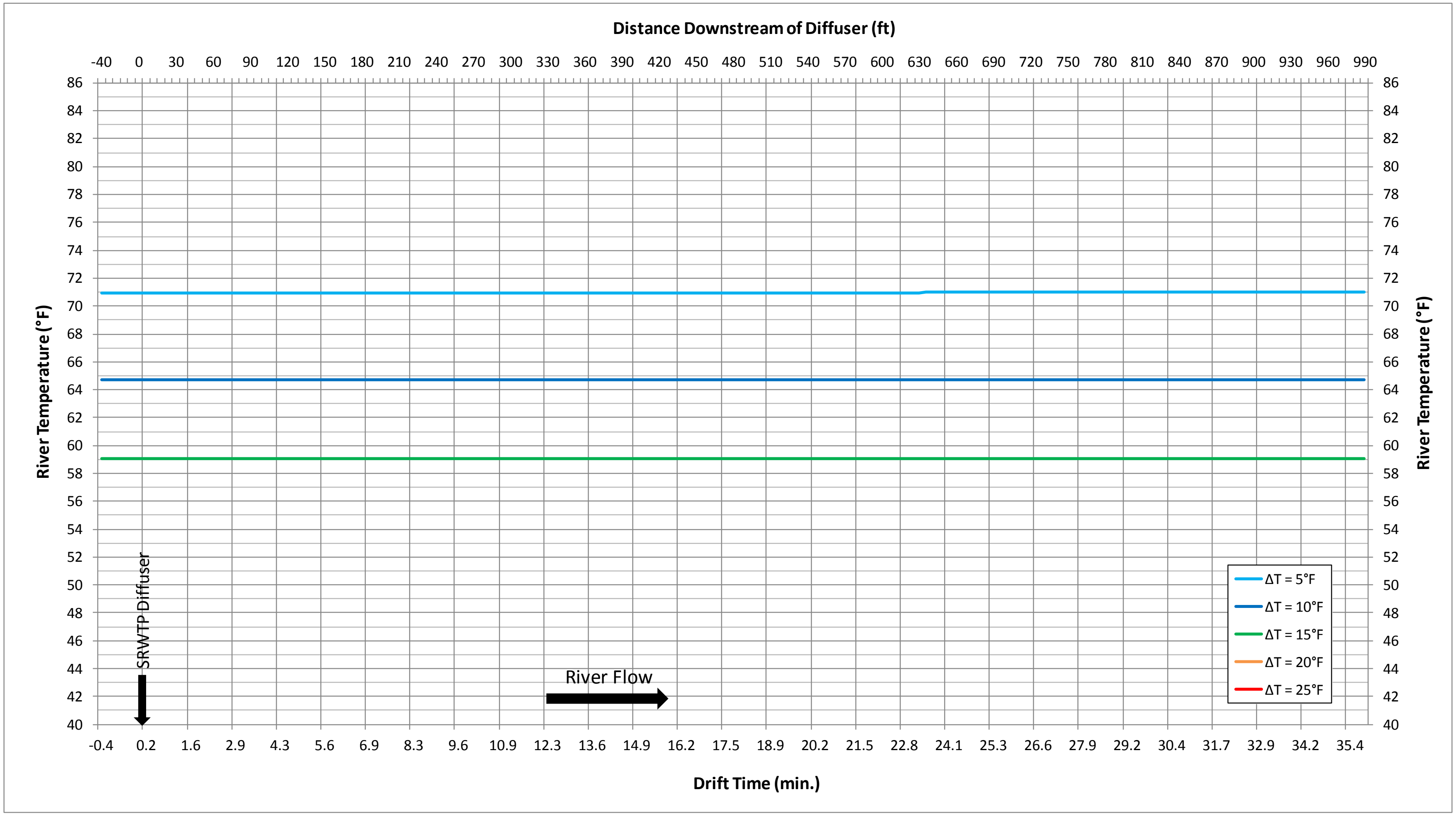


Figure F-4. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of April at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in April at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

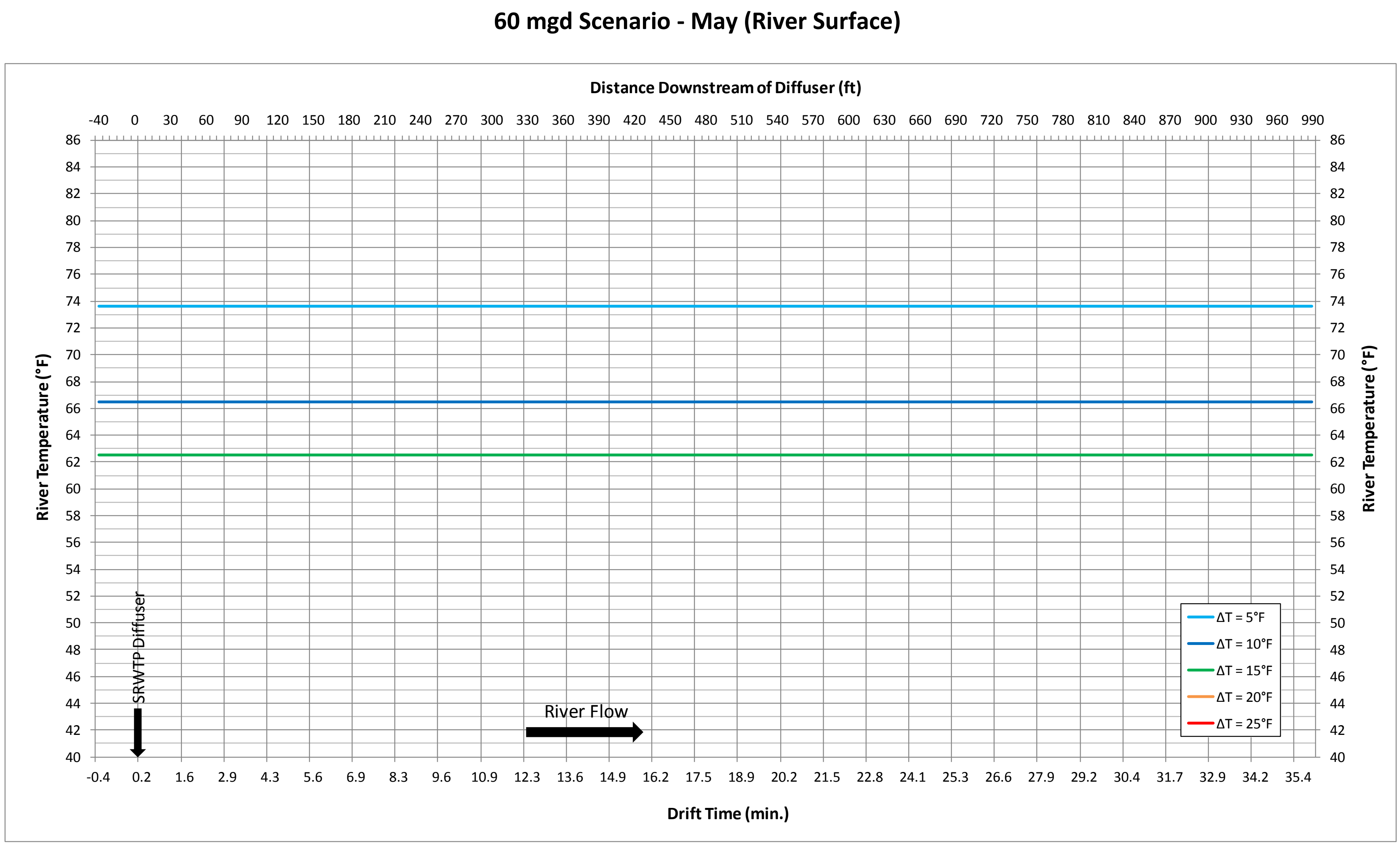


Figure F-5. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of May at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in May at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - June (River Surface)

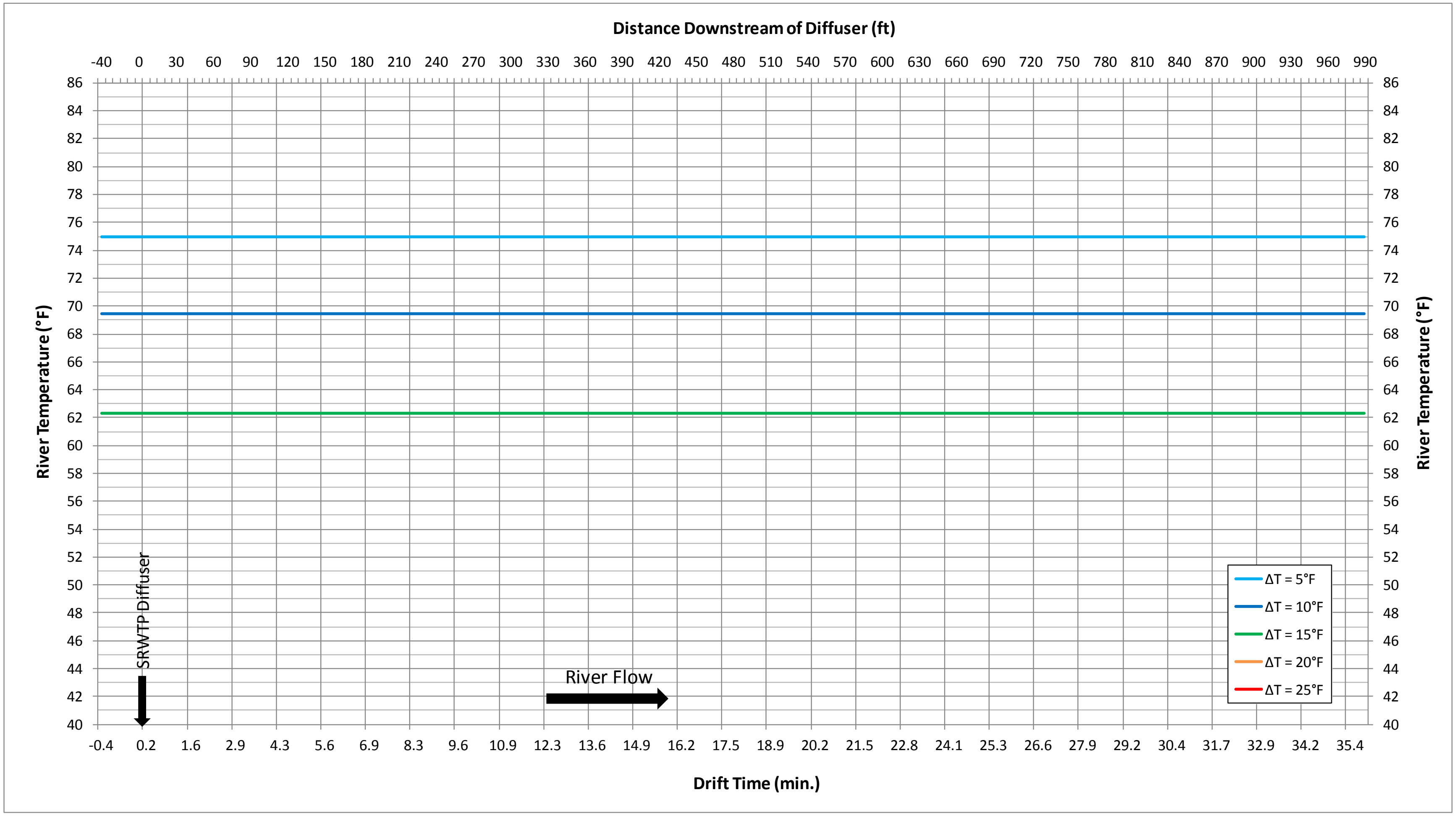


Figure F-6. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of June at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in June at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - July (River Surface)

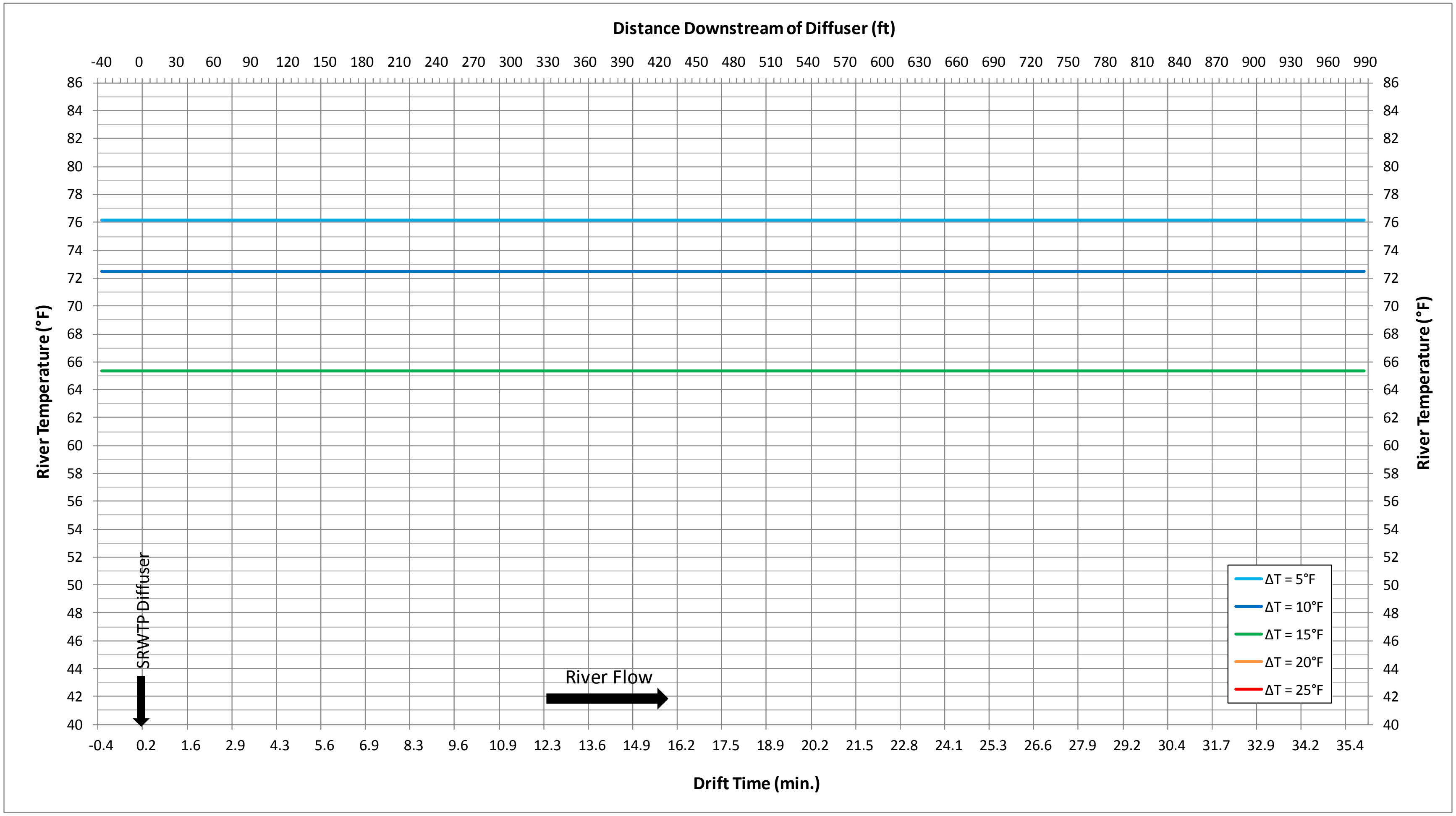


Figure F-7. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of July at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in July at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

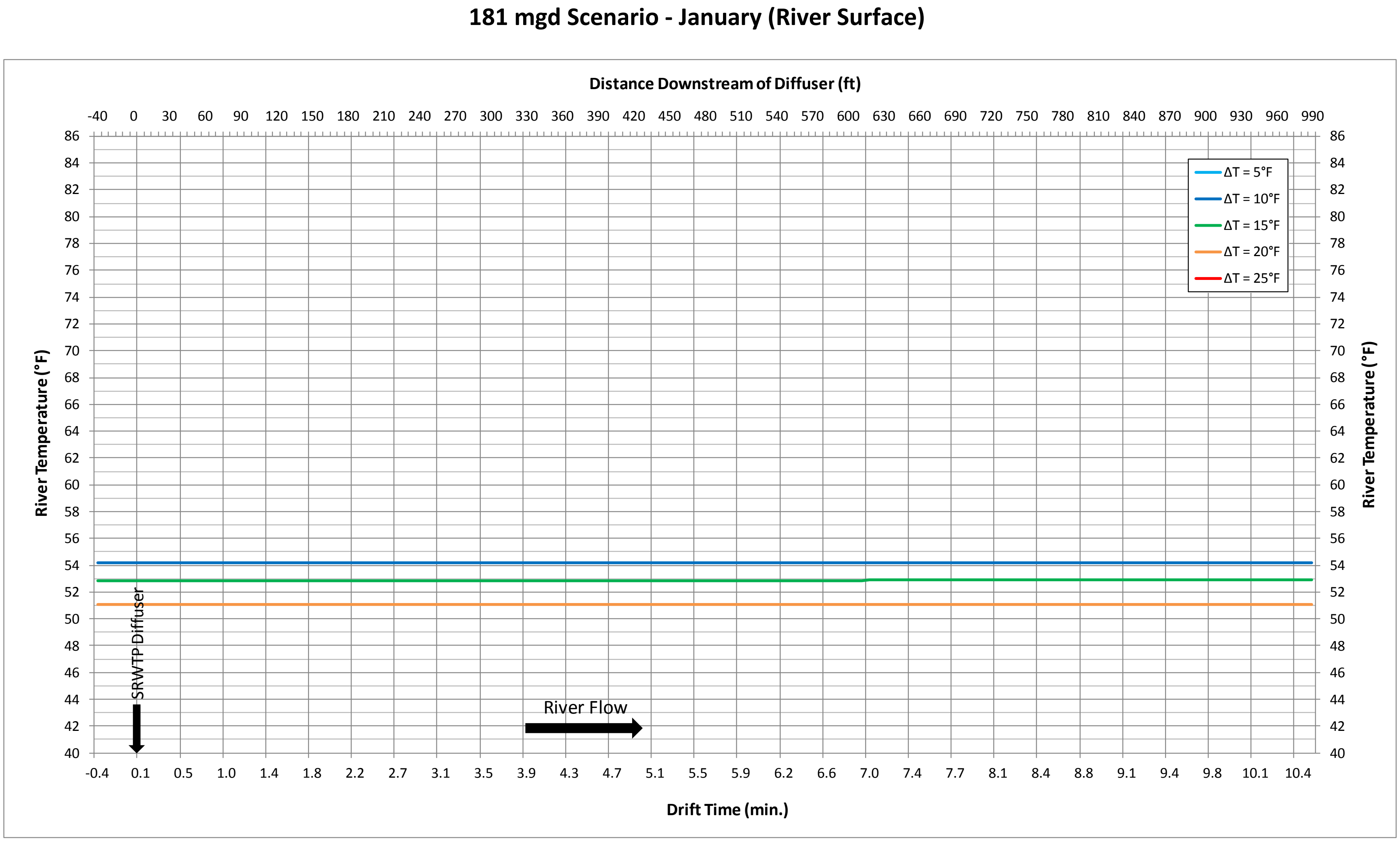


Figure F-8. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of January at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in January at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - February (River Surface)

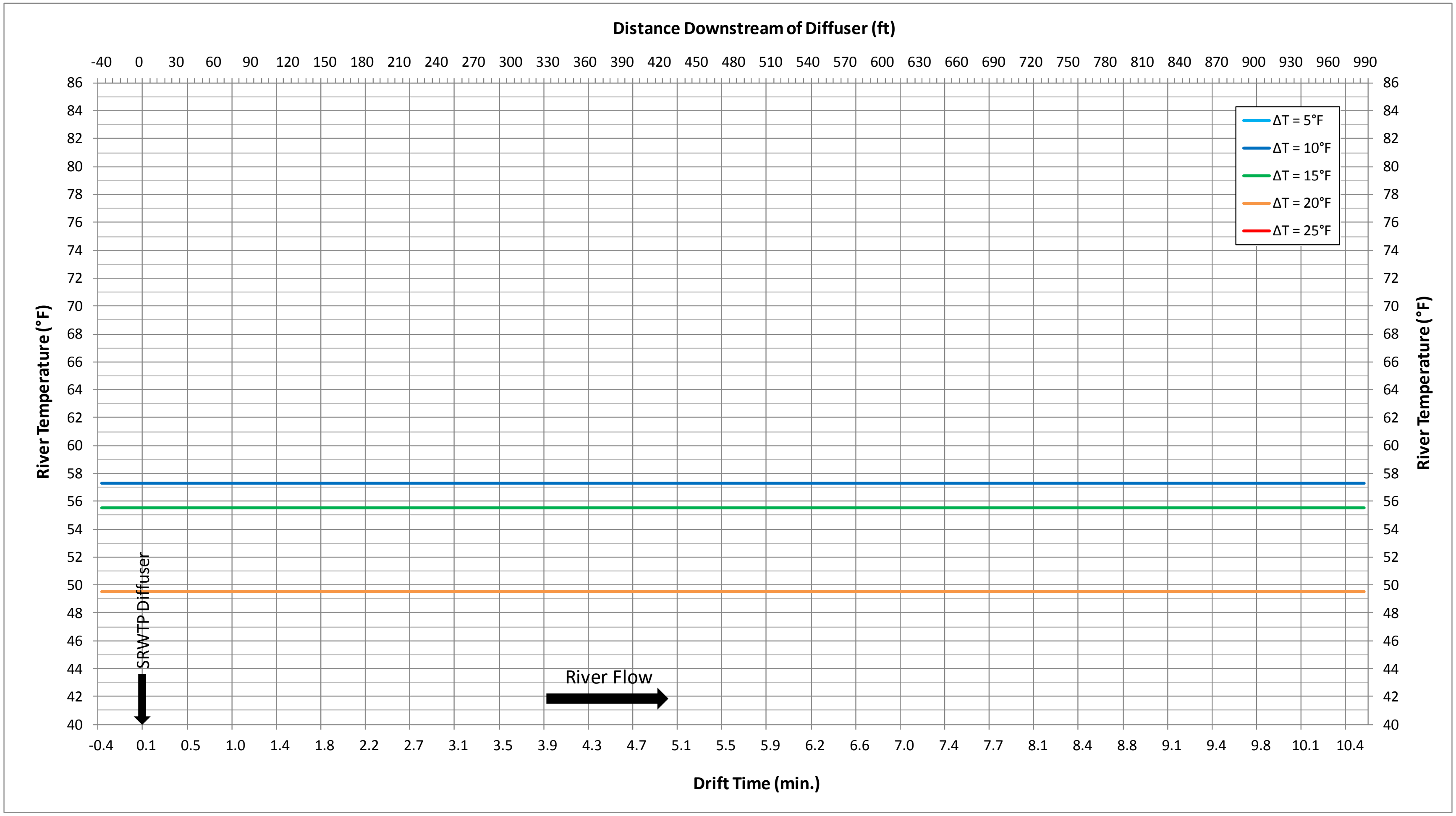


Figure F-9. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of February at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in February at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - March (River Surface)

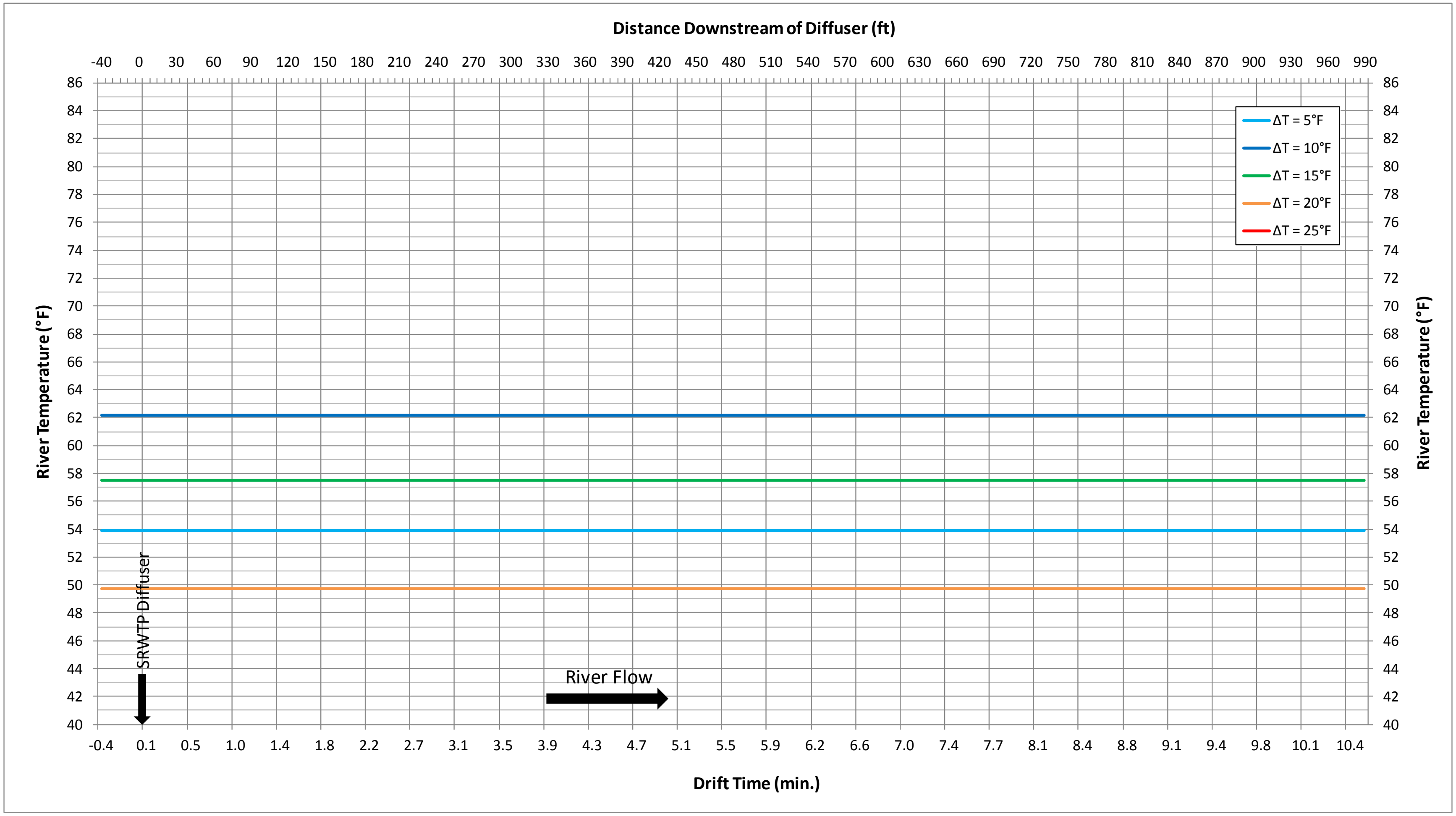


Figure F-10. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of March at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in March at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

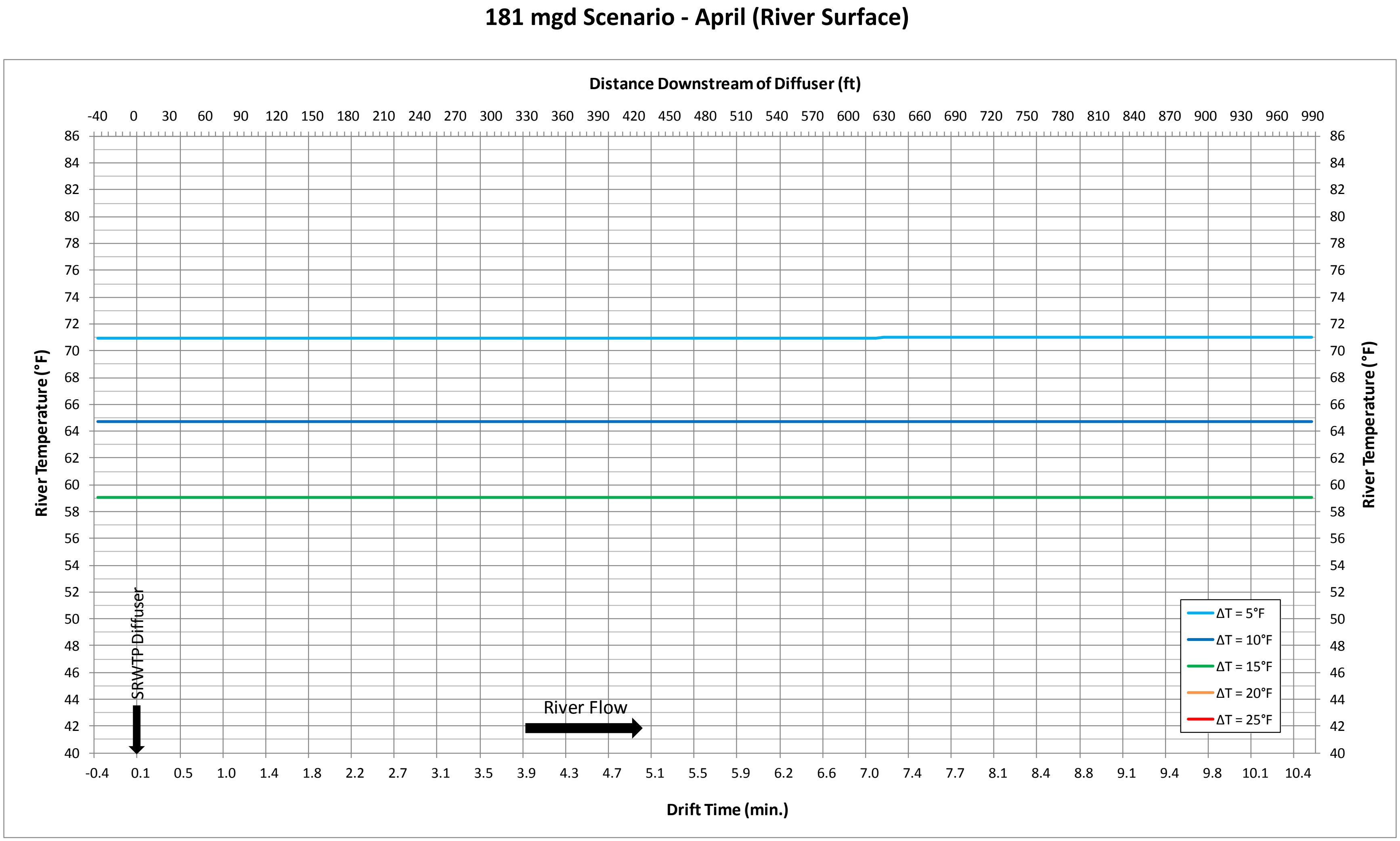


Figure F-11. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of April at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in April at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - May (River Surface)

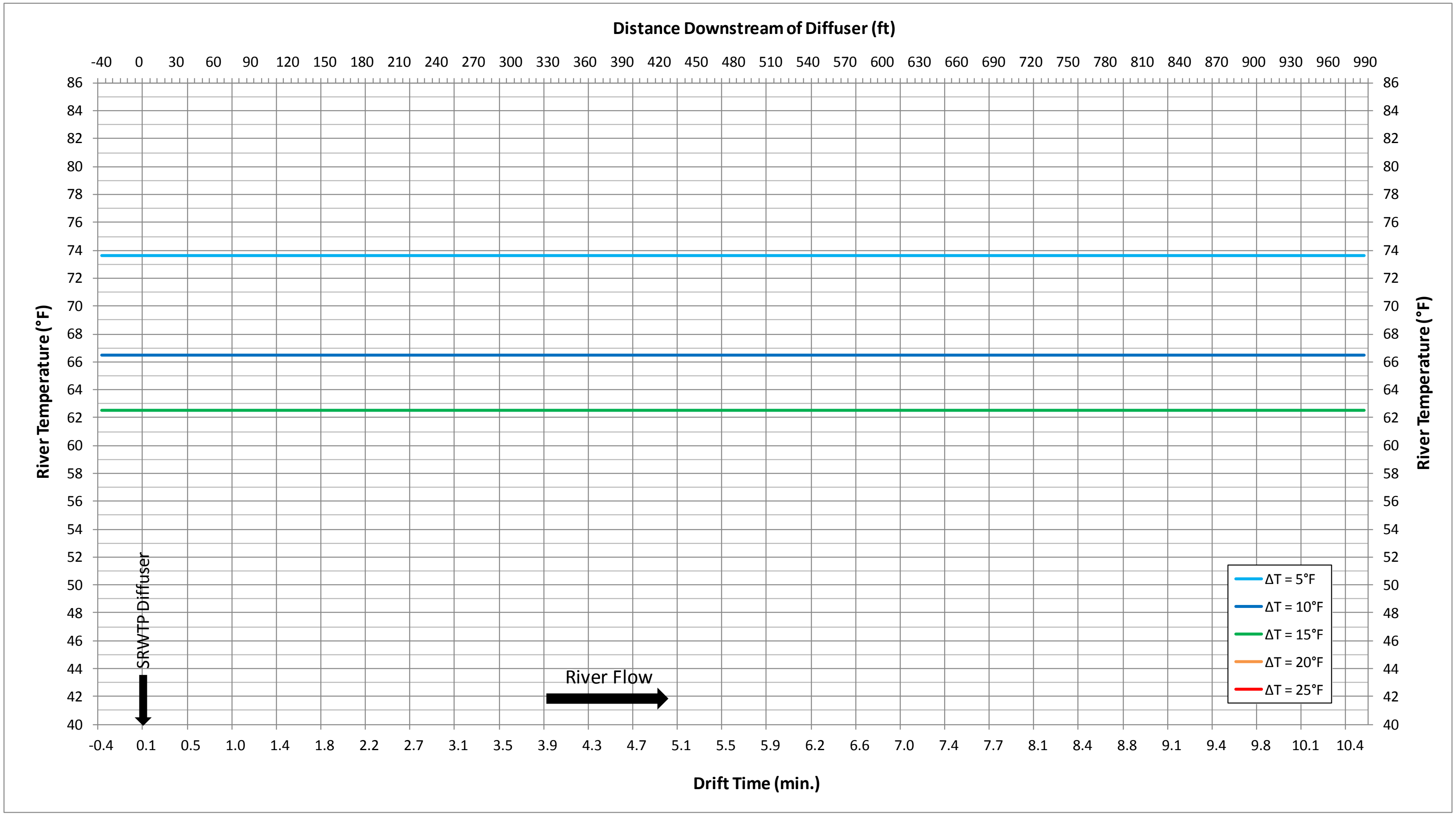


Figure F-12. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of May at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in May at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - June (River Surface)

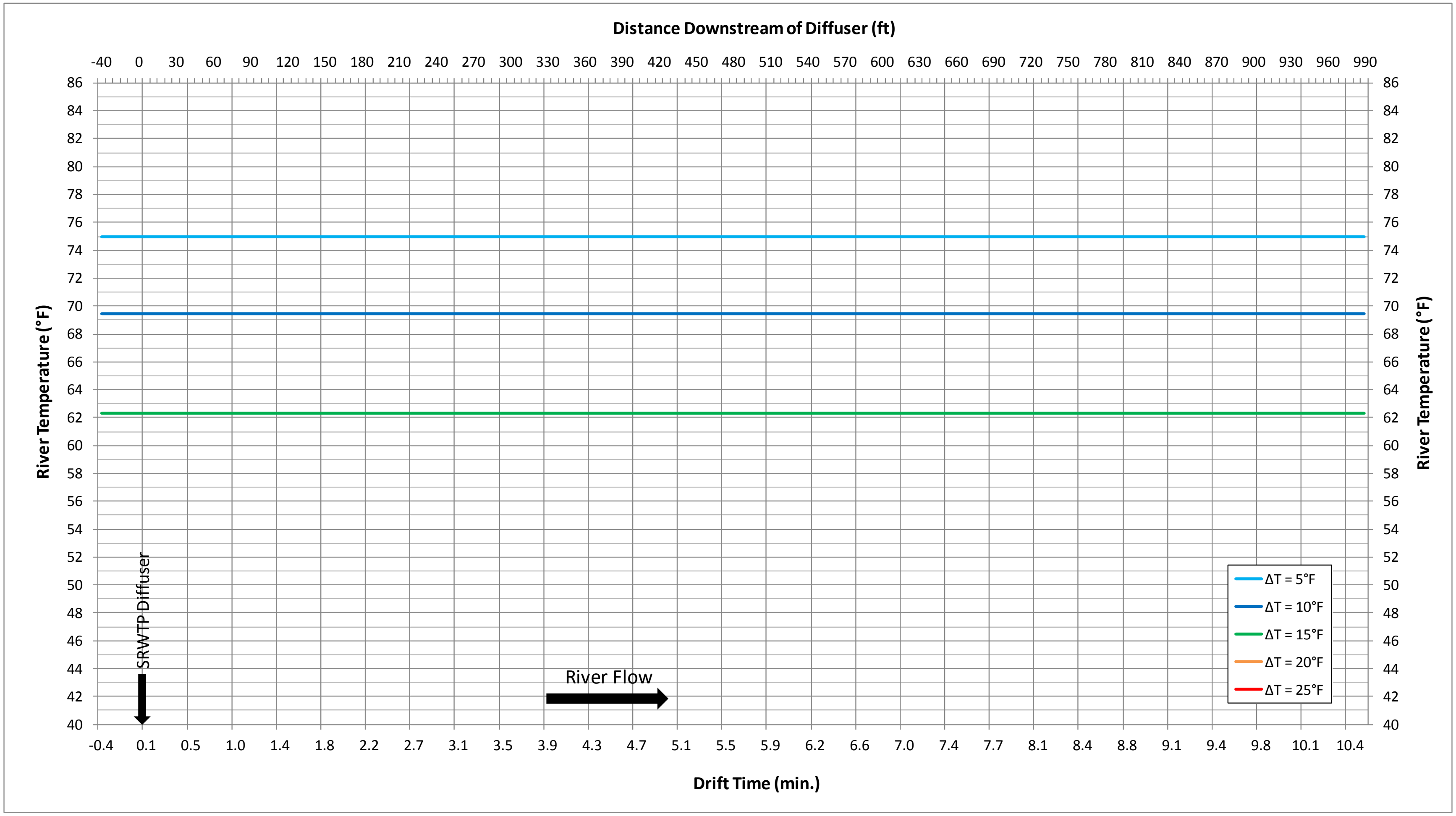


Figure F-13. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of June at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in June at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

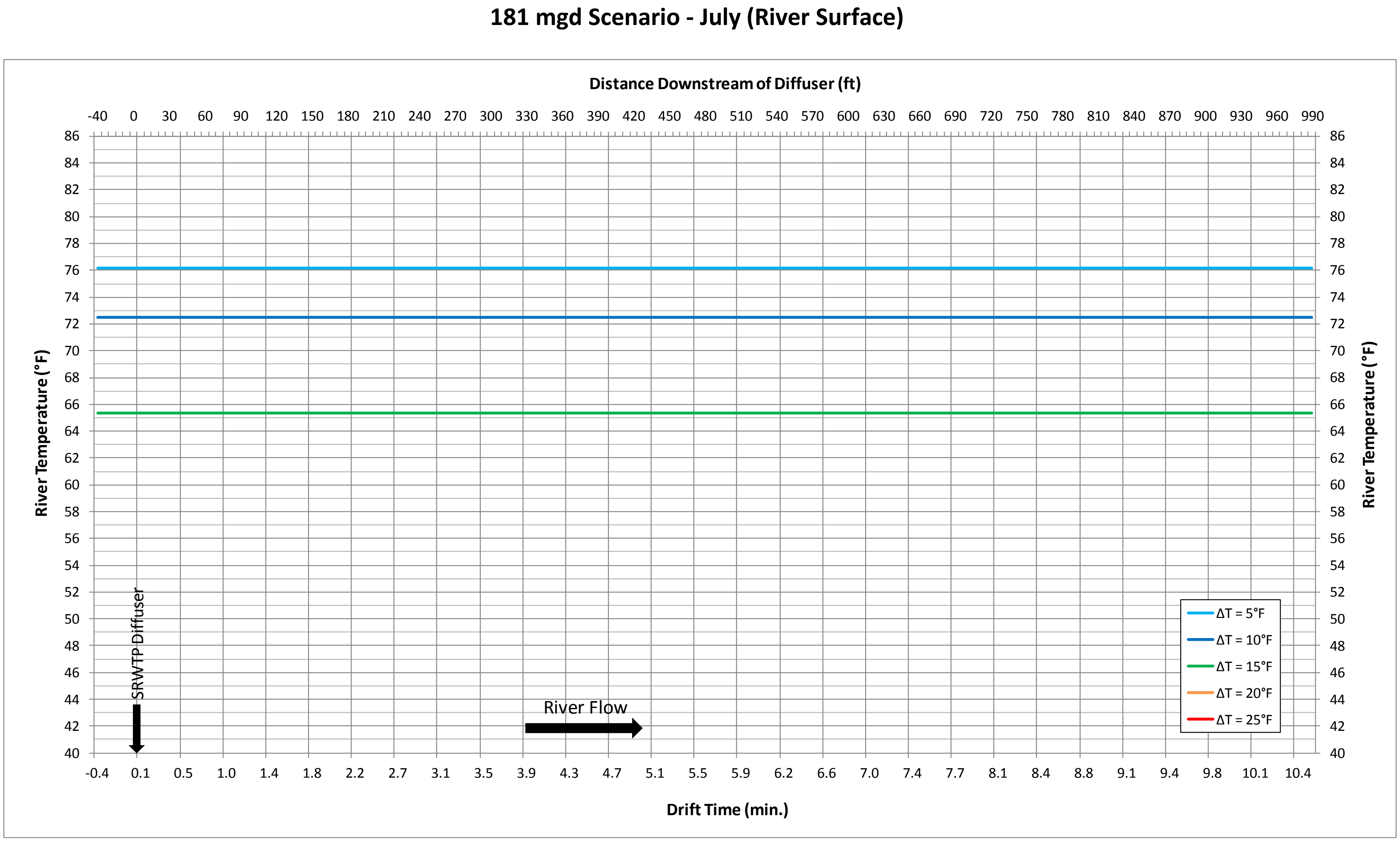


Figure F-14. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of July at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in July at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

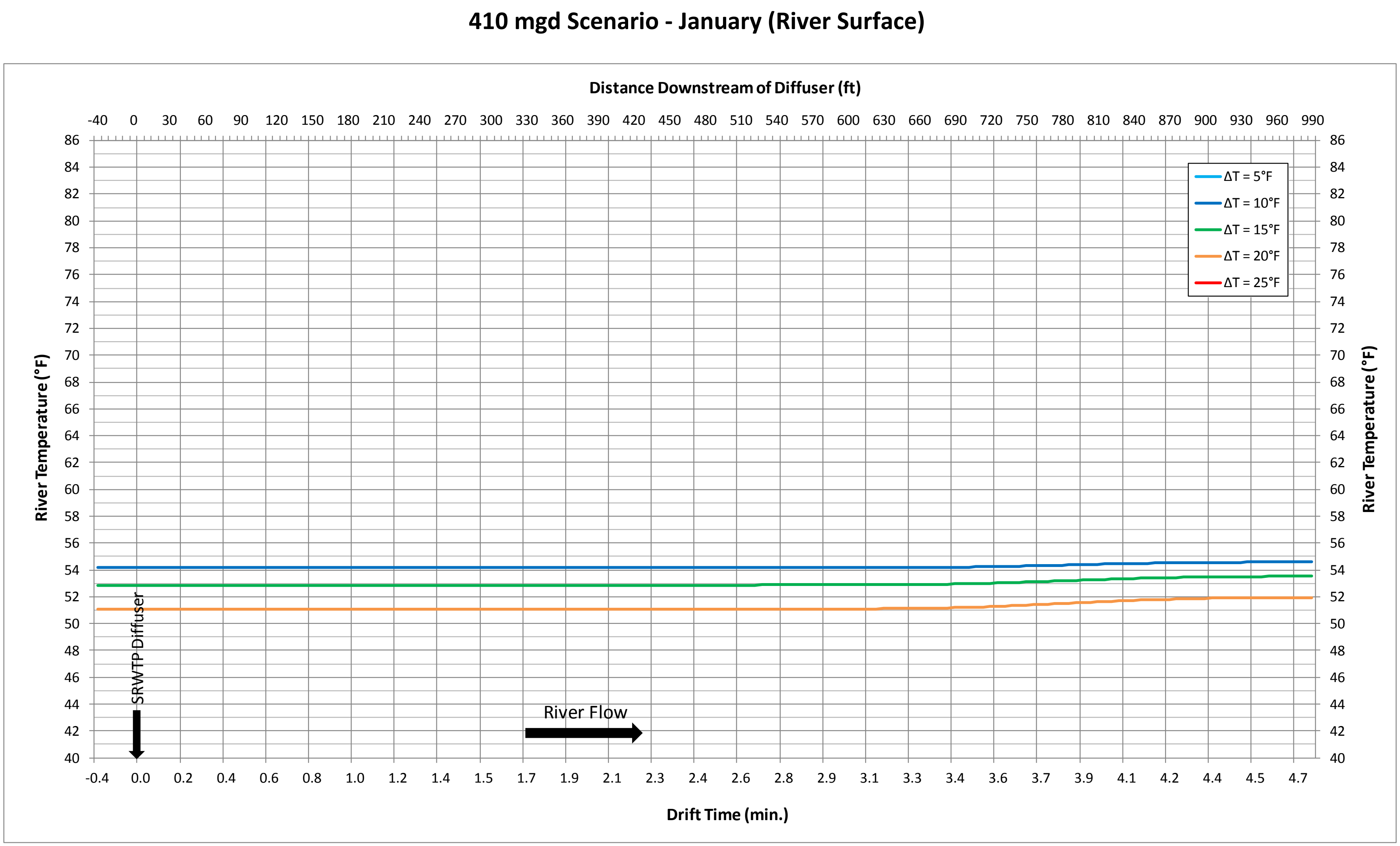


Figure F-15. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of January at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in January at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

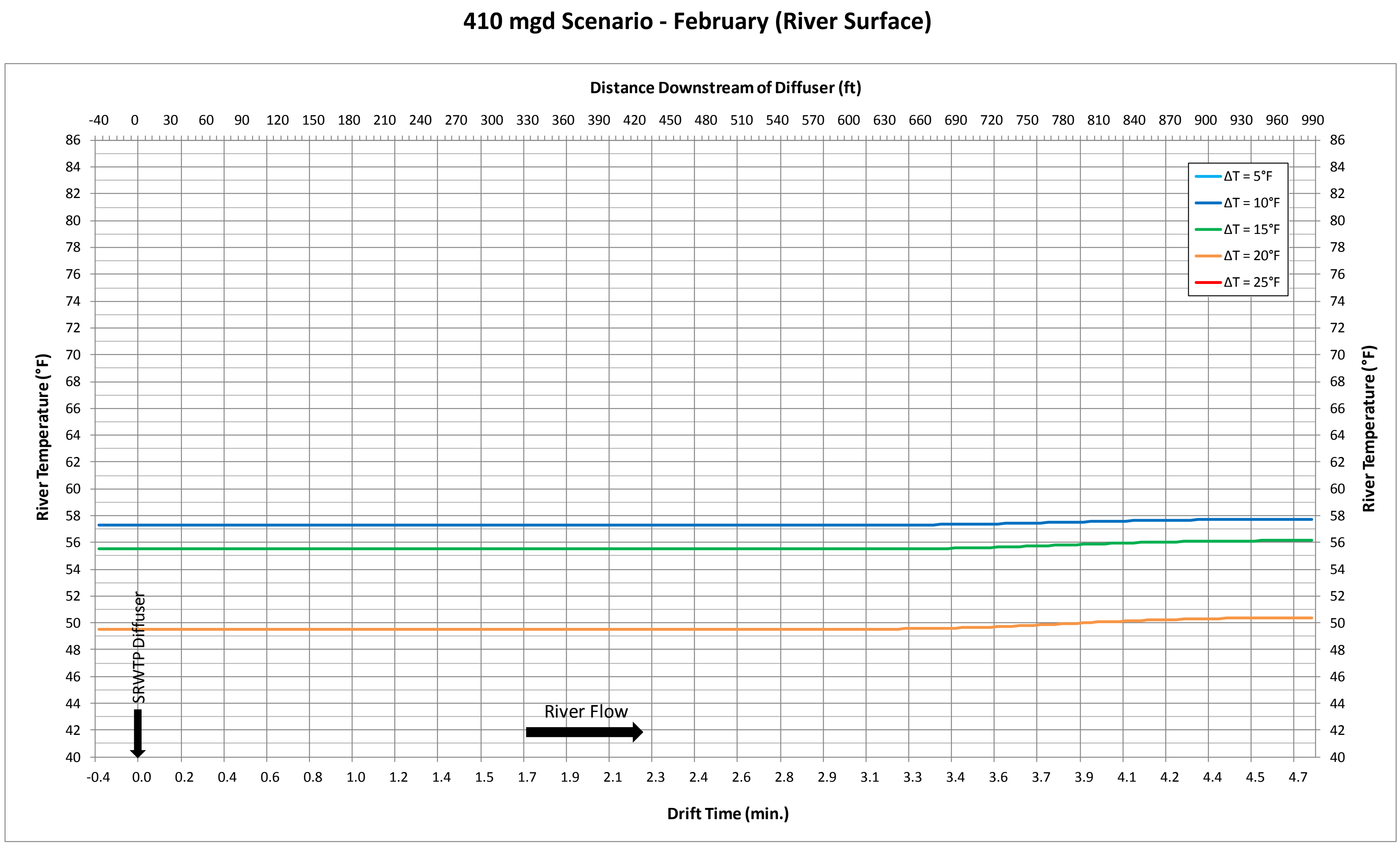


Figure F-16. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of February at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in February at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

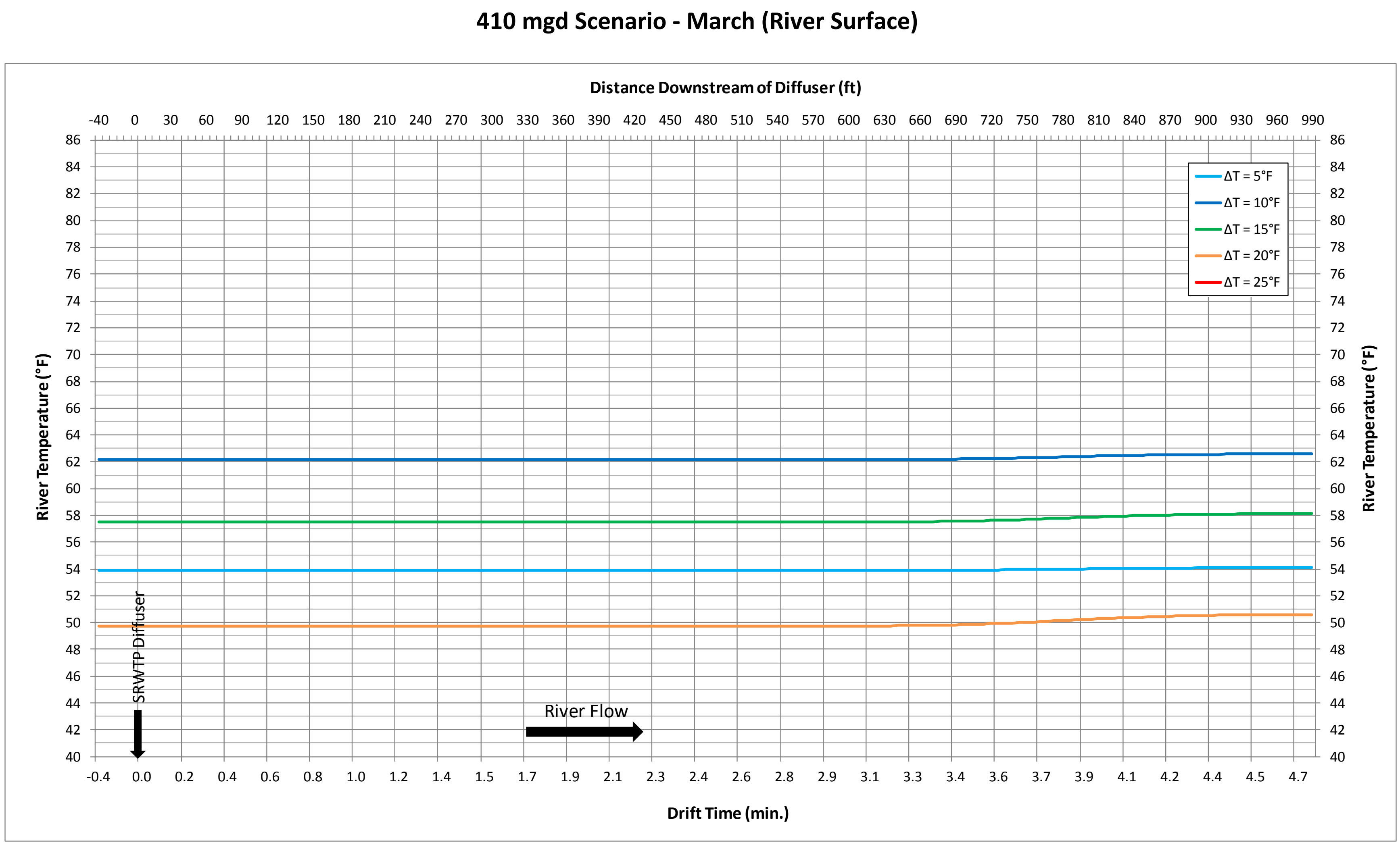


Figure F-17. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of March at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in March at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

410 mgd Scenario - April (River Surface)

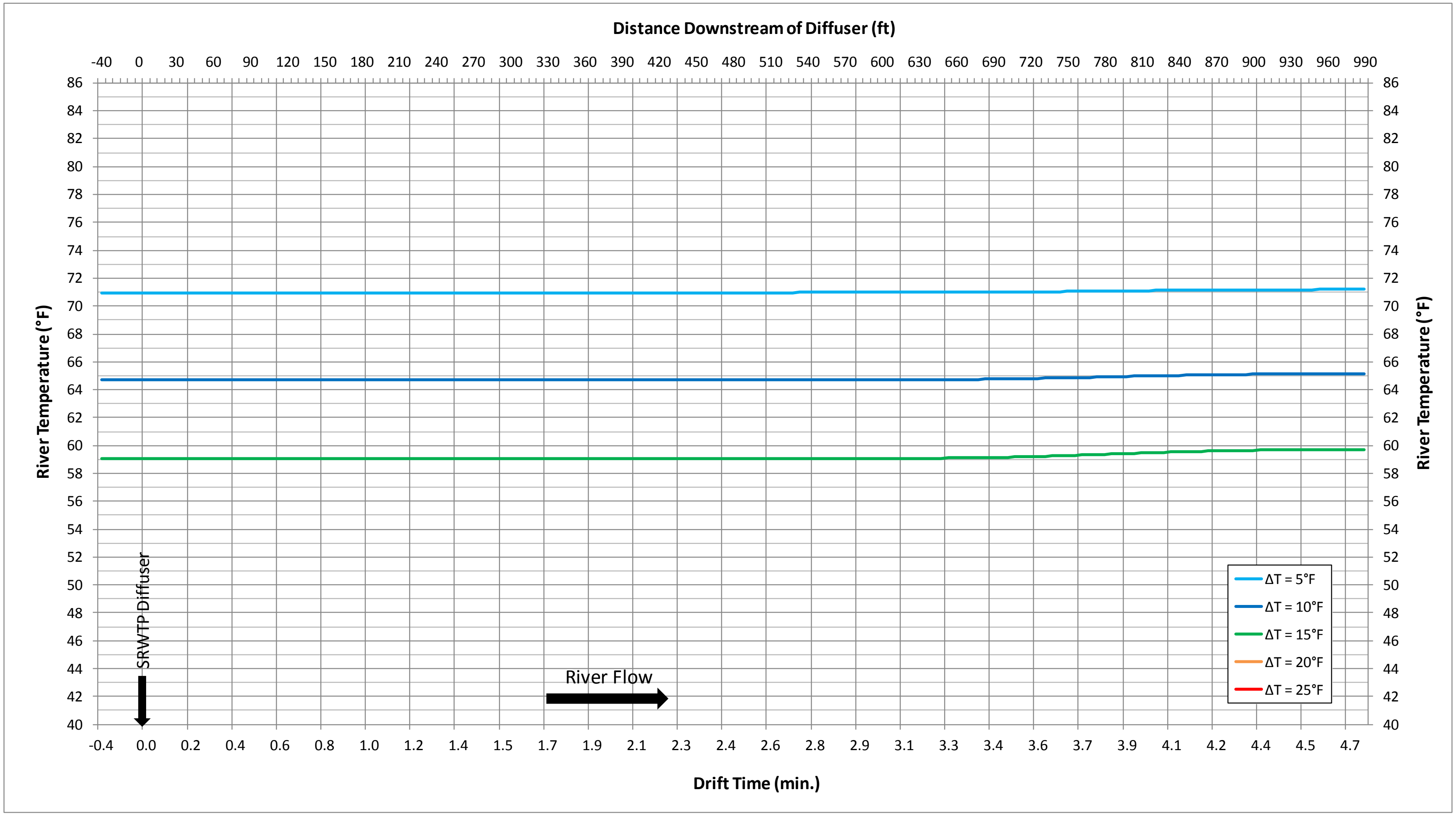


Figure F-18. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of April at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in April at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

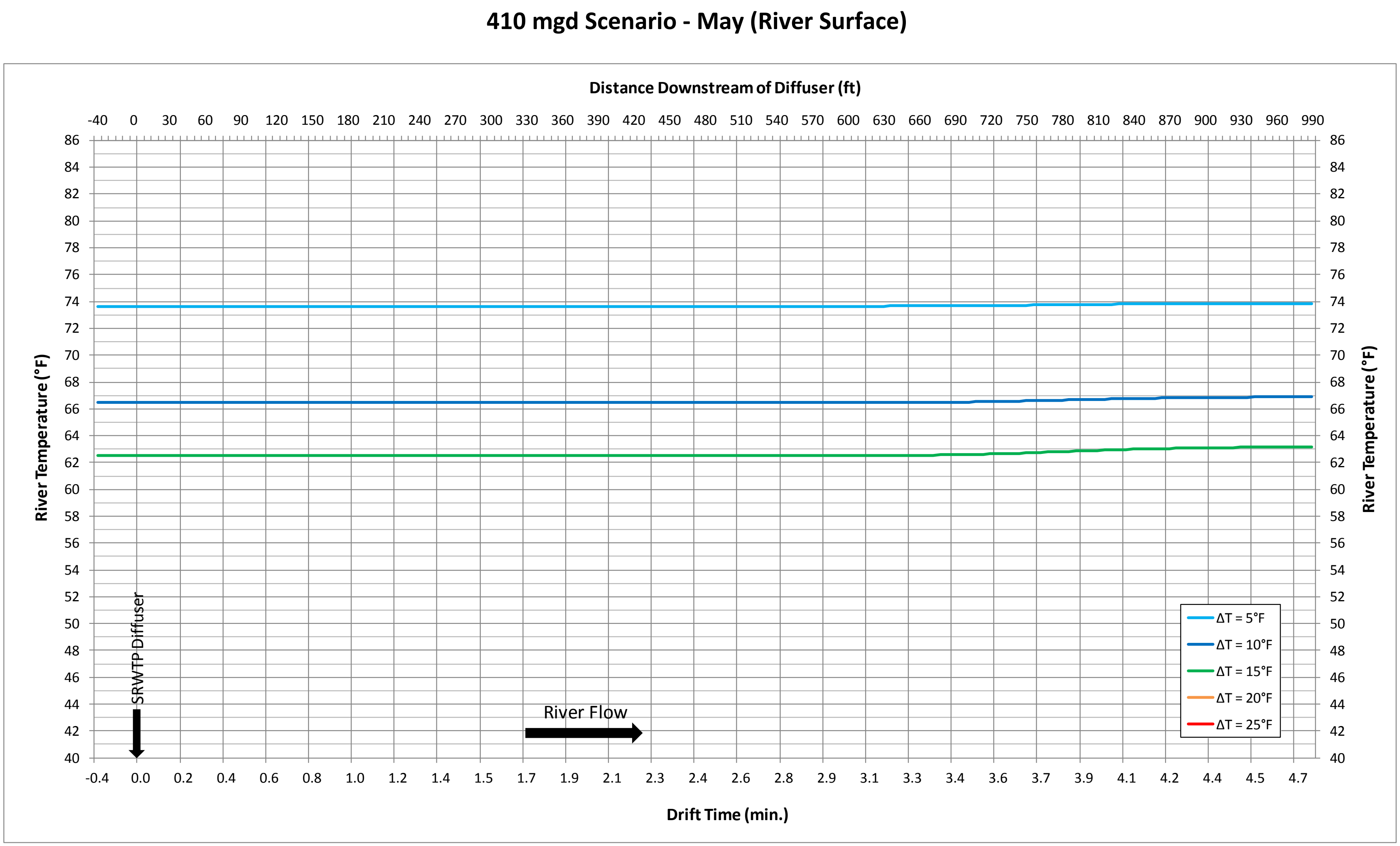


Figure F-19. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of May at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in May at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

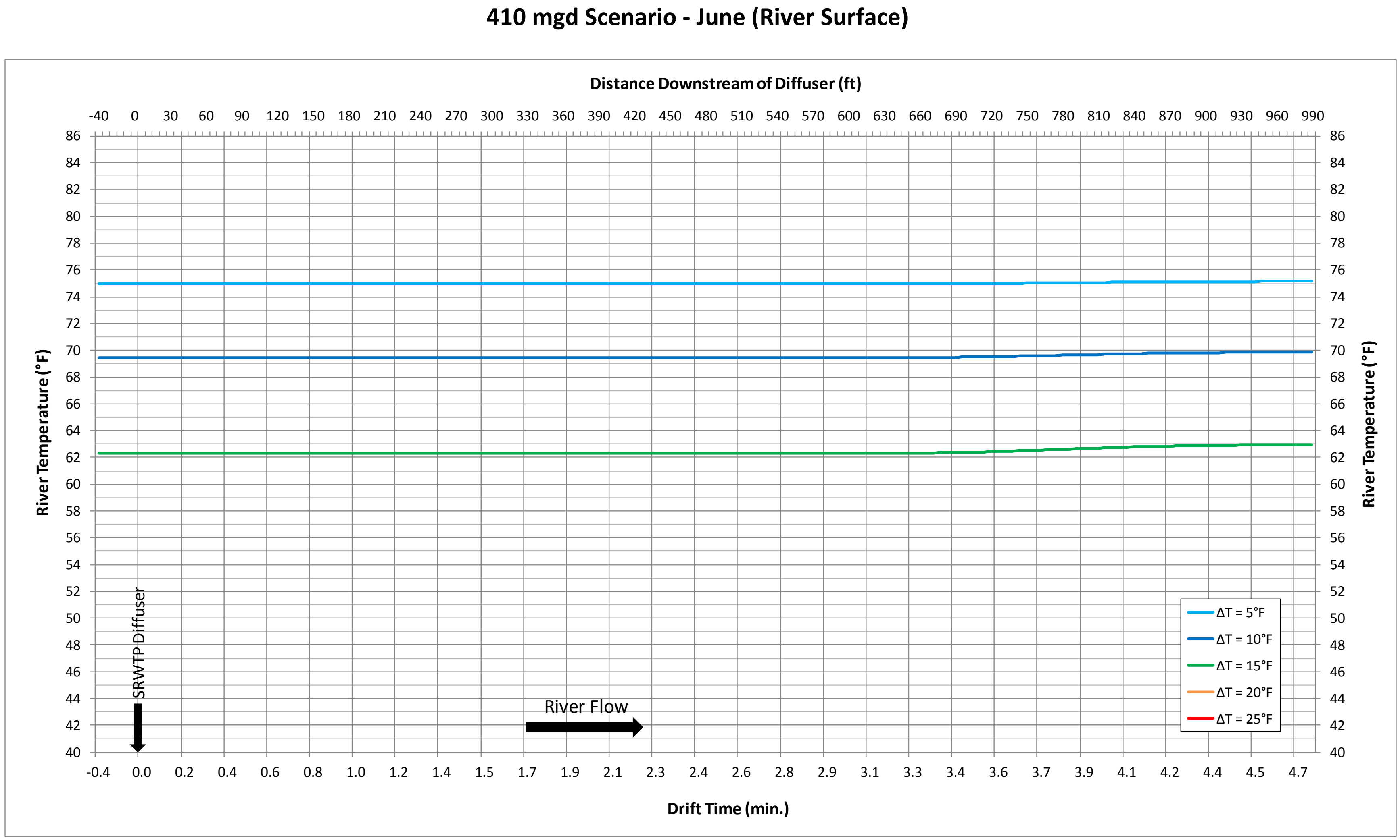


Figure F-20. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of June at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in June at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

410 mgd Scenario - July (River Surface)

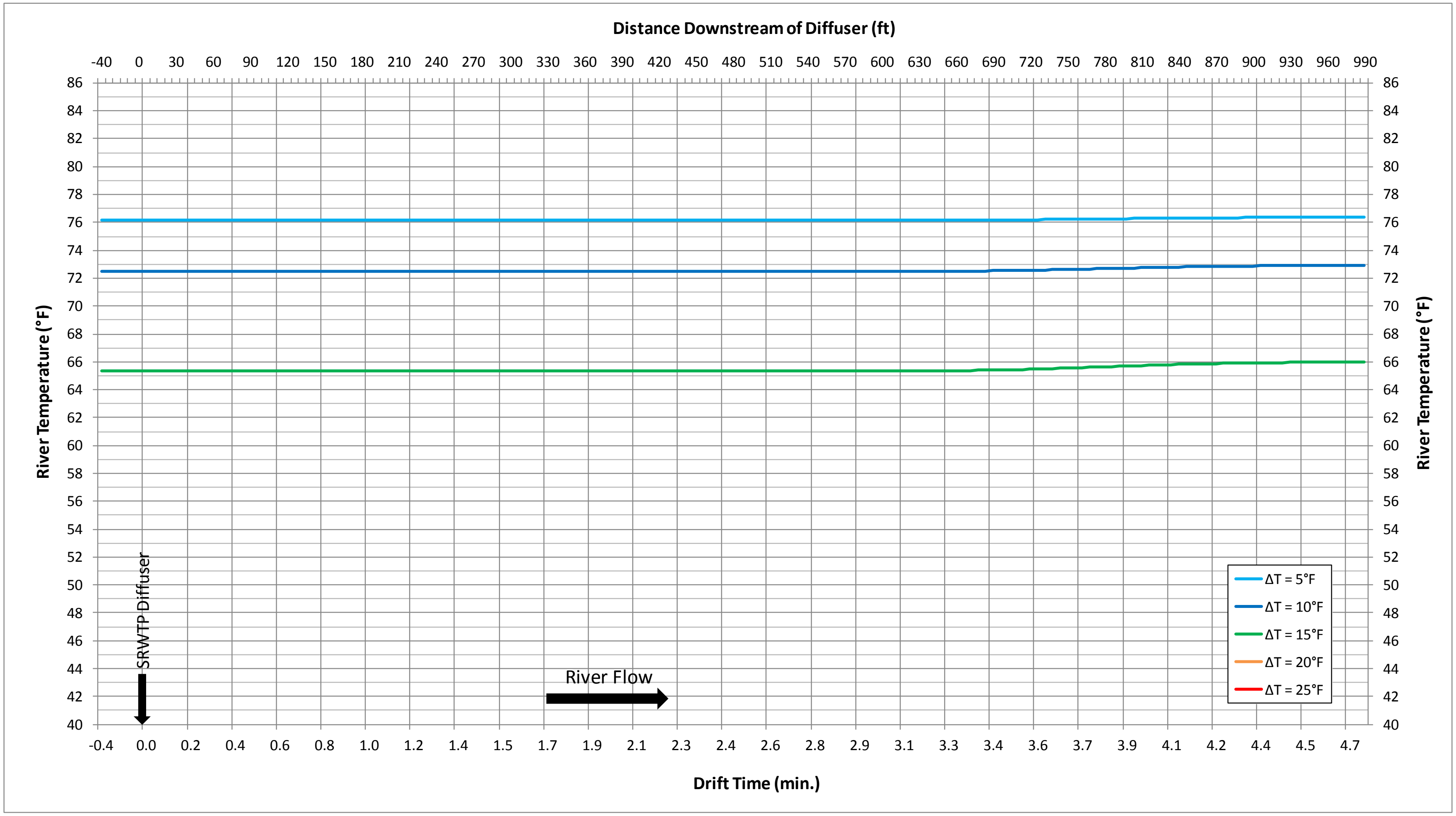


Figure F-21. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the water surface during the month of July at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in July at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

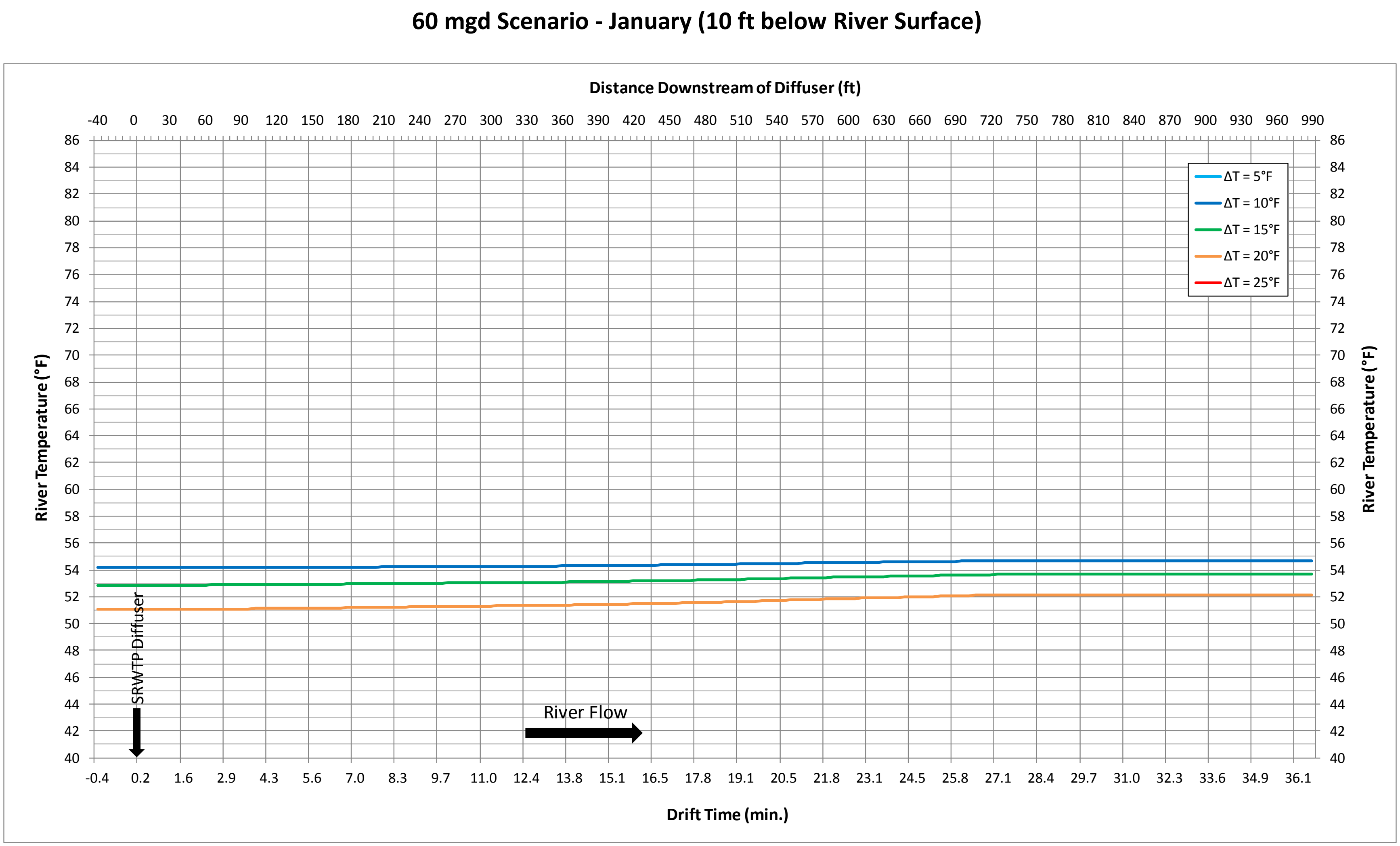


Figure F-22. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of January at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in January at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - February (10 ft below River Surface)

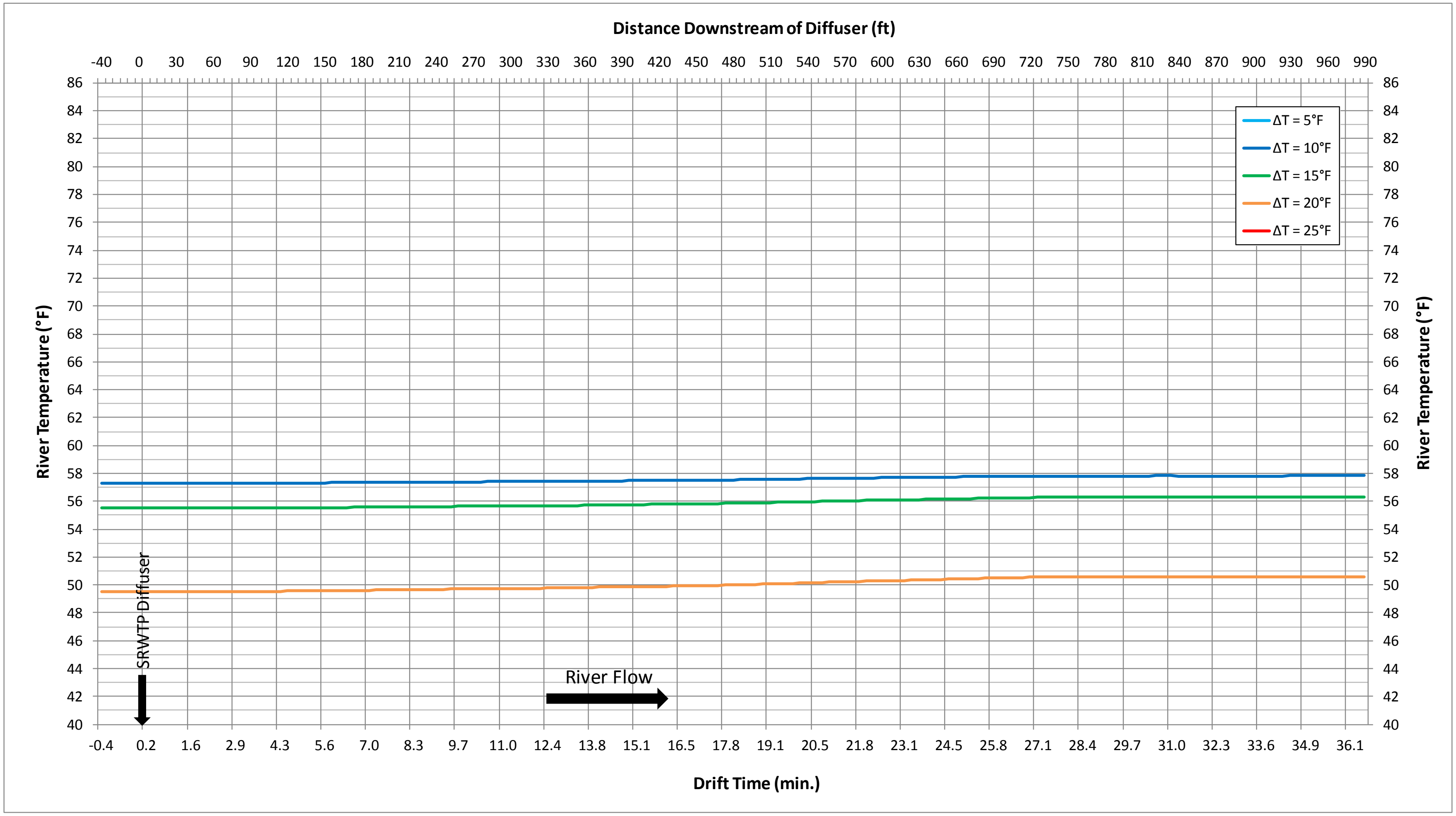


Figure F-23. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of February at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in February at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

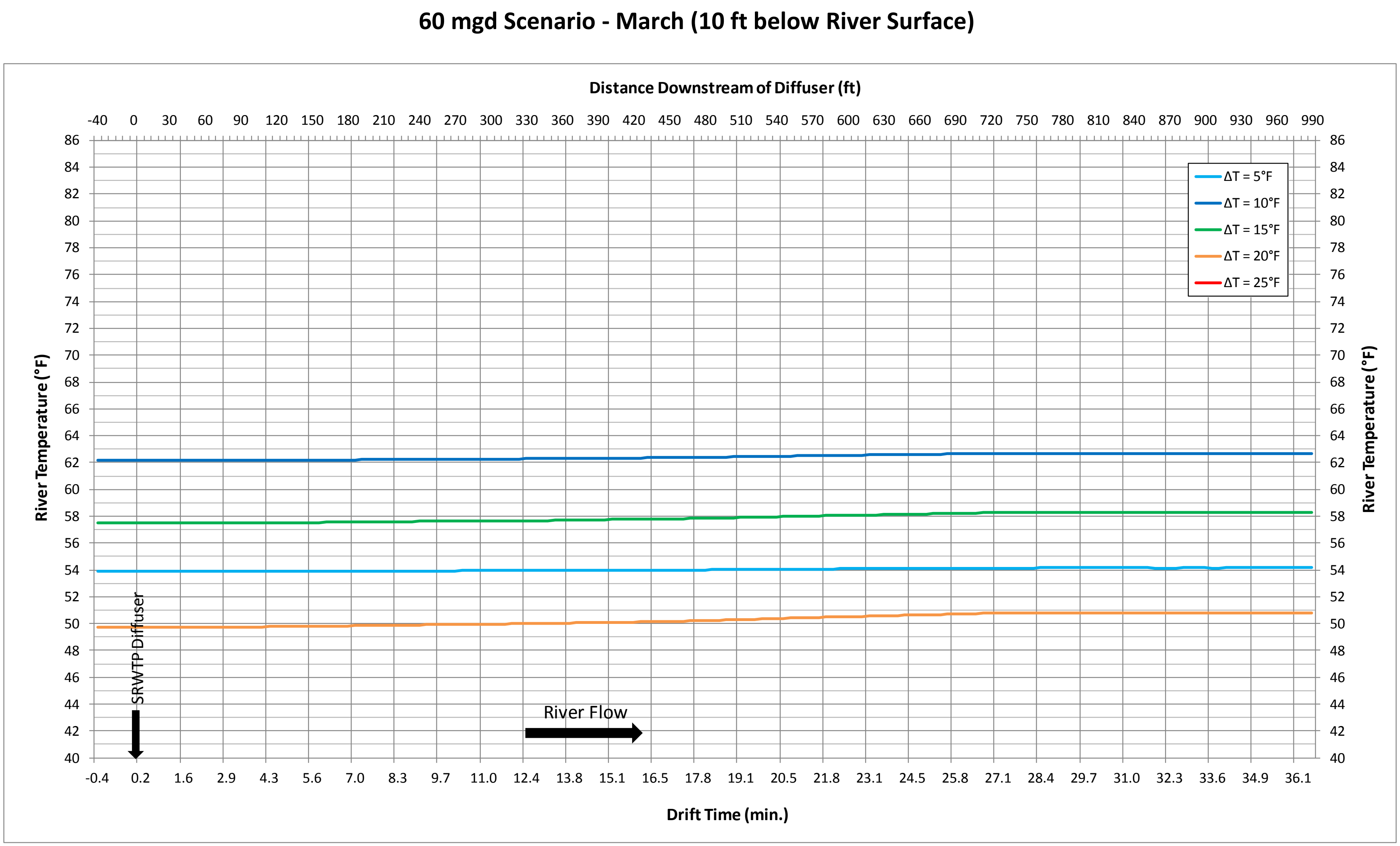


Figure F-24. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of March at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in March at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - April (10 ft below River Surface)

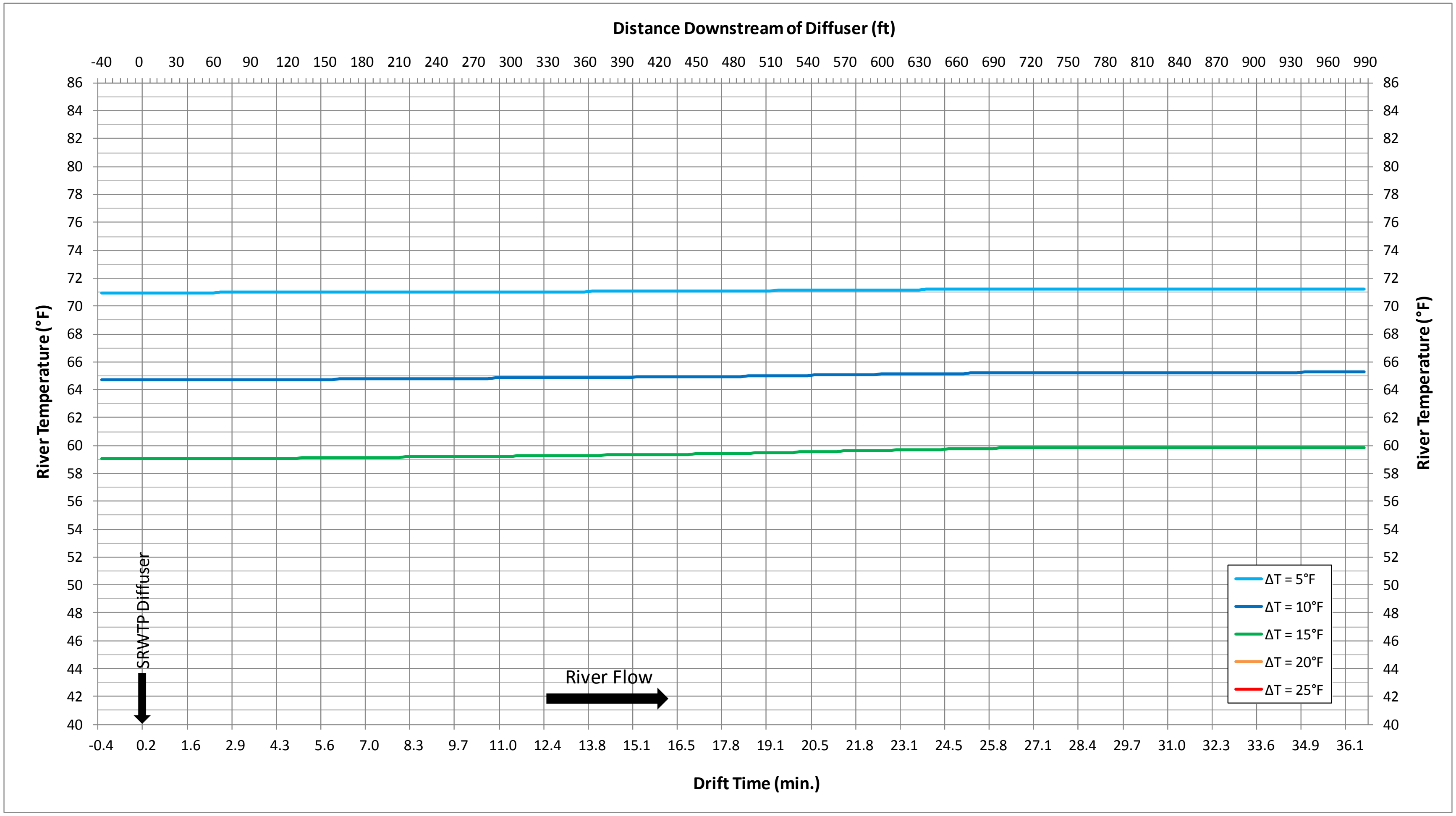


Figure F-25. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of April at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in April at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - May (10 ft below River Surface)

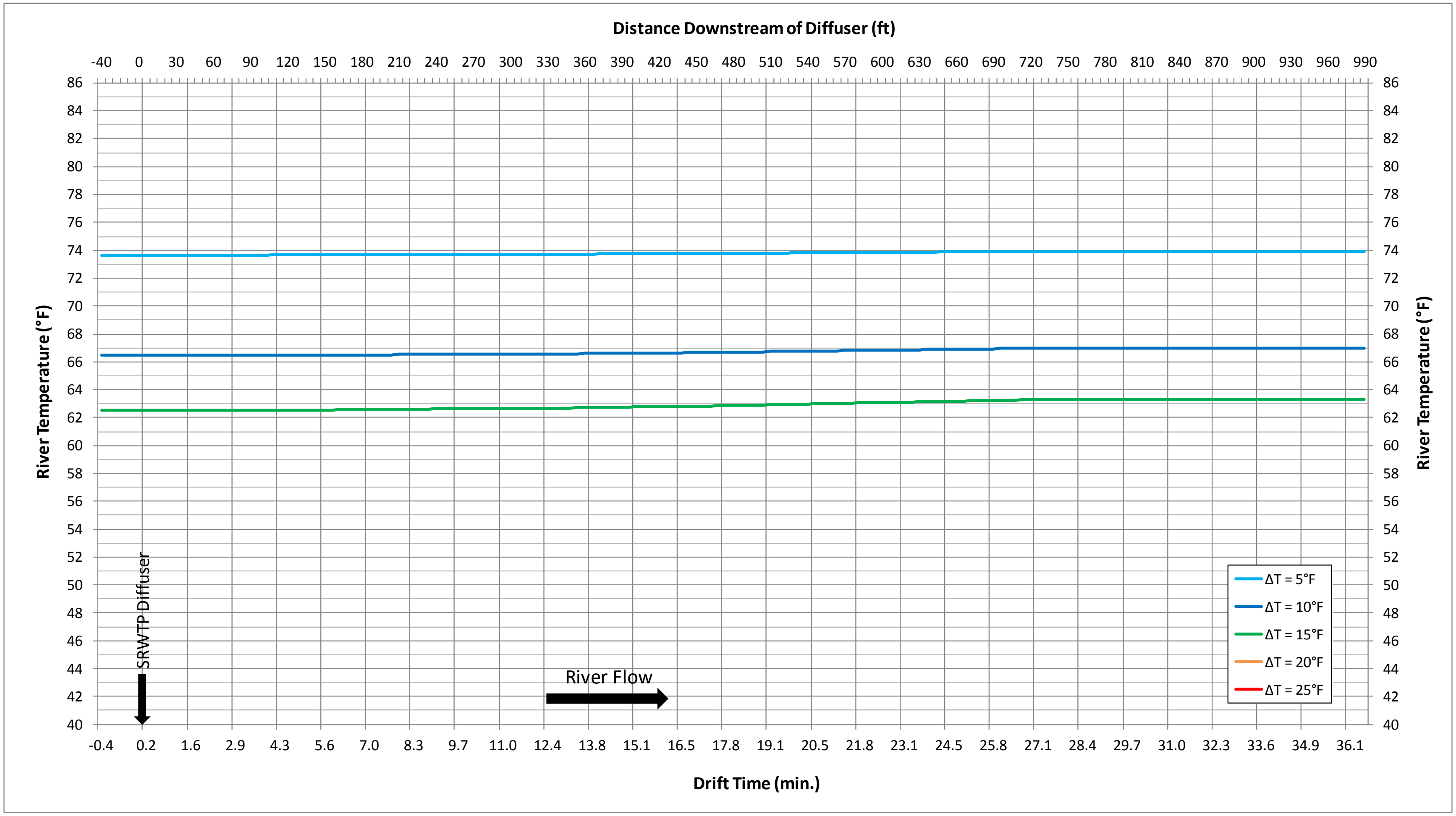


Figure F-26. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of May at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in May at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

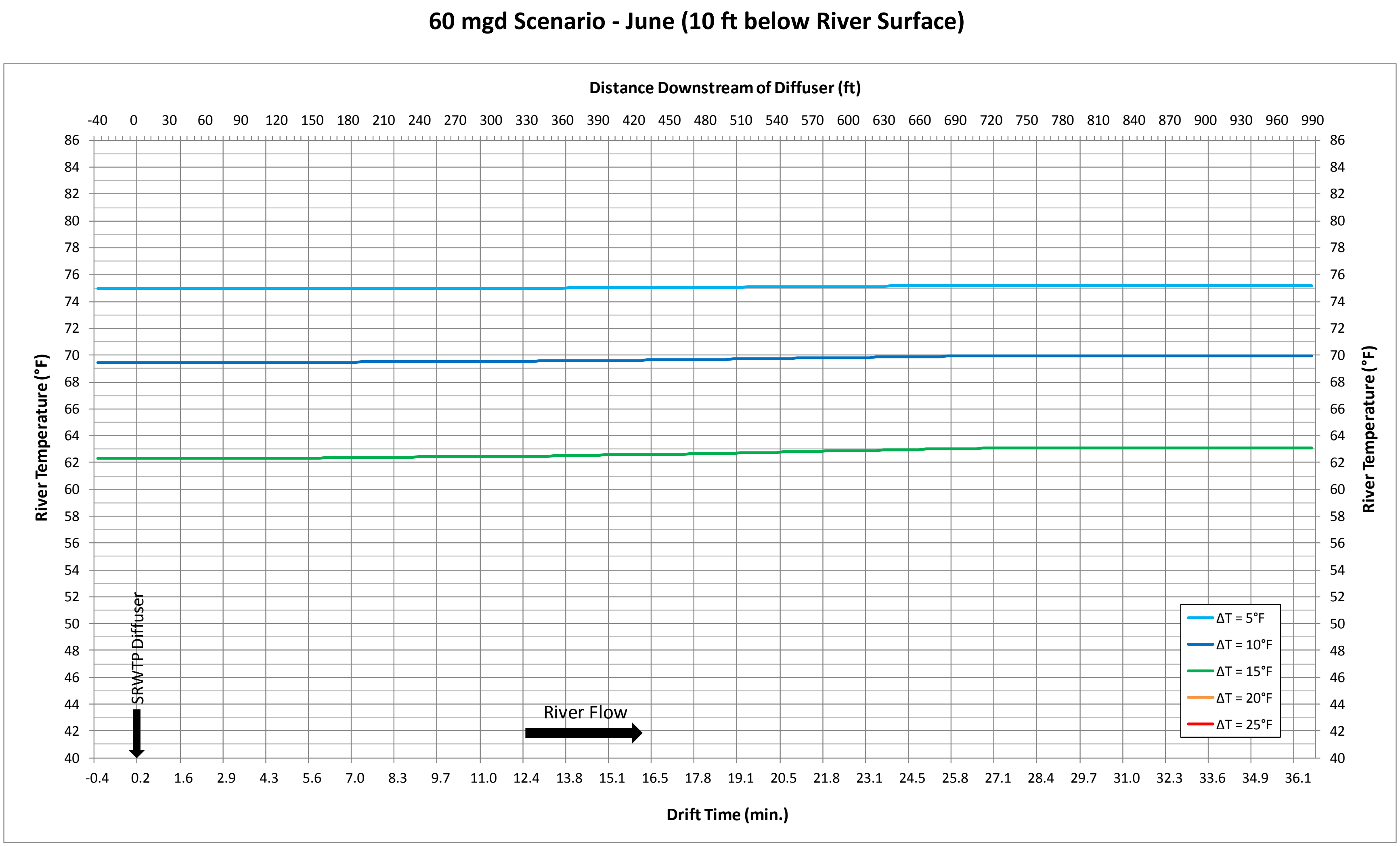


Figure F-27. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of June at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in June at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

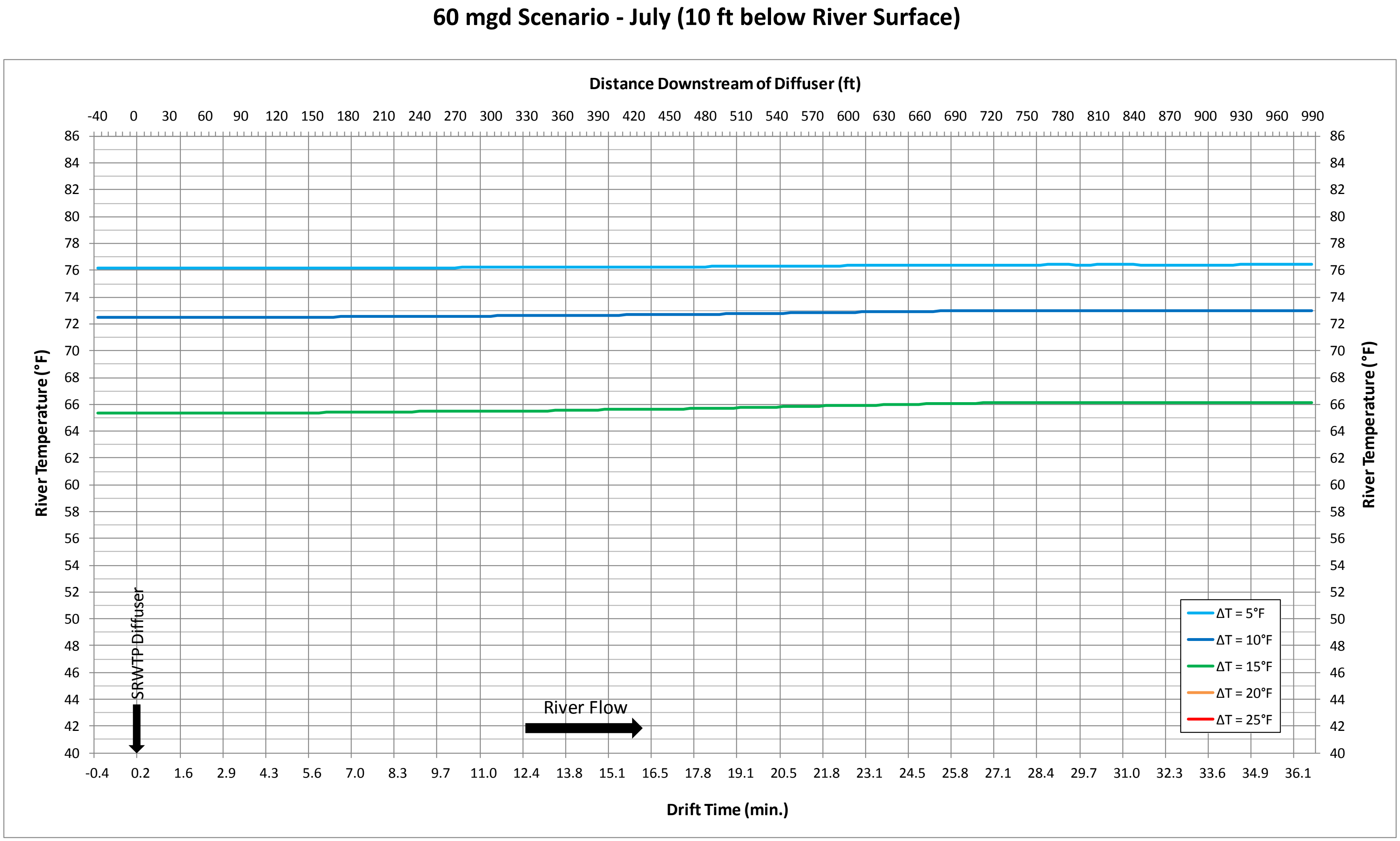


Figure F-28. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of July at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in July at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

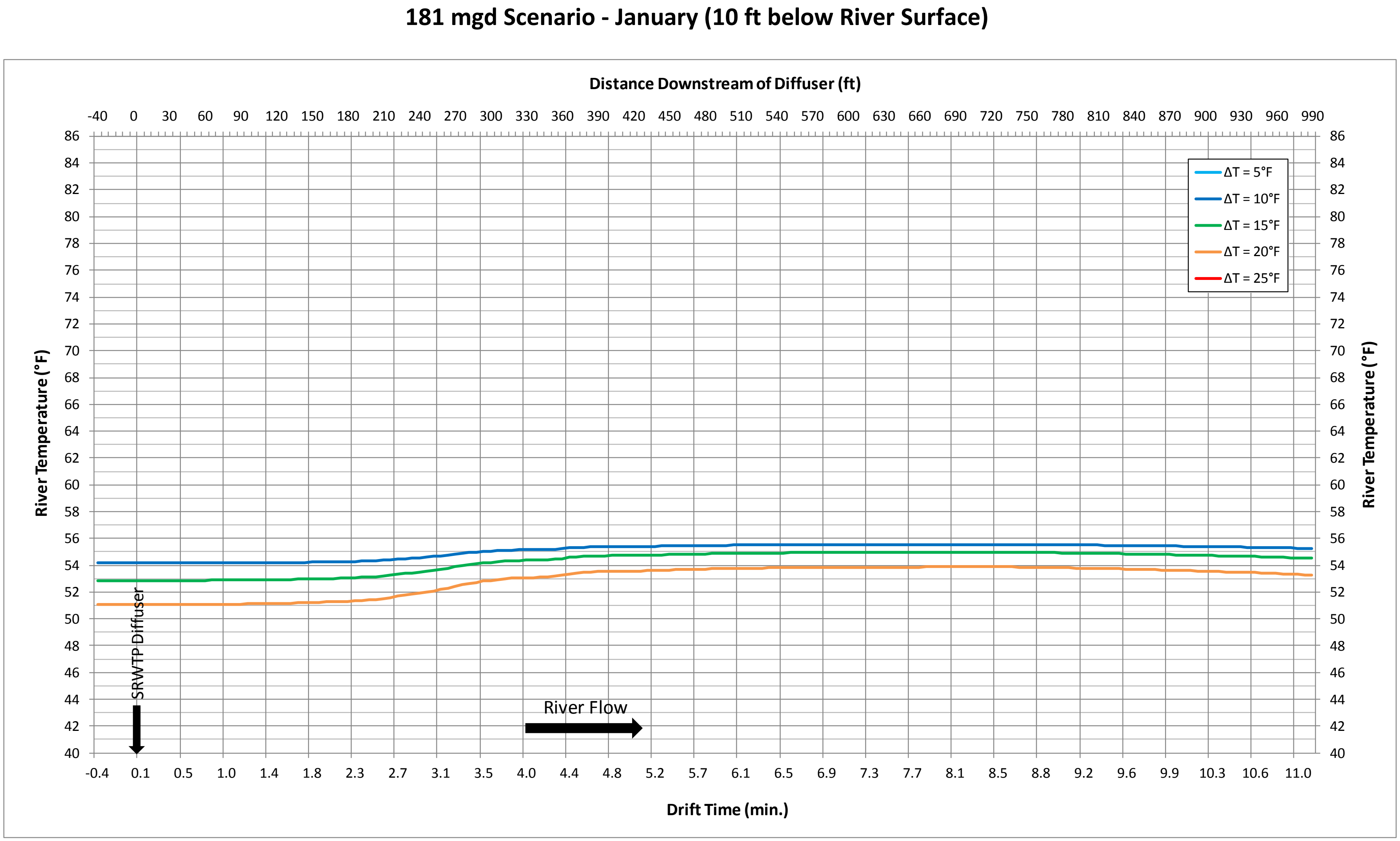


Figure F-29. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of January at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in January at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

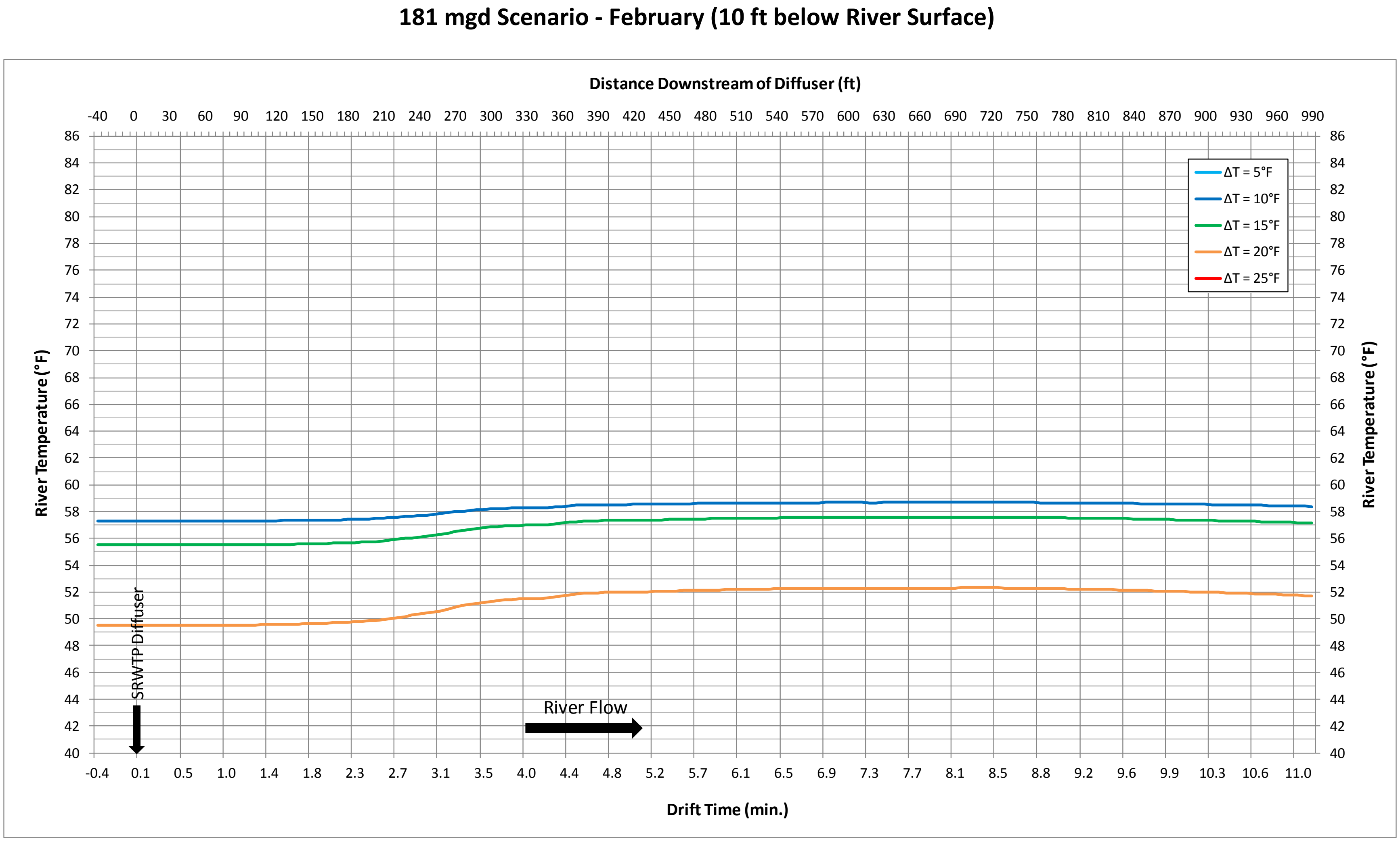


Figure F-30. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of February at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in February at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

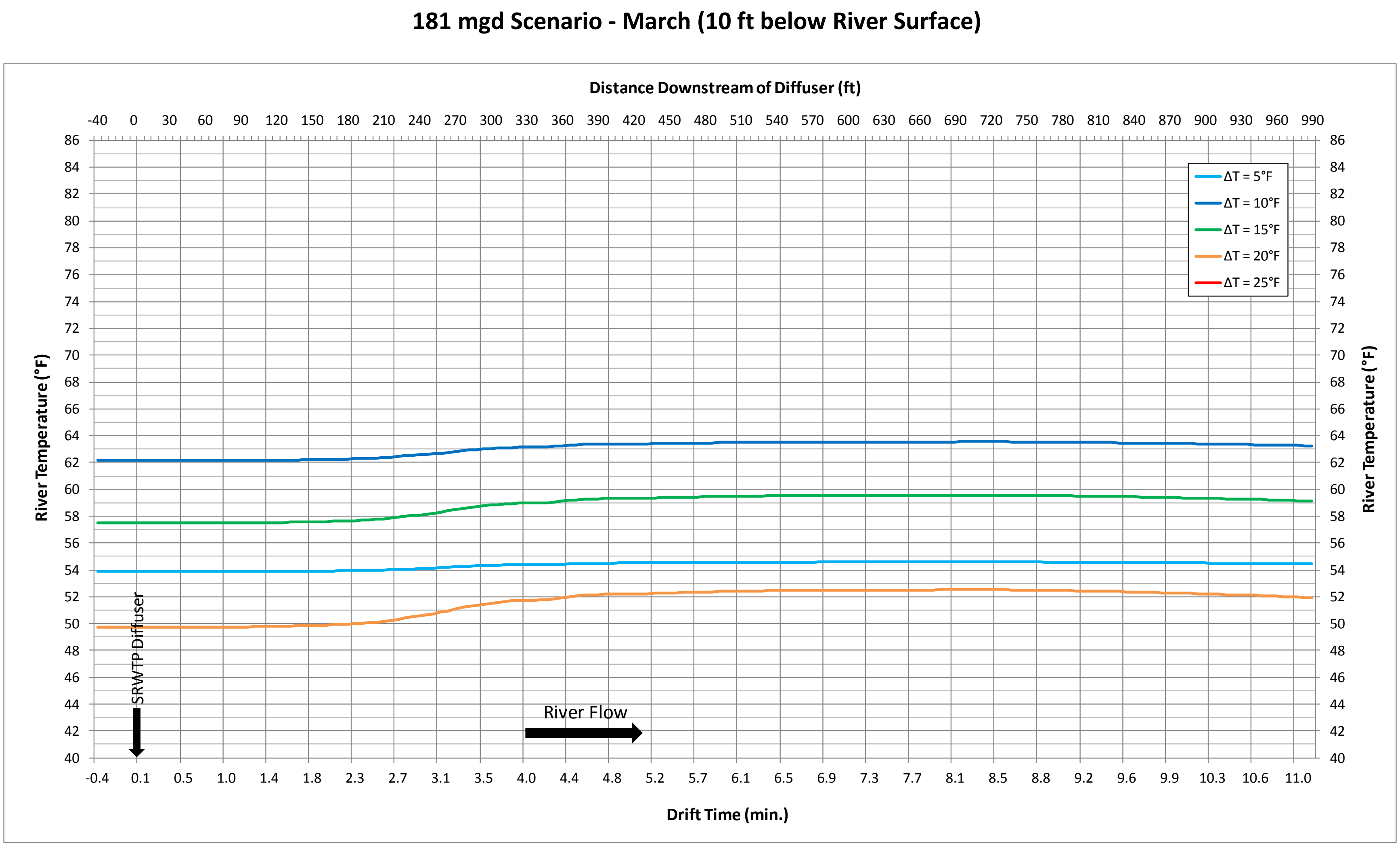


Figure F-31. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of March at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in March at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - April (10 ft below River Surface)

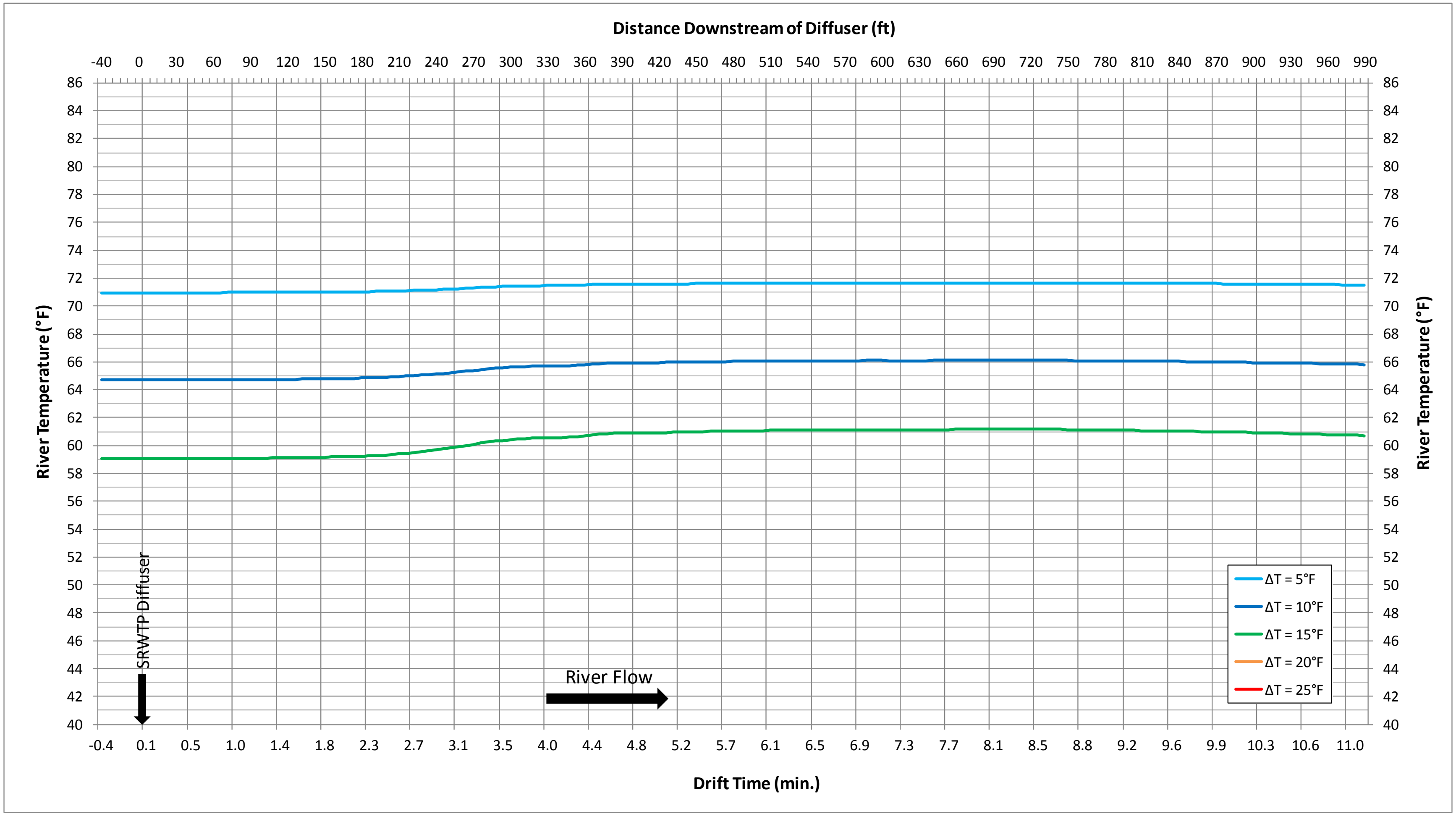


Figure F-32. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of April at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in April at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - May (10 ft below River Surface)

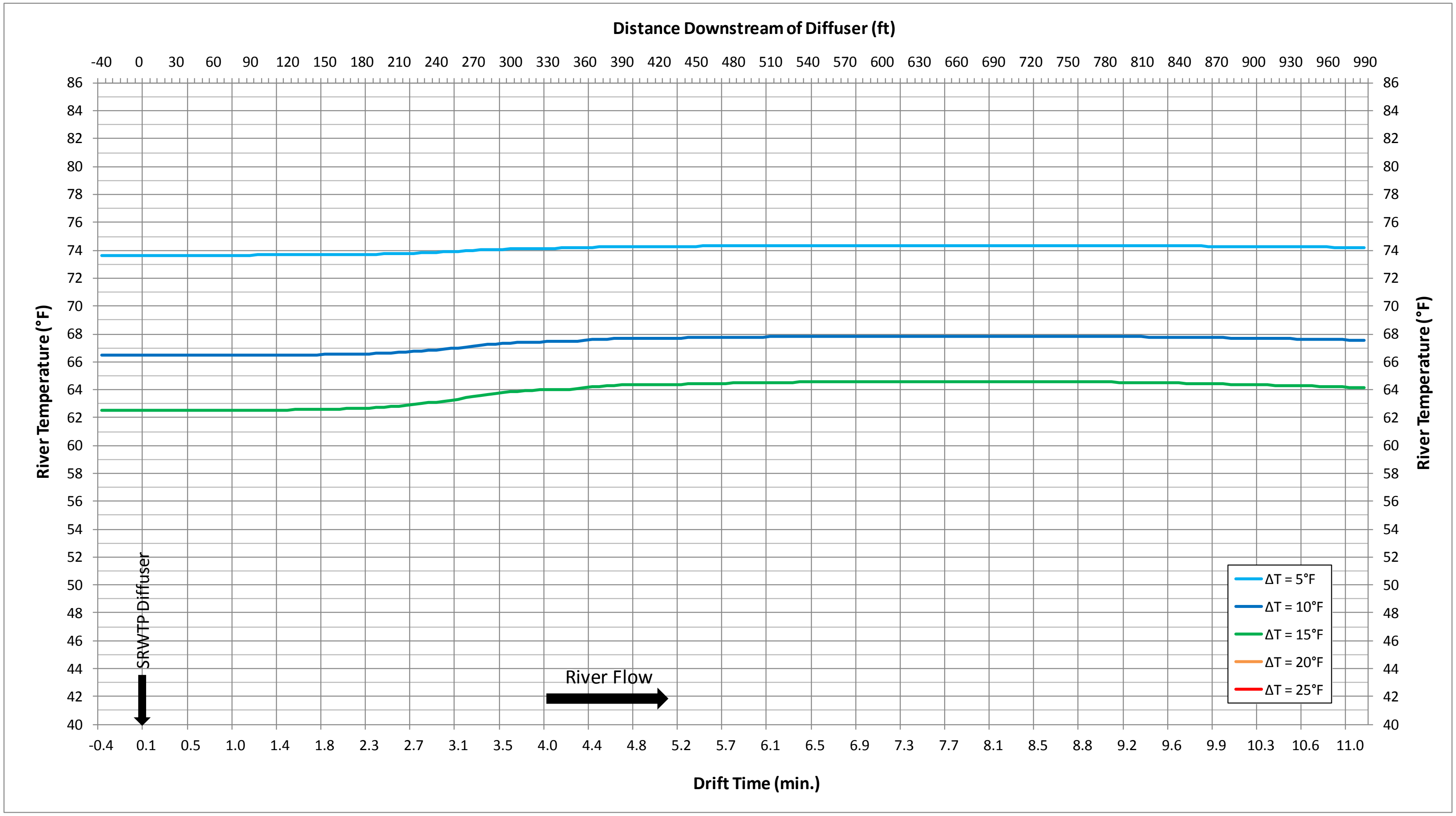


Figure F-33. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of May at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in May at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

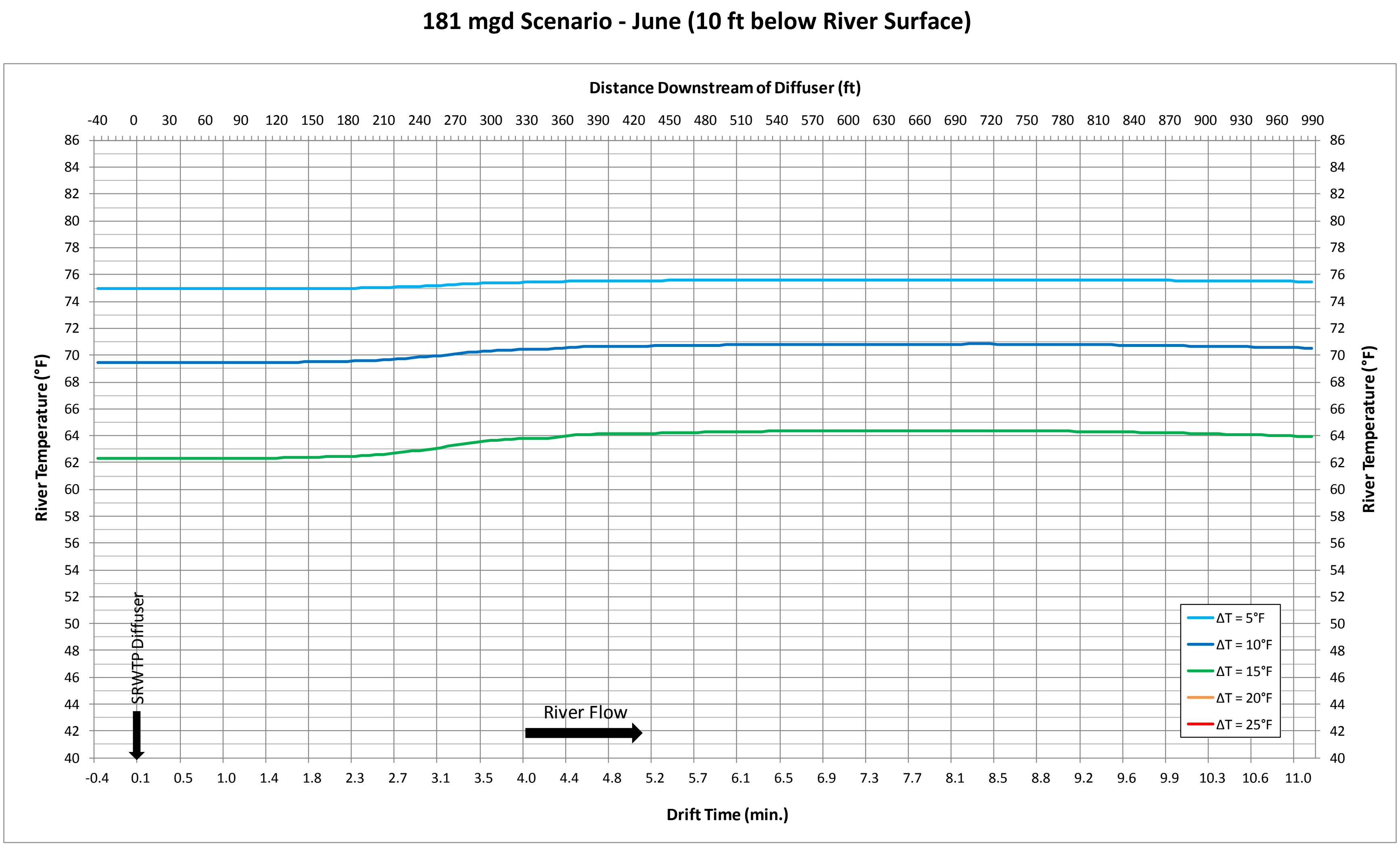


Figure F-34. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of June at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in June at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

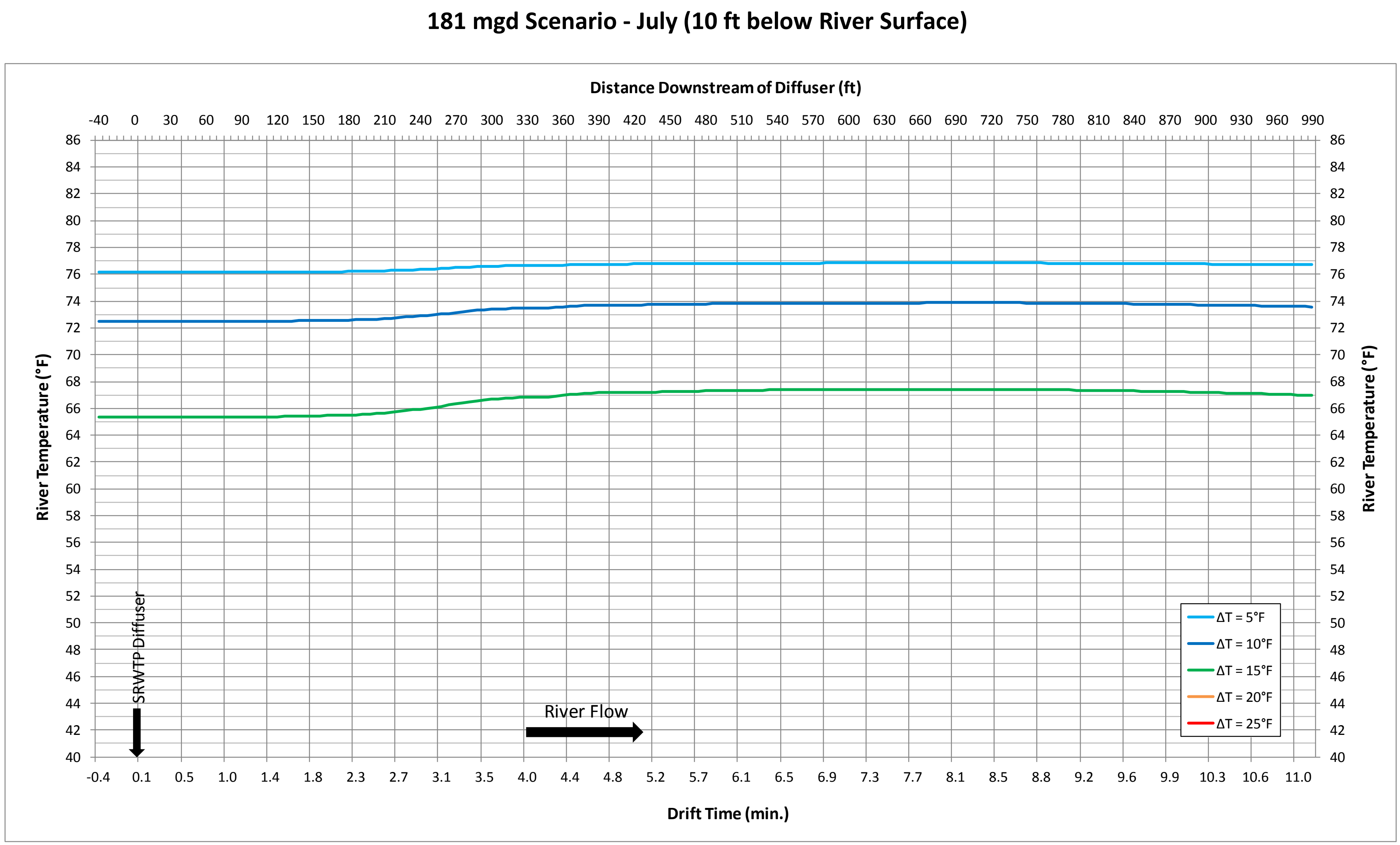


Figure F-35. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of July at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in July at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

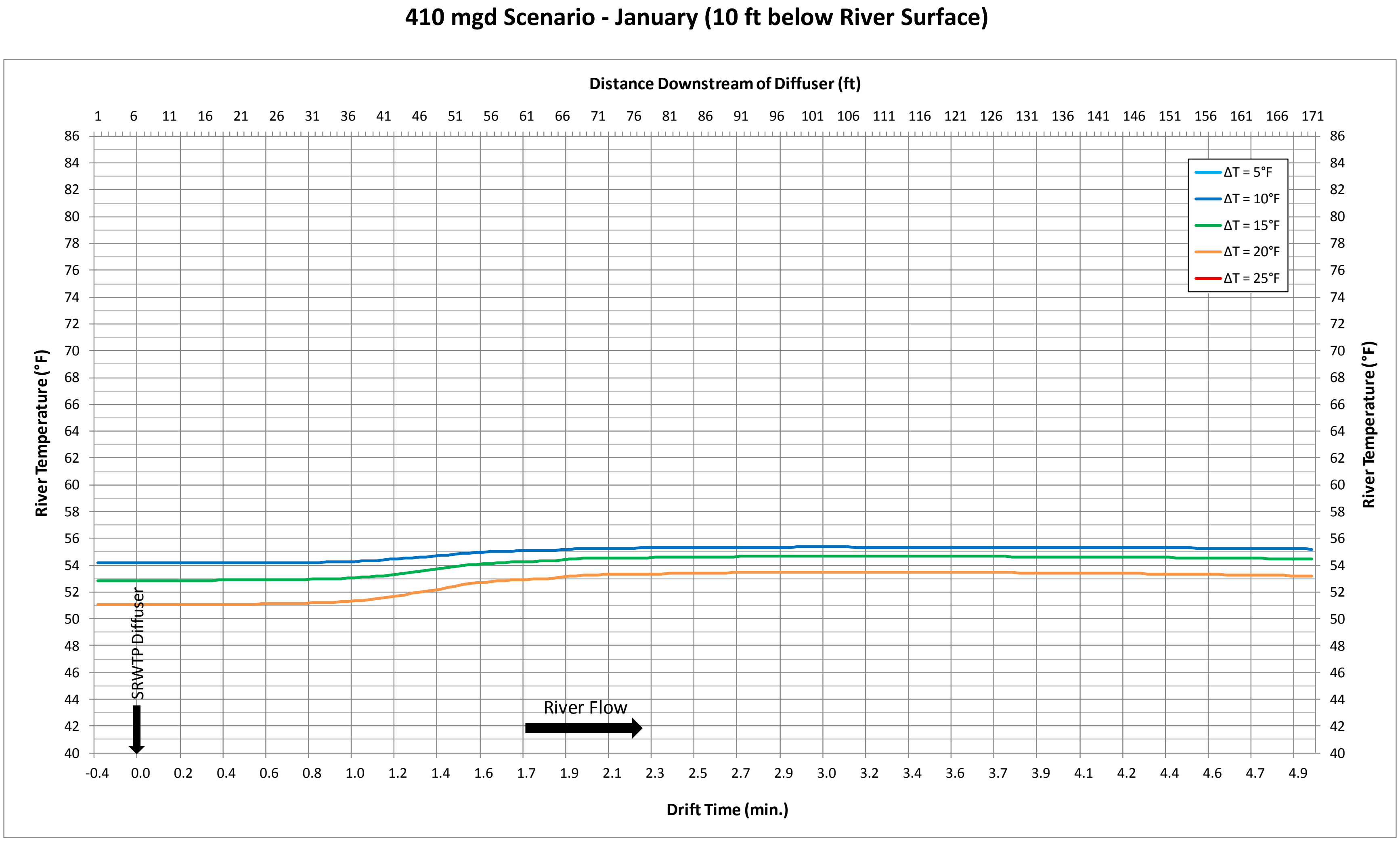


Figure F-36. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of January at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in January at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

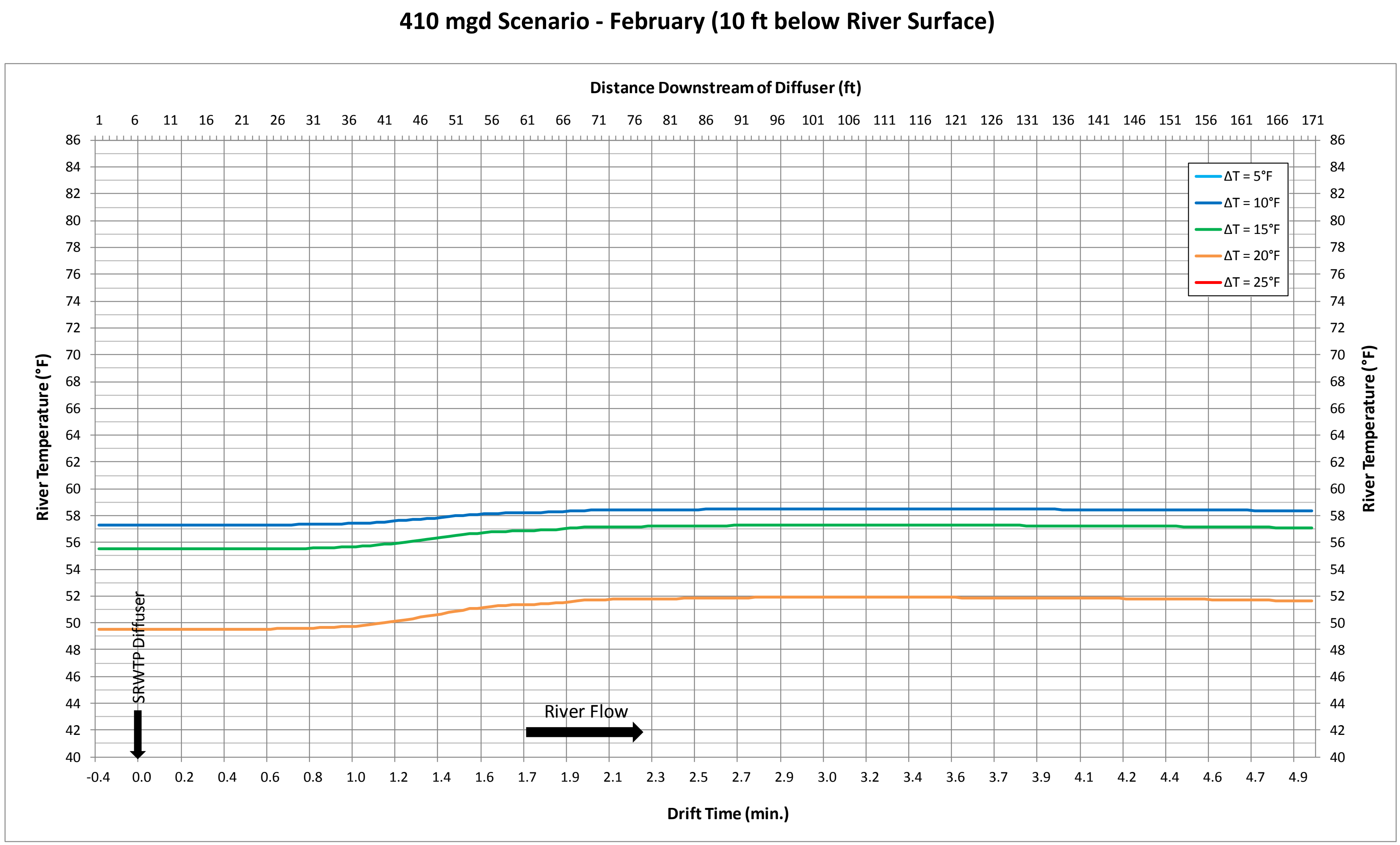


Figure F-37. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of February at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in February at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

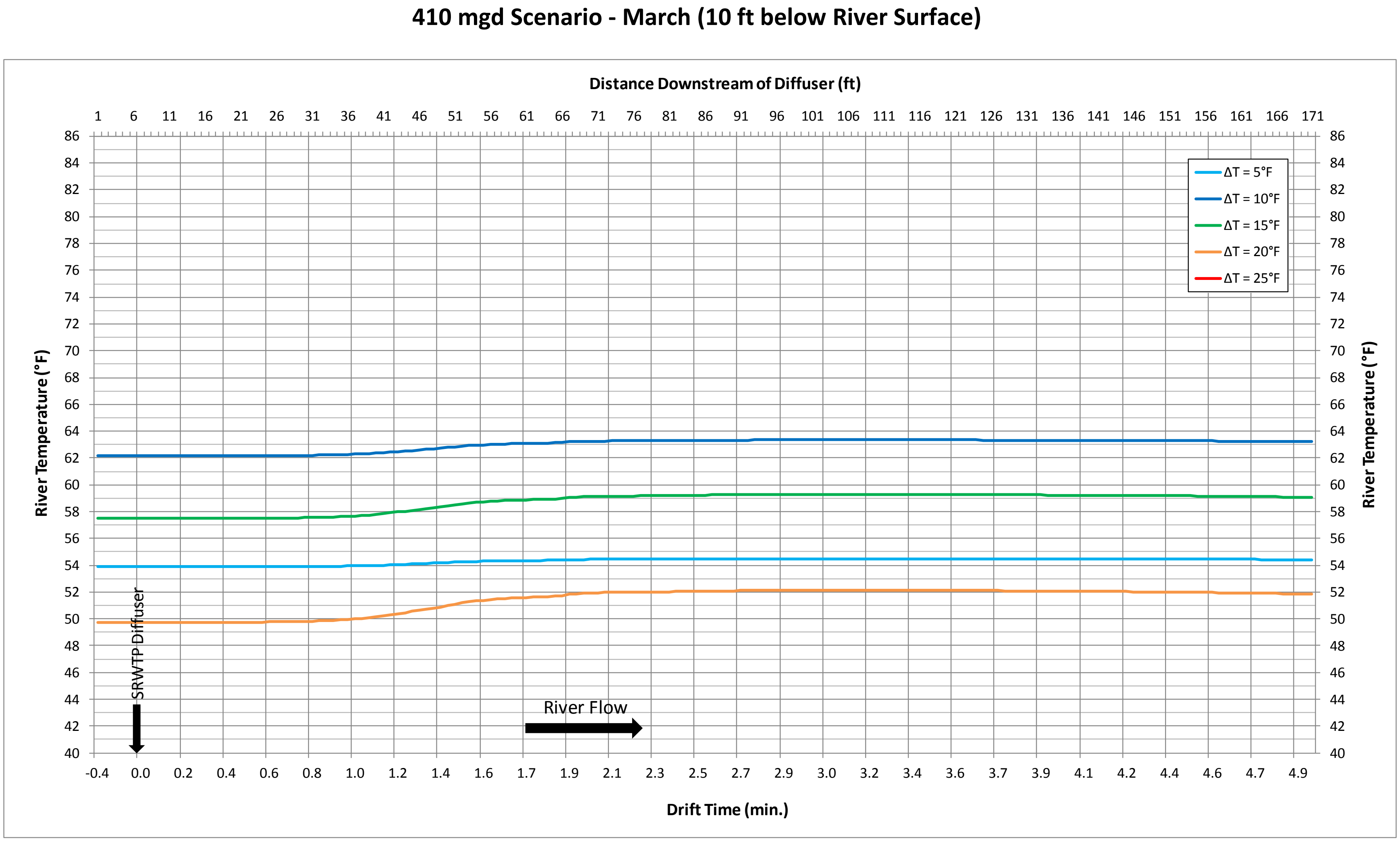


Figure F-38. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of March at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in March at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

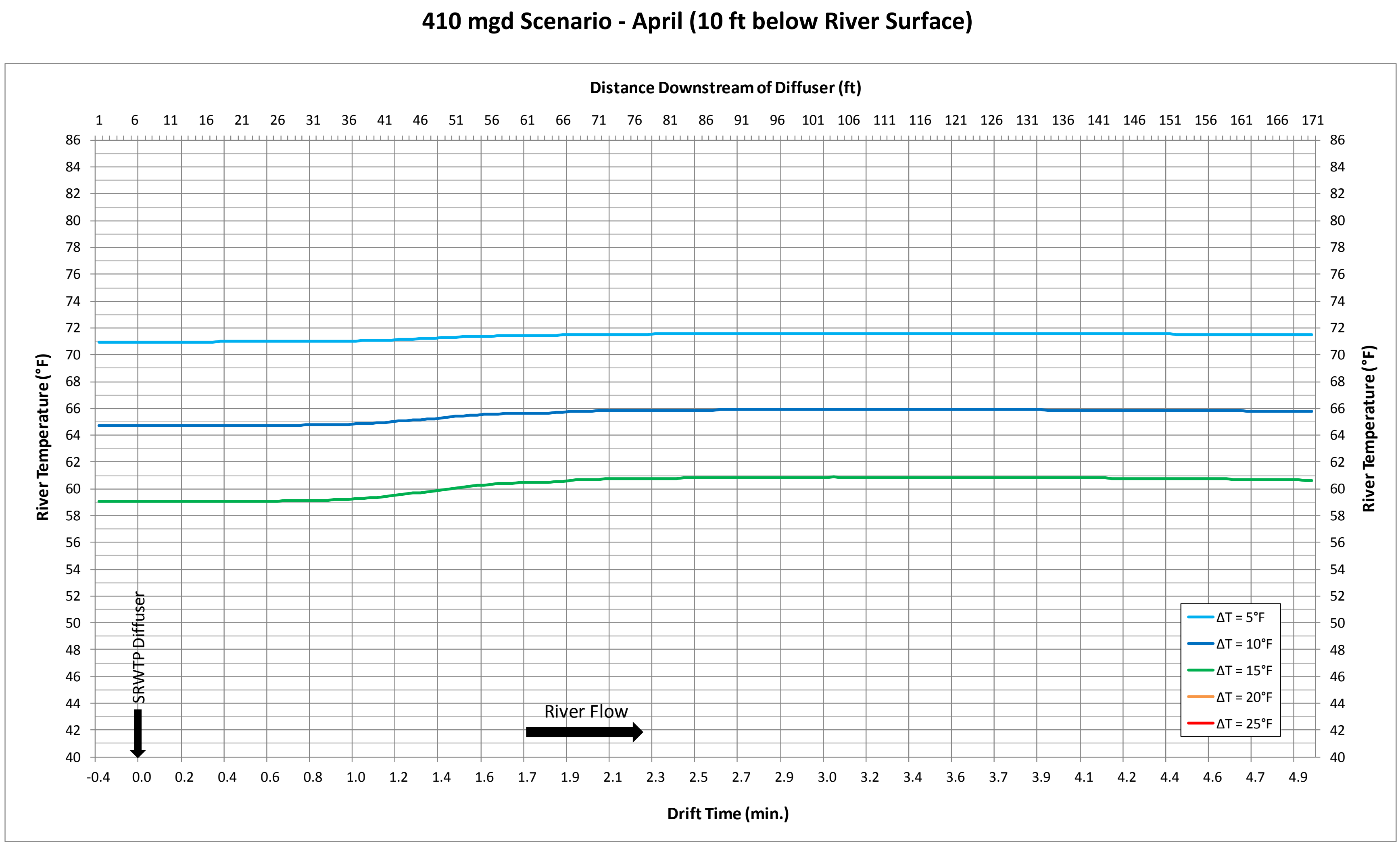


Figure F-39. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of April at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in April at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

410 mgd Scenario - May (10 ft below River Surface)

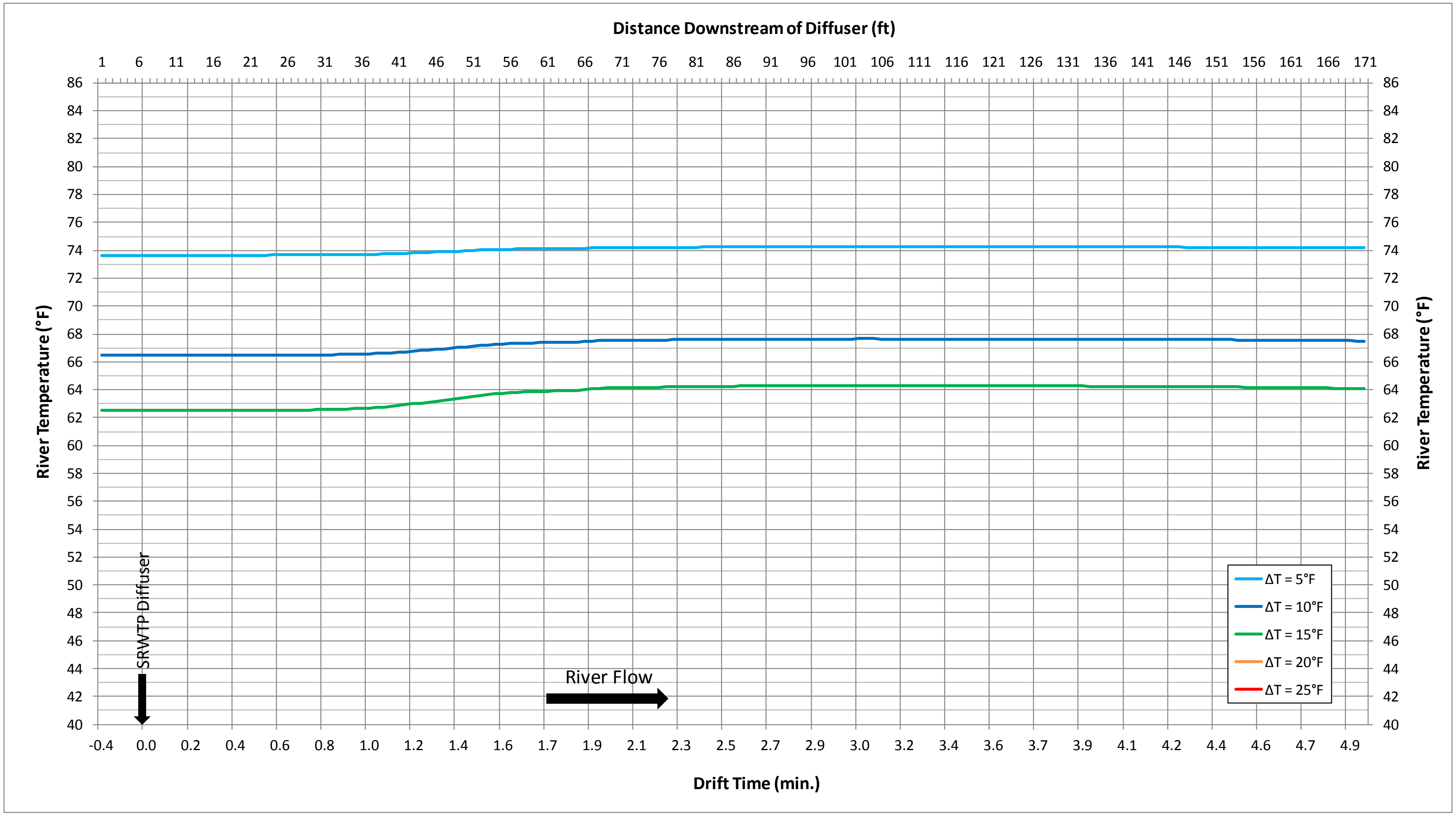


Figure F-40. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of May at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in May at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

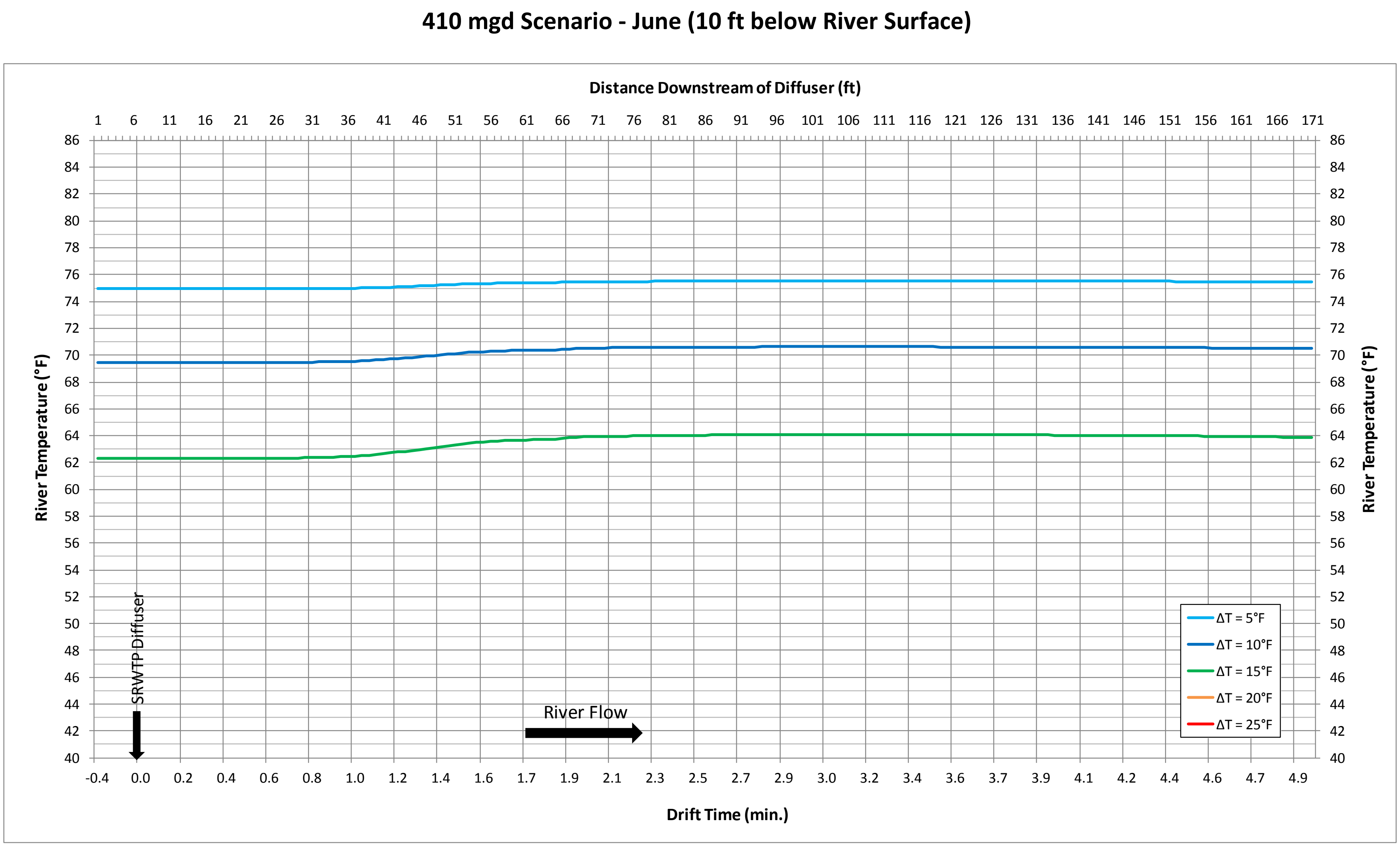


Figure F-41. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of June at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in June at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

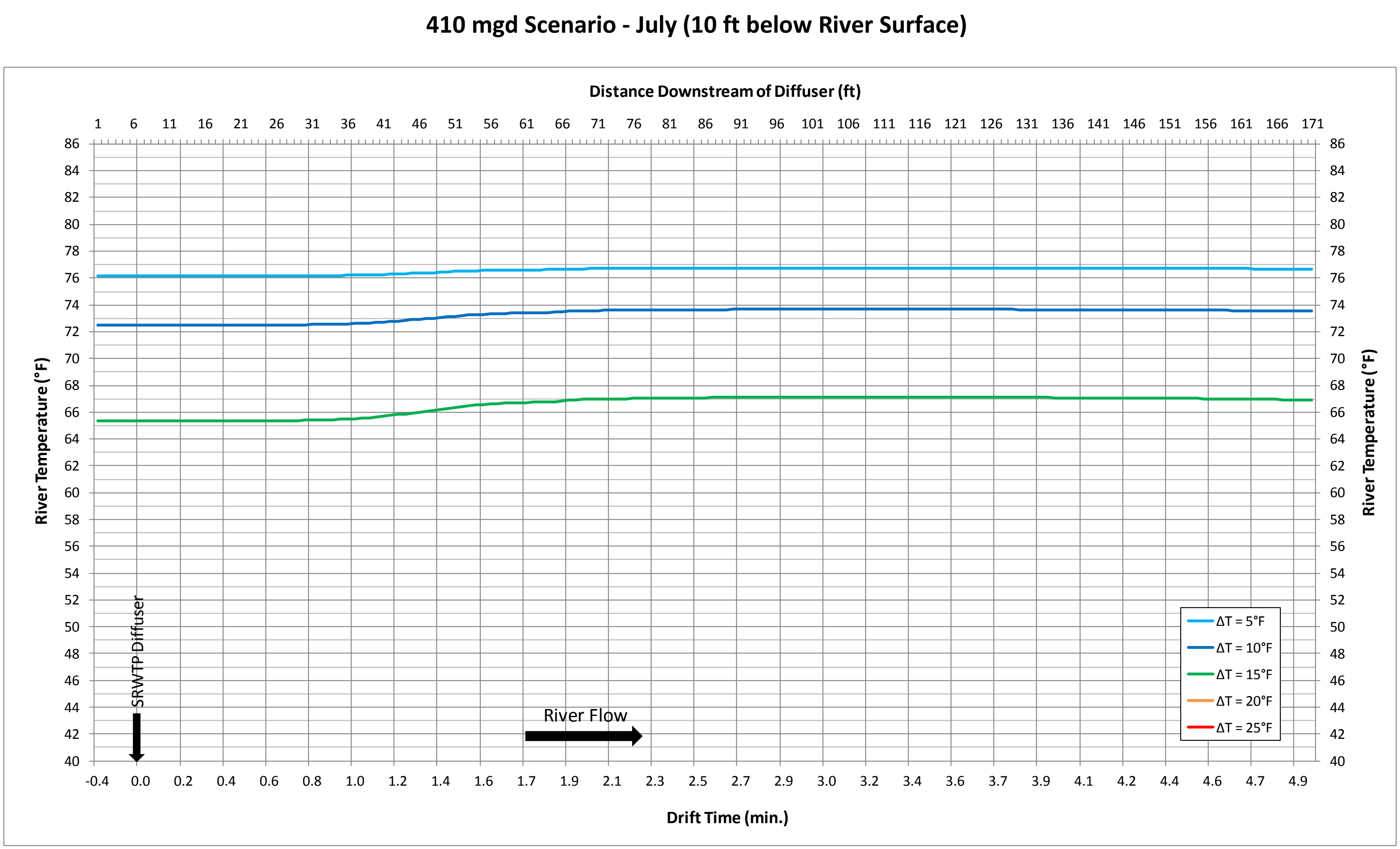


Figure F-42. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at 10 ft below the water surface during the month of July at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in July at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - January (River Bottom)

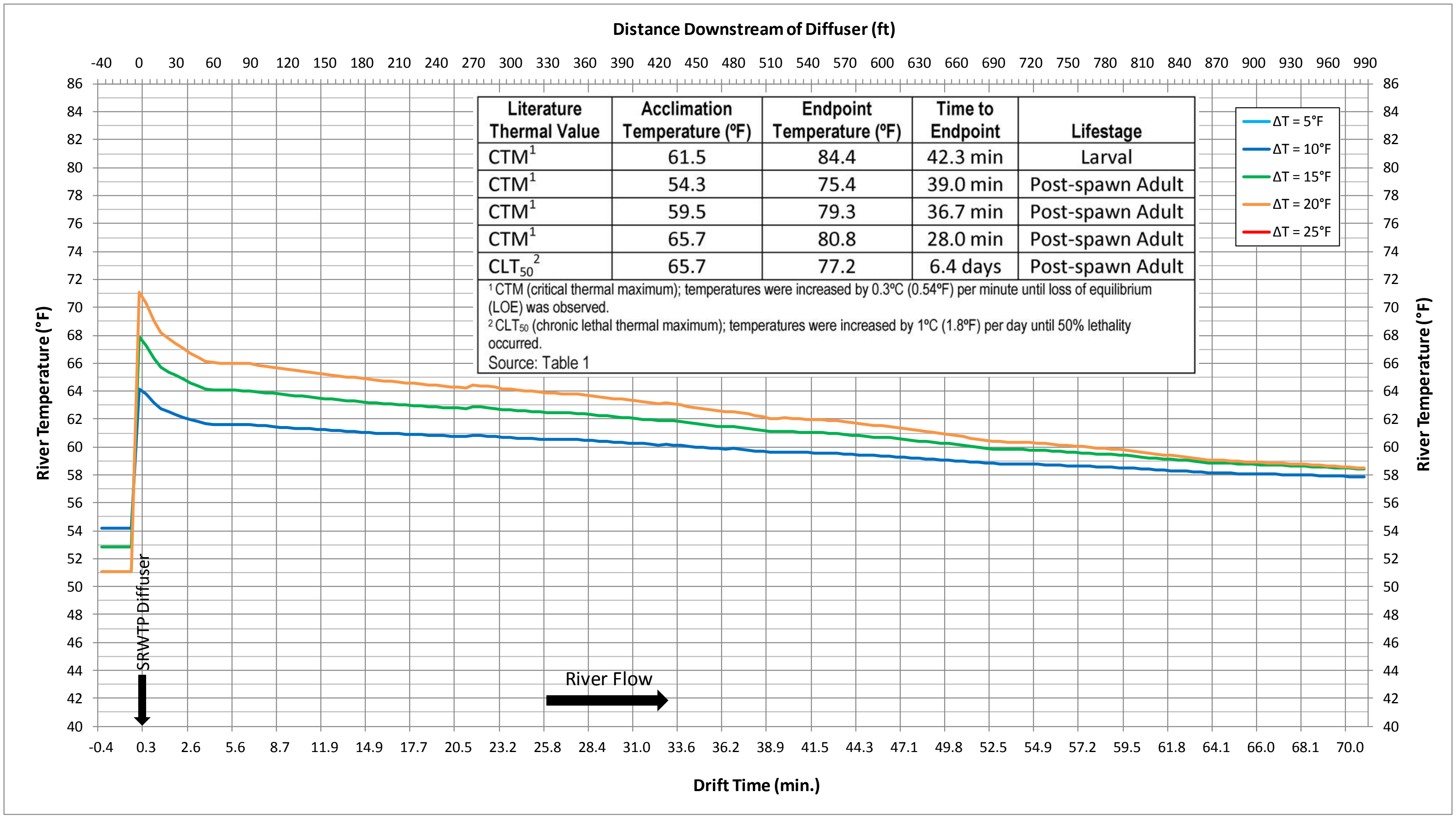


Figure F-43. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of January at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in January at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - February (River Bottom)

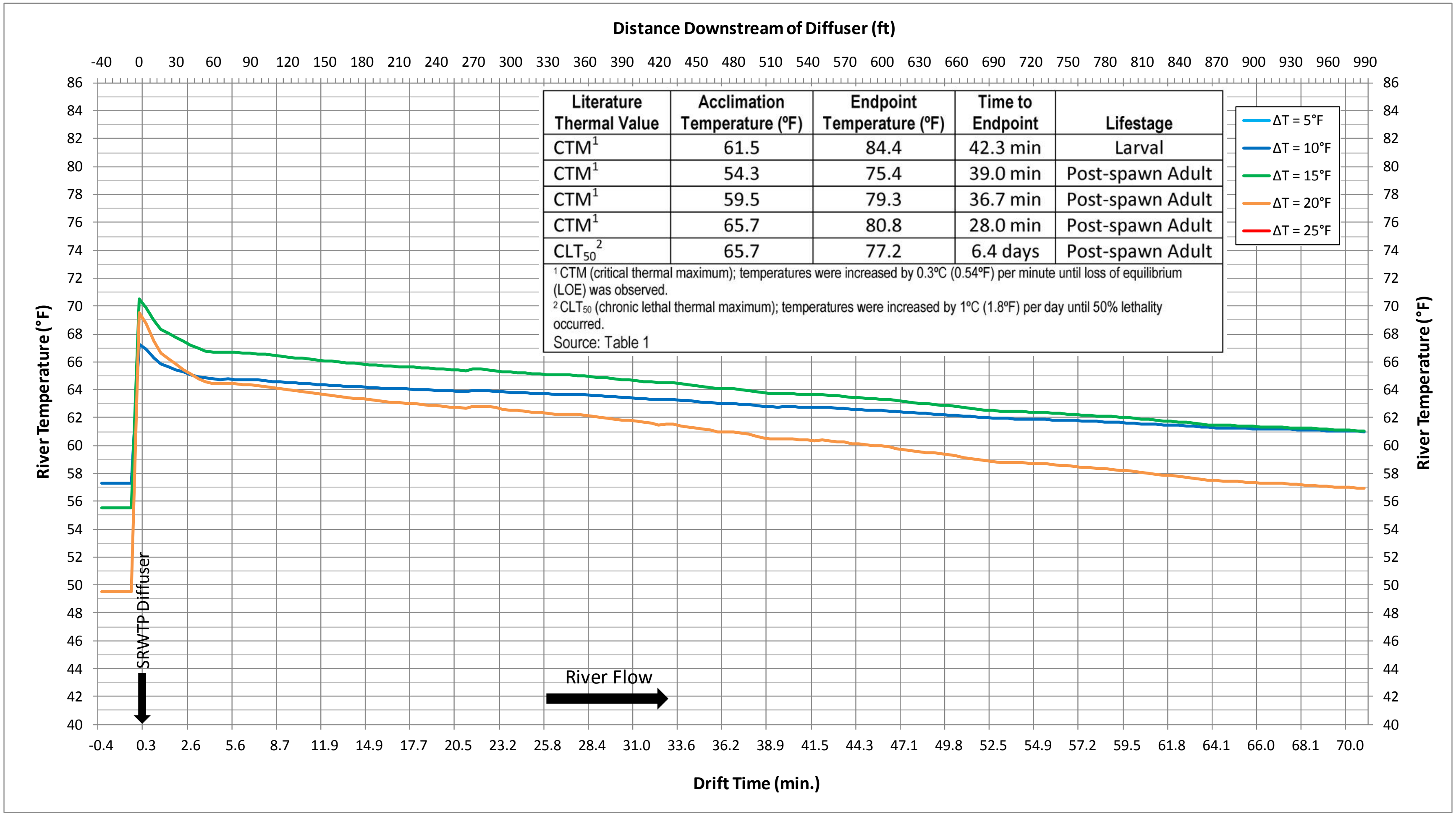


Figure F-44. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of February at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in February at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - March (River Bottom)

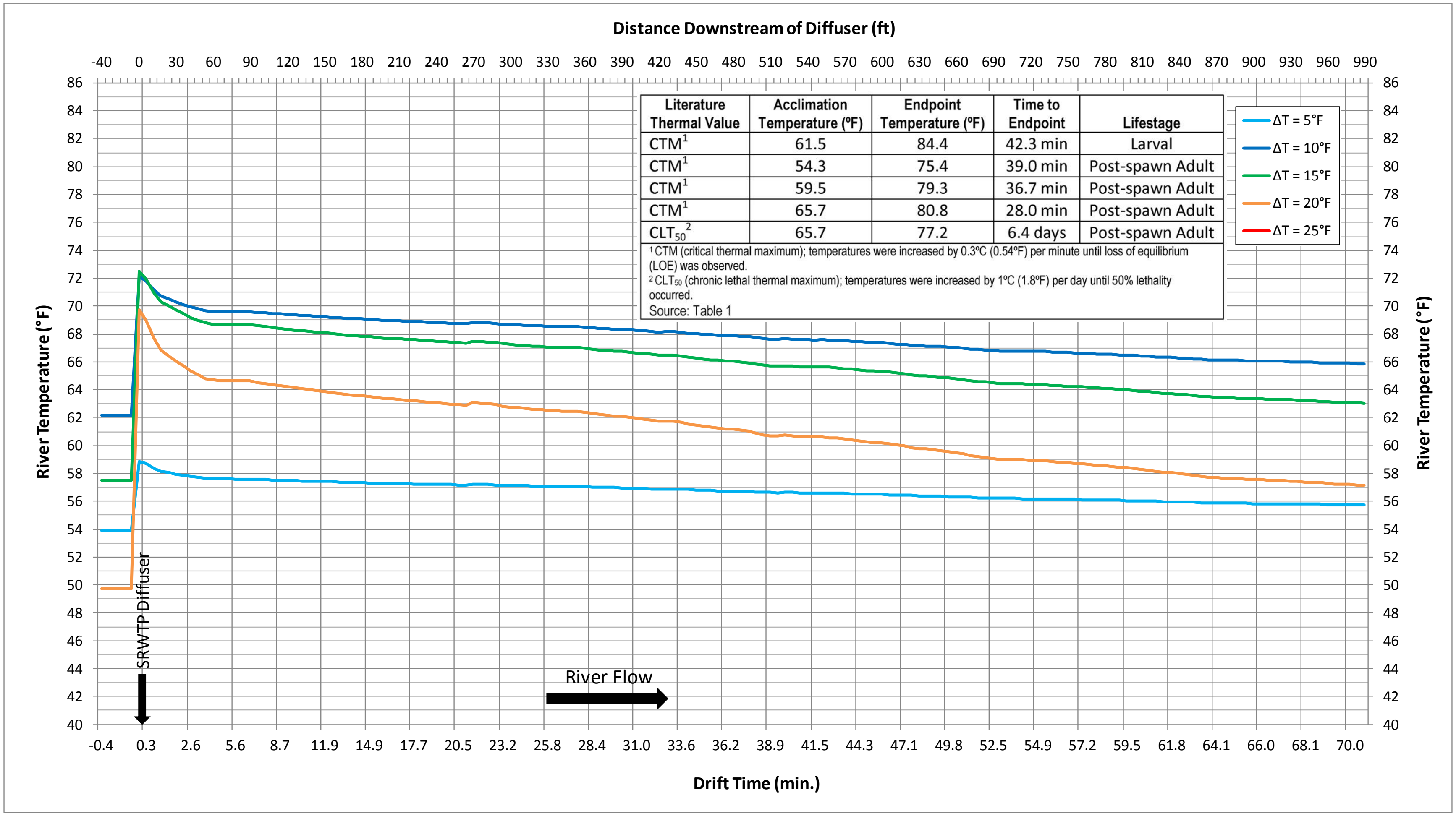
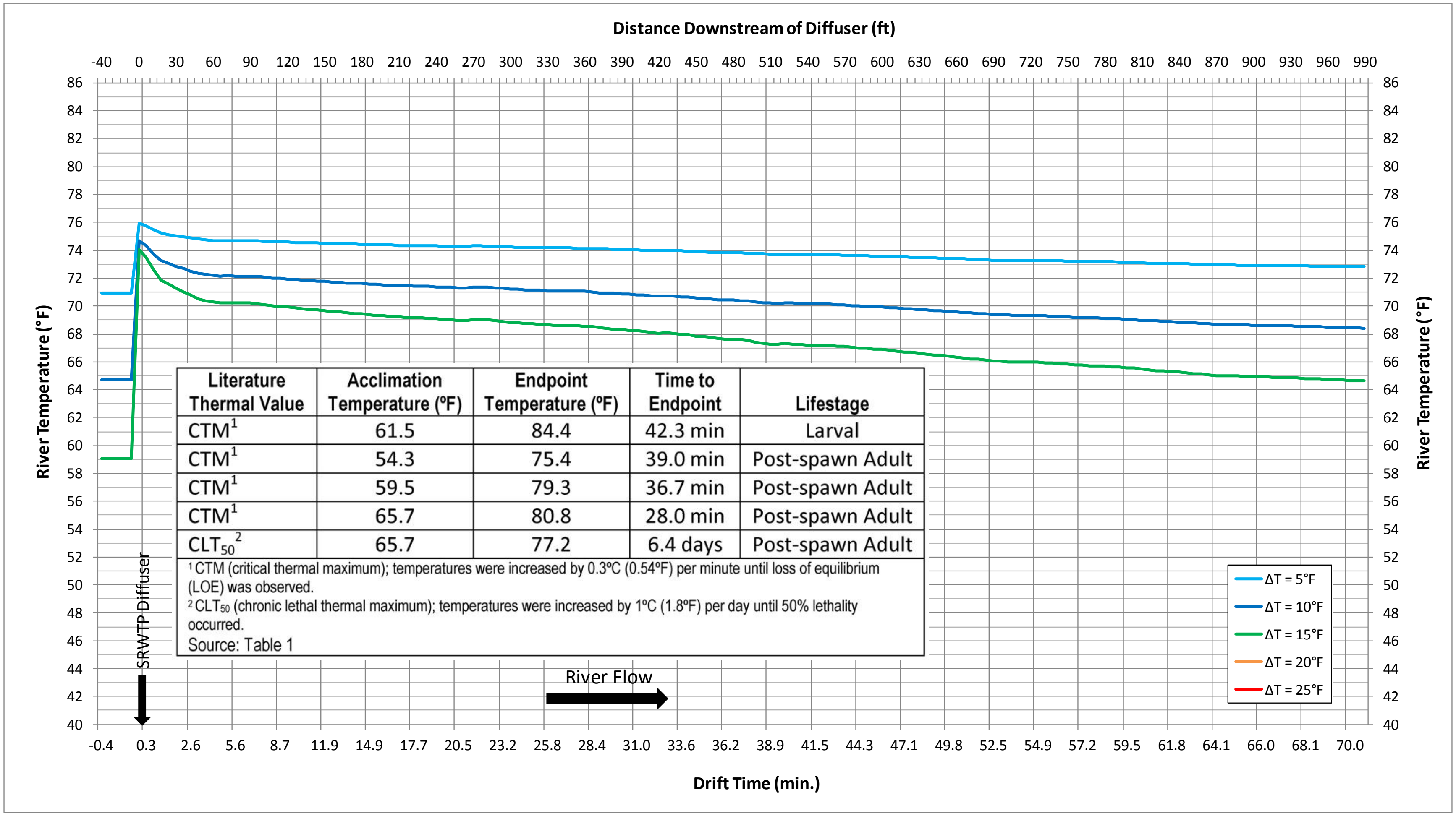


Figure F-45. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of March at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in March at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - April (River Bottom)

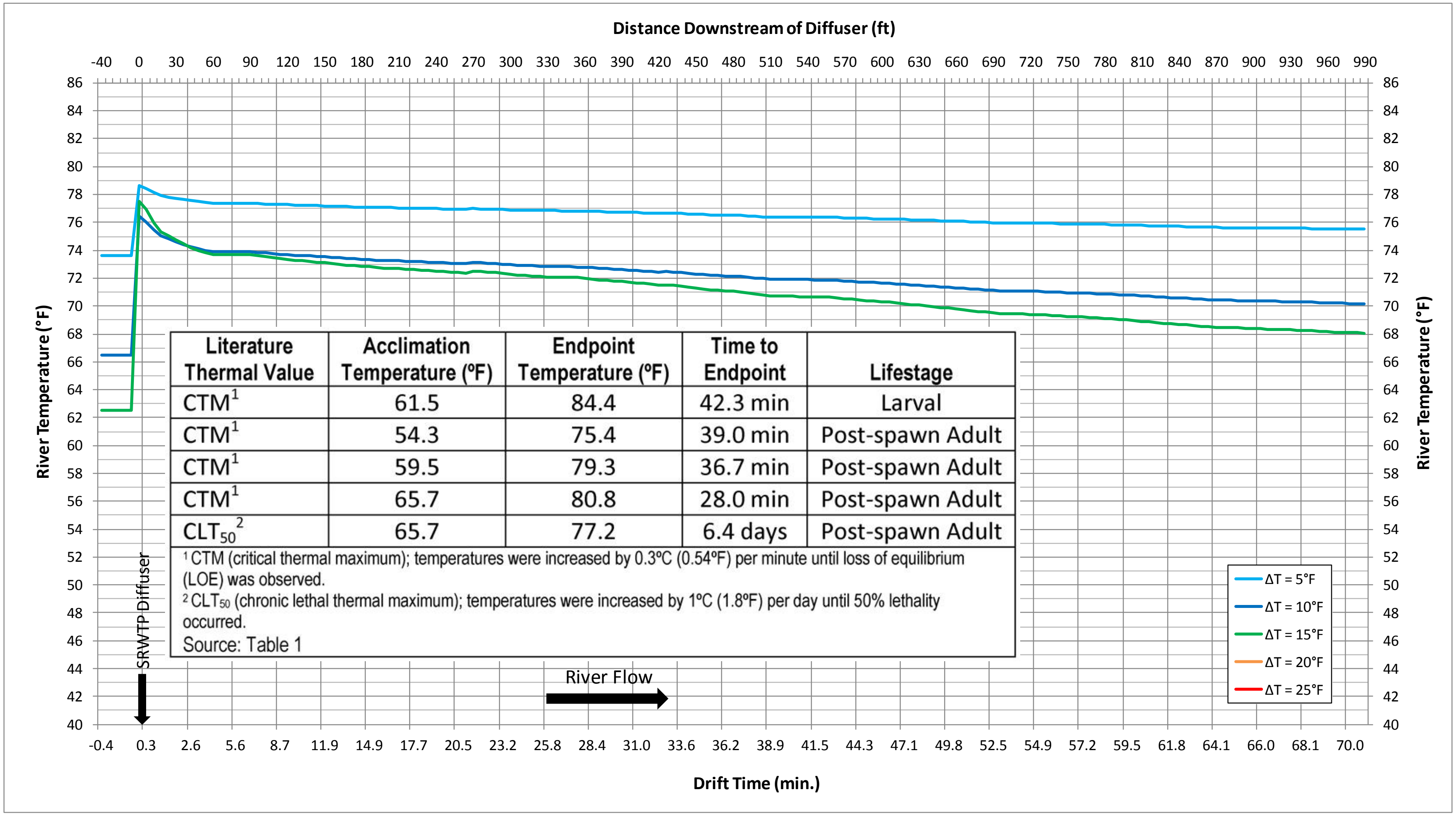


Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure F-46. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of April at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in April at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - May (River Bottom)



Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.

[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.

Source: Table 1

Figure F-47. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of May at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in May at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - June (River Bottom)

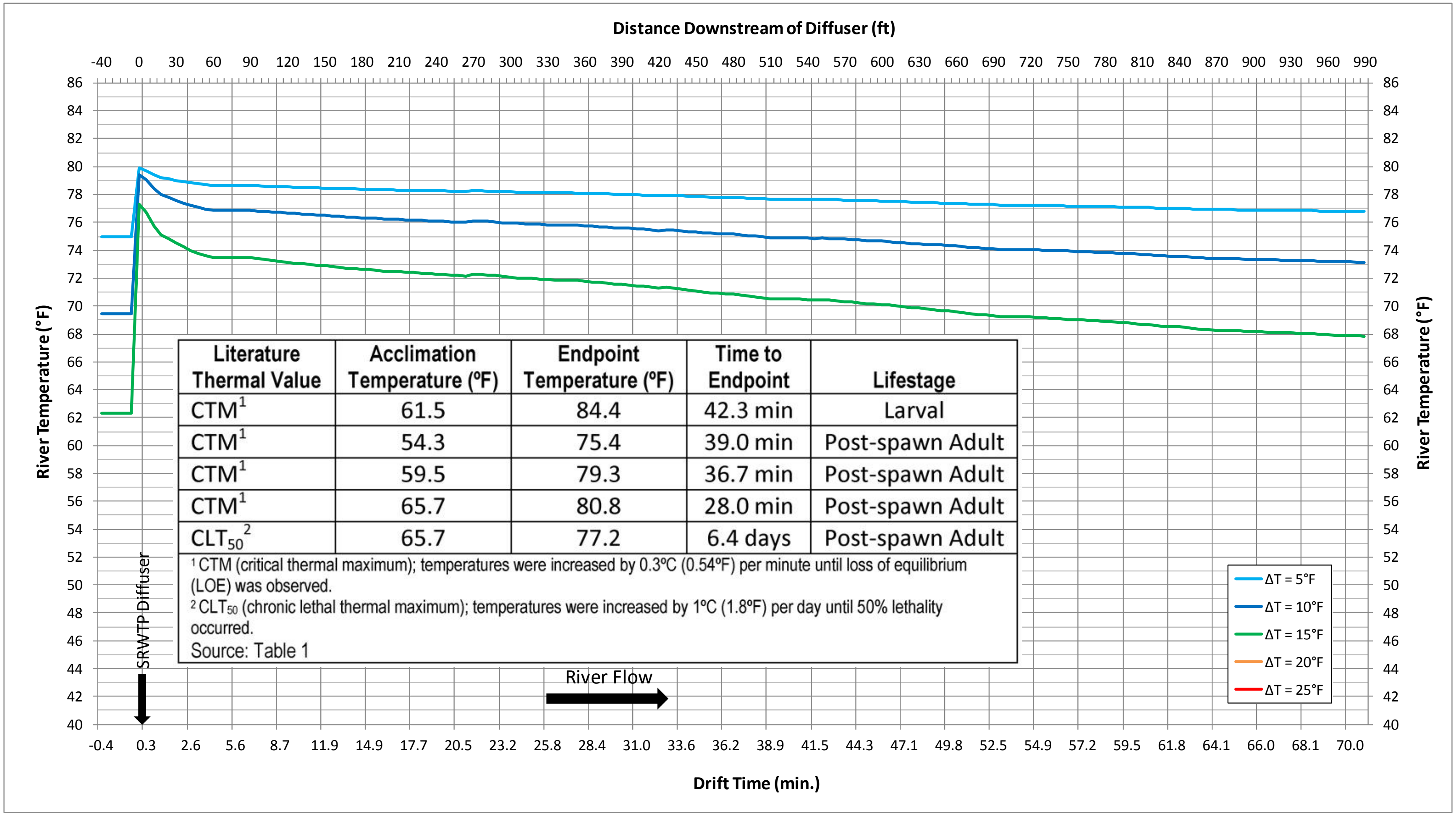
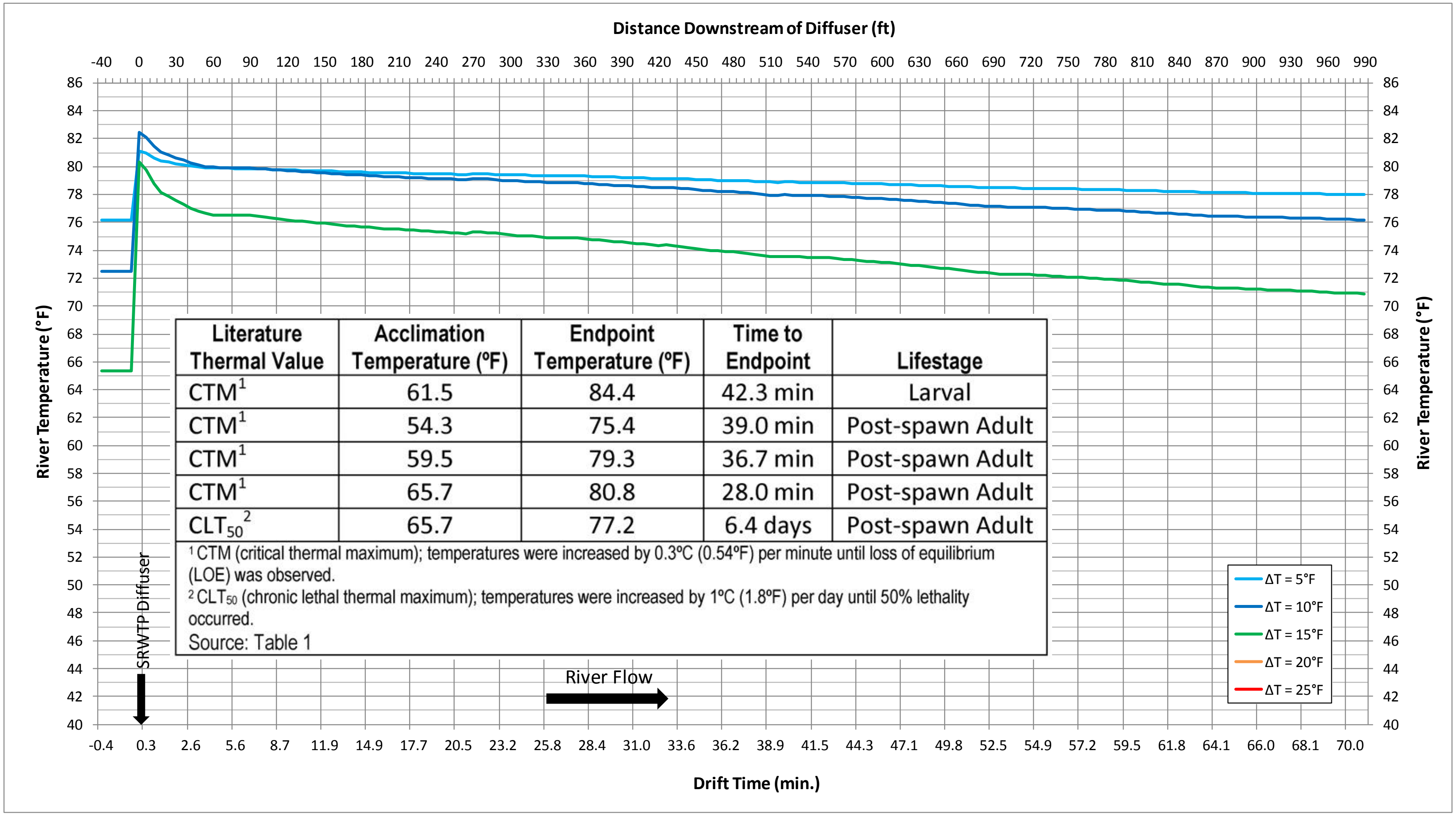


Figure F-48. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of June at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in June at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

60 mgd Scenario - July (River Bottom)



Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.

[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.

Source: Table 1

Figure F-49. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of July at a SRWTP discharge rate of 60 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in July at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - January (River Bottom)

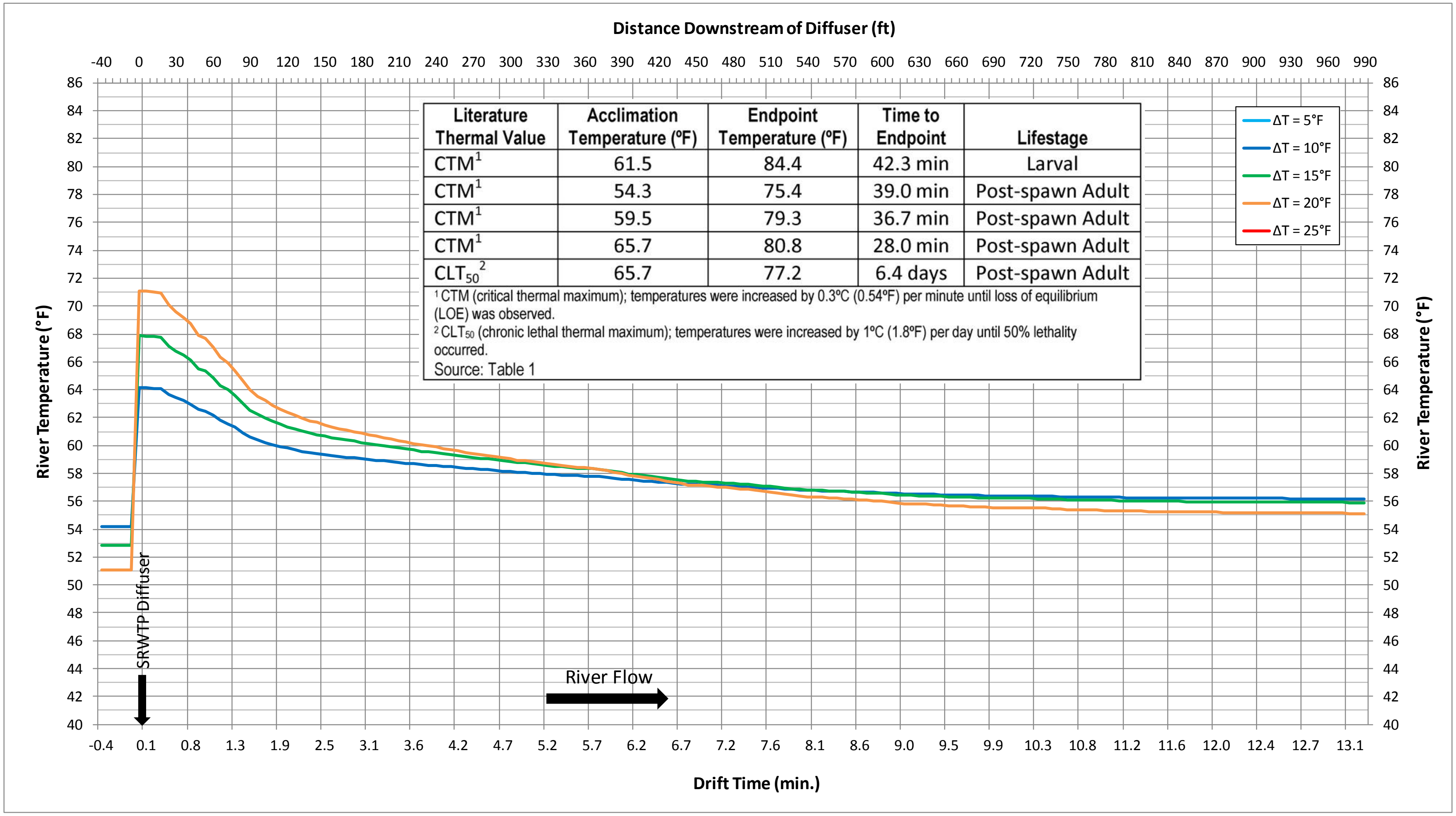
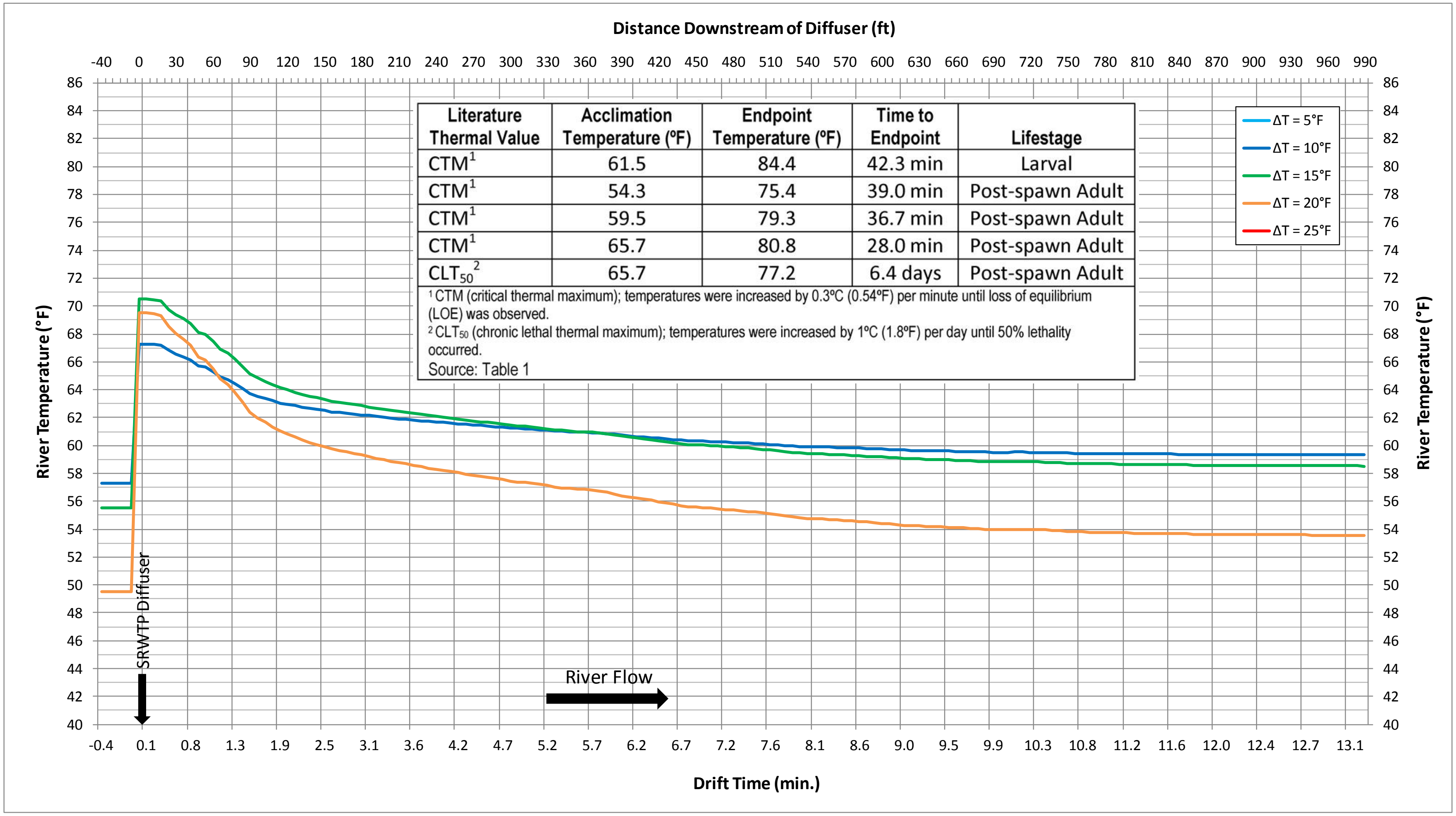


Figure F-50. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of January at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in January at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - February (River Bottom)

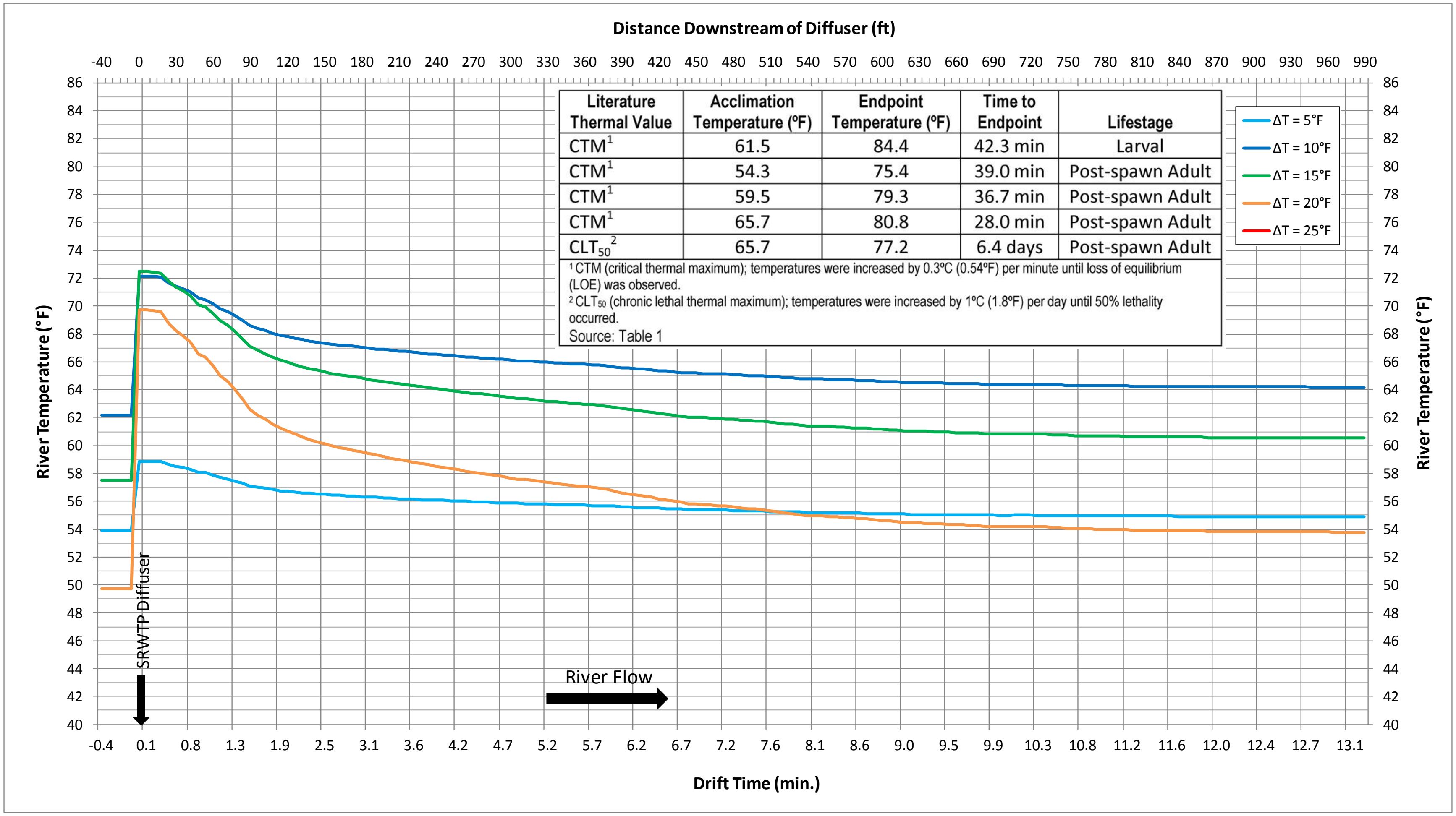


Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure F-51. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of February at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in February at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - March (River Bottom)

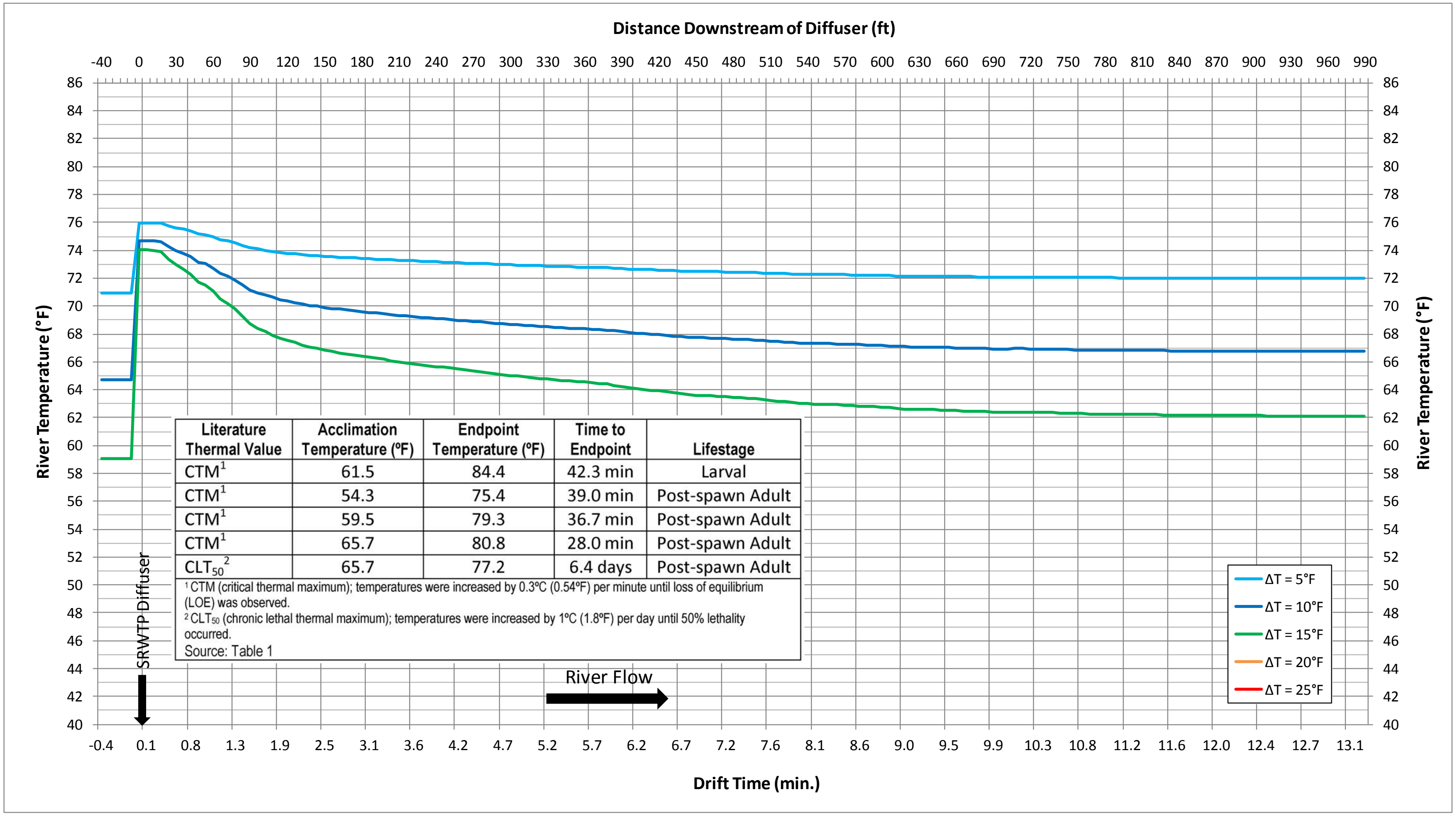


Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure F-52. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of March at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in March at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - April (River Bottom)

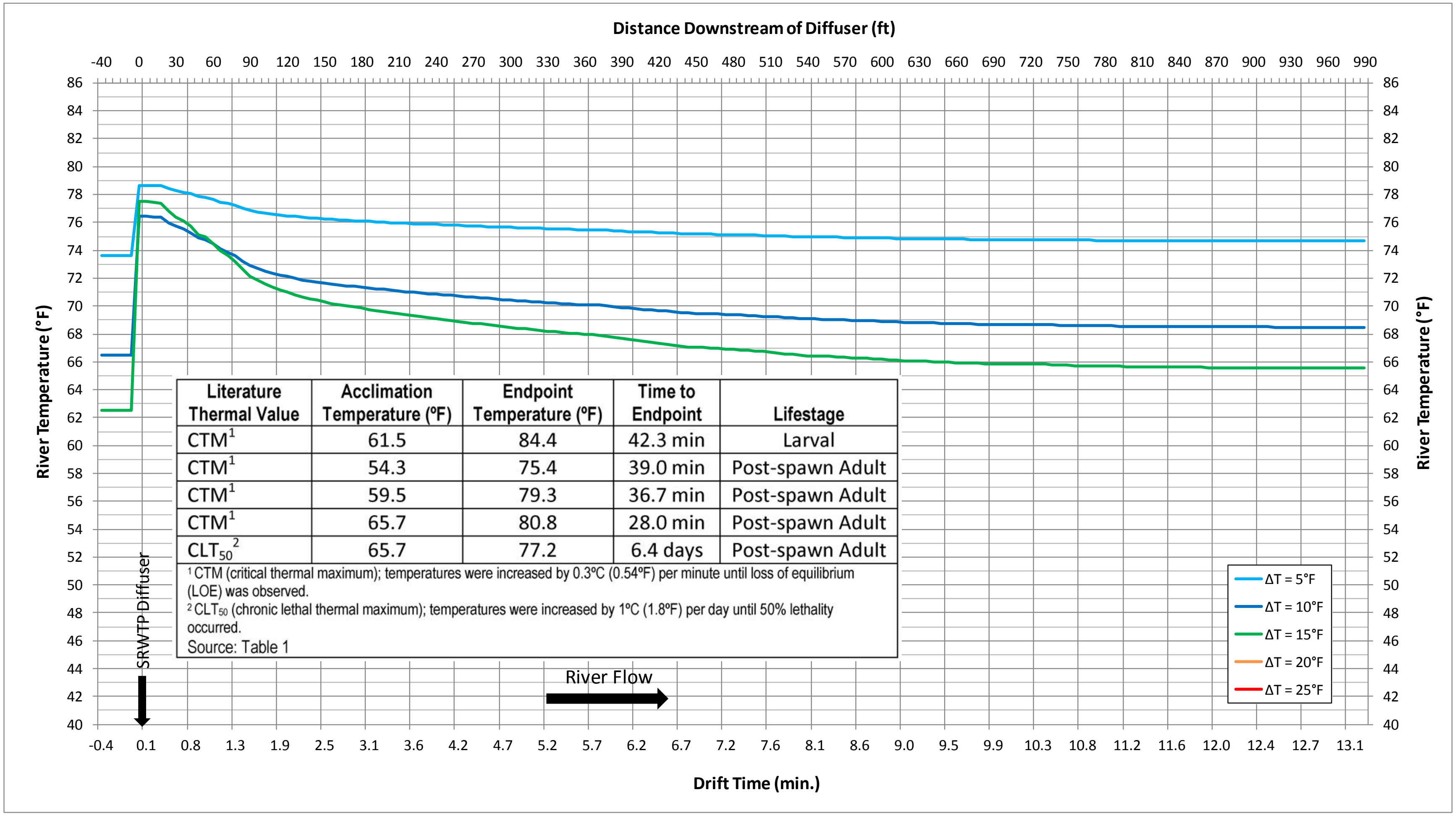


Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure F-53. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of April at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in April at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - May (River Bottom)

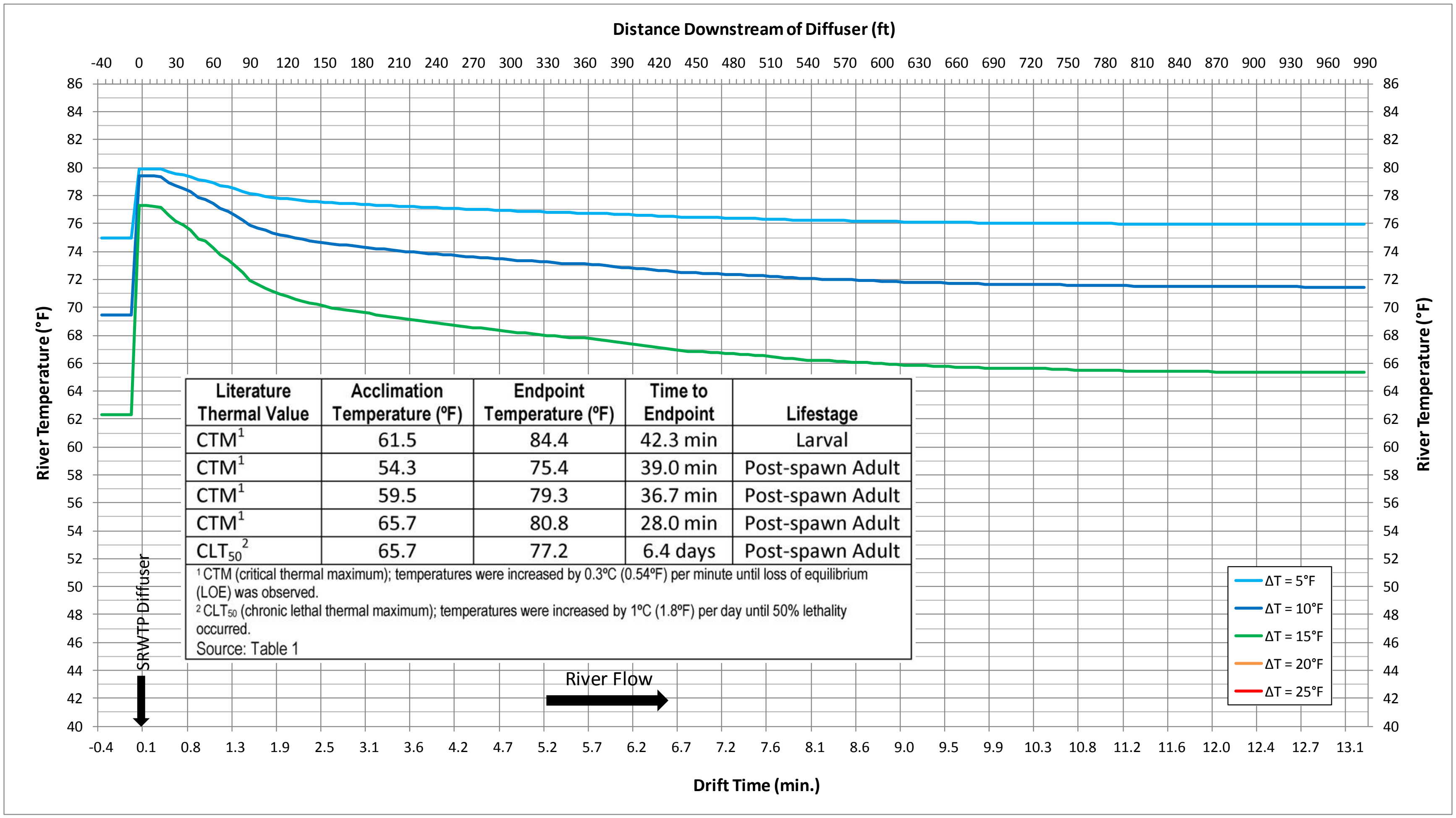


Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure F-54. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of May at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in May at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - June (River Bottom)

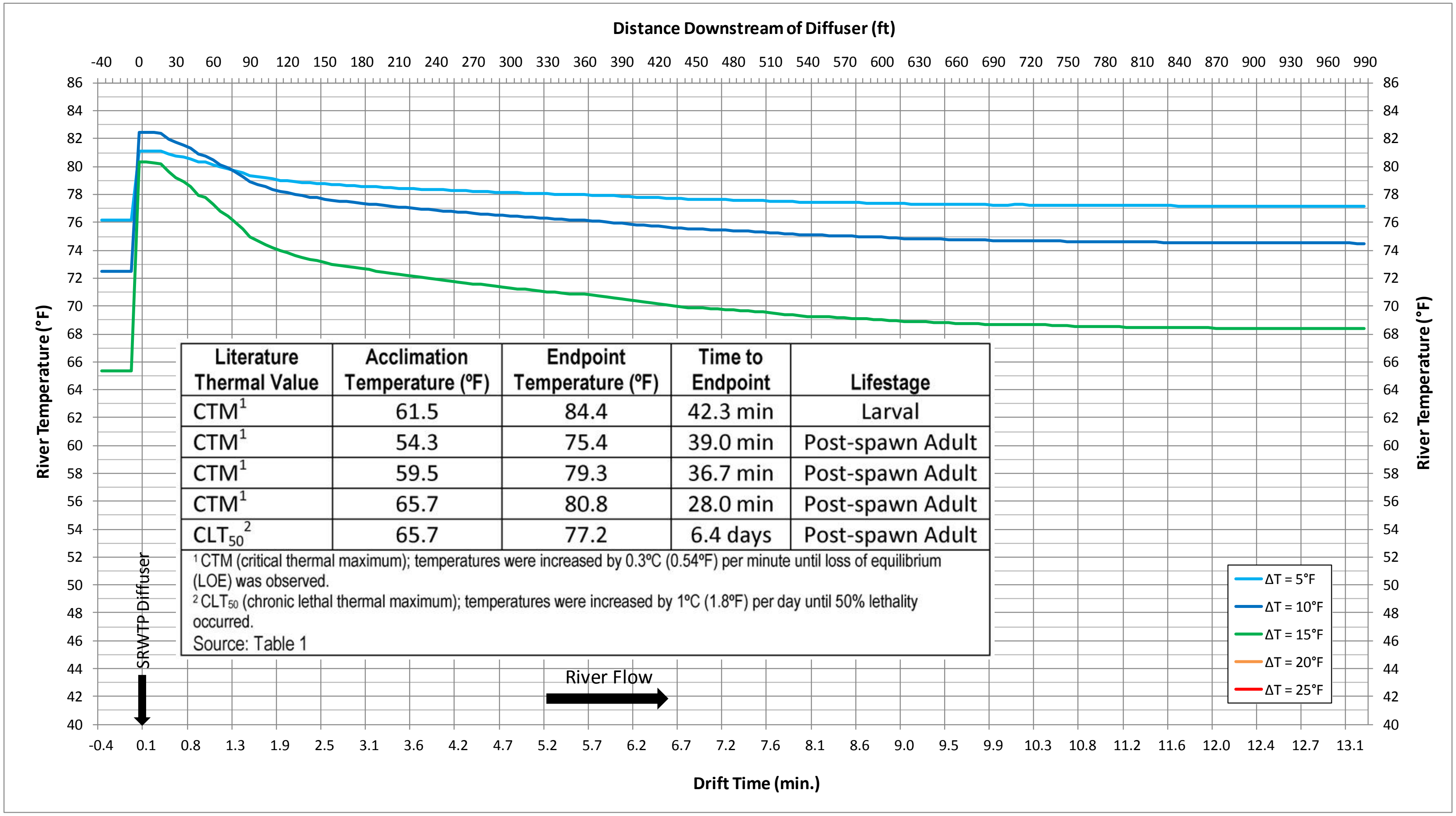


Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure F-55. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of June at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in June at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

181 mgd Scenario - July (River Bottom)



Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.

[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.

Source: Table 1

Figure F-56. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of July at a SRWTP discharge rate of 181 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in July at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

410 mgd Scenario - January (River Bottom)

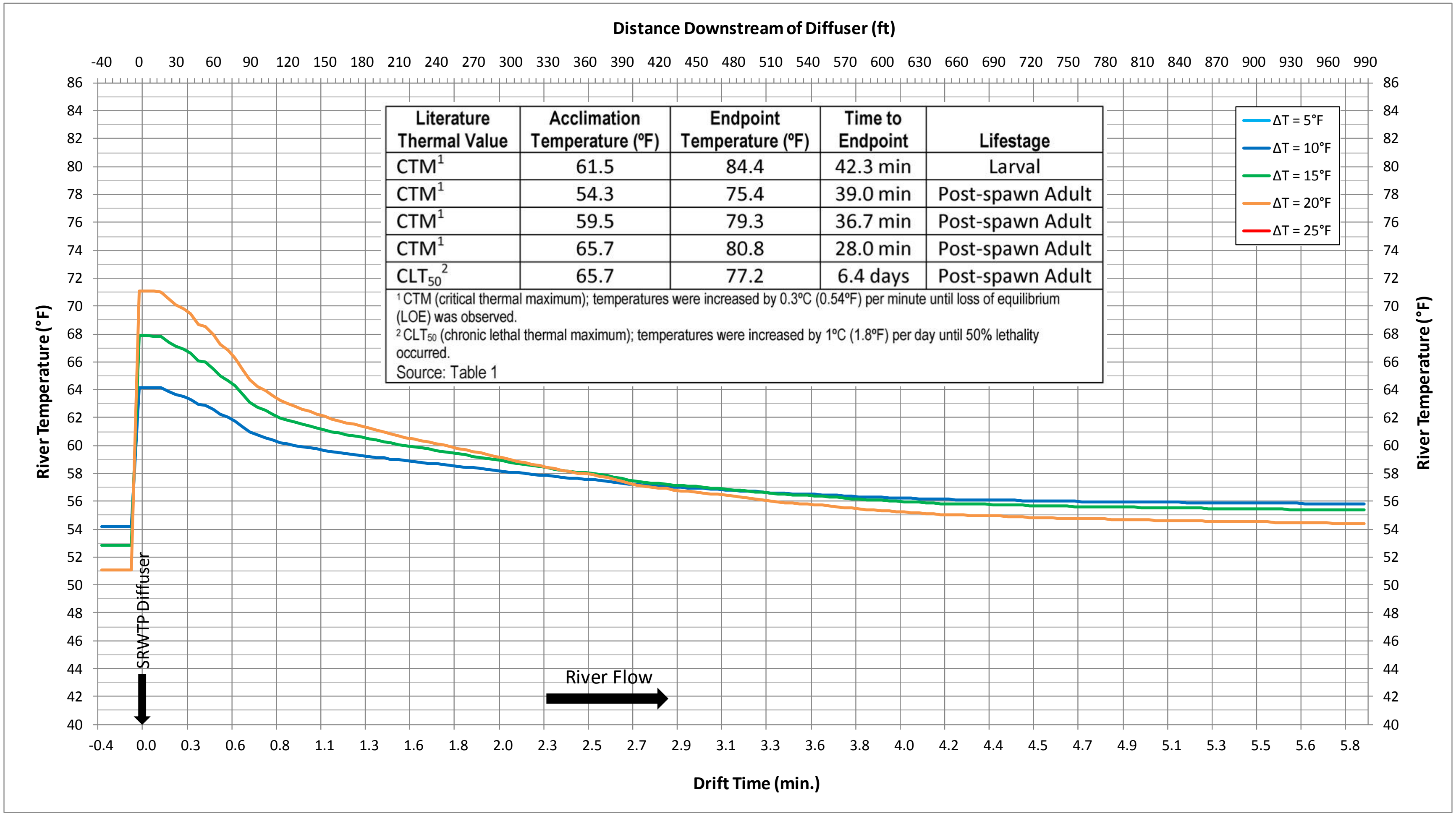


Figure F-57. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of January at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in January at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

410 mgd Scenario - February (River Bottom)

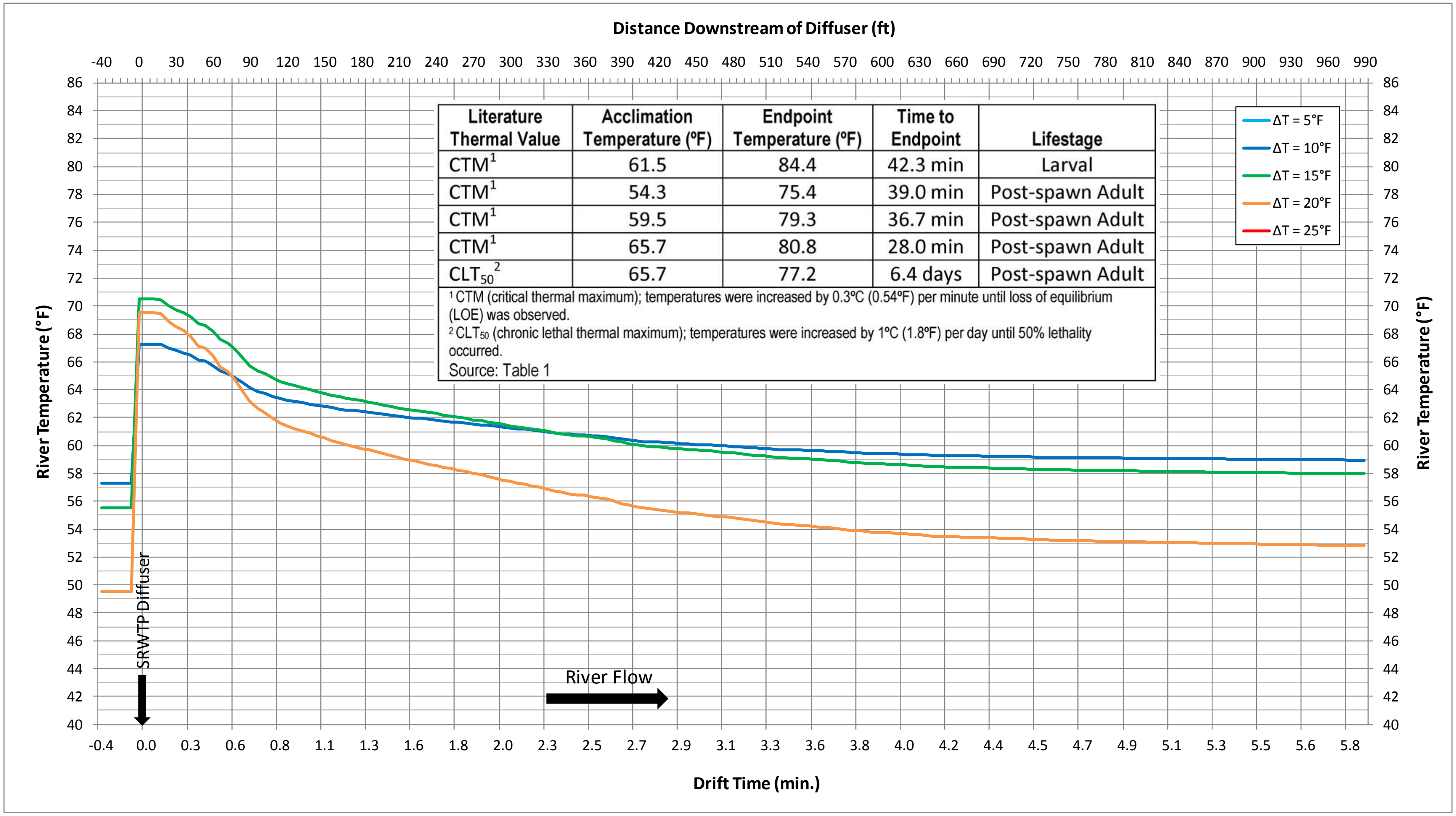
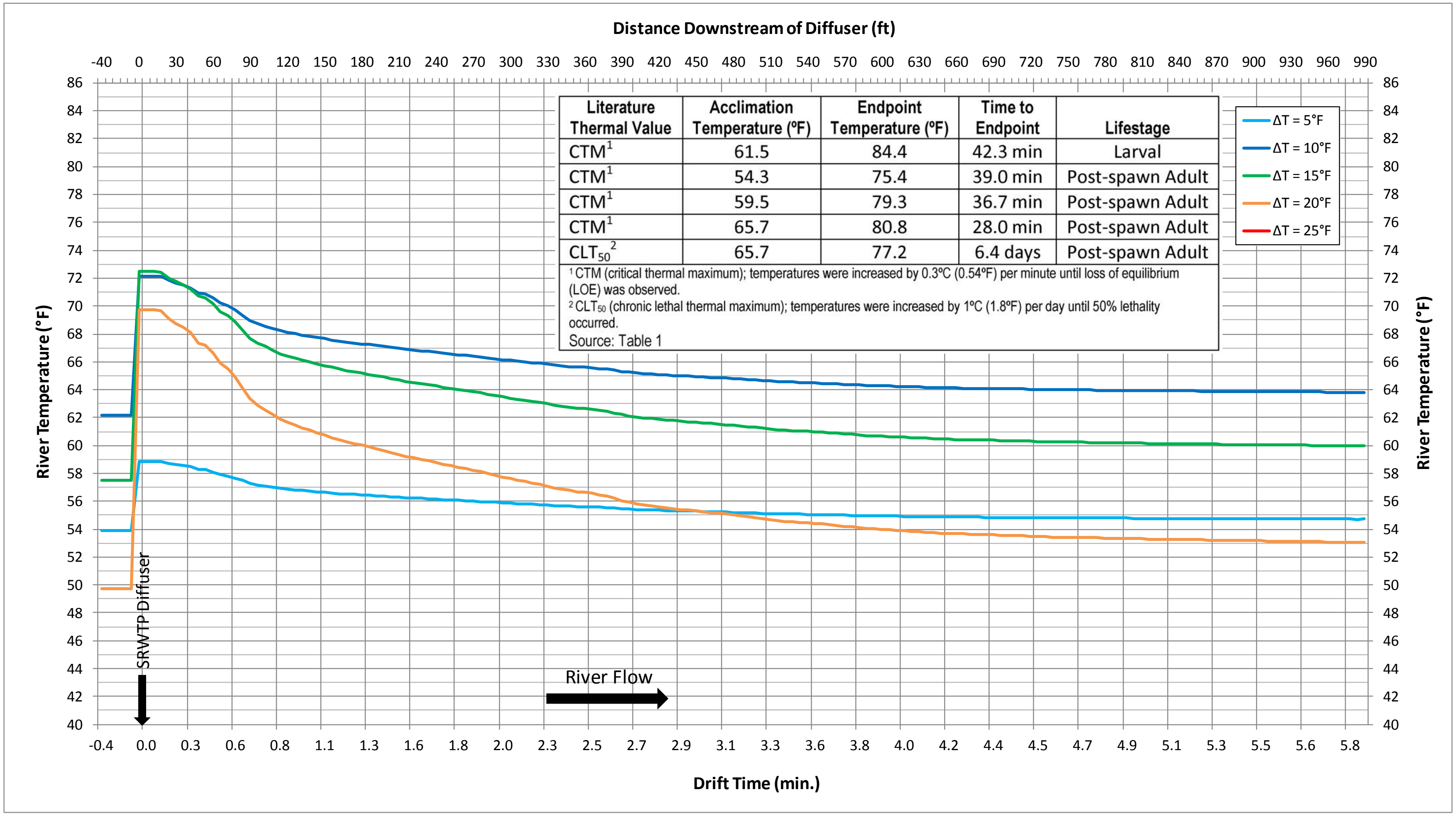


Figure F-58. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of February at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in February at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

410 mgd Scenario - March (River Bottom)

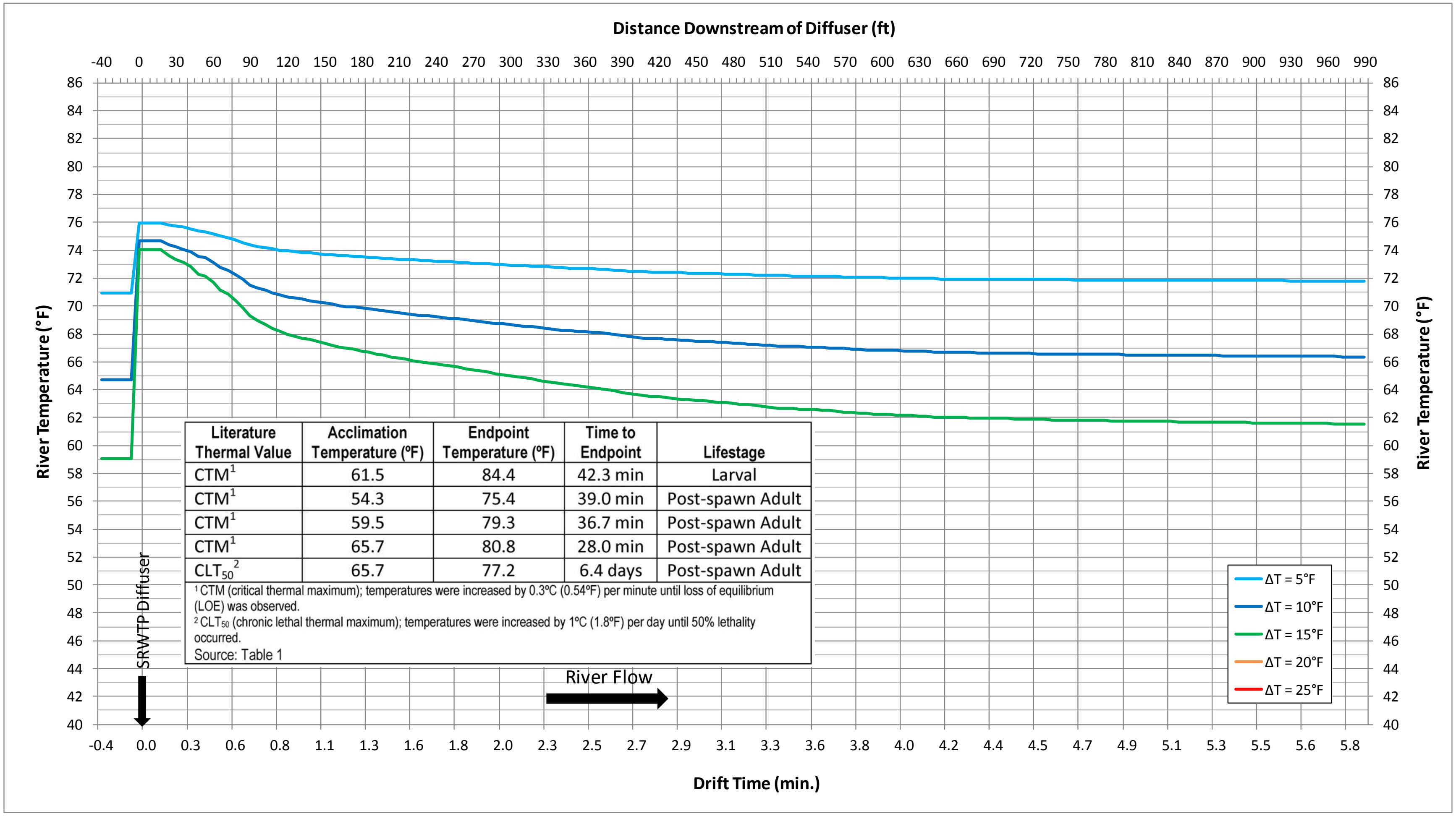


Literature Thermal Value	Acclimation Temperature (°F)	Endpoint Temperature (°F)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3°C (0.54°F) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1°C (1.8°F) per day until 50% lethality occurred.
Source: Table 1

Figure F-59. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of March at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, 15°F, and 20°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in March at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

410 mgd Scenario - April (River Bottom)

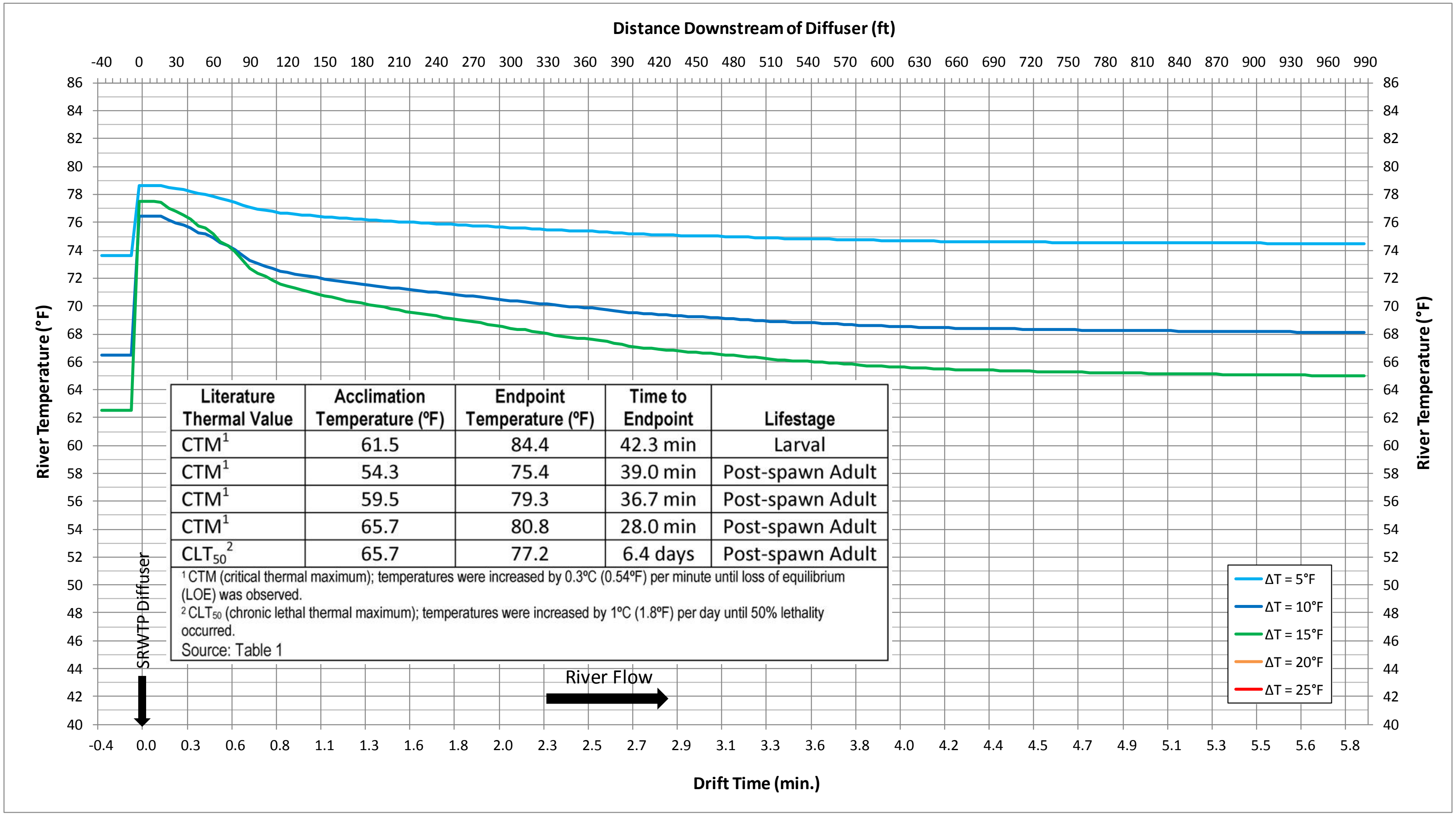


Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure F-60. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of April at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in April at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

410 mgd Scenario - May (River Bottom)



Literature Thermal Value	Acclimation Temperature (°F)	Endpoint Temperature (°F)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

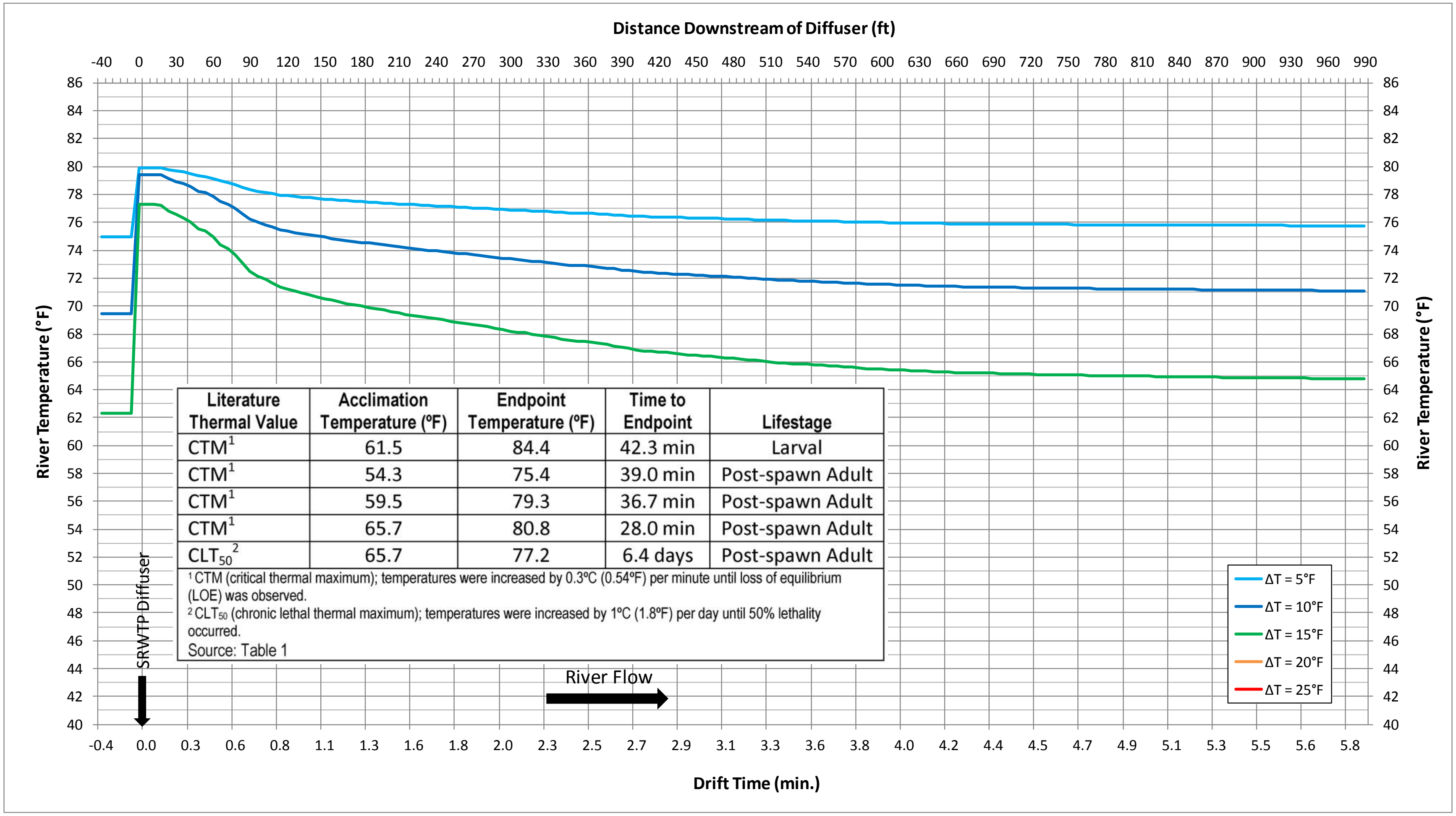
[1] CTM (critical thermal maximum); temperatures were increased by 0.3°C (0.54°F) per minute until loss of equilibrium (LOE) was observed.

[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1°C (1.8°F) per day until 50% lethality occurred.

Source: Table 1

Figure F-61. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of May at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in May at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

410 mgd Scenario - June (River Bottom)

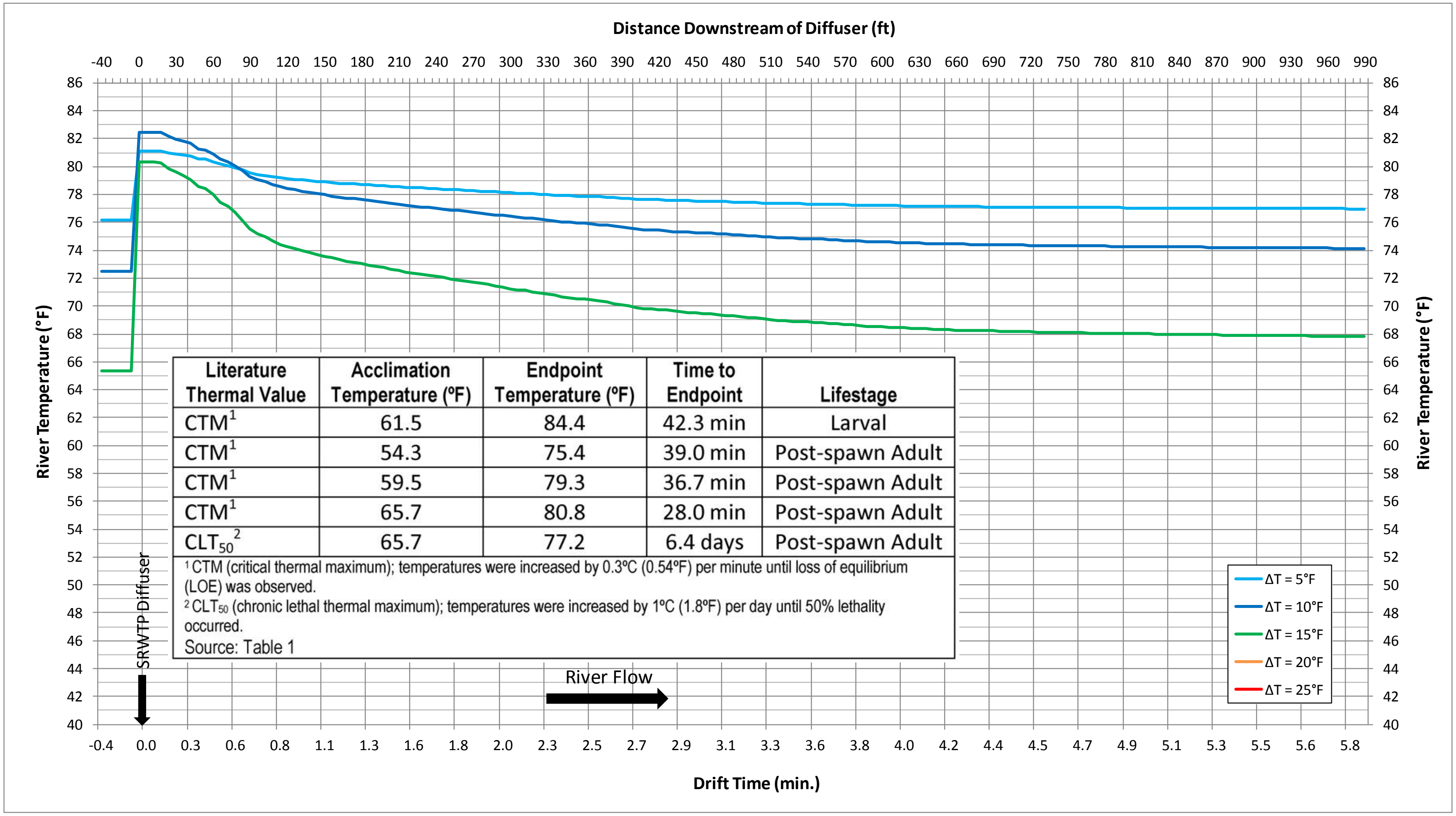


Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure F-62. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of June at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in June at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.

410 mgd Scenario - July (River Bottom)



Literature Thermal Value	Acclimation Temperature (ºF)	Endpoint Temperature (ºF)	Time to Endpoint	Lifestage
CTM[1]	61.5	84.4	42.3 min	Larval
CTM[1]	54.3	75.4	39.0 min	Post-spawn Adult
CTM[1]	59.5	79.3	36.7 min	Post-spawn Adult
CTM[1]	65.7	80.8	28.0 min	Post-spawn Adult
CLT_{50}[2]	65.7	77.2	6.4 days	Post-spawn Adult

[1] CTM (critical thermal maximum); temperatures were increased by 0.3ºC (0.54ºF) per minute until loss of equilibrium (LOE) was observed.
[2] CLT_{50} (chronic lethal thermal maximum); temperatures were increased by 1ºC (1.8ºF) per day until 50% lethality occurred.
Source: Table 1

Figure F-63. Worst-case temperature encountered by an organism drifting through the SRWTP thermal plume at the river bottom during the month of July at a SRWTP discharge rate of 410 mgd and effluent-river temperature differentials (ΔT) of 5°F, 10°F, and 15°F. Worst-case temperature lines represent the effect of the SRWTP discharge on the maximum hourly river temperature observed in July at the respective ΔT value for the February 22, 1992 through September 30, 2012 period of record.