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Adult Spring Chinook Salmon Monitoring in Clear Creek, California, 1999-2002

USFWS Report

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Abstract.—Spring Chinook salmon *Oncorhynchus tshawytscha* are listed as a threatened species under the federal Endangered Species Act. Restoration actions on Clear Creek targeted for the recovery of this species include dam removal, increased instream flows, and spawning gravel supplementation. To evaluate the effectiveness of these actions, we used snorkel surveys to monitor adult spring Chinook in Clear Creek from April through November, 1999-2002. The number of live Chinook observed during August surveys was used as an index of annual adult spring-run abundance. August index survey counts were 35 in 1999, 9 in 2000, 0 in 2001, and 66 in 2002. Spring-run spawning began as early as September 9 and continued into October. The size of spring-run redds ranged from 2.9 to 219 ft^2 with an average of 60 ft^2. The size of substrate found in redds had an average geometric mean of 34 mm and an average geometric variance of 2.6. Seven coded-wire tags were recovered from hatchery origin carcasses and included winter and fall Chinook from Coleman National Fish Hatchery and fall and spring Chinook from Feather River Hatchery.

In conjunction with our snorkel surveys, we conducted fish barrier studies. Results indicated that there are no total, temporary, or partial barriers to spring Chinook passage below Whiskeytown Dam, but there is a partial barrier (i.e. a barrier to some salmon at all flows) to fall Chinook at the Gorge Cascade (river mile 6.5). At the Gorge Cascade, we estimated an average passage rate of 2.0% for fall Chinook based on carcass recoveries upstream and downstream of the barrier. At the same barrier, we estimated a passage rate of ≥70% for spring Chinook based on snorkel counts of live fish. Snorkel surveys and barrier studies both showed that there is not a complete spatial or temporal separation between spring and fall Chinook spawning and the potential exists for hybridization of these runs.

Water temperature monitoring results demonstrated that it is feasible, using managed flow releases, to provide suitable conditions between Whiskeytown Dam and the Igo gaging station for all life stages of spring Chinook. Over the four-year study period, maintaining temperatures ≤60˚F for adult holding and juvenile rearing from June 1 through mid-September required instream flows from 68 to 90 cfs. Temperatures ≤56˚F for egg incubation were maintained from mid-September through November 1, at flows ranging between 121 and 250 cfs.

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Introduction

This report summarizes four years of monitoring associated with spring Chinook restoration on Clear Creek in Shasta County, California. Monitoring the response of adult salmonid populations to restoration activities is crucial to recovery of threatened species such as California's Central Valley spring Chinook. In the Sacramento River Valley, spring Chinook are listed as threatened under the federal Endangered Species Act. Extensive dam building was a primary cause for the decline of the spring Chinook Evolutionarily Significant Unit (ESU; CDFG 1998). Spring Chinook typically return to freshwater in the spring, hold in their natal streams through the summer, and spawn in the early fall. Water temperatures must remain cool during holding and spawning. Therefore, spring Chinook in California spawn at higher elevations than fall and late-fall Chinook, typically at 3,000 to 5,500 feet elevation. Access to higher-elevation habitat has been reduced or eliminated by dams. In Clear Creek, Whiskeytown Dam and McCormick-Saeltzer Dam (Saeltzer Dam, removed in 2000) have both contributed to the decline of anadromous salmonids.

Whiskeytown Dam diverts most of the Clear Creek natural streamflow into Spring Creek and blocks recruitment of spawning gravel from upstream. Whiskeytown Reservoir also provides a unique opportunity for restoration for spring Chinook. Cold water stored in Trinity Reservoir in the Klamath River Basin, is diverted to the Sacramento River through Whiskeytown Reservoir. When released into Clear Creek in the summer, this cold water may allow restoration of spring Chinook in reaches below 1,000 feet in elevation by providing water temperatures suitable for all life history stages.

The U.S. Fish and Wildlife Service (USFWS), Red Bluff Fish and Wildlife Office (RBFWO) has been conducting an adult salmonid monitoring project focused on spring Chinook in Clear Creek since April 1999. One goal of the monitoring is to provide information to guide and evaluate the success of the Clear Creek Restoration Program of the Central Valley Project Improvement Act (CVPIA). A second goal of the monitoring is to evaluate and mitigate impacts of the Central Valley Project as required by the National Marine Fisheries Service (NMFS) in the Terms and Conditions of the 2000 Biological Opinion for Operation of the Central Valley Project.

The Clear Creek Restoration Program has five major elements (De Staso and Brown 2002): increase stream flow (Brown 1996), improve passage at Saeltzer Dam (DWR 1997), supplement the gravel supply which has been blocked by Whiskeytown Dam (McBain and Trush 2001), restore the degraded stream channel (McBain and Trush et al. 2000), and control erosion (WSRCD 1998) to prevent negative impacts to salmonid habitat. While all of these restoration elements may have a positive impact on salmonids, the first three elements have directed actions specifically towards spring Chinook.

The Dedicated Project Yield Program authorized by Section 3406(b)2 of the CVPIA has played a major role in the success of the Clear Creek restoration by providing increased water releases from Whiskeytown Dam. Increased stream flows have been the primary reason for the five-fold increase in fall Chinook spawning escapements in Clear Creek from 1995 to 2002 over the baseline period of 1967 to 1991 (De Staso and Brown 2002). The Dedicated Project Yield Program has provided water releases specifically for spring Chinook since 2001.

Increased stream flows were largely based on a USFWS Instream Flow Incremental Methodology (IFIM) study summarized in the Clear Creek Fishery Study (DWR 1986). The Clear Creek Fishery Study recommended a salmon and steelhead flow schedule which was incorporated into the CVPIA Anadromous Fisheries Restoration Program Plan (Doubling Plan):

> Action 1. Release 200 cfs October 1 to June 1 from Whiskeytown Dam for spring-, fall-, and late fall-run chinook salmon spawning, egg incubation, emigration, gravel restoration, spring flushing and channel maintenance; release 150 cfs, or less, from July through September to maintain ≤60˚F temperatures in stream sections utilized by spring-run chinook salmon.
>
> Evaluation 1. Evaluate the feasibility of reestablishing habitat for spring-run chinook salmon and steelhead; including ensuring that water temperatures five miles downstream of Whiskeytown Dam do not exceed upper temperature limits for each of the life history stages present in the creek from June 1 to November 1, ≤60˚F for holding of prespawning adults and for rearing of juveniles, and ≤56˚F for egg incubation.

The Clear Creek Fishery Study included a flow-temperature model which suggested that adequate temperatures could be obtained during the summer with flows less than 150 cubic feet per second (cfs). A flow experiment in August 1998 demonstrated that during hot periods, flows higher than 150 cfs may be required to meet temperature targets (M. Brown, USFWS, unpublished data).

In 1999, a Biological Opinion was issued for Central Valley steelhead and spring Chinook by NMFS for the U.S. Bureau of Reclamation's operation of the Central Valley Project. This Biological Opinion required that releases from Whiskeytown Dam be provided to support steelhead rearing downstream of Saeltzer Dam during the summer of 1999. Whiskeytown releases were further increased in mid-September 1999 to reduce water temperatures for spring Chinook spawning and incubation downstream of Saeltzer Dam. The increased stream flows from June 1 to October 1 could also increase attraction of federally endangered winter Chinook salmon and federally threatened spring Chinook salmon into Clear Creek. Due to this potential, snorkel surveys for Chinook salmon and steelhead were initiated to evaluate the impact of increased flows on winter and spring Chinook salmon, and to evaluate the benefits to steelhead.

Other actions taken specifically for spring Chinook have included the removal of Saeltzer Dam in 2000 and placement of spawning-sized gravel below Whiskeytown Dam and the Placer Road Bridge. The impacts of increased flows, dam removal, and gravel placements will be considered in this report.

Separation of fall and spring Chinook was a concern before the removal of Saeltzer Dam. The approach adopted was to remove the dam, monitor the distribution of the two runs, and take action as indicated by the monitoring. If sufficient separation was not achieved, as a worst case, a physical barrier weir could be installed seasonally to keep fall Chinook out of spring Chinook spawning areas. However, a physical barrier could negatively impact Central Valley steelhead, another species federally listed as threatened. Strong concerns were expressed on the potential for impacts of blocking, delaying, or handling steelhead, which begin entering the Sacramento River watershed during the fall.

Natural barriers may provide spatial separation between spring and fall Chinook. This possibility was considered for Clear Creek as survey data from 1999 and 2000 suggested fall Chinook that passed the Saeltzer Dam site appeared to spawn in lower reaches than spring Chinook that passed the dam site. Three barriers were identified during reconnaissance snorkel surveys as potential temporary or partial barriers. An understanding of the nature of these barriers could be used in management of spring Chinook. For example, if a particular feature was a temporary barrier, then flow releases might be used to aid or prevent Chinook migration past a particular point. Potential barriers were evaluated using a variety of methods. Observations of Chinook immediately below Whiskeytown Dam demonstrated that there were no total barriers on lower Clear Creek.

One potential temporary barrier was the Gorge Cascade at river mile (rm) 6.5. The Gorge Cascade is a 70-yard stretch of high gradient, high velocity, and turbulent falls and cascades narrowly confined by bedrock. Observations in 2001 made at flows $\geq$195 cfs included large numbers of Chinook holding in the pools immediately below the Gorge Cascade, Chinook unsuccessfully attempting to jump up through the Gorge Cascade, and decreasing snorkel counts of Chinook above the cascade. In 2002, we used experimental flow releases to test the hypothesis that the Gorge Cascade was a temporary barrier to Chinook at flows $\geq$200 cfs (Giovannetti 2003). Experimental releases of 250 and 200 cfs were made. Monitoring included snorkel surveys described in this report, intensive counts of Chinook downstream of the barrier, and direct counts of fish attempting to jump the Gorge Cascade. In 2003, a physical barrier weir was installed and monitored in a similar manner for comparison.

Some spring Chinook in Clear Creek may be descendants of Chinook from the Feather River Hatchery (FRH) which were stocked into Clear Creek in the early 1990's. In order to re-establish spring Chinook in Clear Creek, approximately 200,000 juveniles from the FRH were planted in Clear Creek annually in 1991, 1992 and 1993 (Brown 1996). Contribution by the stocked FRH fish to the current spring Chinook population may be limited due to 1) a lack of suitable water temperatures during their holding and early spawning periods and 2) probable hybridization with fall-run. Also, FRH spring-run stock are considered to be a hybrid of spring and fall Chinook based on an evaluation of past hatchery practices (Brown and Greene 1993).

Therefore, as part of the Clear Creek Restoration Program, this ongoing monitoring project has five primary objectives:

1) Guide adaptive management of flows;
2) Evaluate the impacts of increased flows on spring and winter Chinook;
3) Evaluate the feasibility of restoring spring Chinook habitat;
4) Evaluate the impacts of the removal of Saeltzer Dam on fish passage; and
5) Evaluate the separation of fall and spring Chinook during spawning.

Study Area

Clear Creek, a westside tributary to the upper Sacramento River, enters the mainstem Sacramento River at rm 289 (river kilometer 465) near the south Redding city limits in Shasta County, California. The Clear Creek study area extends downstream from Whiskeytown Dam (rm 18.1; Table 1, Figure 1). Whiskeytown Dam is a complete barrier to fish passage and is the uppermost boundary of habitat available to anadromous salmon and steelhead. The study area ends at the USFWS' rotary screw trap (rm 1.7). The Anderson-Cottonwood Irrigation District (ACID) siphon and associated sheetpile dam is located downstream of the rotary screw trap (RST) at rm 1.3. Most salmonid spawning habitat is upstream of the ACID siphon. For this reason, the California Department of Fish and Game (CDFG) fall Chinook carcass survey also ends at the RST. The Clear Creek study area is 16.4 miles long and drops in elevation from 1000 feet down to 440 feet above mean sea level.

The stream channel below Whiskeytown Dam can be divided into two predominant types at Clear Creek Road Bridge (rm 8.5). Upstream, the creek is mainly confined by steep canyon walls and is characterized by falls, high gradient riffles, and deep pools. The substrate is mainly bedrock, large boulders, and fine sand. Downstream from rm 8.5 is the alluvial reach with a much lower gradient and a much wider valley relatively unconstrained by bedrock. Substrate is mainly a mixture of cobble, gravel, and sand.

Methods

Snorkel Surveys

Snorkel surveys were used to monitor adult spring Chinook in Clear Creek beginning in 1999. In this report, we classify adult spring Chinook as salmon immigrating into the creek from late April through August and spawning after August 1. This classification may exclude some spring Chinook immigrating after August or include some winter or fall Chinook. Spring Chinook surveys were snorkel surveys conducted from late April through November. The survey included a16.4 mile-long section of Clear Creek starting at Whiskeytown Dam (rm 18.1) and extending downstream to the USFWS' rotary screw trap (rm 1.7). The survey was divided into six reaches (Figure 1, Table 2) and required five or six days to complete. Surveys began at the upstream most reach (Reach 1) and continued downstream on consecutive days. Moving downstream with the current, three snorkelers counted adult Chinook, Chinook carcasses, and Chinook redds. (Although not included in this report, rainbow trout were also counted and divided into three size categories.) Generally, snorkelers were adjacent to each other in a line perpendicular to the flow and would keep track of individual counts within their lane or area of the creek. As needed, snorkelers would confer with each other to make sure no salmon were missed or double counted and then sum and record their counts. When entering large plunge pools where salmon could be concealed below bubble curtains, one snorkeler would walk around and enter from downstream to count salmon while the other two snorkelers would enter at the head of the pool through the bubble curtain.

In 1999, spring Chinook snorkel surveys were conducted weekly and were mainly limited to Reach 6. Infrequent surveys were conducted in upstream reaches. Few, if any, salmon were known to use the fish ladder at Saeltzer Dam (rm 6.5) and pass upstream of Reach 6. Also, the feasibility of conducting snorkel surveys in the high gradient canyon reaches was unknown. The downstream boundary of Reach 6 was at rm 2.2 in 1999 whereas in all other years it was at rm 1.7.

Beginning in 2000, we conducted monthly surveys of reaches 1-6. In 2002, surveys were conducted twice a month in September and October to more accurately determine spawning timing. Supplemental surveys of particular reaches were occasionally added to the survey schedule. In all years, surveys of Reach 6 were terminated in late September or early October due to the high abundance of fall Chinook.

Stream flow, water turbidity, and water temperature can all influence the effectiveness of snorkel surveys (Thurow 1994). We collected data on these three parameters for each snorkel survey. Stream flow was recorded at the US Geological Survey (USGS) gaging station near Igo (rm 10.9). Turbidity samples were taken at the beginning and end of each reach and analyzed the same day using a Model 2100 Hach Turbidimeter. We measured water temperature at the beginning and end of each survey reach with a hand-held submersible thermometer.

Migration timing and spatial distribution of live Chinook.—Snorkel surveys were used to document the migration timing and spatial distribution of Chinook in Clear Creek. The date and number of live Chinook observed per reach were recorded. Additionally, Chinook locations were documented using a hand-held Global Positioning System (GPS) receiver or aerial photographs. Our annual spring Chinook population index was the highest number of Chinook observed during an August snorkel survey.

Time and spatial distribution of Chinook carcasses.—Carcass locations were documented using a hand-held GPS receiver or aerial photographs. Data gathered from carcasses included tissue and scale samples, fork length, gender, presence or absence of eggs, presence of an external tag (e.g. floy tag) and presence of an adipose fin. Heads were collected from all adipose-fin clipped carcasses and from carcasses where the presence of a fin clip could not be determined due to decomposition. Coded-wire tags (CWTs) were later extracted from heads in the laboratory. After sampling, we marked (e.g. removed the caudal fin) or removed the carcasses from the creek in order to not double count them on subsequent surveys.

Tissue samples for genetic analyses were taken in triplicate, usually from a fin (the operculum was sampled if the carcass was highly decayed). Two of the samples were placed in vials containing tris-glycine buffer then frozen and one was dried for 24 hours before storing in a small envelope. Samples are archived at the RBFWO.

Spawning timing and spatial distribution of Chinook redds.—Redd locations were documented using a hand-held GPS receiver or aerial photographs. All redds were marked by tying flagging to nearby vegetation in order to differentiate between old and new redds. Documented redds needed to have both a clearly defined pit and tailspill. "Practice" or "test" redds lacking clear form were not classified as redds.

In order to evaluate spawning gravel supplementation projects, we recorded the origin of the gravel at redd locations as native, supplementation gravel, mixture of native and supplementation gravel, or unknown. Supplementation gravel was identified by tracer rock (chert-laced reddish rock not found in the Clear Creek watershed), size, and shape.

Redd Measurements

We measured spring Chinook redds and conducted pebble counts of redd surface substrate. We selected spring-run redds for measurement based on date and location. Redd measurements included maximum length, maximum width, maximum depth (redd pit), minimum depth (redd tailspill) and pre-redd depth (measured immediately upstream of the redd). Redd area was calculated using the formula for an ellipse (area = π•½ width•½ length). Pebble counts were used to characterize the size distribution of spawning substrate. We selected 50 pebbles from both the redd pit and tailspill, measured the intermediate diameter, and classified them according to 9 size categories (0-2mm, 2-4mm, 4-8mm, 8-16mm, 16-32mm, 32-64mm, 64-128mm, 128-256mm, 256-512mm, and 512-1024mm). Stones were systematically selected by moving over a redd in a series of transects parallel and perpendicular to stream flow. Any particular stone could be selected more than once. We used pebble count data to plot cumulative size distribution curves from which the D_{16} (i.e. particle diameter at which 16% of sample was smaller), D_{50} (median diameter), and D_{84} (i.e. particle diameter at which 84% of sample was smaller) were obtained. Size distribution summary statistics included the geometric mean (dg) and geometric variance (sg) and were calculated as follows:

$dg = (D_{84} \bullet D_{16})^{0.5}$
$sg = (D_{84}/D_{16})^{0.5}$

Stream Flow and Temperature Conditions

Stream temperatures were evaluated based on the criteria stated in the Doubling Plan (USFWS 2001) and the Biological Opinion for the Central Valley Project (CVP) and State Water Project (SWP) operations (NMFS 2002). From June 1 to November 1, temperature criteria for spring Chinook were ≤60˚F for holding of adults and rearing of juveniles and ≤56˚F for egg incubation. The transition date from ≤60˚F to ≤56˚F varied among years and was designated as the day after resource managers increased flows to meet the more stringent ≤56˚F criteria, generally in mid-September. The transition date was specified to be September 15 (NMFS 2002), but occurred earlier in 2002 and 2003 due to recommendations of the Clear Creek Restoration Program Technical Team.

We varied the temperature target location among years based on management objectives. In 1999 the target location was designated as rm 5.0 in an attempt to provide suitable water temperatures below Saeltzer Dam (rm 6.5) for spring Chinook and steelhead. In 2000, to facilitate the removal of Saeltzer Dam, flows were decreased to 50 cfs and no attempt was made to provide cool water habitat for spring Chinook. After the removal of Saeltzer Dam, the target location was moved upstream to rm 10.9 (USGS gaging station) beginning in 2001. In the future, resource managers will continue to seek to provide suitable cool water habitat for spring Chinook and steelhead between Whiskeytown Dam and the USGS gaging station. Although the gaging station was not the temperature target location in 1999 and 2000, we evaluated temperatures at this location for these years in an effort to better understand the relationship between flow and temperature at this site.

Water release (outflow) data for Whiskeytown Dam was obtained from the Department of Water Resources (DWR) web site. Stream flow data measured at rm 10.9 was obtained from the USGS web site. USGS stream flow data is published through September 30, 2002 and is provisional thereafter. Water temperature data measured at rm 10.9 was obtained from the DWR web site and is provisional. Temperature data from all other locations was obtained from Optic StowAway® Temp loggers placed and maintained by the USFWS or DWR.

Barrier Analyses

We classified natural barriers to upstream passage of adult Chinook salmon (e.g. waterfalls, chutes, and cascades) as "partial barriers" (i.e. barriers to some fish at all flows) or "temporary barriers" (i.e. barriers to all fish at some flows) as defined by Dane (1978, cited in Powers and Orsborn 1985). Four methods were used to test if potential barriers were partial or temporary: experimental flow releases, carcass distribution, August snorkel counts, and physical measurements. The three potential barriers evaluated were the Gorge Cascade (rm 6.5, top of Reach 6), Placer Falls (rm 10.6, Reach 4), and Two Tier Falls (rm 11.9, Reach 3). There are no total barriers (i.e. barriers to all fish at all flows) downstream of Whiskeytown Dam.

Experimental flow releases.—In 2002, we used experimental flow releases to test the hypothesis that the Gorge Cascade was a temporary barrier to Chinook salmon at flows ≥200 cfs (Giovannetti 2003). To test our hypothesis, flow releases from Whiskeytown Dam were increased from base flows of 70 cfs up to 250 cfs on September 13, held at 250 cfs for two weeks and then decreased to 200 cfs on September 27. Experimental flows were timed to coincide with the beginning of the fall Chinook immigration period. Three snorkel surveys were used to determine if salmon were passing above the Gorge Cascade at the two experimental flows; the first survey immediately preceded the increase to 250 cfs (September 9-13), the second began 10 days following the increase to 250 cfs and immediately preceded the decrease to 200 cfs (September 23-27), and the third began 11 days following the decrease to 200 cfs (October 8-11). We also used the experimental flow study to determine if Placer Falls and Two Tier Falls were temporary barriers.

Carcass distribution.—We used the spatial distribution of carcasses to determine if the Gorge Cascade was a partial barrier to spring and fall Chinook combined. The percent of Chinook passing the Gorge Cascade was calculated based on the total number of carcasses recovered between late April and early November. Carcasses in reaches 1-5 (above the Gorge Cascade) were recovered by snorkel survey. Carcasses in Reach 6 (below the Gorge Cascade) were recovered by snorkel survey (April-September) and by CDFG's weekly walking carcass survey (October- November). Assumptions of this analysis include: 1) carcass recovery rates were the same for all reaches, 2) carcass recovery rates were the same for snorkel and walking surveys, and 3) carcasses did not drift from reaches 1-5 into Reach 6.

August snorkel counts.—We used the distribution of live Chinook observed during our August index surveys to evaluate all three barriers specifically in relation to spring Chinook passage. For example, a low percentage of observations upstream of a barrier may indicate that it is a partial barrier to spring Chinook.

Physical measurements.—Physical measurements were taken of Placer Falls to determine if it was passable to Chinook salmon at various flows. Each passage route through Placer Falls was measured and evaluated individually. Barrier measurements included the following.

1) vertical height: height from the water surface of the plunge pool to the water surface flowing over the barrier.
2) width at base of passage route.
3) breadth (horizontal distance parallel to flow from the top to bottom of the structure).
4) depth of plunge pool.
5) water velocity: at the top of barrier.
6) water velocity: at the tail out of the barrier

Based on these measurements, a determination was made if barrier conditions were within the swimming and leaping capabilities of adult Chinook. For swimming up chutes, we assumed the swimming capabilities of Chinook in poor to good physical condition ranged from 11.2 - 16.8 ft/s which is 50 - 75% of the maximum burst speed of 22.4 ft/s for Chinook (Powers and Orsborn 1985, Bell 1990). For successful jumping of cascades and small waterfalls, the capability of a salmon to both clear the height and the breadth of the structure was evaluated using the following equation described by Powers and Orsborn (1985) for the parabolic trajectory of a leaping salmon:

$$H = (\tan\theta)X - 32.2(X)^2/2(V\cos\theta)^2$$

where:

H = height of leap;
θ = angle of trajectory upon leaving the water (evaluated at 80˚, 60˚, and 40˚);
X = horizontal distance of leap;
V = 75% of the maximum burst speed of a Chinook = 0.75 * 22.4 ft/s.

In addition to the leaping capabilities of Chinook, we also assumed that, for a successful jump, the depth of the jump pool needed to be either 1.25 times the vertical height or greater than about 8 feet (Reiser and Peacock 1985, cited in Bain and Stevenson 1999).

Physical measurements were not used to evaluate Two Tier Falls and the Gorge Cascade. Conditions were too hazardous at these sites to obtain good measurements of all passage routes.

Results

Snorkel Surveys

The average number of spring Chinook snorkel surveys in each reach ranged from 8 to 10 in all years except 1999 (Table 3). In 1999, we completed 22 surveys in Reach 6 and ≤4 in all other reaches. We conducted snorkel surveys in flows ranging from 50 to 305 cfs with annual averages being <179 cfs (Table 4). Turbidity ranged from 0.5 to 5.5 nephelometer turbidity units (NTU) with annual averages being <1.7 NTU. Turbidity was lower in 2001 and 2002 as annual averages were <1.0 NTU. Temperature ranged from 47˚ to 79˚F. Our spring Chinook August index surveys were conducted under better than average viewing conditions; flows were near their annual low, turbidity was at or below average levels, and water temperature was suitable for snorkelers (Table 4).

Migration timing and spatial distribution of live Chinook.—In 1999, our spring Chinook August index was 35 (i.e. the maximum number of live Chinook observed during an August survey). The particular survey on which the population index was based did not include reaches 3-5 and therefore may slightly under represent Chinook in the creek at that time (earlier in August one Chinook was seen in Reach 5 and zero in reaches 3 and 4). Throughout the season, observations in Reach 6 generally increased from one Chinook on May 5 to 957 on September 29 (Figure 2, Table A1). Early in the survey season, we found that debris (evidently from beaver activity) was blocking the upstream exit of the Saeltzer Dam fish ladder making it impassable to fish. Survey crew members removed the debris weekly. Each week enough debris accumulated to completely block fish passage. Initial reconnaissance surveys upstream of Reach 6 (and Saeltzer Dam) were conducted from August 19 to September 2 to determine if salmon were using the fish ladder. During these initial surveys, only one Chinook was observed in Reach 5 although 22 to 35 Chinook were observed during this same time period in Reach 6. We again surveyed Reach 5 on September 23 and observed only two Chinook although 247 Chinook were observed in Reach 6 the same week. A third survey effort above Saeltzer dam (reaches 4 & 5 only) was done on October 19 during which 41 live Chinook and 20 carcasses were observed, setting the minimum passage through the fish ladder at 61 salmon. Therefore, we estimate most Chinook passing above Saeltzer Dam did so between September 23 and October 19 (Table A1). We did not document Chinook in reaches 1-3 but these surveys were conducted prior to most fish moving above Saeltzer Dam. Surveys of reaches 1-4 showed that snorkel surveys were feasible in the higher gradient canyon reaches of Clear Creek.

In 1999, 44 observations (1 in Reach 5 and 43 in Reach 6) of Chinook were made at locations on days when the mean daily temperature (MDT) exceeded 60˚F (our criteria for holding of pre-spawning adults is ≤60˚F). These observations were made between June 15 and August 30 during which period 185 total observations of Chinook were made (Table 5). The duration of exposure to high water temperatures could not be determined as Chinook may have been migrating upstream.

In 2000 we began monthly surveys of reaches 1-6. Our spring Chinook August index was nine. Observations of Chinook fluctuated between 6 and 17 from April through September then increased to 637 Chinook the week of October 14 (Figure 3, Table A2). Our next survey was in late November (reaches 4&5 only) and zero Chinook were seen. Although Chinook were observed in all reaches in 2000, few were distributed above Saeltzer Dam (reaches 1-5). Observations in reaches 1-5 peaked at 17 the week of July 10 then decreased on each subsequent survey (the initial decrease corresponded to the recovery of two carcasses in Reach 3). Of the 637 Chinook observed the week of October 14, only three were located upstream of Reach 6 as the deconstruction of Saeltzer Dam made upstream passage nearly impossible after the first week in September. An important observation of one Chinook in Reach 1 was made on April 26. This was the first observation of a Chinook upstream of Reach 4 and also the earliest we have seen a Chinook in the uppermost reach.

In 2000, 35 observations (11 in Reach 4 and 24 in Reach 6) of Chinook were made at locations on days when the MDT exceeded 60˚F. These observations were made between May 25 and September 28 during which period 73 total observations of Chinook were made (Table 5).

In 2001, our spring Chinook August index was zero. Observations of Chinook during regularly scheduled monthly surveys fluctuated between zero and four from April though August. On September 13 we counted 37 Chinook in Reach 6 during a supplemental survey and then 619 (49 in reaches 1-5) the week of September 26 (Figure 4, Table A3). In late October, total observations in reaches 1-5 continued to increase to 69 Chinook and then declined to one in November (Reach 6 was not surveyed). Chinook were observed in all reaches during the late September and late October surveys with October counts being higher than September in the uppermost and lowermost two reaches.

In 2001, five observations (all in Reach 6) of Chinook were made at locations on days when the MDT exceeded 60˚F. These observations were made between June 18 and September 13 during which period 44 total observations of Chinook were made (Table 5).

In 2002, our spring Chinook August index was 66. Monthly observations of Chinook increased gradually from three in April to 75 in early September, then increased to 732 (96 in reaches 1-5) in late September (Figure 5, Table A4). In early October, observations in reaches 1-5 continued to increase to 219 Chinook and then declined in late October and November (Reach 6 was not surveyed). The distribution of Chinook gradually shifted from the lower to the upper reaches from April through early September: in April and May, the majority were in the lower two reaches; by June, the majority were in the middle two reaches; and in August and early September the majority were in the upper two reaches (Figure 5). By late September, flows were increased and the fall-run immigration had begun. Total counts of Chinook in late September increased in reaches 3-6 but decreased in the upper two reaches. Then in early October counts increased in all reaches.

In 2002, 45 observations (3 in Reach 5 and 42 in Reach 6) of Chinook were made at locations on days when the MDT exceeded 60˚F. These observations were made between July 15 and August 16 during which period 129 total observations of Chinook were made (Table 5).

Time and spatial distribution of Chinook carcasses.—In 1999, one Chinook carcass was encountered on August 11, one week prior to the first observations of Chinook redds. Carcasses were again encountered on September 22 and on every survey thereafter. We encountered a total of 92 carcasses during the survey period, of which two had an adipose-fin clip (Figure 3, Table A1). Based on CWT information, these clipped salmon included one spring-run from Feather River Hatchery (FRH, collected September 29 in Reach 6) and one fall-run from FRH (collected

September 29 in Reach 6; Table A5). Tissue samples for genetic analyses were collected from 18 unclipped carcasses (Table 6).

In 2000, two carcasses were encountered in Reach 3 on August 3, seven weeks prior to the first redd observations. The two carcasses were only skins and appeared to have been preyed upon or poached. River otter scat was observed with the skins. In the vicinity these carcasses, we estimate MDTs had ranged from 60˚ to 63˚F following the previous July 11 survey when three live Chinook were observed. Other carcasses were observed on the final two surveys of the season in late September and October. We encountered a total of 39 carcasses during the survey period, of which zero had an adipose-fin clip (Figure 3, Table A2). Tissue samples for genetic analyses were collected from five unclipped carcasses (Table 6).

In 2001, one carcass was encountered in Reach 6 on July 9, five weeks prior to the first redd observations. The July carcass had a CWT and was a winter Chinook from Coleman National Fish Hatchery (CNFH). Carcasses were again observed during the week of September 26 and on each survey thereafter. We encountered a total of 96 carcasses during the survey period, of which one additional clipped fish was recovered (Figure 3, Table A3). CWT information revealed that the second clipped fish was a spring-run from FRH (collected September 28 in Reach 6; Table A5). Tissue samples for genetic analyses were collected from 40 unclipped carcasses (Table 6).

In 2002, one carcass (highly decayed) was encountered in Reach 6 on May 17, 16 weeks prior to the first redd observations. Carcasses were again observed during the week of September 16, one week following the first redd observations, and on each survey thereafter. During the survey period, we encountered a total of 124 carcasses, of which three had adipose-fin clips (Figure 3, Table A4). Clipped salmon included one CNFH fall-run (collected October 10 in Reach 3), one FRH fall-run (collected October 11 in Reach 5), and one FRH spring-run (collected October 24 in Reach 4; Table A5). Tissue samples for genetic analyses were collected from 79 unclipped carcasses (Table 6).

From 1999 through 2002, we collected 335 tissue samples from adult Chinook carcasses during snorkel surveys and other Clear Creek monitoring activities (Table 13). Of these samples, 96 were from potential spring-run, being collected between July 15 and October 15. Future genetic analyses of samples from potential spring-run may answer questions as to the true run designation and contributing populations (e.g. Mill-Deer Creek spring-run, Butte Creek spring-run, FRH spring-run). Genetic samples will not be used as a baseline genotype of Clear Creek spring-run as they may include Chinook from other runs. All samples were taken from unmarked Chinook (adipose fin present) with the exception of one winter-run in 2001.

Spawning timing and spatial distribution of Chinook redds.—In 1999, we observed a total of 85 redds in reaches 4-5 and 281 in Reach 6 (Figure 4, Table A1). Reaches 1-3 were surveyed one time, prior to the spring Chinook spawning period. Reach 6 surveys ended on September 29, prior to the end of the spawning period. The first redd was observed in Reach 6 on September 9. This redd was constructed sometime after August 30. Redd counts continued to increase through the final Reach 6 survey on September 29. Occasional surveys of Reach 5 indicated that the majority of spawning activity in this reach occurred between the weeks of September 22 and October 20. Spawning densities were 5 redds/mile in Reach 4 and 37 redds/mile in Reach 5 (Table 7). Ninety-five redds were exposed to MDTs greater than 56˚F but less than 60˚F and were observed in Reach 6 from September 9-21. Based on temperature exposure following the date redds were first observed (actual spawning date unknown), the minimum number of days exposed to MDTs exceeding 56˚F included 16 days for 1 redd, 12 days for 5 redds, and 5 days for 89 redds (Table 5).

In 2000, we observed a total of 13 redds in reaches 1-5 and 469 in Reach 6 (Figure 4, Table A2). Unlike other years, we observed Chinook redds on the first three surveys of the season in Reach 6; 2 redds on April 24, 2 on May 3, and 2 on May 10. These six early season redds were constructed when MDTs were less than 56˚F and Whiskeytown Dam releases were 200 cfs but were exposed to excessively high MDTs beginning May 18 when dam releases were reduced to 100 cfs. Early season redds were exposed to a minimum of 30 to 42 days of MDTs greater than 56˚F. Early season redds were exposed to maximum MDTs of 65˚ to 71˚F. Minimum days of exposure was based on the criteria that 1) 1,600 Daily Temperature Units (DTU = MDT - 32) were required for egg incubation to time of emergence (Piper et al. 1982) and 2) the redds were constructed the day following the preceding survey (i.e. April 15 following a walking type survey, April 25, and May 4).

Following early season observations in 2000, nine redds were observed the week of September 25. The nine redds were located upstream in reaches 1, 2, and 4 and represented the majority of spawning activity in reaches 1-5. These redds were constructed sometime after the week of August 30 and were constructed prior to flows being increased for fall Chinook spawning (from 50 to 125 cfs on September 30). On the next survey, the week of October 14, we observed 467 new redds of which 463 were located in Reach 6. Saeltzer Dam deconstruction made fish passage above Reach 6 nearly impossible following the first week in September. Supplemental surveys of reaches 4 and 5 in late November indicated that no new redds were constructed in these reaches following the October 14 survey. Redd densities within reaches 1-5 were low in 2000, ranging from 0 redds/mile in Reach 3 to 2 redds/mile in Reach 2 (Table 7). One redd, observed September 28 in Reach 4, was exposed to at least two days when MDTs exceeded 56˚F (but <60˚F, Table 5).

In 2001, we observed a total of 81 redds in reaches 1-5 and 99 in Reach 6 (Reach 6 was not included as part of the final two surveys of the season) (Figure 4, Table A3). The first redd was observed on September 13 during a Reach 6 supplemental survey (flows were increased from 75 to 100 cfs on September 7) and was constructed after August 17. Approximately two weeks later (the week of September 26), a survey of all reaches documented 102 new redds, 98 of which were in Reach 6 (flows were increased from 100 to 120 cfs on September 15). All redds observed in September were located in the lowermost 3 reaches with 96% being in Reach 6. By the week of October 24, redds were observed in all reaches (flows were increased from 120 to 200 cfs by October 16). Counts of new redds for reaches 1-5 peaked during the week of October 24 indicating that spawning activity was highest between the weeks of September 26 and October 24. Spawning density within reaches 1-5 was highest in Reach 5 at 22 redds/mile, followed by Reach 4 at 9 redds/mile. Reaches 1-3 ranged from 2 to 3 redds/mile (Table 7). In 2001, 98 redds (all in Reach 6) were exposed to MDTs exceeding 56˚F (but <60˚F). Minimum number of days exposed to MDTs exceeding 56˚F included 23 days for one redd and 8 to 11 days for 87 redds (Table 5).

In 2002, we observed a total of 227 redds in reaches 1-5 and 199 in Reach 6 (Reach 6 was not included as part of the final three surveys of the season) (Figure 4, Table A4). The first redds were observed during the week of September 11 (13 redds). These early season redds, in contrast to 2001, were located in the upstream most three reaches, were constructed sometime after the week of August 14, and were constructed prior to flows being increased for fall Chinook spawning (from 70 to 250 cfs on September 13). On the next survey, the week of September 25, redds were observed in all reaches. Spawning activity was the highest in reaches 1-3 in the two weeks prior to the week of September 25 whereas it was highest in reaches 4 and 5 in the two weeks following the week of September 25. A supplemental survey of Reach 1 on September 16 indicated that spawning activity in the uppermost reach was highest between September 11 and 16. Spawning density within reaches 1-5 was highest in Reach 5 at 48 redds/mile, followed by Reach 1 at 20 redds/mile. Reaches 2-4 (the canyon reaches) ranged from 10 to 14 redds/mile (Table 7). In 2002, three redds in Reach 3 were exposed to MDTs exceeding 56˚F (but <60˚F) for a minimum of three days (Table 5).

Supplemental spawning gravel was placed in two locations upstream of Reach 6; below Whiskeytown Dam (Reach 1) and below Placer Road Bridge (Reach 4). During our four-year survey period, Chinook redds were not observed in the Whiskeytown Dam supplementation gravel and one redd was observed in the Placer Road Bridge supplementation gravel (November 16, 2001). Although, outside the scope of this report, we documented multiple steelhead redds in the Whiskeytown Dam supplementation gravel in 2001 and 2002.

Redd Measurements

Measurements were taken from 39 Chinook redds observed between September 2 and October 26 in the years 2001 and 2002 (Table A6). Redds in the lowermost two reaches were not measured following the first week in October due to the presence of many fall Chinook. Redd area ranged from 2.9 to 219 ft^2 with an average of 60 ft^2 (Table 8). In a review of published literature, Healey (1991) reported a size range of 5.4-482.2 ft^2 for Chinook redds. Three redds on Clear Creek had areas less than what has been reported in the literature and may have been under construction as they were observed early in the spawning season (September 11, 2002). Redd depths (pre-construction) ranged from 0.9 to 4.8 ft with an average of 2.2 ft (Table 8). Water velocity was measured at only five redds and ranged from 1.0 to 2.8 ft/s with an average of 1.6 ft/s. Both redd depths and velocities were within the range reported for stream type (spring-run) Chinook (Healey 1991).

We conducted pebble counts in 19 of the 39 redds measured (Table A7, Figures A1-A19). For the total redd (pit and tailspill combined) the D_{16}, D_{50}, and D_{84} were within the suitable range for Chinook spawning gravel (DWR 1994, based on bulk sample size distributions). The total redd D_{50} ranged from 26 to 57 mm and the dg ranged from 19.1 to 54.8 mm (Table 9). Sorting coefficients (sg) ranged from 1.8 to 3.9. In comparing pit and tailspill distributions, the average D_{50} and dg (measures of central tendency) were very similar but pit material was less sorted (higher sg; Table 9). Pit material included more fines (lower D_{16}) and more coarse material (higher D_{84}) than the tailspill. This would be expected as larger particles which the salmon were unable to move would remain in the pit and fines would settle out in the lower velocities of the pit.

Stream Flow and Temperature Conditions

Prior to 1999, stream flows below Whiskeytown Dam (rm 18.1) were reduced annually to approximately 50 cfs during the summer and increased in early October to provide suitable water temperatures for fall Chinook spawning below Saeltzer Dam (rm 6.5). In response to Central Valley steelhead being listed as threatened on March 19, 1998 under the federal Endangered Species Act (ESA), minimum summer flows were increased in 1999 to 150 cfs to provide suitable habitat for steelhead rearing below Saeltzer Dam (NMFS 2000). Subsequently, anticipating the imminent listing of spring Chinook salmon as threatened (listed on September 16, 1999), flows were further increased to provide suitable spawning habitat for spring-run in early September. Thus, Whiskeytown releases were set at 150 cfs on June 1, increased to 200 cfs on September 7, increased to 250 cfs on September 10, and decreased to 200 cfs on October 1 (Figures 2-4). Water temperatures were evaluated according to the ≤60˚F criteria (suitable for holding of pre-spawning adults and juvenile rearing) for the period of June 1 to September 11 and the ≤56˚F criteria (suitable for egg incubation) from September 11 to November 1. The temperature target location was set 1.5 miles downstream of Saeltzer Dam at rm 5.0. MDTs exceeded 60˚F on 32 days of the 102 day period. The 32 days occurred between June 22 and August 22 at mean daily flows (MDFs) of 143-149 cfs. MDTs exceeded 56˚F on 14 days of the 51 day period. The 14 days occurred between September 11 and September 25 at a MDF of 244 cfs. In contrast to the target location, water temperatures at Saeltzer Dam exceeded criteria only five days during the holding period and five days during the egg incubation period. Temperature criteria were not exceeded in 1999 at the Igo gage (rm 10.9; Figure 5).

In 2000, the deconstruction and removal of Saeltzer Dam occurred in the fall during the typical holding and spawning period for spring Chinook. Dam deconstruction required low flows, potentially blocking upstream access, and making it difficult to provide cool water habitat for spring Chinook confined to Reach 6. Therefore, in an effort to discourage spring Chinook strays from entering Clear Creek, flows were lowered to 100 cfs on May 21 and then to 50 cfs in June. Although no attempt was made to meet temperature criteria for spring Chinook, we evaluated temperatures at the Igo gage to better understand the flow-temperature relationship. Whiskeytown Dam releases were 100 cfs on June 1, decreased to 50 cfs on June 28, and increased to 125 cfs beginning September 28 for fall Chinook spawning. In late October releases fluctuated between 50 and 140 cfs to facilitate the final stages of dam deconstruction (Figures 2-4). We used the ≤60˚F criteria for the period of June 1 to October 1 and the ≤56˚F criteria from October 1 to November 1. MDTs at the Igo gage exceeded 60˚F on 44 days of the 123 day period. The 44 days occurred between June 28 and August 17 at MDFs of 54-76 cfs. MDTs did not exceed 56˚F during October (Figure 6).

With the removal of Saeltzer Dam, Chinook had improved access to the upper reaches of lower Clear Creek beginning in 2001. The temperature target location was designated as the Igo gage in order to provide habitat suitable for spring Chinook in the 7.3 miles below Whiskeytown Dam. Whiskeytown Dam releases were 125 cfs from June 1 to July 2. Flows were then ramped down to 75 cfs by July 5 and remained there until September 6. Dam releases were set at 100 cfs on September 6 and 120 cfs on September 14. Flows remained at 120 cfs until October 1 at which time flows were gradually ramped up to 200 cfs over a 15 day period. Flows remained at 200 cfs through November 1 (Figures 2-4). We used the ≤60˚F criteria for the period of June 1 to September 15 and the ≤56˚F criteria from September 15 to November 1. MDTs at the Igo gage did not exceed 60˚F during the 106 day period and only exceeded 56˚F on 1 day of the 47 day period. The one day above 56˚F occurred on September 16 at a MDF of 121 cfs (Figure 7).

During the summer of 2002, instream construction activities were scheduled as part of the Clear Creek Floodway Restoration Project (Phase 3A). Resource managers sought to meet temperature criteria at the Igo gage while minimizing instream flows to facilitate restoration activities. Dam releases were changed 14 times between July 2 and September 13 in response to high air temperatures or specific project needs. Whiskeytown releases were steady at 150 cfs for the month of June. Flows were ramped down to 65 cfs beginning July 1 and fluctuated between 65 and 95 cfs from July 1 through September 13. After the completion of instream restoration activities, flows were increased to 250 cfs on September 13 and then decreased to 200 cfs on September 27 where they remained through November 1 (Figures 2-4). We used the ≤60˚F criteria for the period of June 1 to September 14 and the ≤56˚F from September 14 to November 1. MDTs at the Igo gage exceeded 60˚F on 1 day of the 105 day period and did not exceed 56˚F during the 48 day period. The one day above 60˚F occurred on July 9 at a MDF of 75 cfs (Figure 8).

In addition to temperature criteria target locations, we also monitored water temperatures at the upper and lower extent of lower Clear Creek. Temperature loggers were placed below Whiskeytown Dam and near the confluence with the Sacramento River (rm 0.5). Below Whiskeytown Dam, MDTs were similar between years (Figure 9) with an annual maximum MDT of 53˚F in 1999, 2000, and 2001 and 54˚F in 2002. Near the confluence, summer MDTs varied between years (Figure 9) with an annual maximum MDT of 68˚F in 1999, 78˚F in 2000, 72˚F in 2001, and 72˚F in 2002. Maximum MDTs at the confluence were inversely correlated to stream flow (r^2=0.85, nonlinear {power} regression).

Barrier Analyses

Experimental flow releases.—We used managed flow releases to determine if the Gorge Cascade (rm 6.5) was a temporary barrier to Chinook at flows of approximately 250 and 200 cfs. Stream flows, as measured at the USGS gaging station, were within approximately 6 cfs of the scheduled experimental dam releases. Snorkel survey counts above the cascade began at 47 live Chinook immediately preceding the flow increase from 76 to 252 cfs. Counts then increased to 96 (104%) while flows were at 252 cfs, and increased to 219 (128%) while flows were at 206 cfs (Figure 10, Table 10).

During the same three snorkel surveys, counts of live Chinook above Placer Falls (rm 10.6) began at 43, increased to 46 (7%), and increased again to 61 (33%). Counts above Two Tier Falls (rm 11.9) began at 41, decreased to 38 (-7%), and then increased to 54 (42%).

Carcass distribution.—The percentage of spring and fall Chinook carcasses recovered above the Gorge Cascade (i.e. passage rate) was 2.1% in 2001 and 1.9% in 2002. Percentages were not calculated in 1999 as monthly surveys were not conducted in the upper reaches and, in 2000, as the removal of Saeltzer Dam prevented many salmon from moving above the cascade.

August snorkel counts.—During the 2002 spring Chinook August index survey, the percentages of live Chinook upstream of potential barriers were 70% above the Gorge Cascade, 55% above Placer Falls, and 48% above Two Tier Falls (n=66). Chinook ascended these barriers at flows ranging from about 70 to 160 cfs. In all years other than 2002, August counts were too low in reaches 1-5 to analyze.

Physical measurements.—Physical measurements of Placer Falls were made at five different flows; 75, 100, 130, 135, and 180 cfs. Measurements were made in the period August-October 2001. The number of passage routes through Placer Falls ranged from 8 to 11. Passage criteria for Chinook were met for all routes except two at 100 and 180 cfs (Table 11). In the cases when criteria were not met, water velocities exceeded the swimming capabilities of salmon in “poor” physical condition (11.2 ft/s) but not for salmon in “good” condition (16.8 ft/s). There were no cases where the jumping capabilities of Chinook were exceeded with respect to either jump dimensions (height vs. breadth) or jump-pool depth. As stream flow increased, water velocities generally did not increase proportionally (Figure 11).

Discussion

Snorkel Surveys

Spring Chinook August population indexes for Clear Creek were 35 in 1999, 9 in 2000, 0 in 2001 and 66 in 2002. Population indexes for all years were low which would be expected as Clear Creek has not had a population of spring Chinook in the recent past (CDFG 1998). Survey results indicate that August is the best time period on which to base an index of the spring Chinook population in Clear Creek. August counts occurred at the end of the spring Chinook immigration period (and did not include pre-spawning mortalities), closely preceded the beginning of spring Chinook spawning, and preceded the immigration of most fall Chinook. Although snorkel observations do not provide a total count of fish, conditions in Clear Creek were generally excellent for viewing salmon, especially in August. In August stream flows were near their annual low, flows were stable, and turbidity was low. Therefore, we feel that we were able to see the large majority of salmon in the creek in August although statistical measures of accuracy and precision cannot be calculated from the data we collected. August spring-run index surveys are also conducted on other Sacramento River tributaries such as Butte Creek, Big Chico Creek, Deer Creek and Mill Creek by CDFG (T. McReynolds and C. Harvey-Arrison, CDFG, personal communication).

1999 survey.—In 1999, high summer instream flows (≥150 cfs) were released from Whiskeytown Reservoir to provide rearing habitat below Saeltzer Dam for steelhead trout, recently listed as threatened under the ESA. The high flows potentially attracted spring Chinook into Clear Creek. Observations of Chinook below Saeltzer Dam increased gradually throughout the summer unlike previous years when Chinook did not enter Clear Creek until typical summer flows were increased above 50 cfs on October 1. The gradual increase appears to be an extended ascending limb of the fall-run temporal distribution in Clear Creek but likely includes spring Chinook. A distinct mode for spring-run in the temporal distribution would not be expected as their numbers would be small.

2000 survey.—In 2000 the spring Chinook August index declined, possibly as a result of low summer instream flows. Flows were lowered in late May (100 cfs) and then again in early July (50 cfs). Initially, snorkel counts of Chinook from May through early July were similar to those during the same period in 1999. Yet, unlike 1999, snorkel counts declined in August when flows were stabilized at 50 cfs. Two carcasses recovered in August indicated the decline was, in part, due to pre-spawning mortality.

In 2000, there appeared to be a nearly complete temporal and spatial separation between the spring and fall Chinook spawning distributions. Spring-run migrated into the upper reaches by early July and no Chinook were observed in the lowermost two reaches between June and late September. Spawning in the upper reaches peaked by late September prior to flows being increased to attract fall-run into Clear Creek. When flows were increased on September 30 and fall Chinook entered Clear Creek in mass, deconstruction of Saeltzer Dam made it nearly impossible for salmon to move above Reach 6 thus creating an additional spatial separation between the runs.

2001 survey.—In 2001, the spring Chinook August index further declined to zero with the pre-August maximum of four salmon observed during the July survey. This index decline appears to be unrelated to flow or water temperature as conditions were more suitable for Chinook in 2001 than in 2000. Attraction releases from Whiskeytown Dam were maintained at

125 cfs through July 2 and then lowered to a minimum summer release of 75 cfs. Because spring Chinook numbers were so low in 2001, it gave us an opportunity to exclusively observe the immigration pattern and movement of fall Chinook throughout Clear Creek following the removal of Saeltzer Dam. Some fall Chinook migrated past all partial barriers all the way up to the base of Whiskeytown Dam and spawned, confirming that there was not a complete spatial separation between spring and fall Chinook in Clear Creek.

2002 survey.—Our highest spring Chinook August index occurred in 2002. Possible causes for the relatively large spring Chinook population include 1) successful juvenile production in Clear Creek in 1999 and 2) an overall high number of spring Chinook in the upper Sacramento River basin due to high juvenile survival rates in the lower Sacramento River and ocean. In 1999, Clear Creek flows from May through September were at their highest level since the construction of Whiskeytown Dam in 1964. These high flows during the immigration, holding, and spawning periods for spring Chinook may have attracted spring Chinook into Clear Creek and led to their successful reproduction. If the majority of spring-run returning to the upper Sacramento River do so as three-year-olds, as suggested by Fisher (1994), much of the 1999 production would have returned in 2002. On the other hand, spring Chinook returns to Mill and Deer Creek were also at a four-year high in 2002, suggesting the basin wide survival rates of juvenile Chinook may have been exceptionally high. If returns were large for other tributaries, more spring-run may have been available to stray into Clear Creek and spawn in 2002.

In 2002, observations of both live Chinook and redds indicated that there was a partial temporal separation between spring and fall Chinook. The peak of spawning activity occurred two weeks earlier in the upper three reaches than in the lower three reaches (mid-September vs. early October). Corresponding to the peak spawning period in the upper reaches, fall Chinook were entering the lower reaches in mass. Two weeks later, after a temporary decline in upstream live Chinook counts, salmon numbers increased and spawning continued but at a lower level. Snorkel counts of live Chinook in 2002 (as well as 2001) indicated that, from the time flows were increased, it took fall Chinook from 2 to 4 weeks to migrate into the uppermost two reaches.

Saeltzer Dam removal and fish passage.—The 15-foot-high Saeltzer Dam was constructed in 1903. A fish passage structure around the dam was built in 1958 but never successfully passed fish (DWR 1986). The structure was modified in 1992 to improve fish passage and the dam was removed completely in the fall of 2000. Improvements in fish passage afforded by the removal of Saeltzer Dam are difficult to assess with snorkel survey data due to a lack of baseline information. In 1999, snorkel surveys upstream of the dam were infrequent and, during 2000 surveys, fish passage was altered with a temporary ladder and other changes during dam deconstruction. Yet, other information indicated that few fish used the 1992 fish ladder. For example, monitoring conducted by CDFG suggested few salmon used the ladder (C. Harvey-Arrison, CDFG, personal communication). CDFG monitoring included the use of a fish counter in the ladder and snorkel observations made both in the ladder and in a 0.5 mile reach immediately below the dam. In conversations between the authors and local landowners and recreationists, sightings of salmon above Saeltzer Dam occurred only after dam removal. Also, two helicopter surveys in September 1998 reported zero redds above Saeltzer Dam compared to 19 redds below Saeltzer Dam (Harvey-Arrison 1998).

Snorkel surveys in 1999 and the spring of 2000 documented that some Chinook passed through the fish ladder. Passage appeared dependent on the frequent maintenance of the ladder. USFWS staff cleaned the upstream water entrance to the ladder weekly, at which times debris was often completely blocking fish passage. Prior to 1999, fish passage may have been compromised by debris accumulation at the entrance of the ladder.

Emergence timing and run classification.—The USFWS operates a rotary screw trap on lower Clear Creek (rm 1.7) to estimate juvenile Chinook production. Currently juveniles are classified as spring, fall, late-fall or winter-run based on length-at-date criteria developed for juveniles rearing in the upper Sacramento River (Greene 1992). It is uncertain if this criteria is applicable to spring-run spawned in the upper reaches of Clear Creek. To investigate this uncertainty, we estimated the time of emergence for juvenile spring-run spawned in 2002. Our first redds in reaches 1-3 were observed the week of September 11 and our peak redd count, in the same reaches, occurred the week of September 25. Assuming eggs were deposited on the Wednesday prior to each survey week, that is September 4 and 18, and that 1,600 Daily Temperature Units are required before emergence (Piper et al. 1982), we roughly estimate juveniles would emerge from early season redds between November 15-20 and from peak season redds between December 3-6. According to length-at-date criteria, juveniles emerging prior to December 1 are classified as spring-run and those emerging after December 1 would be fall-run. Therefore, it is possible that a large proportion of spring-run juveniles may be mis-classified as fall Chinook.

CWT recoveries.—We recovered CWTs from three spring Chinook from FRH over the four-year survey period. Three additional FRH spring Chinook were recovered by CDFG during their fall-run carcass surveys conducted during the same four years (C. Harvey-Arrison, CDFG, personal communication). As only a small portion of FRH spring-run are adipose fin-clipped, it is difficult to estimate the number straying into Clear Creek. Although these hatchery Chinook are called spring-run, they are considered to be a hybrid of spring and fall-run based on an evaluation of past hatchery practices (Brown and Greene 1993). Genetically, FRH spring-run are much closer to fall-run than Deer-Mill Creek spring-run or Butte Creek spring-run (Hedgecock 2002) and are viewed as a major threat to the genetic integrity of the remaining wild spring Chinook populations in the Central Valley (NMFS 2003). Efforts to found a spring-run population in Clear Creek depend largely on strays from other populations. Since FRH spring-run have had high rates of straying compared to wild populations (CDFG 2001, NMFS 2003), they may pose a threat to recovery efforts in Clear Creek as well. Management practices at FRH have changed in recent years and may lead to reduced straying of FRH spring-run (C. Harvey-Arrison, CDFG, personal communication).

Offspring of FRH spring Chinook stocked into Clear Creek in the early 1990's may make a limited contribution to the current spring-run population in Clear Creek. Their contribution may be limited due to 1) excessively high water temperatures for over-summer holding of adults, 2) excessively high water temperatures for egg incubation prior to October 1, for two generations of returning adults, and 3) probable hybridization of later spawning spring-run with fall-run as there was no spatial or temporal separation between the two prior to the removal of Saeltzer Dam.

Genetic analysis techniques have recently become available to determine if an individual fish is genotypically similar to Deer-Mill Creek spring-run, Butte Creek spring-run, or other runs of Central Valley Chinook (M. Banks, Oregon State University, personal communication). We recommend analyzing Clear Creek tissue samples collected from non-adipose fin-clipped (phenotypic) spring-run to determine if they are strays from wild or hatchery spring Chinook populations.

Tagged fall Chinook, originating from CNFH and FRH, were recovered as early as

September 29 and as far upstream as Reach 3. This further confirms that there is not a complete spatial or temporal separation between spring and fall Chinook in Clear Creek. The fall Chinook recovered on September 29, 1999 originated from FRH, a population considered to be introgressed with spring-run and have an intermixed life history pattern (CDFG 1998). Brown and Greene (1993) found that approximately 22% of FRH juveniles tagged as fall-run were subsequently classified and spawned in 1988 as spring-run. Forty-three additional FRH fall Chinook were recovered by CDFG during their Clear Creek fall-run carcass surveys conducted during the same four years (C. Harvey-Arrison, CDFG, personal communication).

One tagged winter Chinook carcass was recovered in 2001, documenting that (hatchery) winter-run occasionally stray into Clear Creek. No redds were observed during the winter Chinook spawning period in 2001 and it is unknown if the tagged carcass was spawned out as it was highly decayed. We did observe six Chinook redds during the winter-run spawning season in 2000 (late April and early May) and documentation of a winter run in Clear Creek in 2001 suggests that the six redds may have been created by winter-run. Although 100% of hatchery winter-run are clipped, CWT recoveries are too few to estimate straying rates into Clear Creek.

Stream Flow and Temperature Conditions

Attraction flows.—Providing adequately high flows may be crucial to attracting stray spring Chinook into Clear Creek to establish a self-sustaining population. The number of Chinook entering may be related to a thermal block, produced by low flows (Armour 1991). Below some threshold for passage flows, few fish enter Clear Creek. Above the threshold, fish passage may be directly related to flow (i.e. the higher the flow the higher the rate of attraction into Clear Creek). Optimal attraction flows are those that pass the greatest number of fish.

Determining the passage flow threshold is complicated by the low and variable numbers of spring-run in Clear Creek and the number of available strays in the Sacramento River. For instance, no amount of Clear Creek flow will provide attraction, if there are no spring Chinook available in the upper Sacramento River. Recognizing these limitations in our data, survey results provide some insight.

Flows of 150 cfs appear to provide adequate passage. For example, observations of live Chinook in 1999 indicated salmon continued to enter Clear Creek throughout late spring and summer. Attraction flows of 150 cfs in 2002 provided similar results. In 2002, consecutive monthly counts from May through July increased at least 23% while flows were at 150 cfs then dropped off to slight increases in August (5%) and September (14%) while flow releases were <95 cfs. The decrease in the number of Chinook entering Clear Creek in August and September may not be an effect of flow but may be the end of the immigration period as Central Valley spring Chinook typically enter their natal streams prior to August (CDFG 1998). Flows of 125 cfs were provided in 2001 but only four observations of Chinook were made. Flows of 100 cfs were provided in late May and June of 2000 and counts in the downstream most reach increased from zero to nine. It is unknown if more would have entered Clear Creek if flows would have been >100 cfs in 2000.

We could not determine optimal attraction flows because we did not test a range of flows above 150 cfs. Careful flow experiments could be used to determine optimal attraction flows. Because of annual differences in the number of available strays in the Sacramento River, it may be best to compare flows within one season to determine optimal attraction flows. Working within one season may be facilitated by experimenting with a sequence of increased flows and using a fish counting weir to evaluate the results.

Discouragement flows.—Opposite of attraction flows, low summer flows of about 50 cfs (and inversely related high water temperatures) have been shown to delay nearly all fall Chinook from entering Clear Creek. Our 2000 survey confirmed this as only four Chinook were observed in the lowermost reach prior to October. Although 50 cfs is too low to meet temperature criteria for spring Chinook holding in Clear Creek, average summer flows of 75 cfs (2001) and 80 cfs (2002) resulted in water temperatures exceeding holding criteria on only one day in 2002. Corresponding salmon counts during these low flow periods showed no increase in live Chinook in 2001 and only slight increases in August (5%) and September (14%), 2002. Maintaining minimum flows in August while providing suitable holding temperatures above the Igo gage, may delay most early arriving fall Chinook from entering Clear Creek, potentially increasing the temporal and spatial separation between spring and fall-run. Minimum flows in August may decrease the potential for hybridization between the runs but it cannot eliminate it.

Spawn timing.— The Biological Opinion for the Central Valley Project (CVP) and State Water Project (SWP) operations (NMFS 2002) stipulates that flow releases below Whiskeytown Dam be utilized to maintain temperatures of <56˚F at the Igo gage for spring Chinook spawning from September 15 through October 30. We had the opportunity to observe the response of spring Chinook to this management plan in 2002; flows were increased on September 13 and our spring-run population index was the highest on record.

In 2002, most spring Chinook holding in the upper reaches spawned soon after the flow increase, but some spawned before the increase. Spawning prior to the flow increase was in the cooler water of the uppermost three reaches. Of the 13 redds created prior to the flow increase, only three were exposed to water temperatures >56˚F. These three redds were exposed to at least three days of water temperatures averaging 57.9˚F. In the two weeks immediately following the increase, spawning peaked in the upper three reaches and began in the lower three reaches as fall-run entered the creek. In the lower reaches, in all four survey years, spawning was not observed until after flows increased.

Water temperature impacts on Chinook adults and eggs.—The percentage of adult Chinook observed in MDTs exceeding 60˚F appears to be related to late-spring and summer minimum flows; the lower the flow, the higher the percentage of adults observed in high water temperatures. Summer flows were lowest in 2000, higher in 2002 and highest in 1999. Similarly, the percentage of Chinook in high temperatures was highest in 2000, followed by 2002 and 1999. The exception to this pattern was in 2001 when we observed very few Chinook throughout the summer months. As Chinook may have been actively migrating upstream to cool water habitat and the duration of exposure to high temperatures is unknown, we could not determine negative impacts of temperature on adult spring Chinook. Potentially three carcasses, recovered in August of 1999 and 2000, may have died due to temperature related causes.

The percentage of redds exposed to MDTs exceeding 56˚F appears to be related to timing and magnitude of spawning flow increases. Percent exposure was highest in 2001 when flow increases were modest and gradual beginning on September 7. The modest increases appeared to induce spawning in the lowermost reach (Reach 6). Yet, these flow increases did not provide adequate spawning temperatures and their gradual nature prolonged the exposure time of redds to high temperatures. Similarly, flows were increased on September 6 in 1999 but the increase was substantial and immediate. The increase induced spawning in Reach 6 and some redds were again exposed to high water temperatures but the percentage and duration was lower than 2001. In contrast, percent exposure in 2000 and 2002 was very low. Flow increases in these years occurred slightly later (September 28 and 13 respectively) and were at a time and of a magnitude to provide suitable water temps for spawning in the lower reaches. Prior to flow increases, early season spawning did occur in 2000 and 2002 but only in the upper cooler reaches.

Although, each year in September, some redds were exposed temporarily to MDTs exceeding the egg incubation criteria, we believe negative effects were minimal. Seymour (1956) found that Chinook egg mortality rates were drastically reduced for eggs incubated under declining temperature conditions and was low for eggs incubated at an initial temperature of 60˚F. This was the case for eggs incubating in Clear Creek during the fall as we did not document a single redd exposed to MDTs >60˚F and eggs were incubated under decreasing fall/winter temperatures.

In 2000, six Chinook redds were observed in the lowermost reach (Reach 6) in late April and early May during the winter-run spawning period. Egg mortality for these redds may have been substantial. Donaldson (1955) studied the effects of limited-duration exposure of Chinook eggs to high temperatures. He found that the exposure time necessary to kill 10% of eggs (LT_{10}) averaged 1.5, 4.25, and 13 days at temperatures of 67˚, 65˚, and 63˚F, respectively. Similarly, Donaldson found that the exposure time necessary to kill 50% of eggs (LT_{50}) averaged 4.75, 13.5, and 22 days at temperatures of 67˚, 65˚, and 63˚F, respectively. Of the six redds, four exceeded the LT_{10} and one exceeded the LT_{50}. Seymour (1956) estimated the temperature above which 50% of chinook eggs die from temperature effects, when raised under constant temperature conditions (LT_{50c}), to be 60.8˚F. The six redds experienced between 17 and 31 days of MDTs ≥60.8˚F. The USFWS (1998) studied temperature tolerance specifically for Sacramento River fall-run and winter-run Chinook. USFWS results showed that the LT_{50c} for fall-run was between 60˚ and 62˚F but the LT_{50c} for winter-run was between 58˚ and 60˚F. Therefore, egg mortality for winter-run may be higher than suggested by Donaldson (1955) and Seymour (1956).

Meeting temperature criteria.—Our evaluation of the relationship between instream flows and water temperatures from 1999-2002 demonstrated that it is feasible to provide suitable water temperatures for all life stages of spring Chinook as described in the Doubling Plan (USFWS 2001). Meeting the ≤60˚F criteria for adult holding and juvenile rearing at the Igo gage required flows as high as 90 cfs (e.g. July 13-15, 2002) and as low as 68 cfs (e.g. August 27, 2002). Flows ranged from 121 to 250 cfs during periods when the ≤56˚F criteria was always met. The critical time period during which temperatures exceeded criteria at target locations was June 22 through September 28.

In 1999, an attempt was made to meet temperature criteria at a temporary compliance point located at rm 5.0 as spring Chinook did not yet have good access to habitat above Saeltzer Dam. Flows of 150 cfs were released to meet holding criteria and 250 cfs to meet spawning criteria but were only adequate to consistently meet criteria as far down as rm 9 (i.e. Clear Creek Road Bridge). These flows were more than adequate to meet criteria at the current Igo gage compliance point (rm 10.9).

In 2000, summer flows were lowered to 50 cfs to facilitate the deconstruction of Saeltzer Dam. As a result, the holding temperature criteria at the Igo gage was often exceeded. Flow releases were increased to 125 cfs for fall-run spawning on September 30. Although spawning temperature criteria were not exceeded in October, it is unlikely that these flows would have consistently met criteria in September for spring-run spawning.

In 2001, an attempt was made to select a minimum summer flow which would be adequate to meet holding criteria throughout the entire summer without being adjusted. A release of 75 cfs was selected and was adequate to meet the holding criteria. To meet spawning criteria at the Igo gage, 120 cfs was released from Whiskeytown Dam after September 15 and spawning criteria was only exceeded on one day (121 cfs at the Igo gage).

Although 75 cfs was adequate in 2001, it was not in 2002. In 2002, summer flows were not fixed but were adjusted 14 times to meet the ≤60˚F criteria based on predicted air temperatures, while minimizing flow. Frequent flow adjustments conserved water, while meeting temperature criteria. Scheduled Dam releases from July 2 to September 13 ranged from 65 to 95 cfs and averaged 77 cfs. Setting flows at 95 cfs, the highest required to meet holding criteria, would have used about an additional 2,643 acre-feet. Flows increased to 250 cfs on September 13 for the experimental flow barrier study and were more than adequate to meet spawning temperature criteria.

Barrier Analyses

Experimental flow releases.—Increases in snorkel counts of live Chinook upstream of the Gorge Cascade during experimental releases were large (104% and 128% increases). We believe these increases are greater than the error associated with our snorkel counts and show that Chinook were successfully passing the Gorge Cascade at these flows. We conclude that the Gorge Cascade is not a temporary barrier at flows greater than about 50 cfs. Flows higher than those tested would likely create alternate passage routes for Chinook.

Increases in Chinook counts upstream of Placer Falls were less than those above the Gorge Cascade (7% and 33% increases). We assume the probability of observing Chinook decreases as flows increase. Because flows increased during experimental releases, the small increases in Chinook counts above Placer Falls suggest that it is not a temporary barrier.

Counts upstream of Two Tier Falls decreased (-7%) at 250 cfs then increased (42%) at 200 cfs. Possible explanations for these counts include: 1) Two Tier Falls is a temporary barrier at 250 cfs but not at 200 cfs, 2) the observed decrease is within the sampling error for snorkel surveys and does not represent a true decrease, and 3) the decrease coincided with the peak of spawning and death of spring Chinook and preceded the arrival of immigrating fall Chinook in the uppermost reaches.

Carcass distribution.—On average, only 2.0% of carcasses were located upstream of the Gorge Cascade. Although carcasses included both spring and fall Chinook, this result is primarily based on fall Chinook passage rates. For example, fall Chinook escapement estimates for Clear Creek were 10,865 in 2001 and 16,071 in 2002 (C. Harvey-Arrison, CDFG, personal communication) compared to spring Chinook August index counts of 0 in 2001 and 66 in 2002. Therefore, the spatial distribution of carcasses indicates that the Gorge Cascade is a partial barrier to fall Chinook but not necessarily spring Chinook. Although the percentage of fall Chinook accessing spring Chinook habitat above the Gorge Cascade is low, the total number is large relative to the small spring Chinook population.

August snorkel counts.—In August 2002, 70% of live Chinook observations were upstream of the Gorge Cascade suggesting a much higher rate of passage for spring Chinook than for fall Chinook. Results indicate that the Gorge Cascade is not a partial barrier for spring Chinook. The percentages of live Chinook located above Placer Falls (55%) and Two Tier Falls (48%) were moderately high and we expect some spring Chinook to spawn downstream of these falls regardless of passaged difficulty. Therefore, Placer and Two Tier falls are probably not partial barriers for spring Chinook. Although August surveys occur near the end of the spring Chinook immigration period, some salmon may continue migrating upstream and the true passage rate may be higher than reported percentages.

Physical measurements.—Physical measurements of Placer Falls corroborated other barrier studies and showed that it was not a barrier to Chinook at flows within the range 75-180 cfs. Snorkel surveys documented that Chinook passed Placer Falls during the period when measurements were taken. Physical measurements are most feasible when structures are relatively simple and stream conditions are safe. Therefore, this method is well suited for evaluating low flow barriers.

Recommendations

Based on our findings, we make the following recommendations to enhance conditions in Clear Creek for the restoration and conservation of spring Chinook salmon and to improve the effectiveness of our future monitoring efforts.

1) Analyze scale samples collected during 1999-2002 surveys to determine population age structure and allow future cohort analysis. This knowledge would help in evaluating the effectiveness of restoration actions.

2) Analyze genetic samples collected from potential spring Chinook in order to determine genotypic similarities and differences from other Central Valley Chinook stocks. Genetic analyses may provide information on the origin of spring-run in Clear Creek (e.g. FRH or Mill, Deer, or Butte creeks), improve criteria for designating salmon as either fall or spring-run, show the spatial and temporal distribution of spring-run in Clear Creek and thus the potential for hybridization with fall-run, and provide more accurate estimates of annual run size.

3) Install a temporary picket weir from early September to late October in order to spatially separate and prevent hybridization between spring and fall Chinook. Having a closed population upstream of the weir may allow us to develop estimates of bias and precision for snorkel survey counts. Also, collecting and analyzing genetic tissue samples from fish upstream and downstream of the weir could improve our ability to identify adult spring Chinook based on immigration timing and location in Clear Creek.

4) Evaluate discrepancies in population indices and estimates based on live Chinook, redd, and carcass counts. Potential factors affecting estimates include: male-female sex ratio; number of redds per female; probabilities of observing live Chinook, redds, and carcasses; and correctly identifying real versus “test” or “practice” redds. The installation of a temporary picket weir will aid this evaluation by providing a closed population of spring-run to observe. To fully understand these factors, the installation of a fish trap in the picket weir may need to be considered at a time when the population is large enough to sustain handling stress.

5) Utilize short duration experimental pulse flows in the spring to test their effectiveness to attract spring-run into Clear Creek. The potential impacts of attracting winter run into Clear Creek would need to be considered.

6) Conduct surveys to estimate the amount of spawning and holding habitat available for spring Chinook in Clear Creek.

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Tables

TABLE 1.—Important locations on Clear Creek with associated river miles (rm). The river mile system was developed by the Red Bluff Fish and Wildlife Office using ortho-rectified aerial photos (Enplan Co., Redding, CA, 1997).

Location name	rm
Confluence - Sacramento River	289 (S.R.)
Confluence T.L. [a]	0.69
Highway 273 Bridge	0.90
A.C.I.D. siphon	1.33
FWS Rotary Screw Trap & T.L.	1.73
Restoration Grove T.L	3.40
Transmission Lines - Center Tower	3.61
Renshaw Riffle T.L.	4.97
Deepest Pool & T.L.	5.95
City of Redding Gravel Supplementation Site	6.26
Gorge Cascade & T.L.	6.46
McCormick-Saeltzer Dam	6.47
Clear Creek Rd Bridge & T.L.	8.50
Placer Road Gravel Supplementation Site	10.58
Placer Falls	10.59
Placer Road Bridge	10.60
Igo Gage & T.L.	10.85
South Fork Clear Creek	10.99
Two Tier Falls	11.88
Kanaka Creek & T.L	13.04
Need Camp Bridge & T.L.	16.00
Paige Boulder Creek	16.27
Peltier Valley Road Bridge	16.90
Whiskeytown Dam Gravel Supplementation Site	18.04
Whiskeytown Dam & T.L.	18.11

[a] T.L. = Temperature Logger

TABLE 2.—Reach numbers and locations with associated river miles (rm) for Clear Creek snorkel surveys.

	Upstream		Downstream	
Reach	Location	rm	Location	rm
1	Whiskeytown Dam	18.1	NEED Camp Bridge	16.0
2	NEED Camp Bridge	16.0	Kanaka Creek	13.0
3	Kanaka Creek	13.0	Igo Gage	10.9
4	Igo Gage	10.9	Clear Creek Rd. Bridge	8.5
5	Clear Creek Rd. Bridge	8.5	Saeltzer Dam Site	6.5
6	Saeltzer Dam Site	6.5	Rotary Screw Trap	1.7[a]

[a] In 1999, the downstream boundary for Reach 6 was rm 2.2.

TABLE 3.—Number of spring Chinook snorkel surveys conducted in Clear Creek by year and by reach.

Year	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
1999	1	1	1	3	4	22
2000	7	6	7	8	8	12
2001	8	8	8	8	8	10
2002	11	10	10	10	10	7

TABLE 4.—Stream flow, turbidity, and temperature during spring Chinook snorkel surveys conducted from 1999 through 2002. The range and mean (in parentheses) for annual survey seasons and conditions during the August index survey (AIS) are given.

Year	Flow (ft^3/s)	Turbidity (NTU)	Temperature (˚F)
1999	144-244 (179)	0.8-5.5 (1.7)	51-70
2000	50-274 (113)	1.1-2.1 (1.5)	49-79
2001	72-305 (139)	0.5-1.3 (0.7)	47-71
2002	67-267 (164)	0.5-1.4 (0.8)	47-73
AIS 1999	146	1.7	53-61
AIS 2000	54	n/a[a]	52-66
AIS 2001	73	0.6	52-68
AIS 2002	85	0.6	52-71

[a] n/a = data not available.

TABLE 5.—Snorkel survey observations of adult Chinook and Chinook redds in water temperatures exceeding criteria of MDTs ≤60˚F and ≤56˚F respectively. Adult exposure includes the number of observations in high MDTs, period during which exposures occurred, and percentage of adults observed in high MDTs within the exposure period. Redd exposures include percent of redds exposed to high temperatures from August through November and the average minimum days redds were exposed to high MDTs.

Year	1999	2000	2001	2002
No. adults in water >60˚F	44	35	5	45
Adult exposure period	6/15-8/30	5/25-9/28	6/18-9/13	7/15-8/16
% Adults in water >60˚F	24%	48%	11%	35%
% Redds in water >56˚F (Aug.-Nov.)	26.0%	0.2%	54.4%	0.7%
Average minimum days of redds in >56˚F	5 days	2 days	10 days	3 days

TABLE 6.—Total number of carcasses recovered, percent of carcasses sampled for genetic analysis, and percent of carcasses possessing coded-wire tags. Carcasses were recovered during annual spring Chinook snorkel surveys conducted by the USFWS from 1999 through 2002.

Year	1999	2000	2001	2002
Total Carcasses	92	39	96	124
% Sampled	19.6%	12.8%	41.7%	63.7%
% CWT	2.2%	0%	2.1%	2.4%

TABLE 7.—Redd density (redds per mile) by reach based on redds observed during Clear Creek spring Chinook snorkel surveys conducted from 1999 through 2002. Reach 6 is not included as it was not surveyed during the entire spawning period.

Year	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
1999				5	37
2000	1	2	0	1	1
2001	2	2	3	9	22
2002	20	10	14	13	48

TABLE 8.—Summary of Chinook redd measurements in Clear Creek from September 2 to October 26 during the 2001 and 2002 snorkel survey seasons. Measurements include excavation area (ft^2, n=39), pre-excavation depth (ft, n=39), and mean column water velocity (ft/s, n=5).

	Area	Depth	Velocity
Average	60.2	2.2	1.6
Minimum	2.9	0.9	1.0
Maximum	219	4.8	2.8

TABLE 9.—Average substrate-size descriptors for pebble counts of potential spring Chinook redds in Clear Creek (n=19). (D_{16} = diameter below which 16% of sample is finer, D_{50} = median diameter, D_{84} = diameter below which 84% of sample is finer, dg = $(D_{84} \bullet D_{16})^{0.5}$, and sg = $(D_{84}/D_{16})^{0.5}$.)[a]

	D_{16}	D_{50}	D_{84}	dg	sg
Redd pit	12.8	36	96	34.2	2.9
Redd tailspill	16.9	38	72	34.1	2.2
Total redd	14.0	37	84	33.6	2.6
Suitable range [b]	(4.5 - 34.3)	(16 - 71)	(32 - 133)		

[a] All measurements are in mm, except for sg which is dimensionless.
[b] Suitable range for Chinook spawning as reported by Vyverberg et al. (1997) for bulk sample size distributions.

TABLE 10.—Observations of live Chinook above and below the Gorge Cascade, a potential temporary barrier on Clear Creek, during experimental flow releases. Snorkel survey observations above the Gorge Cascade (reaches 1-5) where made from Whiskeytown Dam (rm 18.1) to the Gorge Cascade (rm 6.5). Observations below the Cascade (reach 6) were made from the Gorge Cascade to the USFWS' rotary screw trap (rm 1.7). Stream discharge was measured as Mean Daily Flow (ft^3/s) at the USGS gaging station (rm 10.9).

Survey date	Chinook (above Cascade: reaches 1-5)	Chinook (below Cascade: reach 6)	Flow (ft^3/s)
Sept' 9-13	47	28	76
Sept' 23-27	96	636	252
Oct' 8-11	219	N/S(>636[b])	206

[b] Not surveyed (N/S) because Chinook were too numerous to effectively count by snorkel survey method. Numbers of live Chinook in Reach 6 were much greater than counted on the previous survey.

TABLE 11.—Results of fish barrier analysis of Placer Falls (rm 10.6) on Clear Creek. Results were based on structural measurements and water velocity taken at five different stream flows. Results include the number of passage routes and the number of routes potentially impassable to Chinook due to high water velocity, structural size, and depth of plunge pool (a.k.a. jump pool).

	Stream flow				
	75 ft^3/s	100 ft^3/s	130 ft^3/s	135 ft^3/s	180 ft^3/s
Number of passage routes	8	10	10	11	10
Routes exceeding velocity criteria [a]	0	2	0	0	2
Routes exceeding jump height vs. breadth criteria	0	0	0	0	0
Routes under pool depth criteria	0	0	0	0	0

[a] Velocity criteria was 11.2 ft/s, the limit for fish in "poor" physical condition.

TABLE 12.—Total number of Chinook carcasses encountered on Clear Creek below the Gorge Cascade (rm 1.7-6.5) and above the Gorge Cascade (rm 6.5-18.1) and the percentage above the Cascade. Carcass totals are from the USFWS's spring Chinook snorkel survey (April - November) and CDFG's carcass survey (October - December 7).

	Carcasses (below Cascade: reach 6)		Carcasses (above Cascade: reaches 1-5)	
Survey year	Snorkel survey	Carcass survey [a]	Snorkel survey	% above Gorge Cascade
2001	12	3836	84	2.1%
2002	7	6091	117	1.9%

[a] (C. Harvey-Arrison, CDFG, personal communication).

TABLE 13.—Number of tissue samples collected from adult Chinook on Clear Creek by the Red Bluff Fish and Wildlife Office between 1999 and 2002.[a] Designation of potential run status was based on date of sample collection: spring-run, July 15-October 15; fall-run, October 15-December 7; late-fall-run, December 7-April 15; and winter run, April 15-July 15.

Potential Chinook run	1999	2000	2001	2002
Spring	20	4	16	56
Fall	30	14	64	75
Late-fall	0	15	18	22
Winter	0	0	1[b]	0
Total	50	33	99	153

[a] Samples collected during snorkel surveys, fall carcass surveys, and late-fall carcass surveys.
[b] Known winter run by CWT. All other samples are from non-adipose fin-clipped fish.

Figures

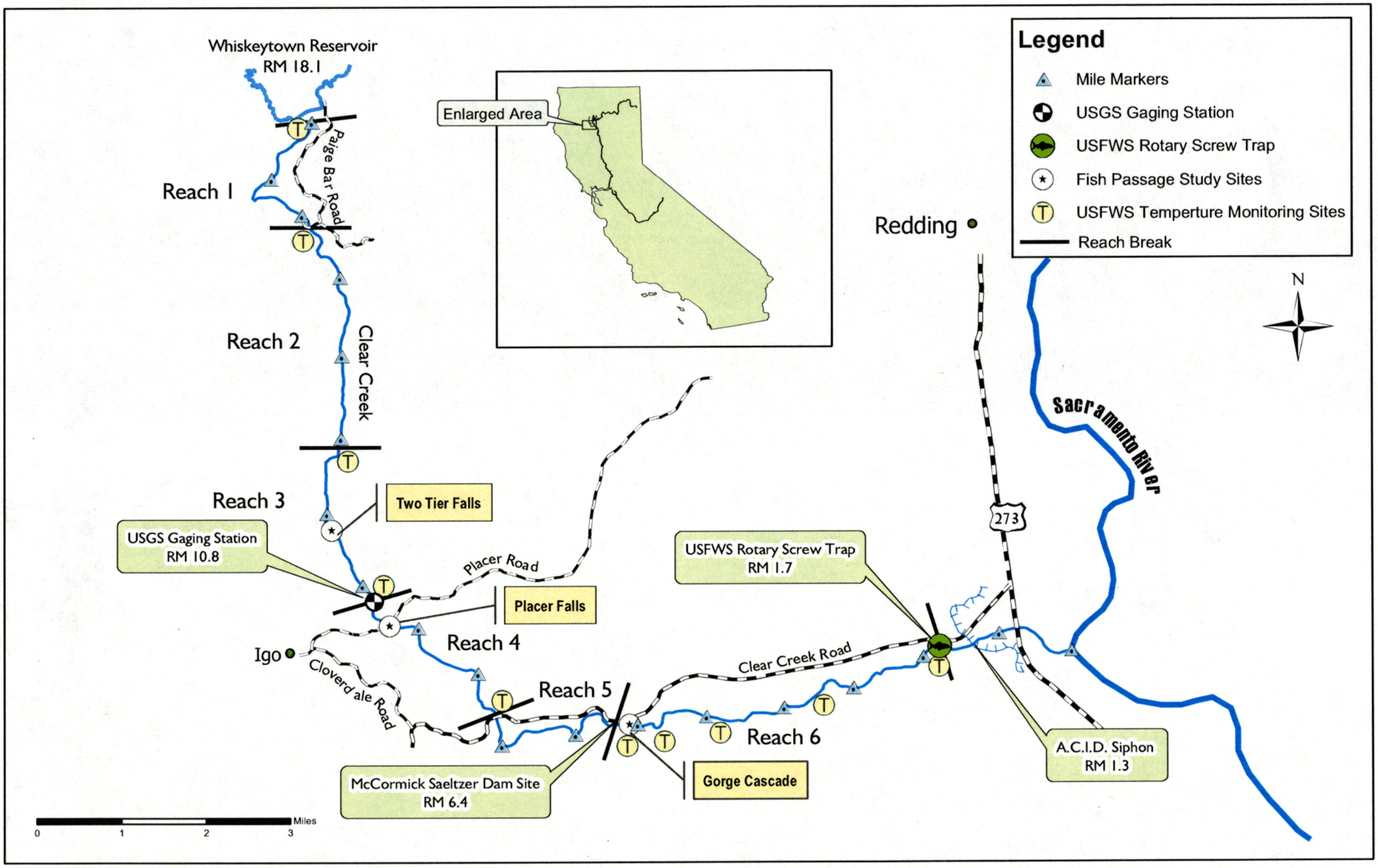

FIGURE 1.—Map of lower Clear Creek, Shasta County, California depicting USFWS spring Chinook snorkel survey reaches and monitoring sites.

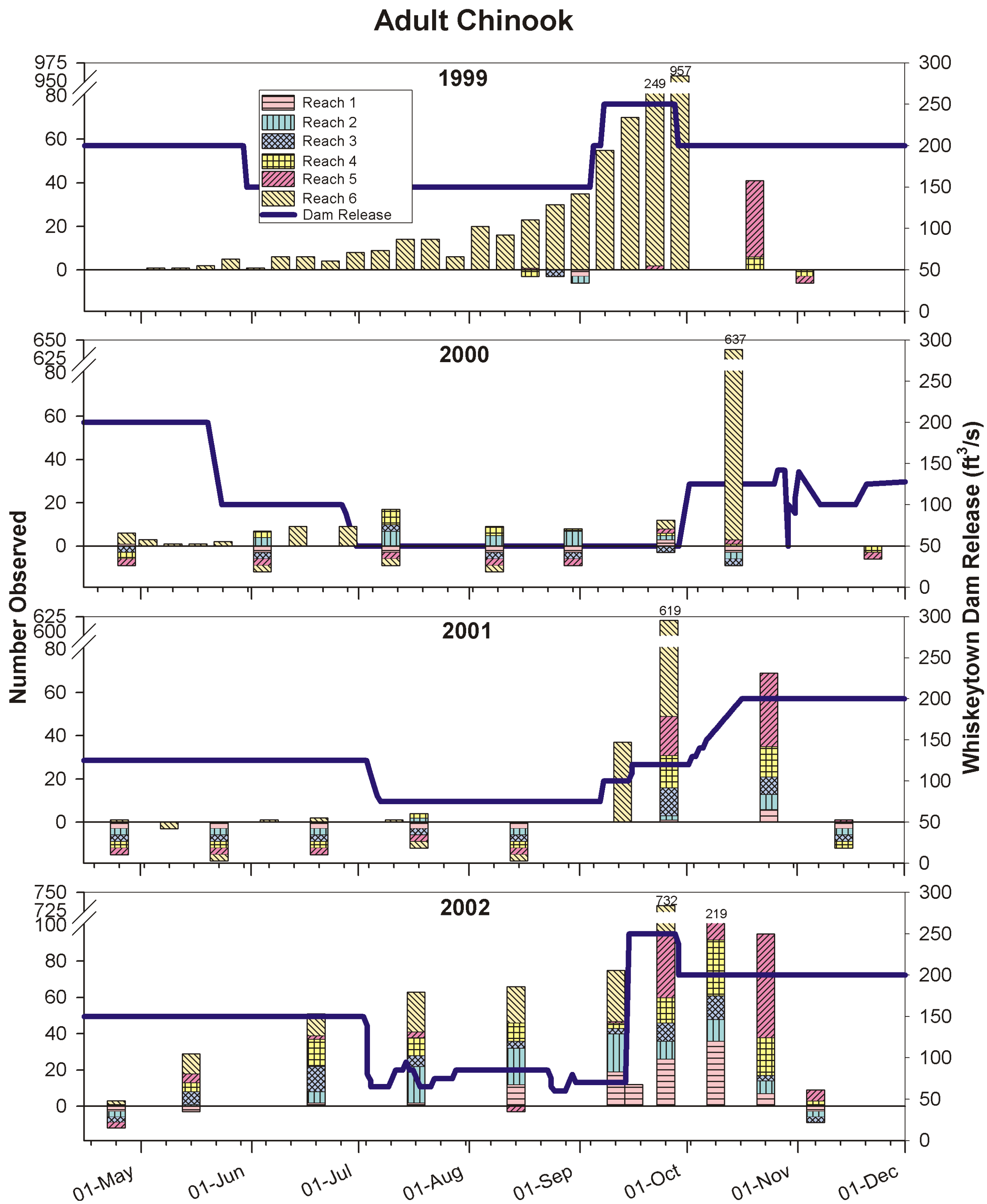

FIGURE 2.—Number of live adult Chinook observed during Clear Creek snorkel surveys from 1999 through 2002 with water releases below Whiskeytown Dam (ft^3/s). Stacked bars <0 represent snorkel surveys with zero observations of live Chinook. Generally, each stack represents one week of surveys. Reach 6 was not surveyed in October and November, except for 2000, due to the very large number of fall-run Chinook.

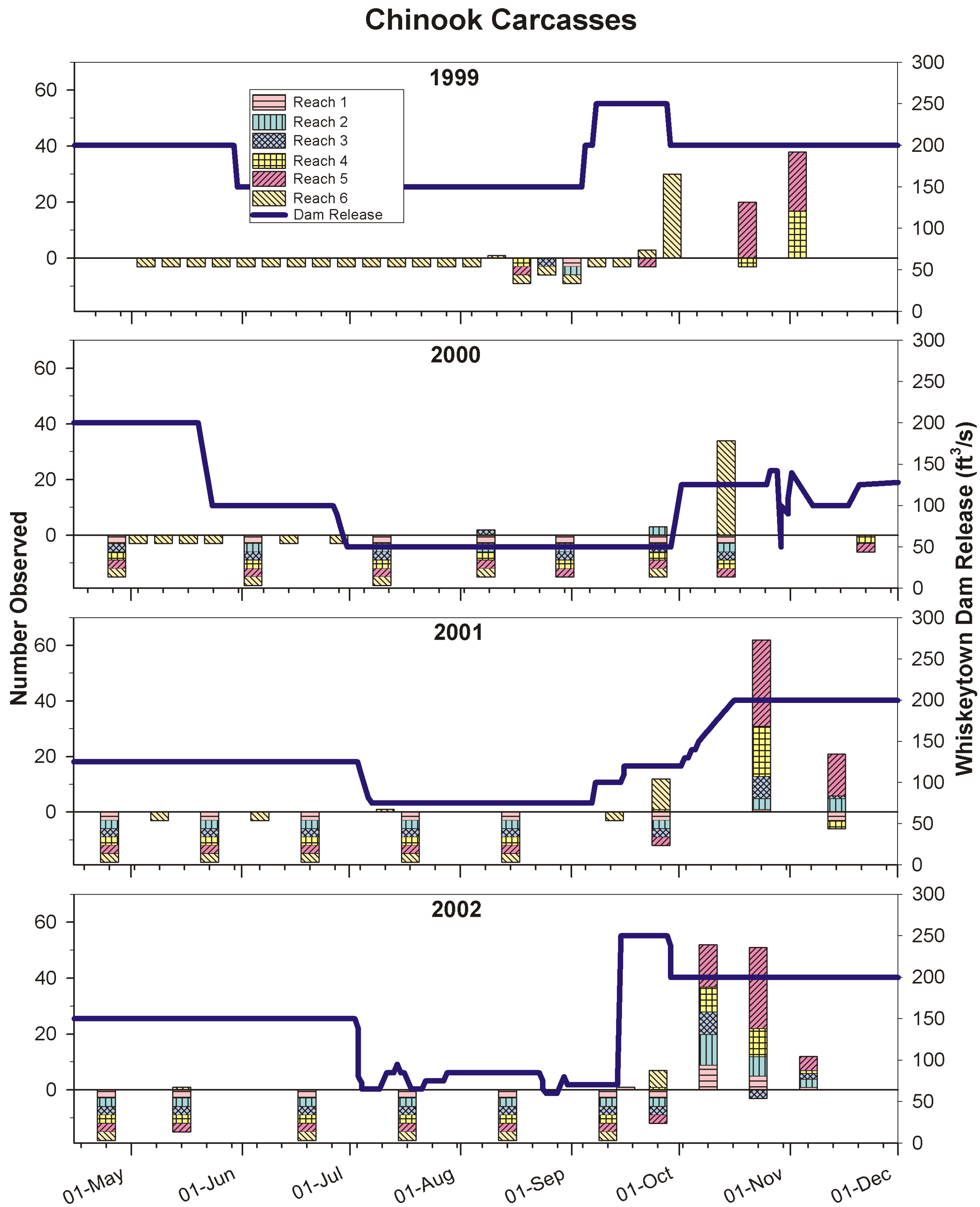

FIGURE 3.—Number of Chinook carcasses observed during Clear Creek snorkel surveys from 1999 through 2002 with water releases below Whiskeytown Dam (ft^3/s). Stacked bars <0 represent snorkel surveys with zero observations of Chinook carcasses. Generally, each stacked bar represents one week of surveys. Reach 6 was not surveyed in October and November, except for 2000, due to the very large number of fall-run Chinook.

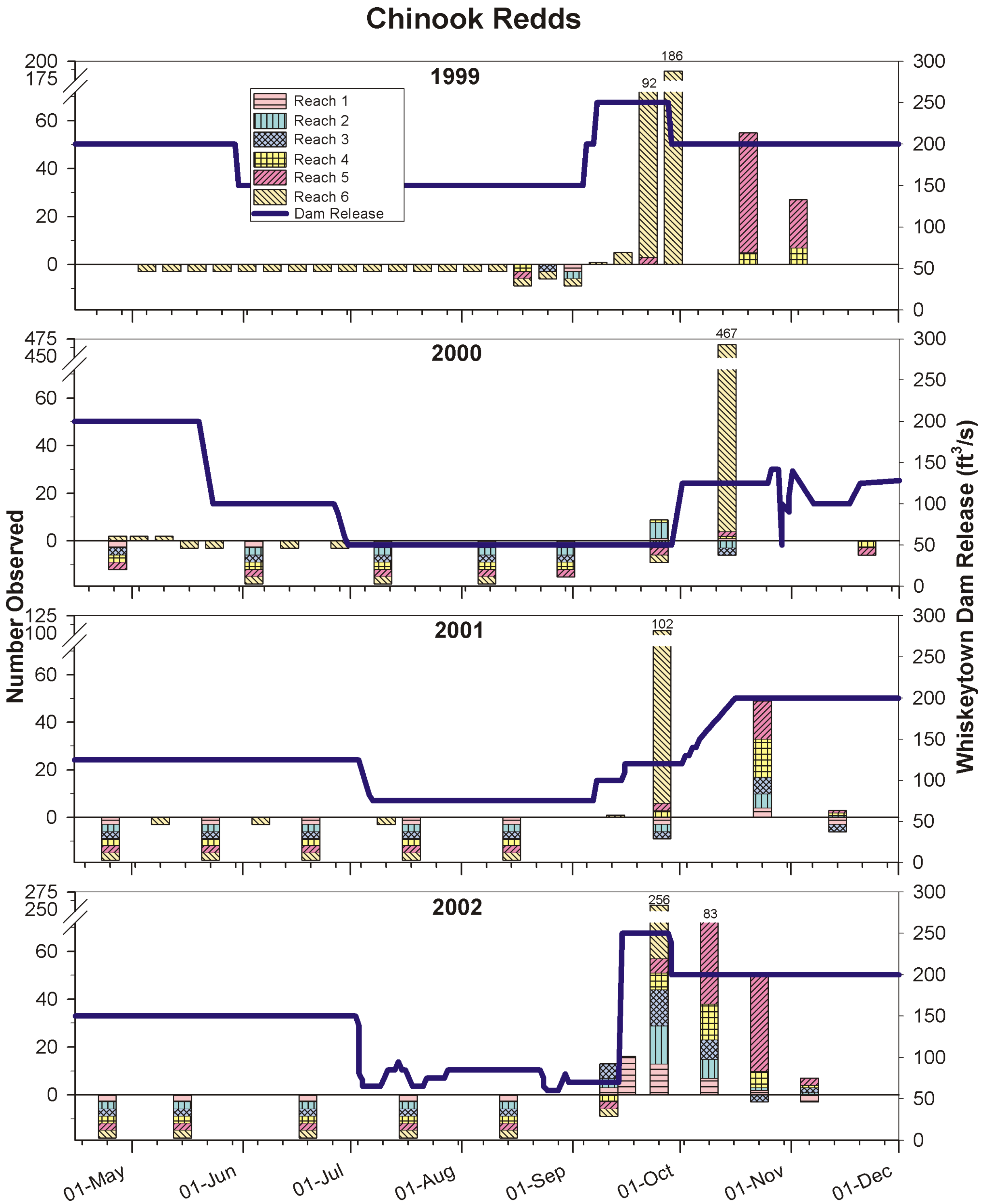

FIGURE 4.—Number of new Chinook redds observed during Clear Creek snorkel surveys from 1999 through 2002 with water releases below Whiskeytown Dam (ft^3/s). Stacked bars <0 represent snorkel surveys with zero observations of new redds. Generally, each stacked bar represents one week of surveys. Reach 6 was not surveyed in October and November, except for 2000, due to the very large number of fall-run Chinook.

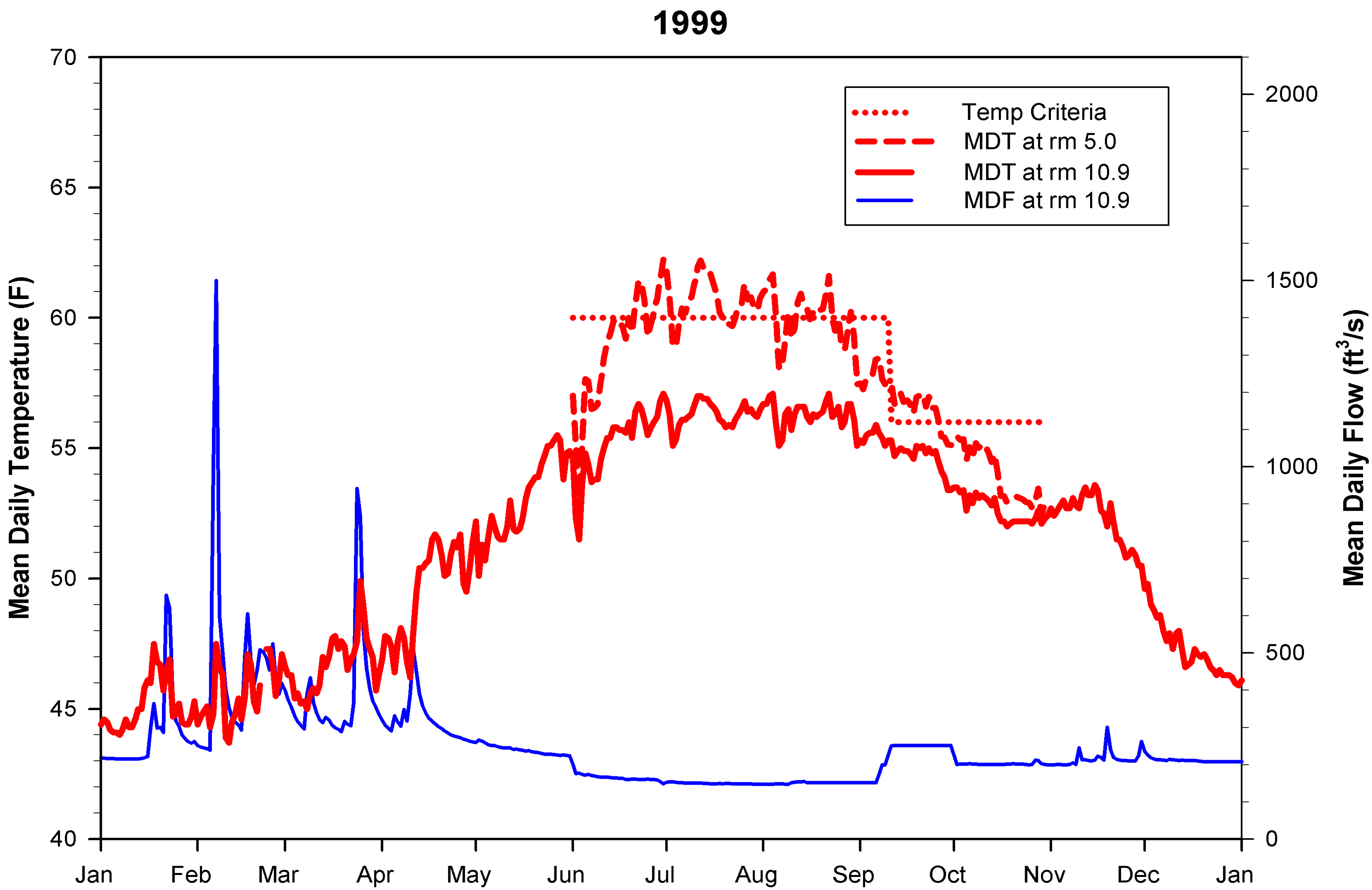

FIGURE 5.—Mean daily temperature (MDT) at the river mile 10.9 (Igo Gage) and river mile 5.0, mean daily flow (MDF) at river mile 10.9, and temperature criteria for spring Chinook holding (≤60˚F) and egg incubation (≤56˚F) on Clear Creek in 1999.

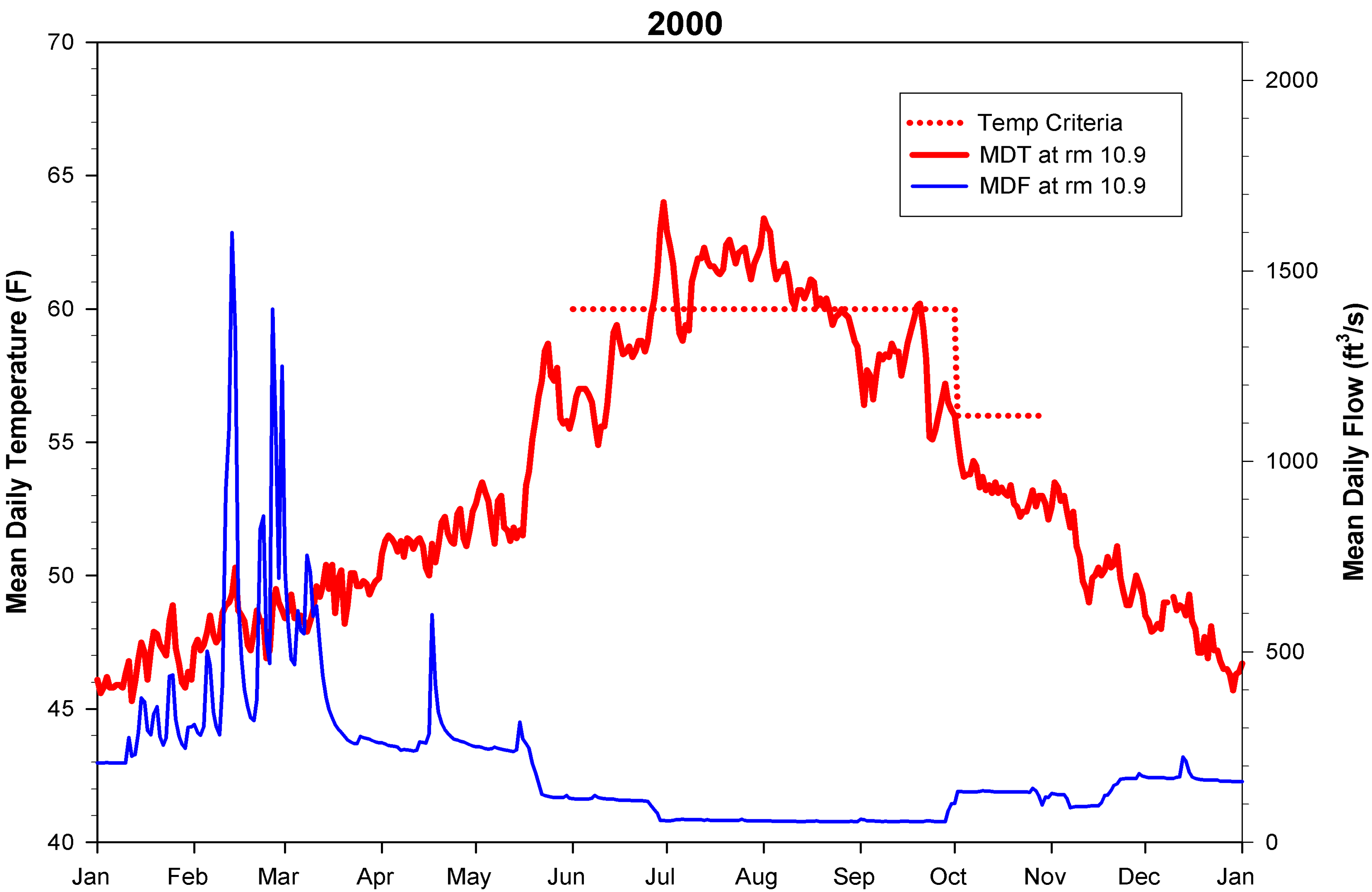

FIGURE 6.—Mean daily temperature (MDT) and mean daily flow (MDF) at the Igo Gage (rm 10.9) with temperature criteria for spring Chinook holding (≤60˚F) and egg incubation (≤56˚F) on Clear Creek in 2000.

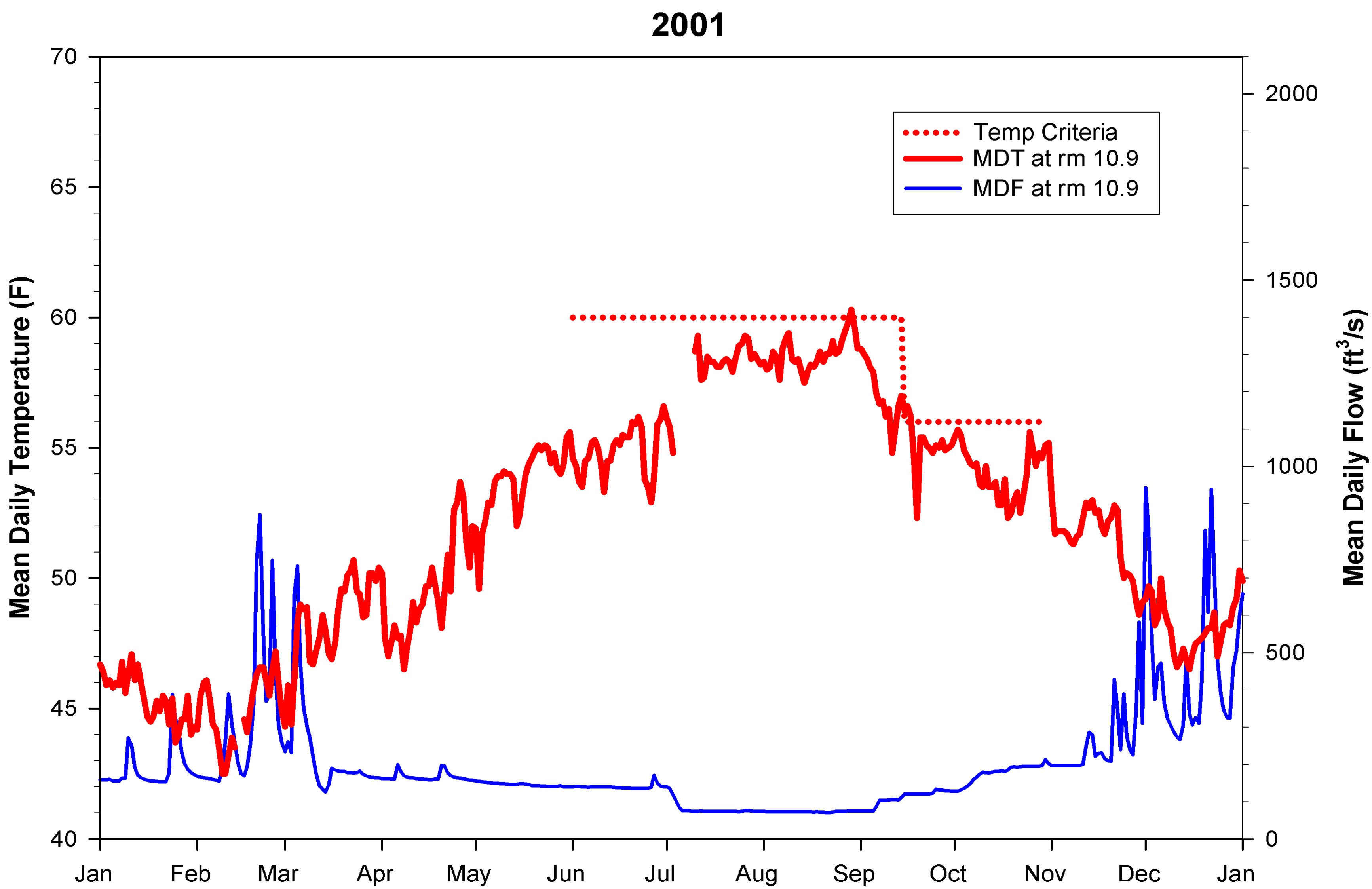

FIGURE 7.—Mean daily temperature (MDT) and mean daily flow (MDF) at the Igo Gage (rm 10.9) with temperature criteria for spring Chinook holding (≤60˚F) and egg incubation (≤56˚F) on Clear Creek in 2001.

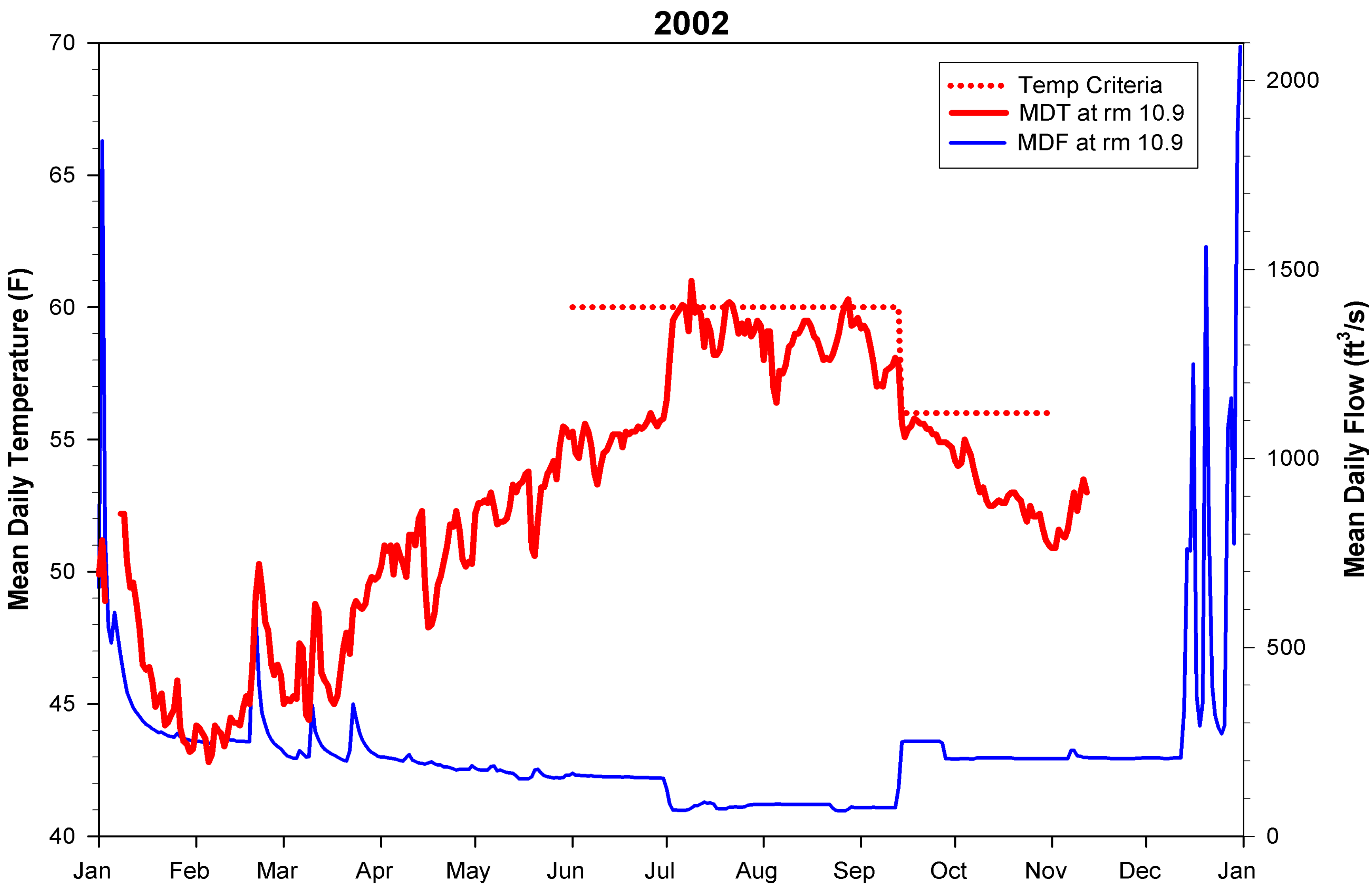

FIGURE 8.—Mean daily temperature (MDT) and mean daily flow (MDF) at the Igo Gage (rm 10.9) with temperature criteria for spring Chinook holding (≤60˚F) and egg incubation (≤56˚F) on Clear Creek in 2002.

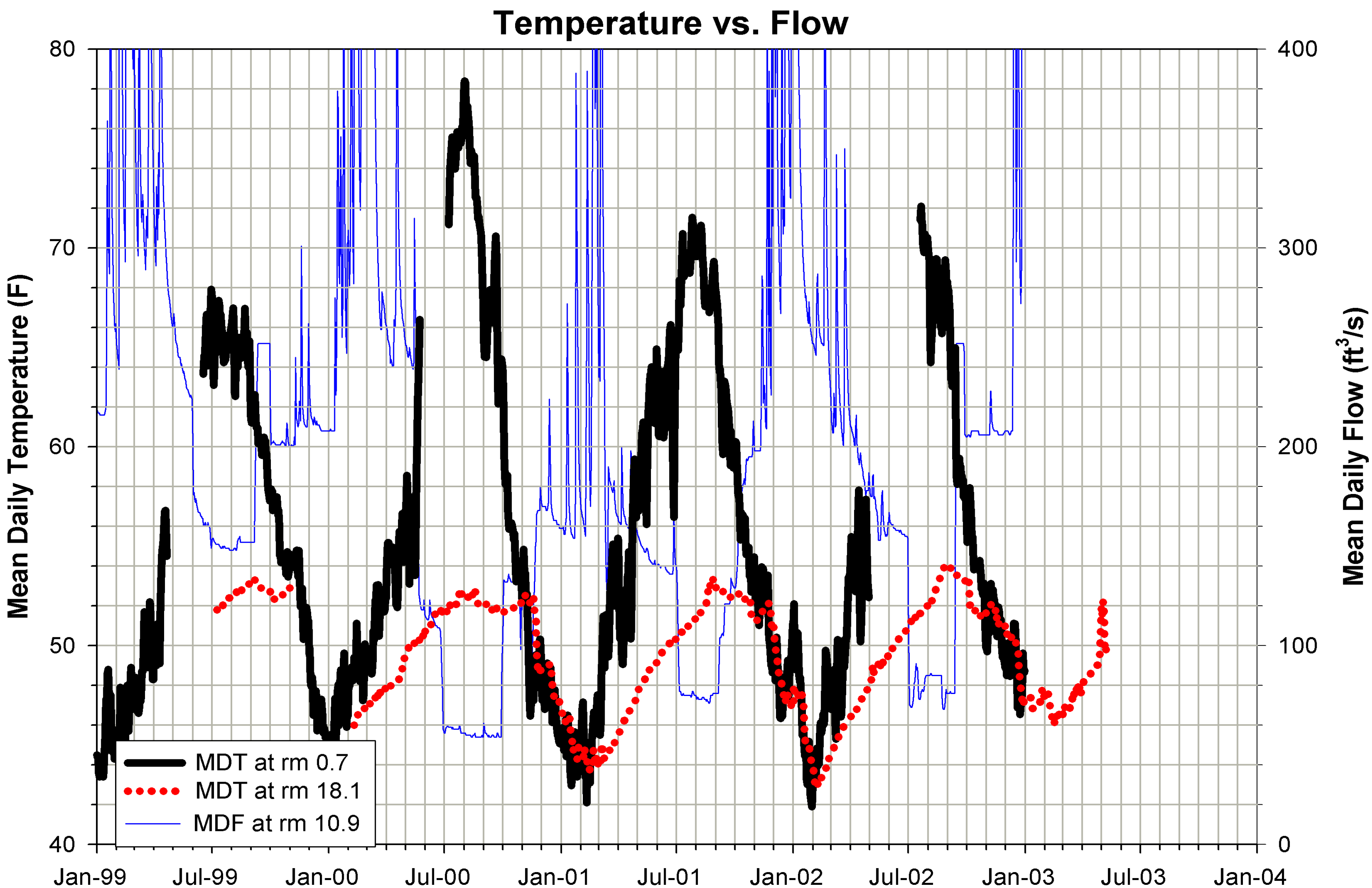

FIGURE 9.—Mean daily water temperatures (MDT) below Whiskeytown Dam (rm 18.1) and near the confluence with the Sacramento River (rm 0.7) plotted with mean daily flow (MDF) at the Igo gage (rm 10.9) for Clear Creek from 1999 through 2002.

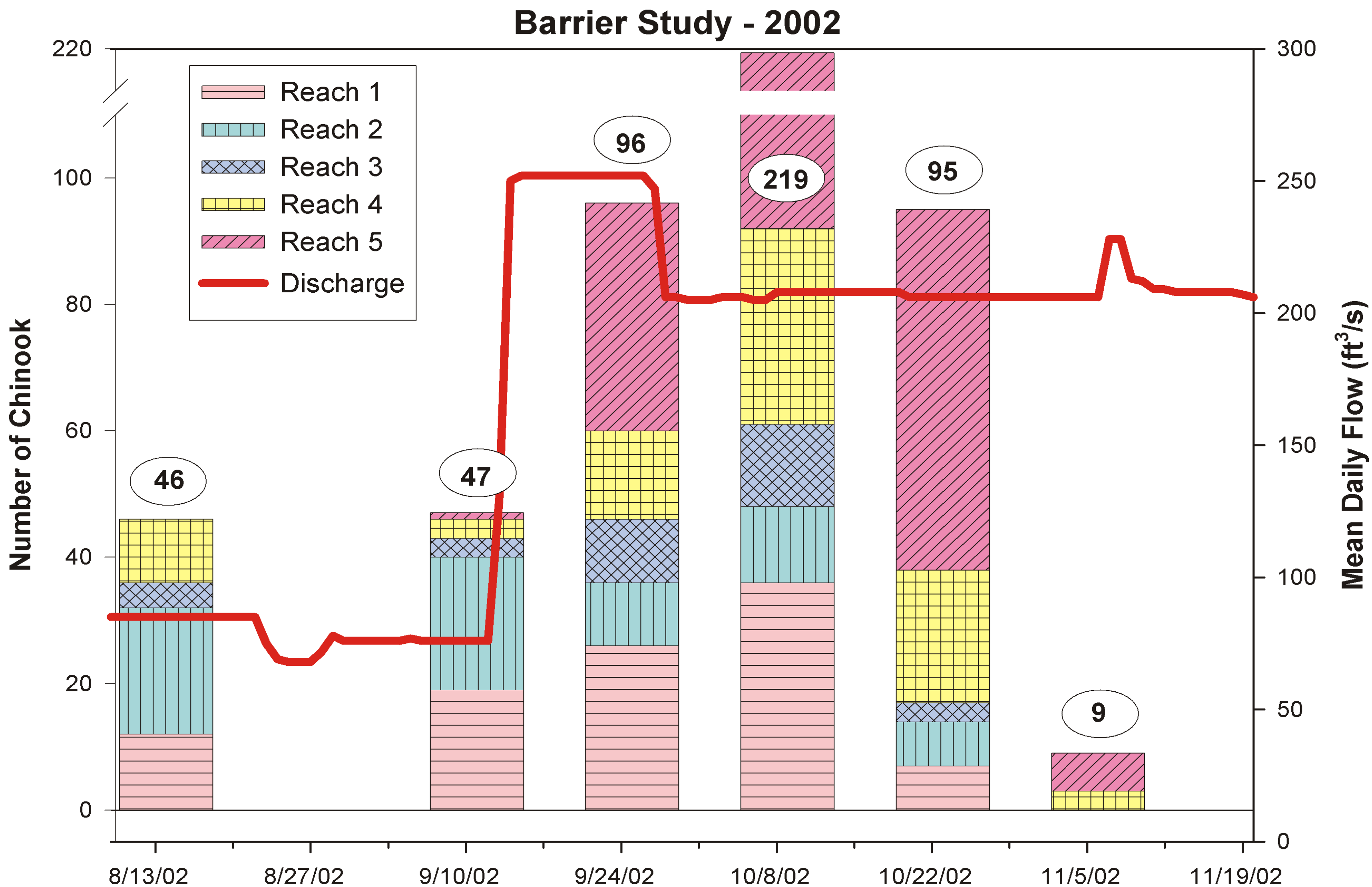

FIGURE 10.—Snorkel survey observations of live adult Chinook above the Gorge Cascade (rm 6.5) and mean daily flow during the 2002 barrier study (experimental flow releases) on Clear Creek.

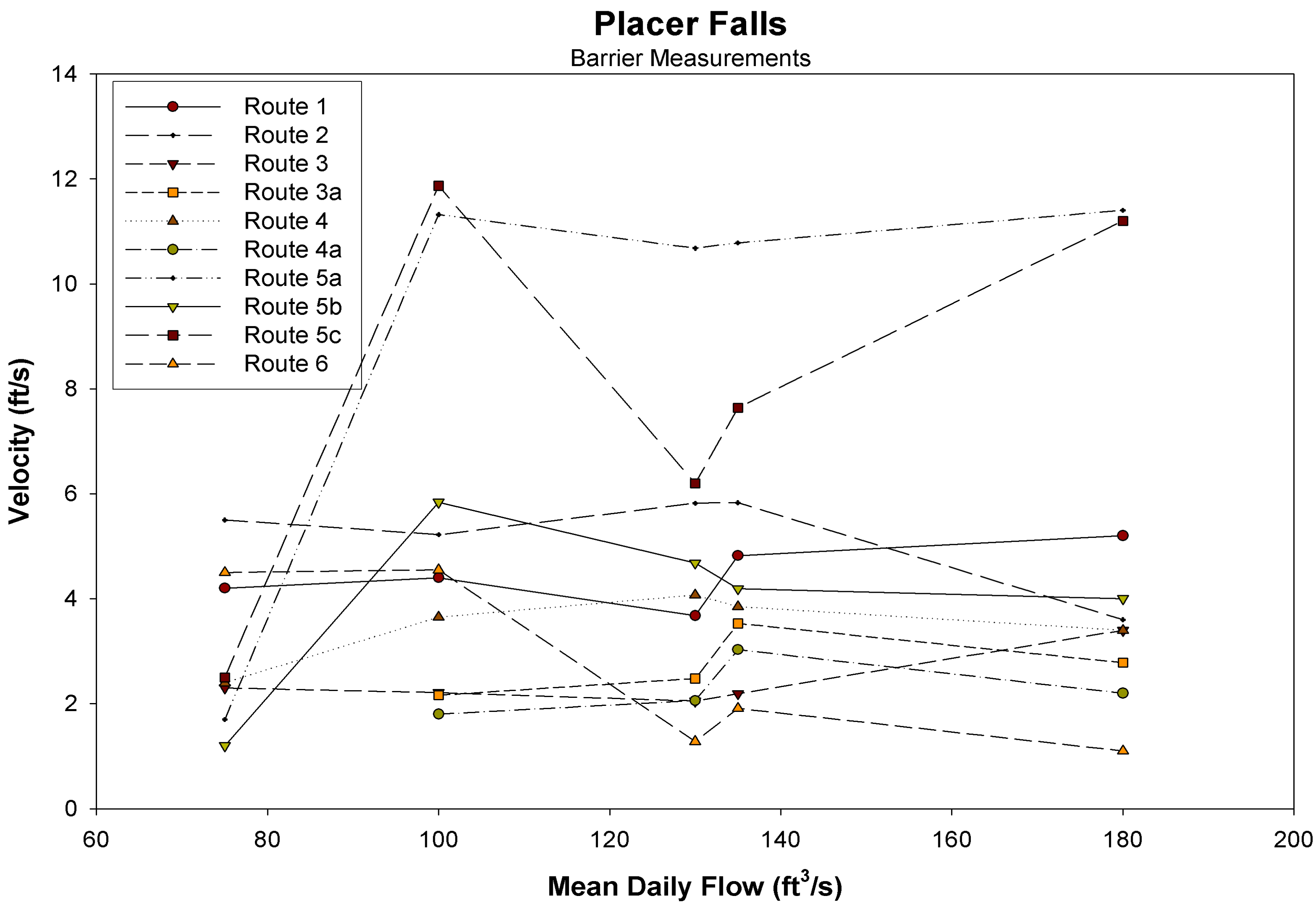

FIGURE 11.—Water velocity measurements for available fish passage routes up Placer Falls (rm 10.6) on Clear Creek. Velocities were measured at five different mean daily flows.

Appendices

TABLE A1.—USFWS Clear Creek snorkel survey observations in 1999 of live adult Chinook, carcasses, and new redds. Survey conditions include stream flow (at the Igo gage), turbidity, and water temperature. Off-season snorkel surveys (December-March) are included.

Reach	Date	Chinook [a]	Carcasses	New redds	Flow (ft^3/s)	Turbidity (NTU)	Temp (˚F)
1	08/30/1999	0	0	0	146	n/a[f]	n/a
2	09/02/1999	0	0	0	146	n/a	55
3	08/25/1999	0	0	0	146	n/a	57
4	08/19/1999	0	0	0	146	n/a	56
4	10/19/1999 [b]	6	0	5	196	n/a	n/a
4	11/02/1999	0	17	7	194	n/a	53
5	08/19/1999	1	0	0	146	n/a	56
5	09/23/1999	2	0	3	244	n/a	57
5	10/19/1999	35	20	50	196	n/a	n/a
5	11/03/1999	0	21	20	195	n/a	53
6	05/06/1999	1	0	0	244	1.1	56
6	05/13/1999	1	0	0	234	1.2	55
6	05/21/1999	2	0	0	222	1.2	58
6	05/27/1999	5	0	0	220	1.1	61
6	06/03/1999	1	0	0	172	1.5	55
6	06/08/1999	6	0	0	165	n/a	n/a
6	06/15/1999	6	0	0	160	0.9	56
6	06/22/1999	4	0	0	155	1.7	64
6	06/29/1999	8	0	0	153	1.6	65
6	07/06/1999	9	0	0	146	1.0	62
6	07/13/1999 [c]	14	0	0	146	n/a	68
6	07/21/1999 [d]	14	0	0	146	1.3	62
6	07/28/1999	6	0	0	144	3.3	65
6	08/04/1999	20	0	0	144	1.3	67
6	08/11/1999	16	1	0	146	1.4	62
6	08/17/1999	22	0	0	146	5.5	63
6	08/24/1999	30	0	0	146	4.2	61
6	08/30/1999	35	0	0	146	1.8	59
6	09/09/1999	55	0	1	200	1.3	59
6	09/13/1999	70	0	5	244	1.4	59
6	09/21/1999	247	3	89	244	1.1	59
6	09/29/1999	957	30	186	244	0.8	57
6	12/07/1999	129	71	2025 [e]	210	clear	48
1-5	Total	44	58	85			
6	Total	1658	105	2306			

[a] Counts may include multiple observations of the same salmon between surveys.
[b] Only the lowermost 1200 yards of Reach 4 were surveyed.
[c] The observation of 14 Chinook in “deepest pool” by USFWS crew was added to this snorkel survey.
[d] The snorkel survey conducted by CDFG on 07/20/99 was omitted from this table.
[e] All redds counted on this survey. No attempt was made to distinguish between new and old redds.
[f] n/a means data not available.

TABLE A2.—USFWS Clear Creek snorkel survey observations in 2000 of live adult Chinook, carcasses, and new redds. Survey conditions include stream flow, average turbidity, and average water temperature. Off-season snorkel surveys (December-March) are included.

Reach	Date	Chinook [a]	Carcasses	New redds	Flow (ft^3/s)	Turbidity (NTU)	Temp (˚F)
1	04/26/2000 [b]	1	0	0	267	n/a	51
1	06/06/2000	0	0	0	112	n/a	55
1	07/07/2000	0	0	0	53	n/a	55
1	07/31/2000	0	0	0	51	n/a	58
1	08/28/2000	0	0	0	54	n/a	56
1	09/25/2000	3	0	1	55	n/a	55
1	10/13/2000	0	0	1	143	n/a	53
2	06/08/2000	4	0	0	115	n/a	53
2	07/10/2000	7	0	0	52	n/a	59
2	08/02/2000	5	0	0	50	n/a	59
2	08/29/2000	7	0	0	54	n/a	55
2	09/26/2000	2	3	7	55	n/a	55
2	10/16/2000	0	0	0	144	n/a	54
3	05/01/2000	0	0	0	250	n/a	53
3	06/07/2000	0	0	0	110	n/a	55
3	07/11/2000	3	0	0	52	n/a	61
3	08/03/2000	0	2	0	52	n/a	61
3	08/30/2000	0	0	0	54	n/a	57
3	09/27/2000	0	0	0	55	n/a	55
3	10/17/2000	0	0	0	143	n/a	53
4	05/02/2000	0	0	0	250	n/a	53
4	06/05/2000	3	0	0	112	n/a	56
4	07/12/2000	7	0	0	52	n/a	63
4	08/04/2000	4	0	0	50	n/a	64
4	08/31/2000	1	0	0	54	n/a	60
4	09/28/2000	1	0	1	55	n/a	30
4	10/18/2000	1	0	1	143	n/a	52
4	11/21/2000 [c]	0	0	0	166	n/a	49
5	04/27/2000	0	0	0	264	n/a	52
5	06/05/2000	0	0	0	112	n/a	60
5	07/12/2000	0	0	0	52	n/a	68
5	08/04/2000	0	0	0	50	n/a	66
5	08/31/2000	0	0	0	54	n/a	64
5	09/28/2000	2	0	0	55	n/a	60
5	10/18/2000	2	0	2	143	n/a	53
5	11/21/2000 [c]	0	0	0	166	n/a	49
5	12/19/2000 [c]	0	0	0	175	n/a	n/a
6	02/18/2000 [c]	13	4	1	360	n/a	47
6	03/13/2000 [c]	1	1	0	455	3.9	51
6	04/24/2000	5	0	2	274	1.1	53
6	05/03/2000 [c]	3	0	2	247	n/a	55
6	05/10/2000 [c]	1	0	2	244	n/a	54
6	05/17/2000 [c]	1	0	0	259	1.4	57
6	05/25/2000 [c]	2	0	0	119	n/a	63
6	05/31/2000	0	0	0	114	n/a	63
6	06/15/2000 [c]	9	0	0	108	1.5	72
6	06/29/2000 [c]	9	0	0	51	2.1	71
6	07/13/2000	0	0	0	51	1.3	72
6	08/16/2000	0	0	0	56	n/a	70
6	09/21/2000	4	0	0	52	1.5	67
6	10/11/2000	634	34	463	144	n/a	56
6	12/12/2000 [c]	114	n/a [d]	984 [e]	182	n/a	49
1-5	Total	53	5	13			
6	Total	796	39	1454			

[a] Counts may include multiple observations of the same salmon between surveys.
[b] This survey ended at Peltier Valley Road Bridge (rm 16.9).
[c] Supplemental surveys added to the normal monthly survey schedule.
[d] n/a means data not available.
[e] All redds counted on this survey. No attempt was made to distinguish between new and old redds.

TABLE A3.—USFWS Clear Creek snorkel survey observations in 2001 of live adult Chinook, carcasses, and new redds. Survey conditions include stream flow, average turbidity, and average water temperature. Off-season snorkel surveys (December-March) are included.

Reach	Date	Chinook [a]	Carcasses	New redds	Flow (ft^3/s)	Turbidity (NTU)	Temp (˚F)
1	02/23/2001 [b]	0	0	0	125	clear	45
1	04/23/2001	0	0	0	150	fair-poor	50
1	05/21/2001	0	0	0	145	fair	55
1	06/18/2001	0	0	0	125	1.0	54
1	07/16/2001	0	0	0	75	0.5	54
1	08/13/2001	0	0	0	75	0.7	56
1	09/24/2001	1	0	0	123	1.0	55
1	10/22/2001	6	1	4	200	1.0	55
1	11/13/2001	0	0	0	275	0.6	52
2	04/24/2001	0	0	0	147	fair	54
2	05/22/2001	0	0	0	145	fair	n/a[c]
2	06/19/2001	0	0	0	123	1.3	54
2	07/17/2001	2	0	0	75	0.6	n/a
2	08/14/2001	0	0	0	74	0.7	55
2	09/25/2001	2	0	0	134	0.7	56
2	10/23/2001	7	4	6	219	0.7	55
2	11/14/2001	0	5	1	305	0.8	53
3	04/25/2001	0	0	0	145	fair	53
3	05/23/2001	0	0	0	145	fair	54
3	06/20/2001	0	0	0	125	0.8	56
3	07/18/2001	0	0	0	75	n/a	55
3	08/15/2001	0	0	0	74	0.5	57
3	09/26/2001	13	0	0	132	0.6	56
3	10/24/2001	8	8	7	219	0.6	54
3	11/15/2001	0	1	0	245	0.6	53
4	04/26/2001	0	0	0	143	fair	55
4	05/24/2001	0	0	0	143	fair	54
4	06/21/2001	0	0	0	125	0.9	59
4	07/19/2001	2	0	0	74	0.7	58
4	08/16/2001	0	0	0	72	0.6	60
4	09/27/2001	15	1	3	132	0.5	57
4	10/25/2001	14	18	16	219	0.6	54
4	11/16/2001	0	0	1	225	0.8	54
5	01/31/2001 [b]	0	0	0	187	n/a	44
5	02/27/2001 [b]	0	0	0	304	fair	46
5	03/27/2001 [b]	0	0	0	150	clear	49
5	04/26/2001	0	0	0	143	fair	55
5	05/24/2001	0	0	0	143	fair	58
5	06/21/2001	0	0	0	125	0.9	59
5	07/19/2001	0	0	0	74	0.7	58
5	08/16/2001	0	0	0	72	0.6	66
5	09/27/2001	18	0	1	132	0.5	59
5	10/26/2001	34	31	33	219	0.9	54
5	11/16/2001	1	15	9	227	0.7	53
5	12/19/2001 [b]	0	0	0	375	2.4	48
6	01/17/2001 [b]	49	8	47	168	n/a	43
6	03/08/2001 [b]	1	0	0	289	3.1	52
6	04/27/2001	1	0	0	140	good	58
6	05/10/2001 [b]	0	0	0	127	fair	61
6	05/25/2001	0	0	0	143	good	61
6	06/07/2001 [b]	1	0	0	140	1.0	61
6	06/22/2001	2	0	0	125	0.7	65
6	07/09/2001 [b]	1	1	0	75	0.5	67
6	07/20/2001	0	0	0	75	0.5	67
6	08/17/2001	0	0	0	72	0.5	60
6	09/13/2001 [b]	37	0	1	99	n/a	63
6	09/28/2001	570	11	98	129	0.6	60
1-5	Total	123	84	81			
6	Total	662	20	146			

[a] Counts may include multiple observations of the same salmon between surveys.
[b] Supplemental surveys added to the normal monthly survey schedule.
[c] n/a mean data not available.

TABLE A4.—USFWS Clear Creek snorkel survey observations in 2002 of live adult Chinook, carcasses, and new redds. Survey conditions include stream flow, average turbidity, and average water temperature. Off-season snorkel surveys (December-March) are included.

Reach	Date	Chinook[a]	Carcasses	New redds	Flow (ft^3/s)	Turbidity (NTU)	Temp (˚F)
1	01/07/2002	0	0	0	200	1.3	47
1	01/24/2002	0	0	0	200	2.7	45
1	02/12/2002	0	0	0	200	1.0	44
1	04/22/2002	0	0	0	185	1.1	49
1	05/13/2002	0	0	0	166	0.8	50
1	06/17/2002	2	0	0	156	0.6	52
1	07/15/2002	2	0	0	83	1.3	55
1	08/12/2002	12	0	0	85	0.5	55
1	09/09/2002	19	0	3	76	0.5	56
1	09/16/2002[b]	12	1	16	267	1.1	54
1	09/23/2002	26	0	13	267	0.9	54
1	10/08/2002	36	9	7	218	0.8	52
1	10/22/2002	7	5	2	219	0.8	52
1	11/05/2002	0	1	0	219	0.8	52
2	03/12/2002	0	0	0	260	1.0	48
2	04/23/2002	0	0	0	182	0.9	51
2	05/14/2002	1	0	0	166	0.7	53
2	06/18/2002	6	0	0	156	0.7	55
2	07/16/2002	20	0	0	78	0.6	57
2	08/13/2002	20	0	0	85	0.7	58
2	09/10/2002	21	0	4	76	0.7	57
2	09/24/2002	10	0	16	267	0.9	55
2	10/09/2002	12	11	8	222	0.8	53
2	10/23/2002	7	7	1	219	0.7	52
2	11/05/2002	0	3	1	219	0.7	52
3	03/13/2002	0	0	0	240	1.0	47
3	04/24/2002	0	0	0	182	0.7	51
3	05/15/2002	7	0	0	152	0.8	52
3	06/19/2002	14	0	0	156	0.6	55
3	07/17/2002	6	0	0	67	0.6	54
3	08/14/2002	4	0	0	85	0.6	57
3	09/11/2002	3	0	6	76	1.0	55
3	09/25/2002	10	0	15	267	0.9	54
3	10/10/2002	13	8	8	222	0.8	52
3	10/23/2002	3	0	0	219	0.9	52
3	11/06/2002	0	2	2	219	0.7	51
4	03/14/2002	0	0	0	230	1.0	45
4	04/25/2002	1	0	0	175	0.6	53
4	05/16/2002	5	0	0	149	0.6	54
4	06/20/2002	15	0	0	155	0.7	56
4	07/18/2002	10	0	0	67	0.8	60
4	08/15/2002	10	0	0	85	0.6	62
4	09/12/2002	3	0	0	76	0.6	57
4	09/26/2002	14	1	7	267	0.7	55
4	10/11/2002	31	9	15	222	0.8	52
4	10/24/2002	21	10	7	219	1.2	51
4	11/07/2002	3	1	1	227	1.2	52
5	01/18/2002	0	0	0	286	1.6	45
5	02/14/2002	0	0	0	255	0.9	45
5	04/25/2002	0	0	0	175	0.6	53
5	05/16/2002	5	0	0	149	0.6	54
5	06/20/2002	2	0	0	155	0.7	56
5	07/18/2002	3	0	0	67	0.8	60
5	08/15/2002	0	0	0	85	0.6	62
5	09/12/2002	1	0	0	76	0.6	57
5	09/26/2002	36	0	6	267	0.7	55
5	10/11/2002	127	15	45	222	0.8	52
5	10/25/2002	57	29	41	219	0.7	51
5	11/08/2002	6	5	3	232	1.4	53
6	04/26/2002	2	0	0	178	0.8	55
6	05/17/2002	11	1	0	152	0.6	59
6	06/21/2002	12	0	0	154	0.7	59
6	07/19/2002	22	0	0	67	1.4	68
6	08/16/2002	20	0	0	85	0.5	68
6	09/13/2002	28	0	0	76	1.0	64
6	09/27/2002	636	6	199	267	1.0	57
1-5	Total	623	117	227			
6	Total	731	7	199			

[a] Counts may include multiple observations of the same salmon between surveys.
[b] Only Reach 1 was surveyed this week.

TABLE A5.—Information on adipose-fin clipped Chinook carcasses and coded-wire tags (CWT) recovered by the USFWS on Clear Creek from 1999 through 2002 including carcasses recovered on surveys other than the spring Chinook snorkel survey.[a]

Survey	Date	Reach	CWT code [b]	Run	Hatchery [c]	Brood year	Sex	Fork length (mm)
SCS Snorkel Survey	09/29/1999	R6	0601060109	Fall	FRH	1995	Male	940
SCS Snorkel Survey	09/29/1999	R6	0601060604	Spring	FRH	1997	Male	520
SCS Snorkel Survey	07/09/2001	R6	0501011512	Winter	CNFH	1997	Female	680
SCS Snorkel Survey	09/28/2001	R6	0601060605	Spring	FRH	1997	Male	1100
SCS Snorkel Survey	10/10/2002	R3	0601061008	Fall	FRH	1999	Male	795
SCS Snorkel Survey	10/11/2002	R5	0501021403	Fall	CNFH	1999	Male	850
SCS Snorkel Survey	10/24/2002	R4	062679	Spring	FRH	2000	Female	610
Late-fall Carcass Survey	11/23/1999	R6	unknown				Female	890
Late-fall Carcass Survey	12/29/1999	R6	055061	Late-fall	CNFH	1997	Male	640
Late-fall Carcass Survey	01/26/2000	R6	055062	Late-fall	CNFH	1997	Female	640
Late-fall Carcass Survey	01/26/2000	R6	055058	Late-fall	CNFH	1997	Male	790
Late-fall Carcass Survey	01/26/2000	R6	055051	Late-fall	CNFH	1997	Male	650
Late-fall Carcass Survey	01/26/2000	R6	NTD				Female	740
Late-fall Carcass Survey	01/06/2000	R6	055052	Late-fall	CNFH	1997	Female	730
Late-fall Carcass Survey	01/06/2000	R6	054240	Late-fall	CNFH	1996	Female	760
Late-fall Carcass Survey	01/12/2000	R6	055062	Late-fall	CNFH	1997	Female	720
Late-fall Carcass Survey	01/12/2000	R6	055062	Late-fall	CNFH	1997	Female	690
Late-fall Carcass Survey	01/26/2000	R6	054125	Late-fall	CNFH	1996	Female	720
Late-fall Carcass Survey	02/03/2000	R6	054123	Late-fall	CNFH	1996	Male	860
Late-fall Carcass Survey	02/03/2000	R6	055056	Late-fall	CNFH	1997	Female	660
Late-fall Carcass Survey	02/03/2000	R6	054127	Late-fall	CNFH	1996	Male	730
Late-fall Carcass Survey	02/03/2000	R6	054126	Late-fall	CNFH	1996	Female	780
Late-fall Carcass Survey	02/03/2000	R6	054237	Late-fall	CNFH	1996	Female	760
Late-fall Carcass Survey	01/12/2000	R6	055042	Late-fall	CNFH	1997	Female	740
Late-fall Carcass Survey	12/27/2000	R6	NTD				Male	unknown
Late-fall Carcass Survey	01/16/2001	R6	055048	Late-fall	CNFH	1997	Female	890
Late-fall Carcass Survey	01/22/2001	R6	054127	Late-fall	CNFH	1996	Female	880
Other	10/11/2002	R6	0501021402	Fall	CNFH	1999	Male	890
Other	10/20/2002	R6	NTD				Unknown	unknown
Other	10/20/2002	R6	062664	Fall	FRH	2000	Unknown	unknown
Other	11/19/2002	R5	055213	Late-fall	CNFH	1999	Female	660
Late-fall Carcass Survey	12/23/2002	R6	062665	Fall	FRH	2000	Male	990

[a] Most CWT recoveries on Clear Creek are made by California Department of Fish and Game during their fall Chinook carcass survey and are not included in this report.
[b] NTD = No tag detected
[c] CNFH = Coleman National Fish Hatchery, FRH = Feather River Hatchery

TABLE A6.—Chinook redd measurements taken during USFWS Clear Creek snorkel surveys in September and October, 2001 and 2002.

Date	Pebble count no.	Reach	Length (ft)	Width (ft)	Area (ft^2)	Depth: pit (ft)	Depth: tailspill (ft)	Depth: pre-redd (ft)	Velocity (ft/s)
09/27/2001		R5	10.8	6.3	53.8	2.3	0.9	1.8	
09/27/2001		R4	8.3	3.8	25.1	1.8	0.9	1.3	
09/27/2001		R4	11.3	4.3	38.3	1.3	0.6	1.1	
10/02/2001	1	R4	14.5	5.7	64.9	1.4	0.6	1.0	1.8
10/02/2001	2	R4	9.6	7.6	57.3	1.8	1.2	1.4	2.8
10/04/2001	3	R6	13.5	10.0	106.0	2.4	0.5	1.9	1.0
10/04/2001	4	R6	9.4	6.6	48.7	2.0	0.6	1.5	1.1
10/04/2001	5	R6	10.7	4.9	41.2	1.6	6.5	1.2	1.1
10/22/2001	6	R1	21.7	5.4	92.2	1.8	0.8	1.6	
10/22/2001	7	R1	17.5	7.5	103.1	2.2	1.1	1.9	
10/24/2001	8	R3	7.8	6.0	36.5	2.3	1.9	2.1	
10/24/2001		R3	22.8	12.0	215.2	4.4	2.5	4.1	
10/25/2001	9	R4	11.5	8.8	79.0	3.0	2.5	2.0	
10/26/2001	10	R4	19.5	14.3	219.0	1.9	1.2	1.5	
10/26/2001	11	R4	9.3	4.6	33.6	2.9	2.2	2.0	
09/09/2002	12	R1	15.5	5.9	72.0	1.8	0.9	1.1	
09/09/2002		R1	7.0	3.1	17.0	1.3	0.7	0.9	
09/09/2002	13	R1	6.6	3.3	17.2	1.2	0.7	0.9	
09/10/2002	14	R2	7.1	4.6	25.5	2.4	2.0	2.3	
09/10/2002		R2	18.8	5.4	79.8	2.3	1.3	1.5	
09/10/2002		R2	12.5	2.9	28.6	3.3	2.2	2.4	
09/10/2002	15	R2	6.8	3.4	18.3	2.0	1.4	1.8	
09/11/2002		R3	5.2	4.3	17.6	3.8	3.2	3.4	
09/11/2002		R3	2.4	2.4	4.5	2.7	2.3	2.5	
09/11/2002		R3	2.5	2.2	4.3	2.9	2.3	2.7	
09/11/2002		R3	6.3	2.3	11.2	3.1	2.7	3.2	
09/11/2002		R3	2.0	1.8	2.9	3.6	3.4	3.4	
09/11/2002	16	R3	6.0	3.5	16.3	3.6	3.0	3.1	
09/23/2002		R1	4.7	2.6	9.5	2.4	3.0	2.6	
09/23/2002		R1	15.6	4.3	52.0	3.3	2.4	2.8	
09/23/2002	17	R1	16.3	5.1	65.2	1.6	0.7	1.4	
09/23/2002		R1	15.8	5.6	69.4	2.7	1.3	2.3	
09/24/2002		R2	6.1	3.2	15.1	3.7	2.8	3.2	
09/25/2002		R3	9.3	6.4	46.6	3.2	2.6	3.0	
09/25/2002		R3	20.5	12.3	198.6	4.0	2.9	4.8	
09/26/2002	18	R4	24.0	7.6	142.9	2.3	1.0	2.1	
09/26/2002		R4	8.0	4.0	25.1	3.6	3.0	3.3	
09/26/2002	19	R4	9.7	13.0	98.7	3.0	2.3	3.2	
10/08/2002		R1	15.1	7.9	93.8	2.2	1.3	1.9	
Average			11.3	5.8	60.2	2.5	1.9	2.2	1.6
Minimum			2.0	1.8	2.9	1.2	0.5	0.9	1.0
Maximum			24.0	14.3	219.0	4.4	6.5	4.8	2.8

TABLE A7.—Chinook-redd substrate-size-distribution descriptors for pebble counts conducted during USFWS Clear Creek snorkel surveys in September and October, 2001 and 2002 (n=19). (D_{16} = diameter below which 16% of sample is finer, D_{50} = median diameter, D_{84} = diameter below which 84% of sample is finer, dg = $(D_{84} \bullet D_{16})^{0.5}$, and sg = $(D_{84}/D_{16})^{0.5}$.)[a]

Pebble count no.	Redd pit					Redd tailspill					Total redd				
	D_{16}	D_{50}	D_{84}	dg	sg	D_{16}	D_{50}	D_{84}	dg	sg	D_{16}	D_{50}	D_{84}	dg	sg
1	6.5	20	50	18.0	2.8	16.0	41	64	32.0	2.0	9.8	29	60	24.2	2.5
2	20.0	54	112	47.3	2.4	21.6	41	72	39.4	1.8	21.1	47	99	45.6	2.2
3	10.6	34	85	30.0	2.8	16.7	41	74	35.2	2.1	13.8	38	81	33.4	2.4
4	12.0	40	112	36.7	3.1	3.6	13	52	13.6	3.8	5.0	29	75	19.4	3.9
5	18.3	44	105	43.8	2.4	18.0	37	72	36.0	2.0	18.1	40	93	41.0	2.3
6	8.0	30	59	21.7	2.7	23.0	40	57	36.2	1.6	13.8	36	58	28.2	2.0
7	30.9	56	123	61.7	2.0	24.9	48	90	47.2	1.9	27.7	52	108	54.8	2.0
8	8.0	25	64	22.6	2.8	12.3	29	82	31.7	2.6	10.3	27	77	28.2	2.7
9	9.6	55	183	41.9	4.4	16.0	52	105	41.0	2.6	11.4	53	135	39.2	3.4
10	14.3	66	128	42.8	3.0	30.3	55	100	55.0	1.8	21.9	57	114	50.0	2.3
11	6.7	26	91	24.7	3.7	4.7	29	58	16.6	3.5	5.7	28	64	19.1	3.4
12	6.0	20	85	22.6	3.8	23.0	51	102	48.5	2.1	11.4	35	97	33.3	2.9
13	12.0	31	100	34.6	2.9	11.4	27	71	28.5	2.5	11.7	29	90	32.4	2.8
14	11.4	34	93	32.6	2.9	8.6	22	64	23.5	2.7	9.6	26	83	28.2	2.9
15	9.0	31	124	33.4	3.7	16.0	36	61	31.3	2.0	9.6	34	94	30.0	3.1
16	14.4	31	85	35.1	2.4	8.0	23	51	20.1	2.5	11.0	27	61	26.0	2.4
17	15.1	29	83	35.4	2.3	21.8	44	64	37.4	1.7	17.6	37	75	36.3	2.1
18	16.0	34	85	36.9	2.3	21.6	41	61	36.2	1.7	18.6	39	68	35.5	1.9
19	13.9	27	55	27.5	2.0	23.8	47	63	38.7	1.6	18.5	37	61	33.5	1.8
Average	12.8	36	96	34.2	2.9	16.9	38	72	34.1	2.2	14.0	37	84	33.6	2.6
Minimum	6.0	20	50	18.0	2.0	3.6	13	51	13.6	1.6	5.0	26	58	19.1	1.8
Maximum	30.9	66	183	61.7	4.4	30.3	55	105	55.0	3.8	27.7	57	135	54.8	3.9

[a] All measurements are in mm, except for sg which is dimensionless.

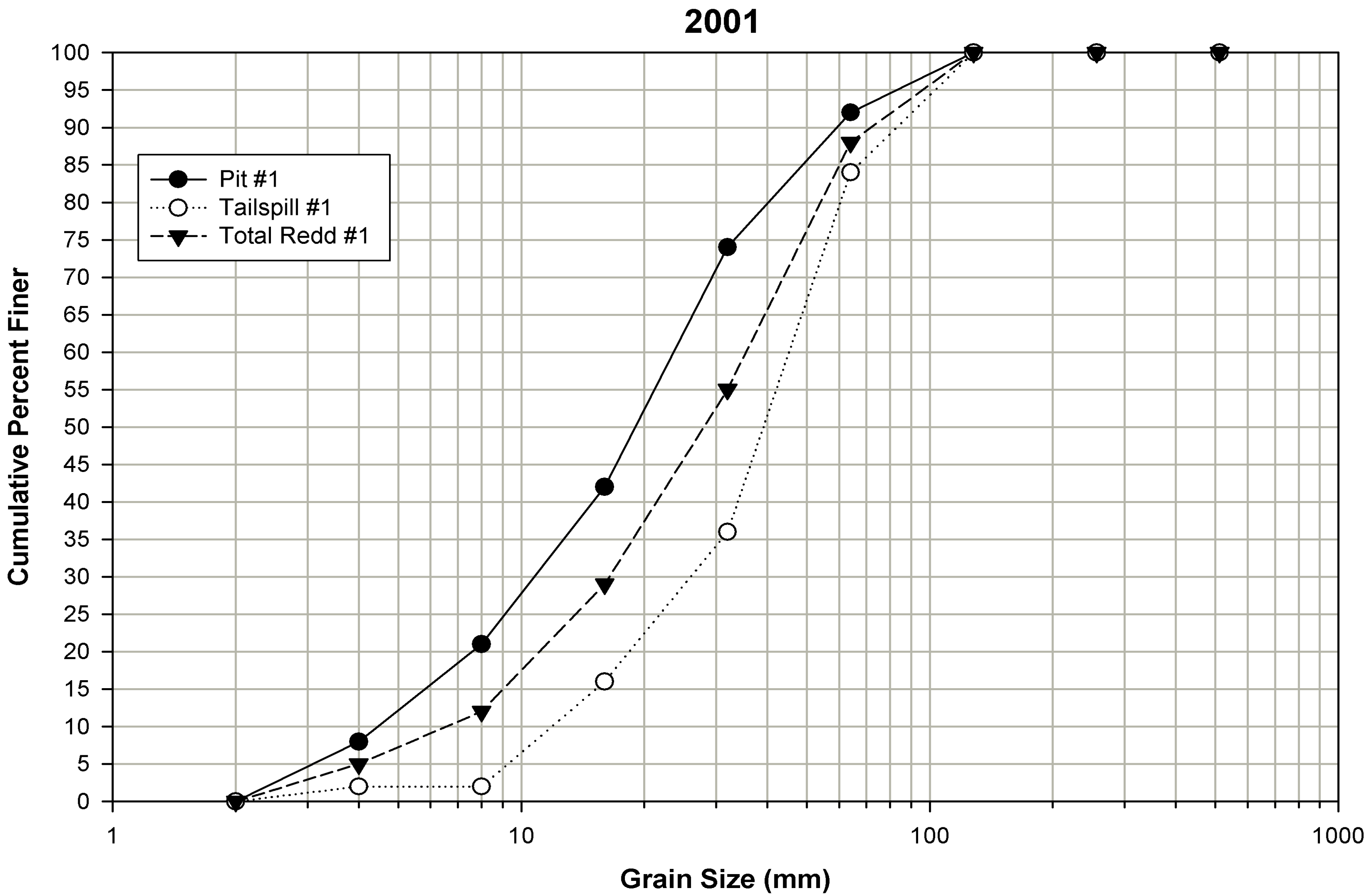

FIGURE A1.—Cumulative particle size distribution for Pebble Count No. 1 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2001.

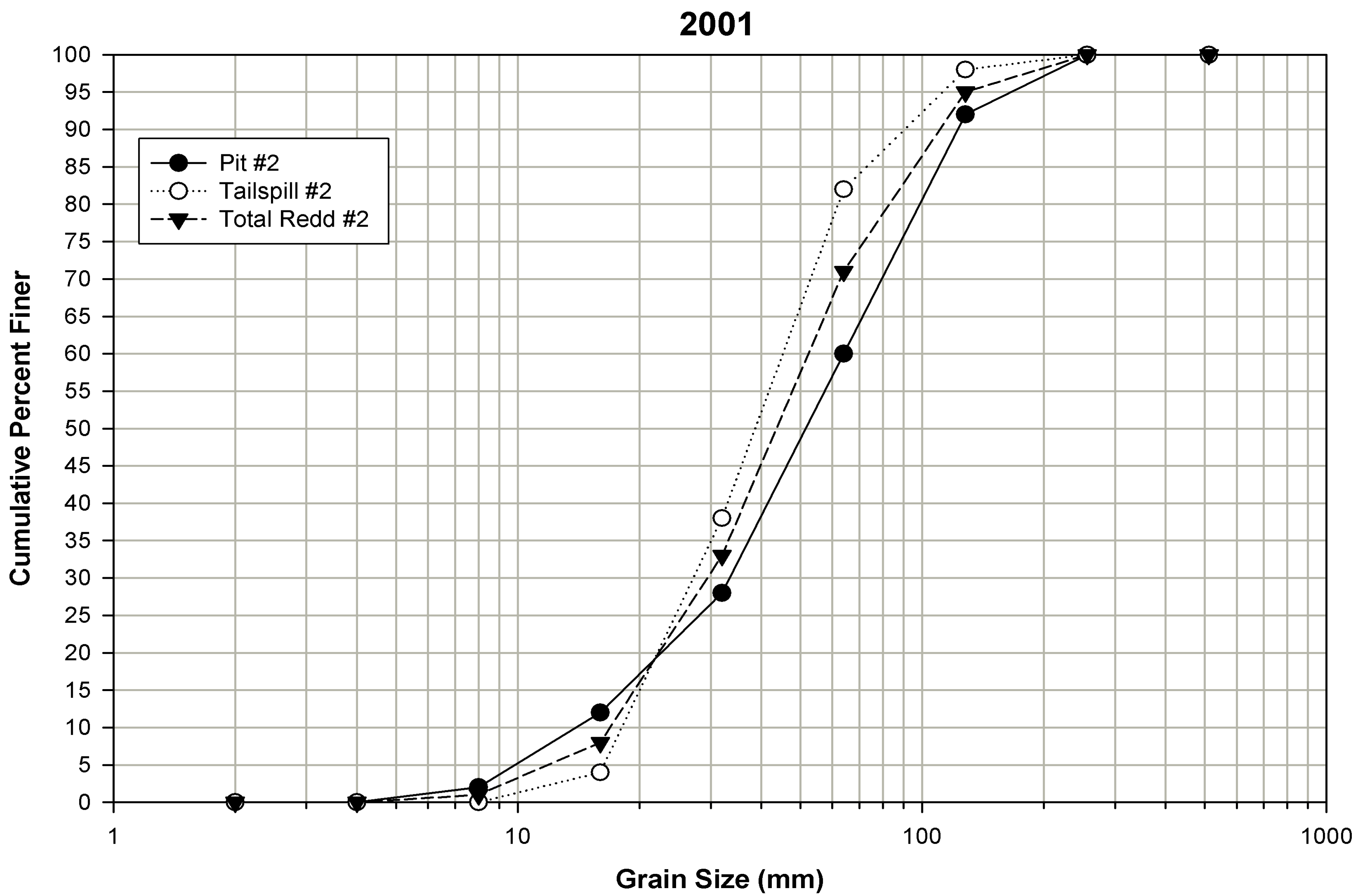

FIGURE A2.—Cumulative particle size distribution for Pebble Count No. 2 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2001.

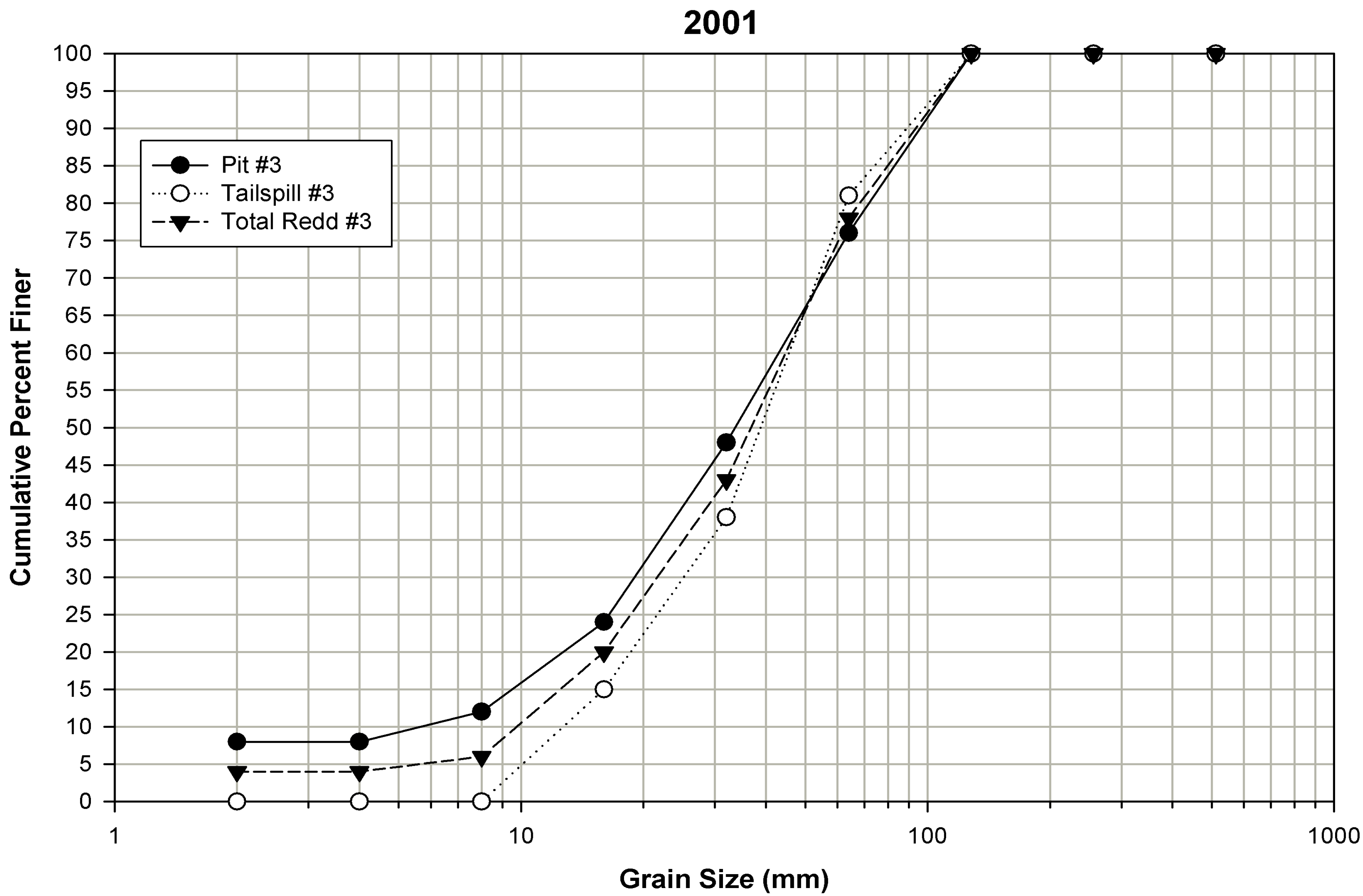

FIGURE A3.—Cumulative particle size distribution for Pebble Count No. 3 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2001.

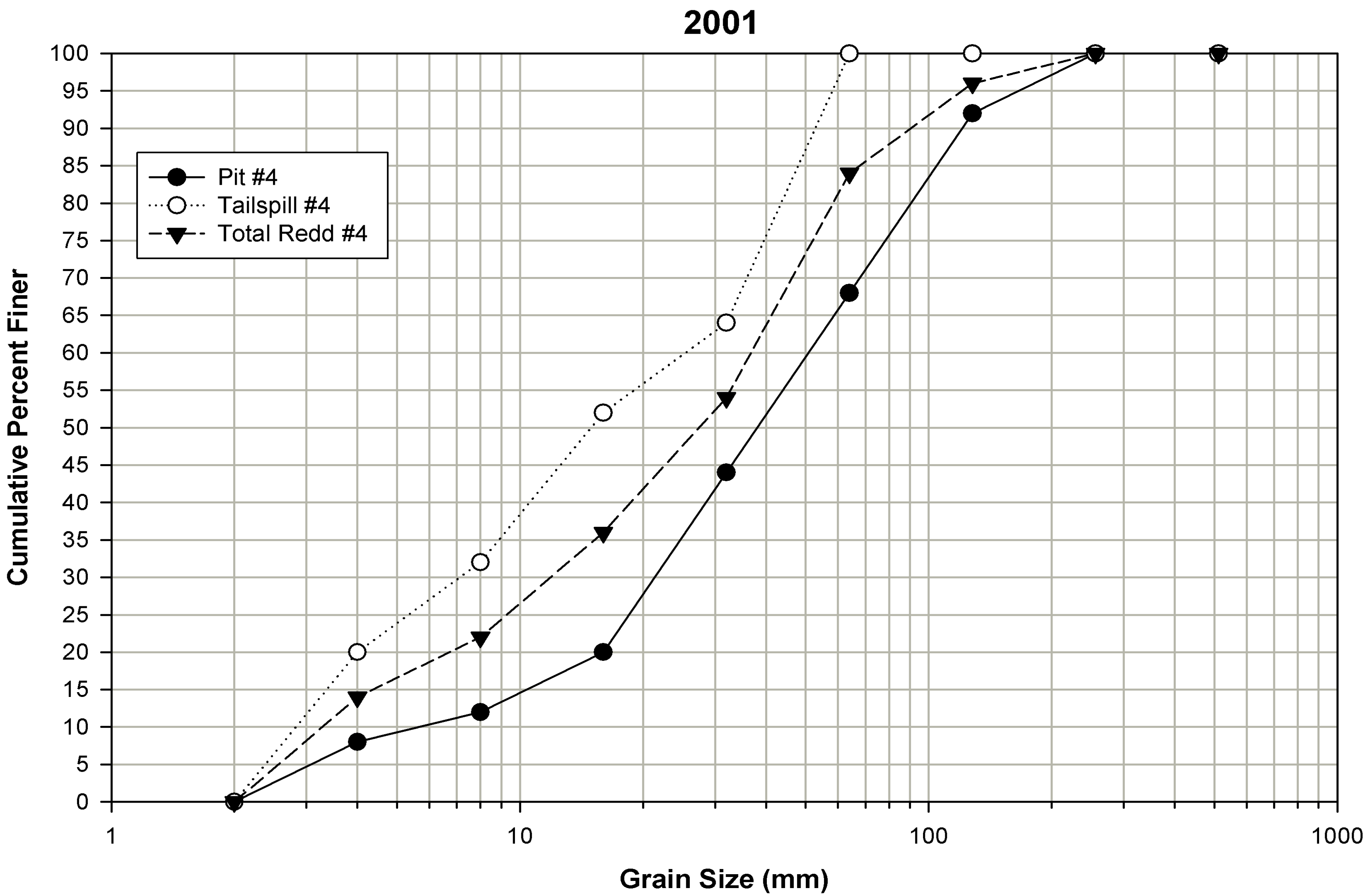

FIGURE A4.—Cumulative particle size distribution for Pebble Count No. 4 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2001.

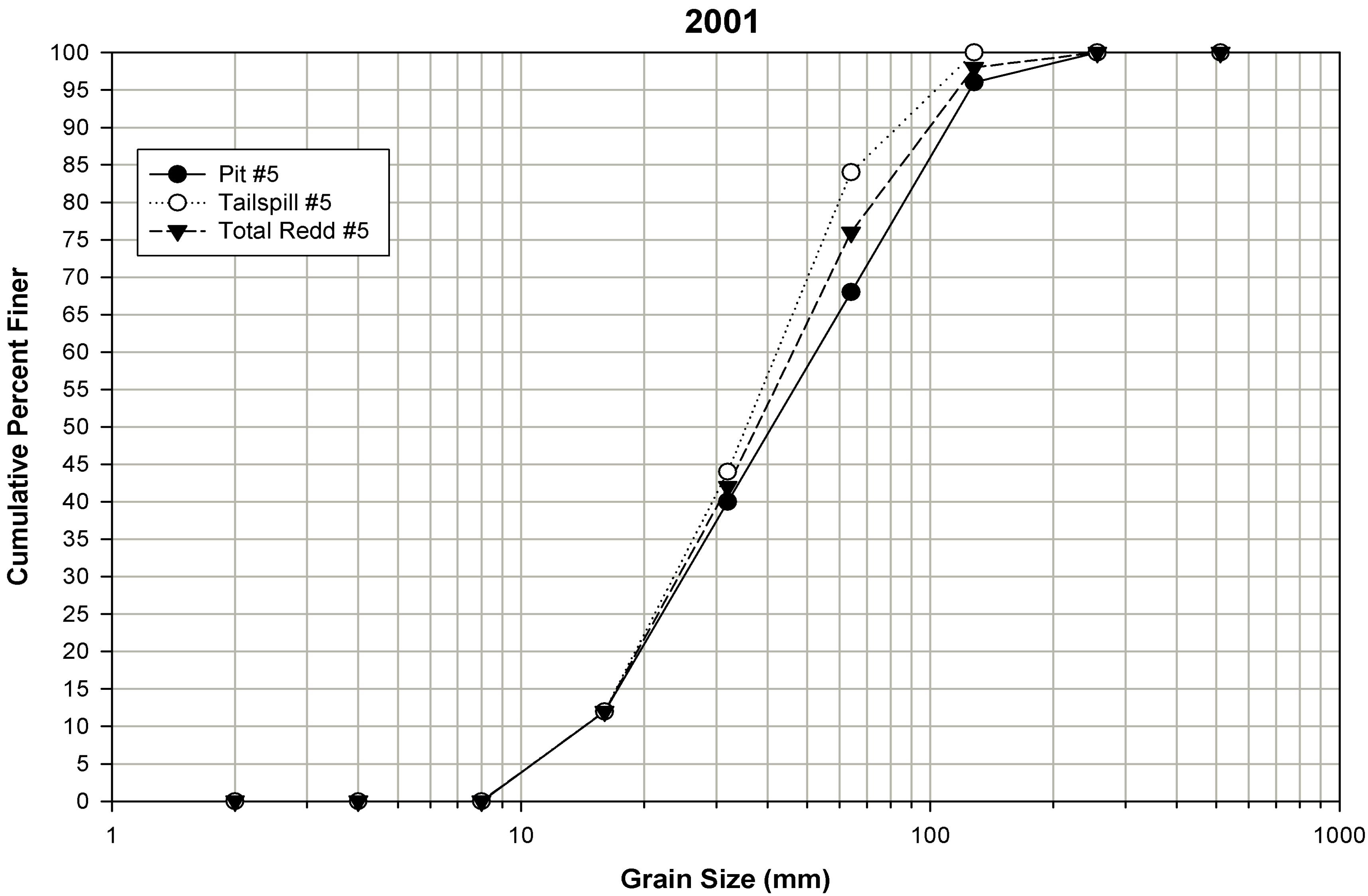

FIGURE A5.—Cumulative particle size distribution for Pebble Count No. 5 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2001.

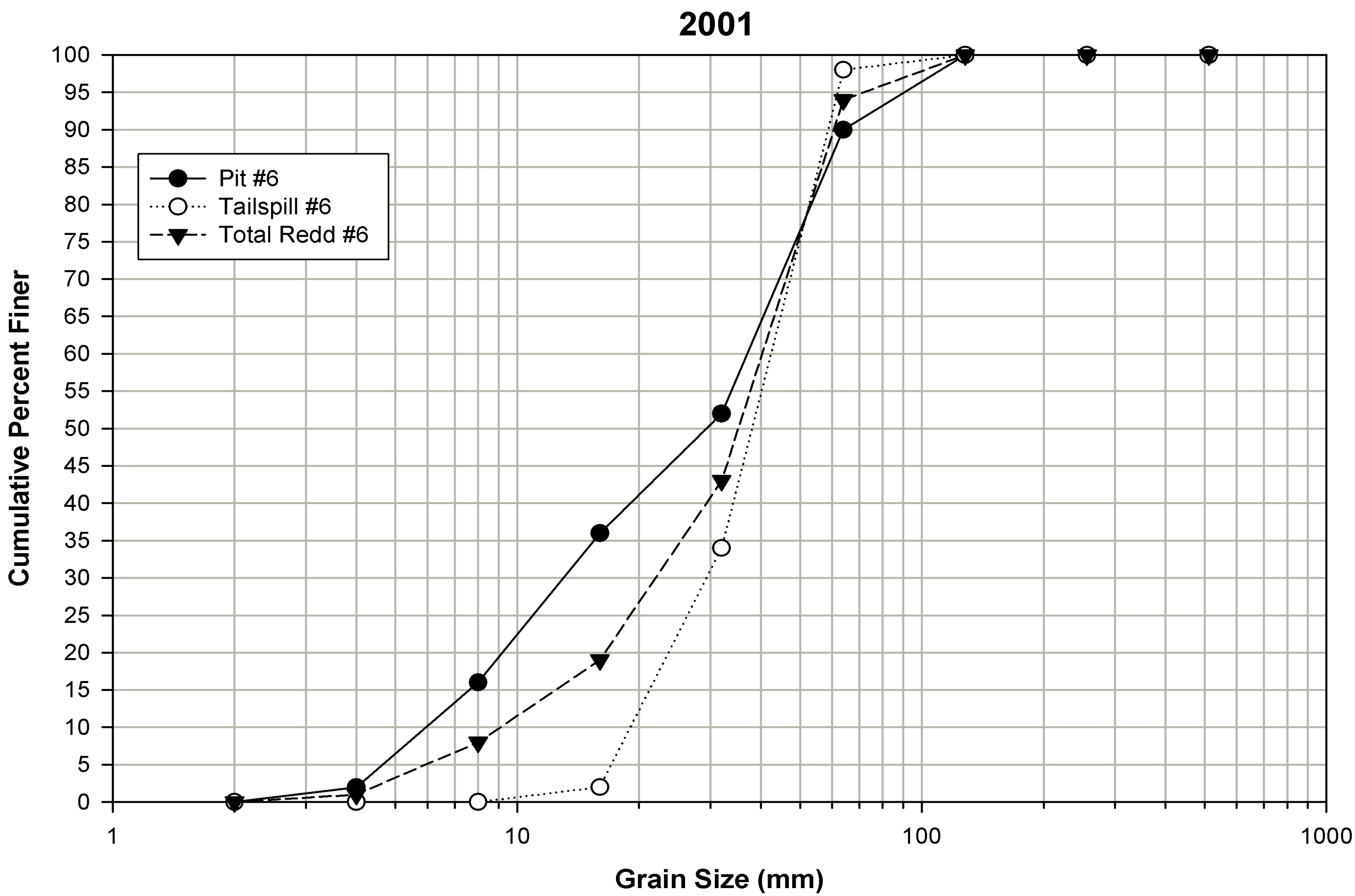

FIGURE A6.—Cumulative particle size distribution for Pebble Count No. 6 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2001.

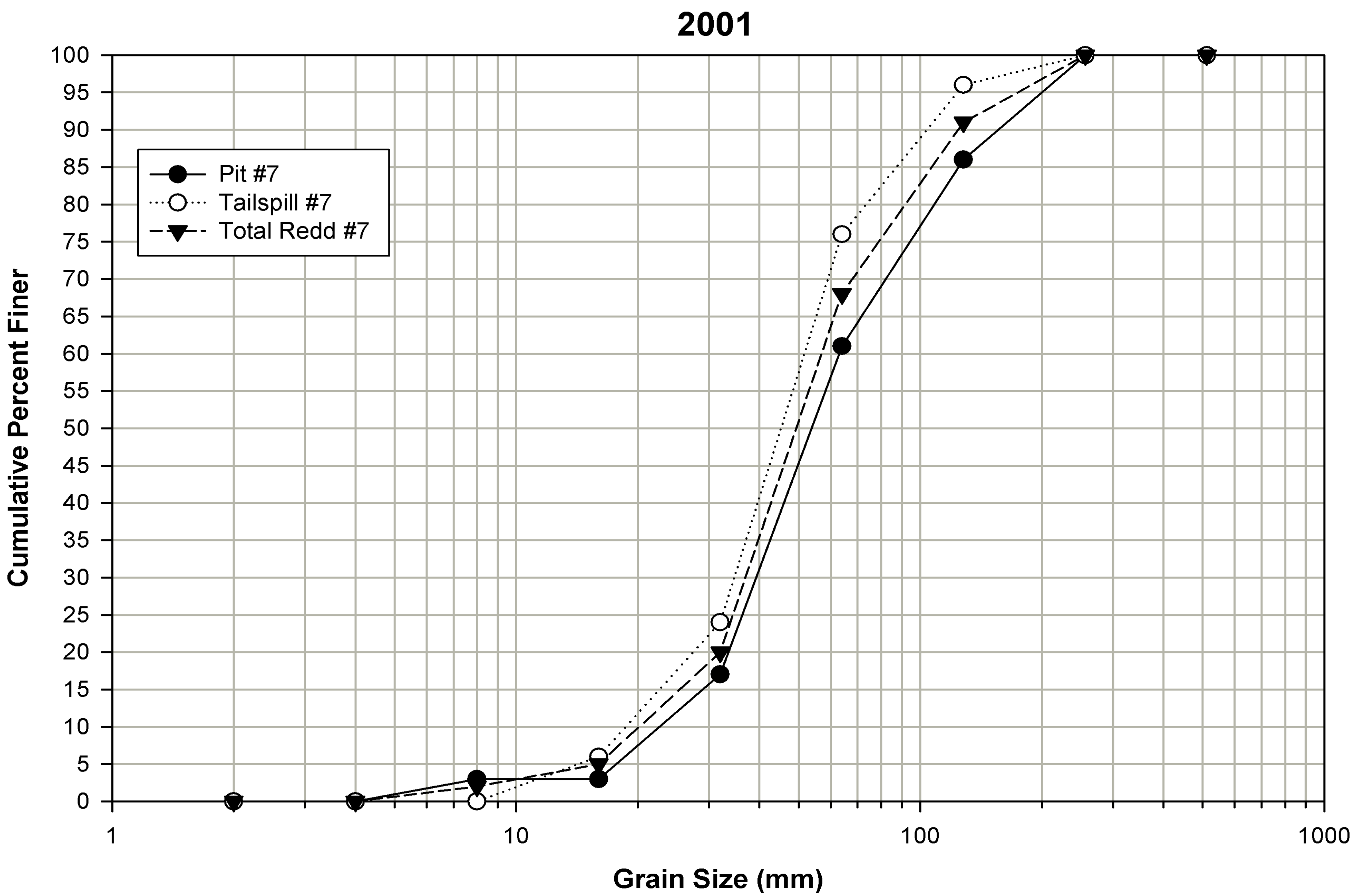

FIGURE A7.—Cumulative particle size distribution for Pebble Count No. 7 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2001.

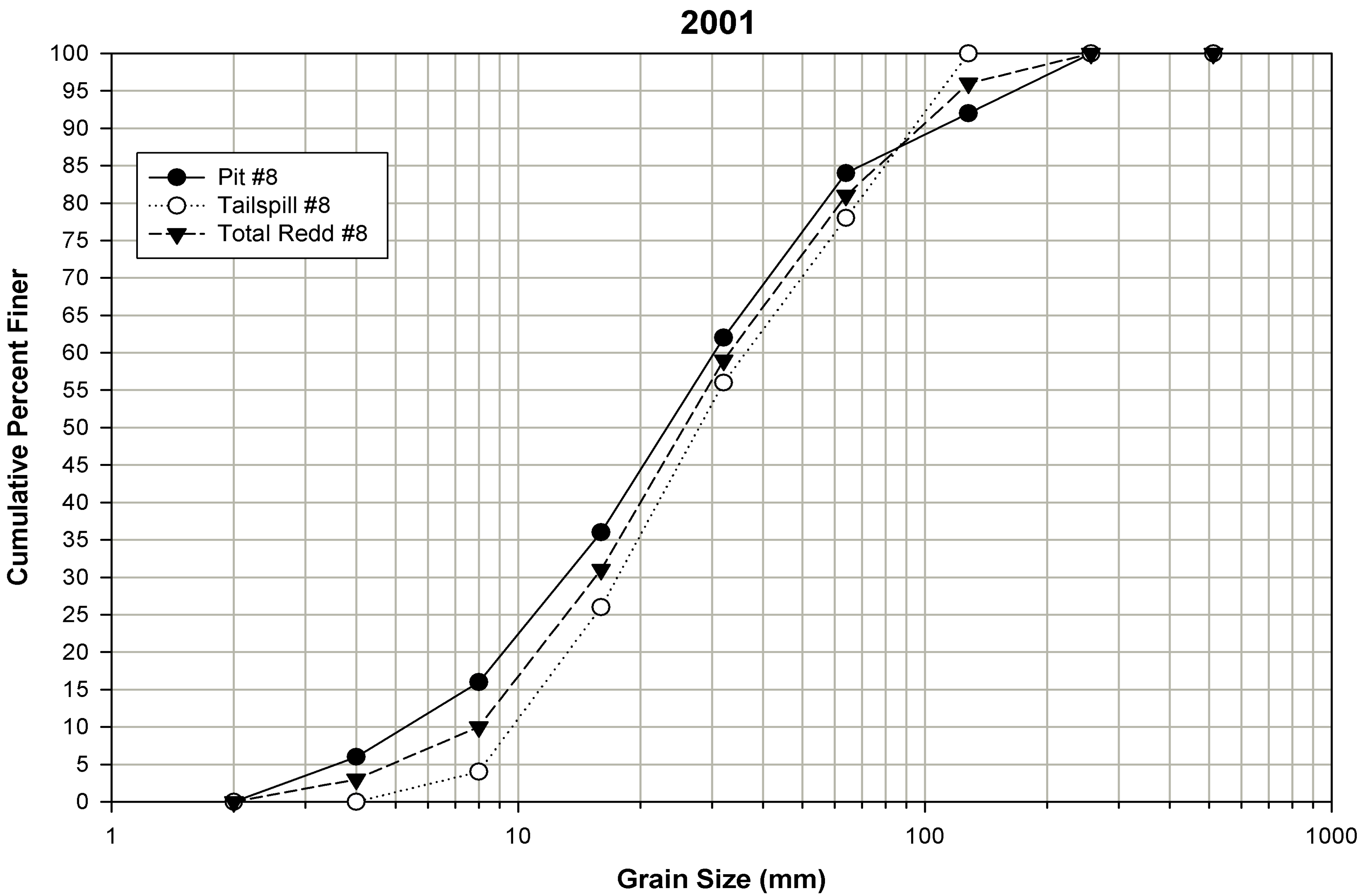

FIGURE A8.—Cumulative particle size distribution for Pebble Count No. 8 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2001.

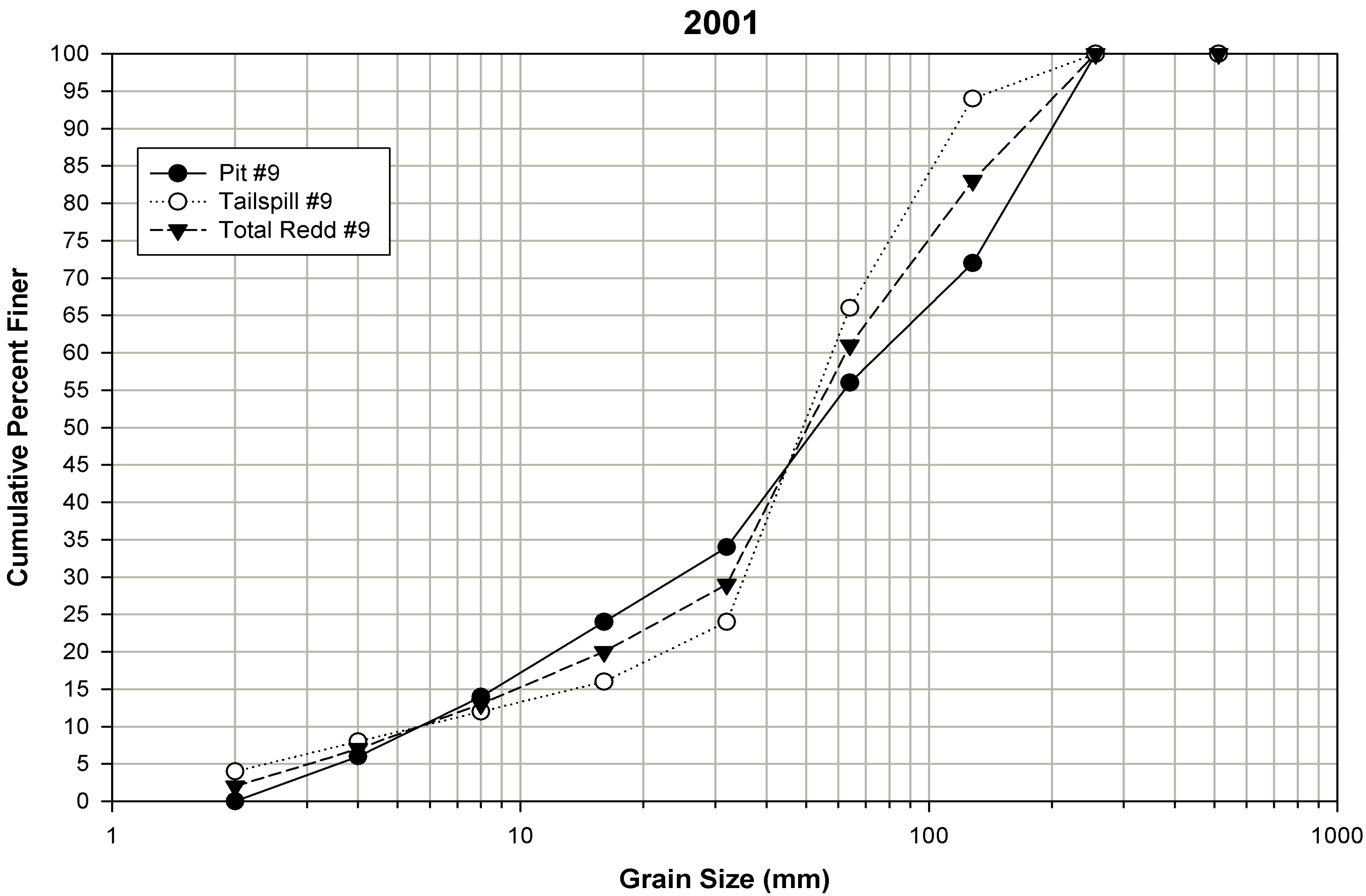

FIGURE A9.—Cumulative particle size distribution for Pebble Count No. 9 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2001.

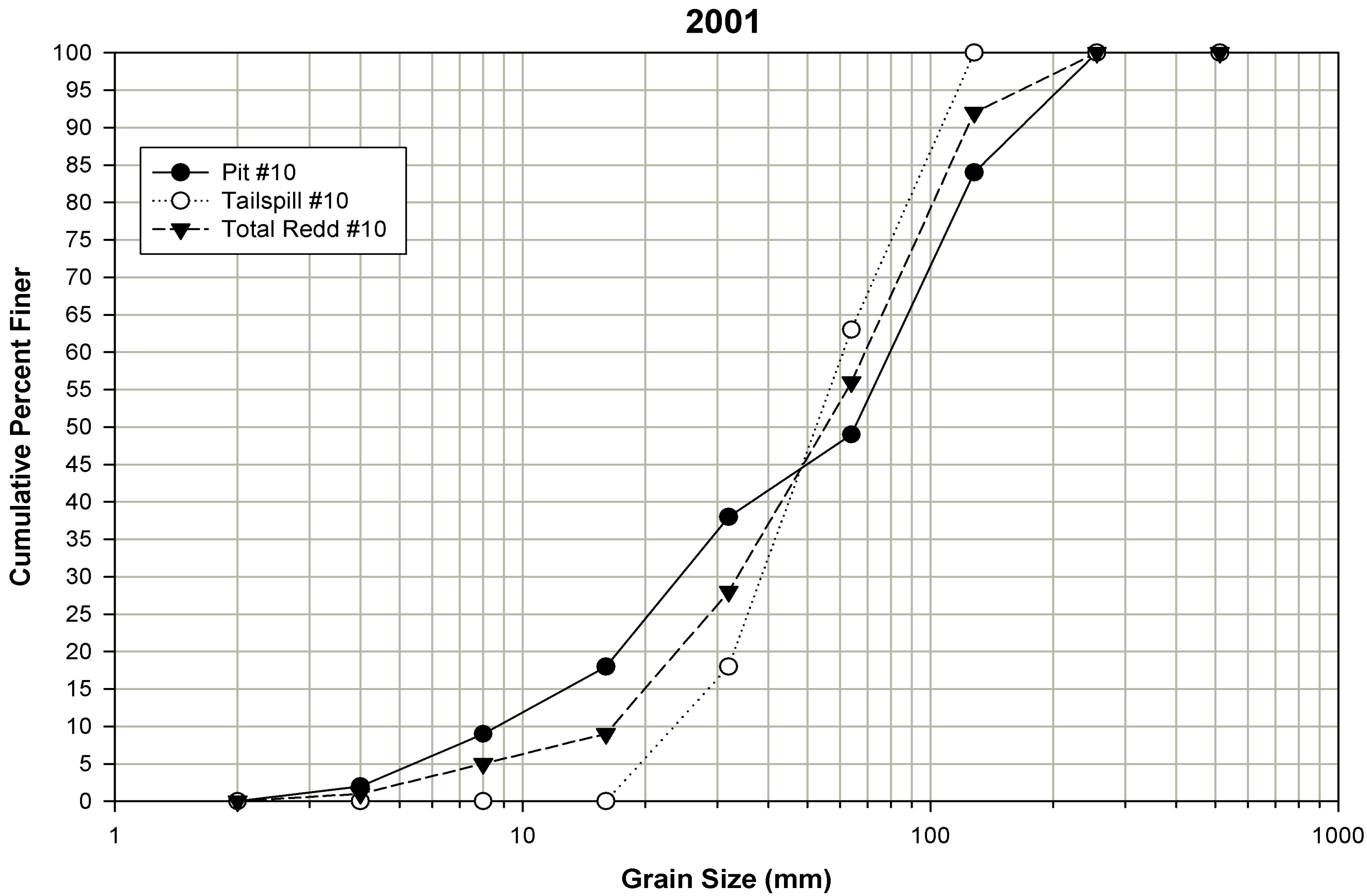

FIGURE A10.—Cumulative particle size distribution for Pebble Count No. 10 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2001.

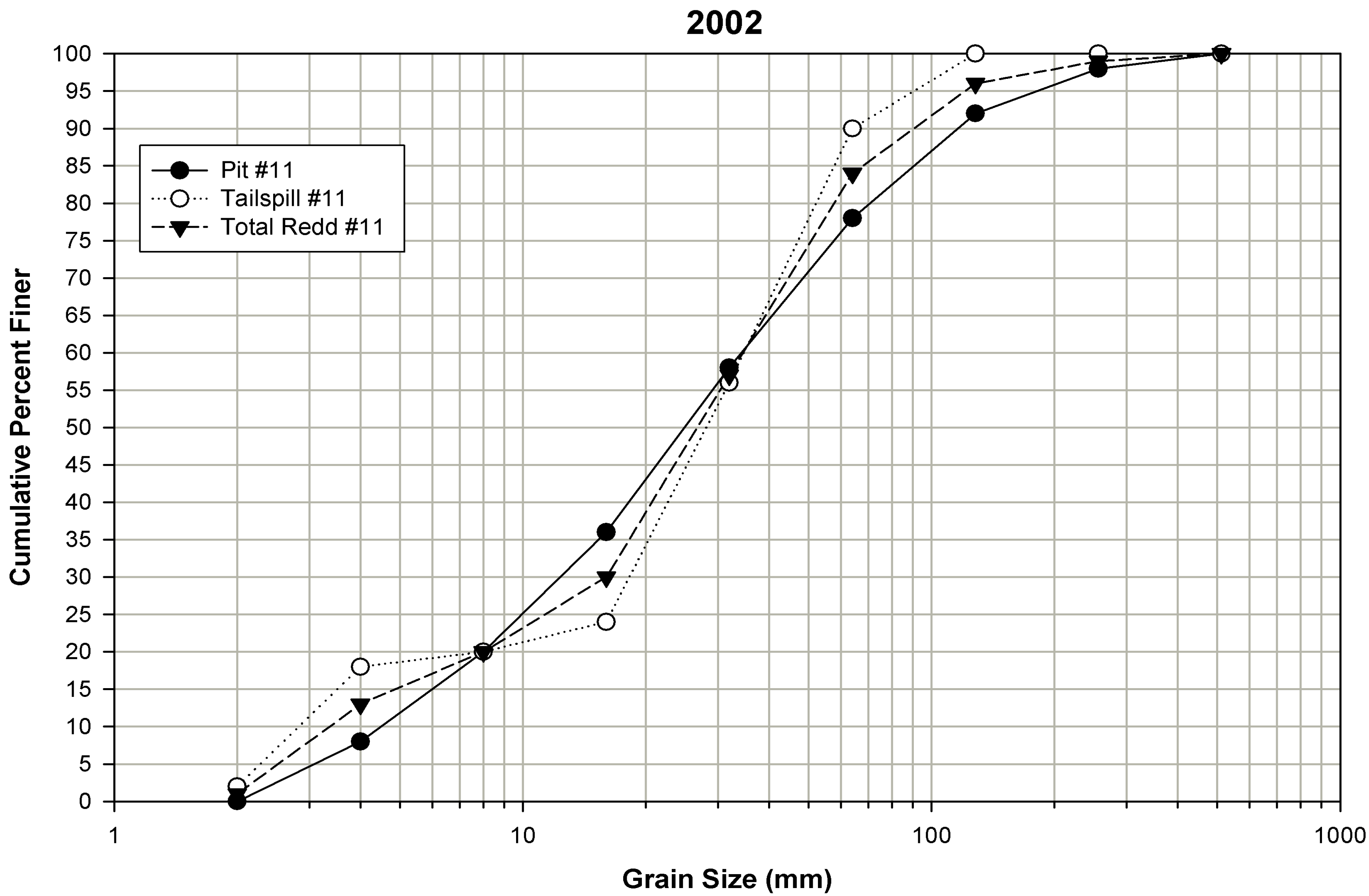

FIGURE A11.—Cumulative particle size distribution for Pebble Count No. 11 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2001.

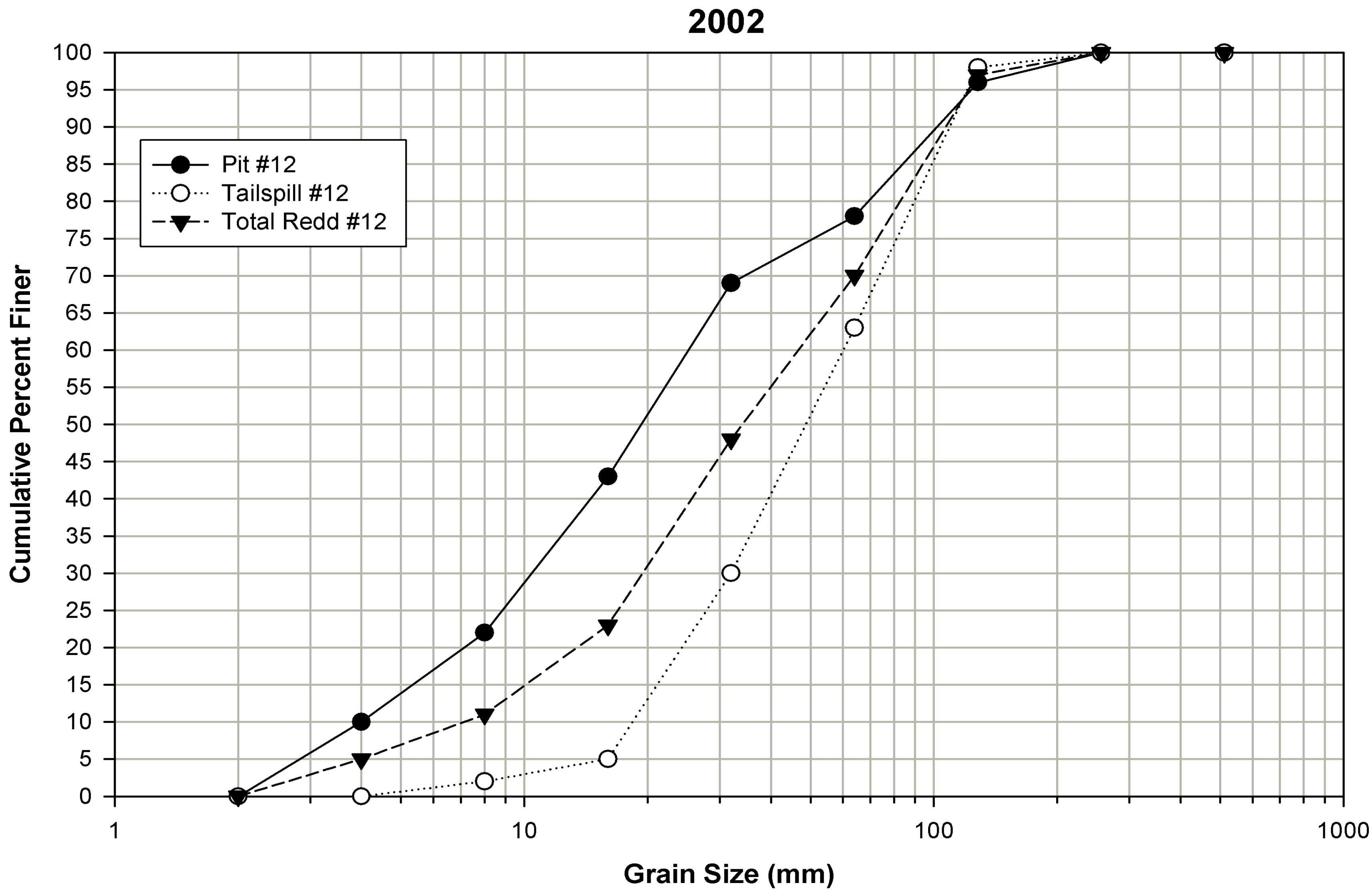

FIGURE A12.—Cumulative particle size distribution for Pebble Count No. 12 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2002.

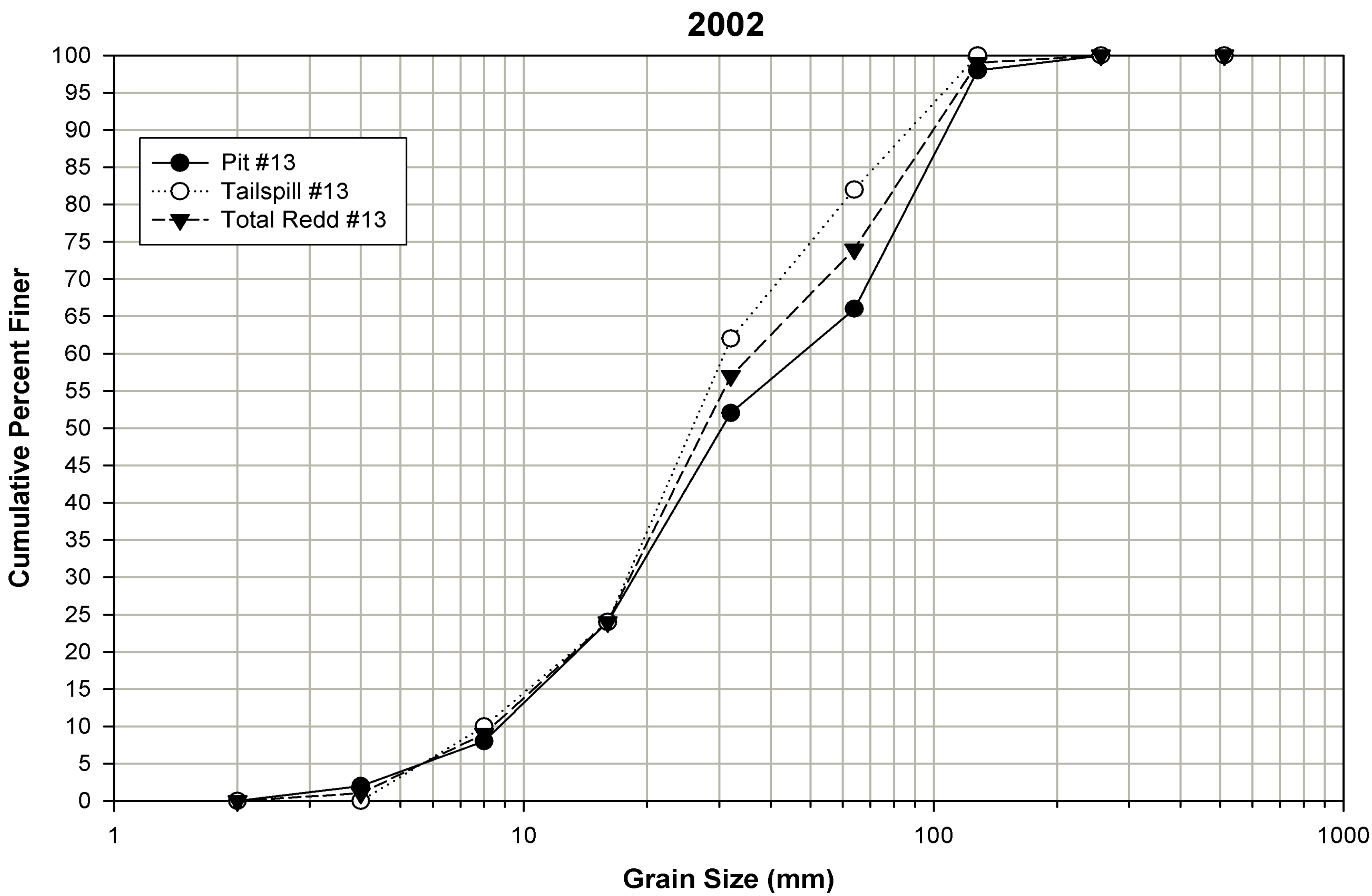

FIGURE A13.—Cumulative particle size distribution for Pebble Count No. 13 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2002.

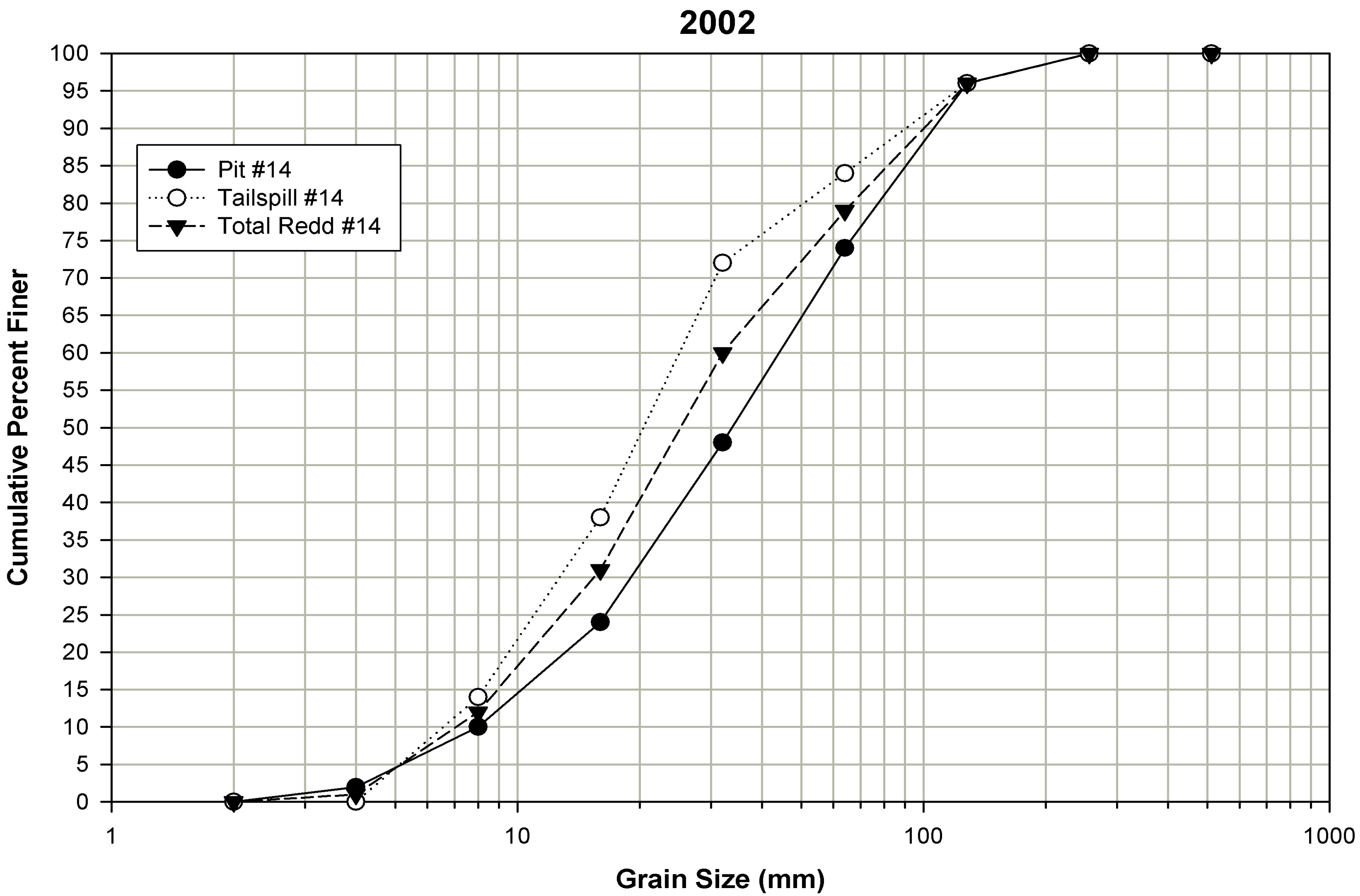

FIGURE A14.—Cumulative particle size distribution for Pebble Count No. 14 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2002.

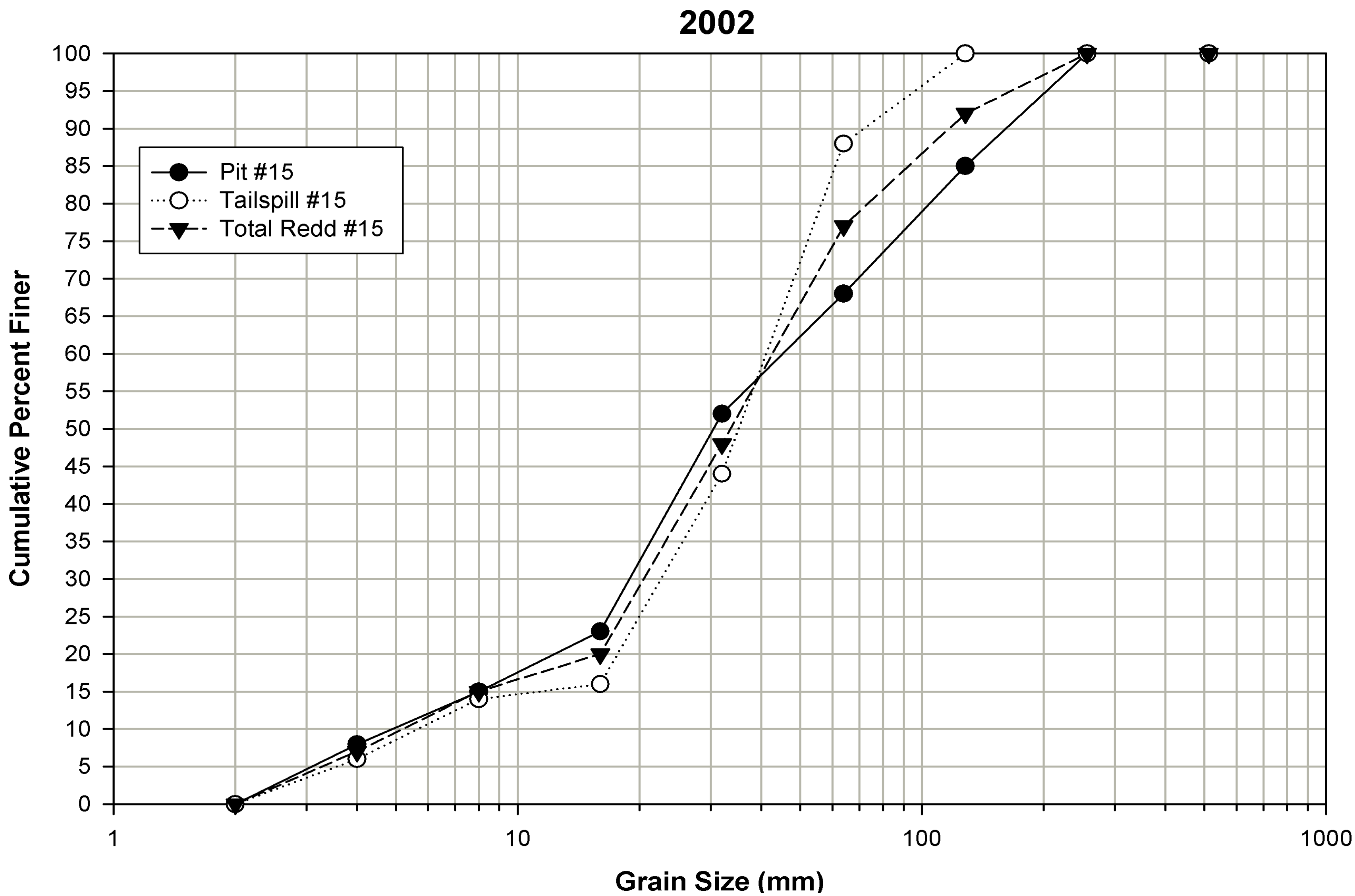

FIGURE A15.—Cumulative particle size distribution for Pebble Count No. 15 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2002.

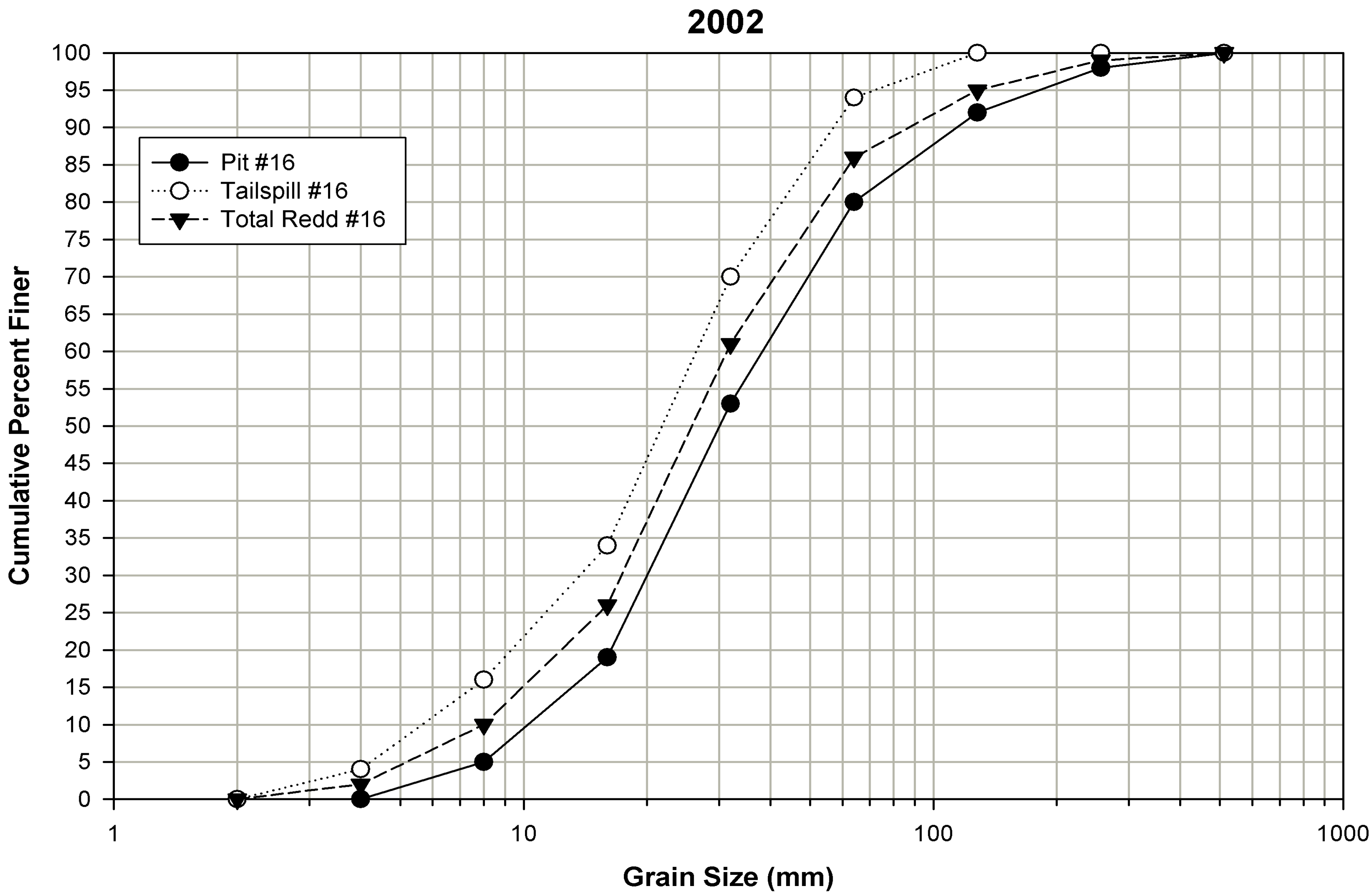

FIGURE A16.—Cumulative particle size distribution for Pebble Count No. 16 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2002.

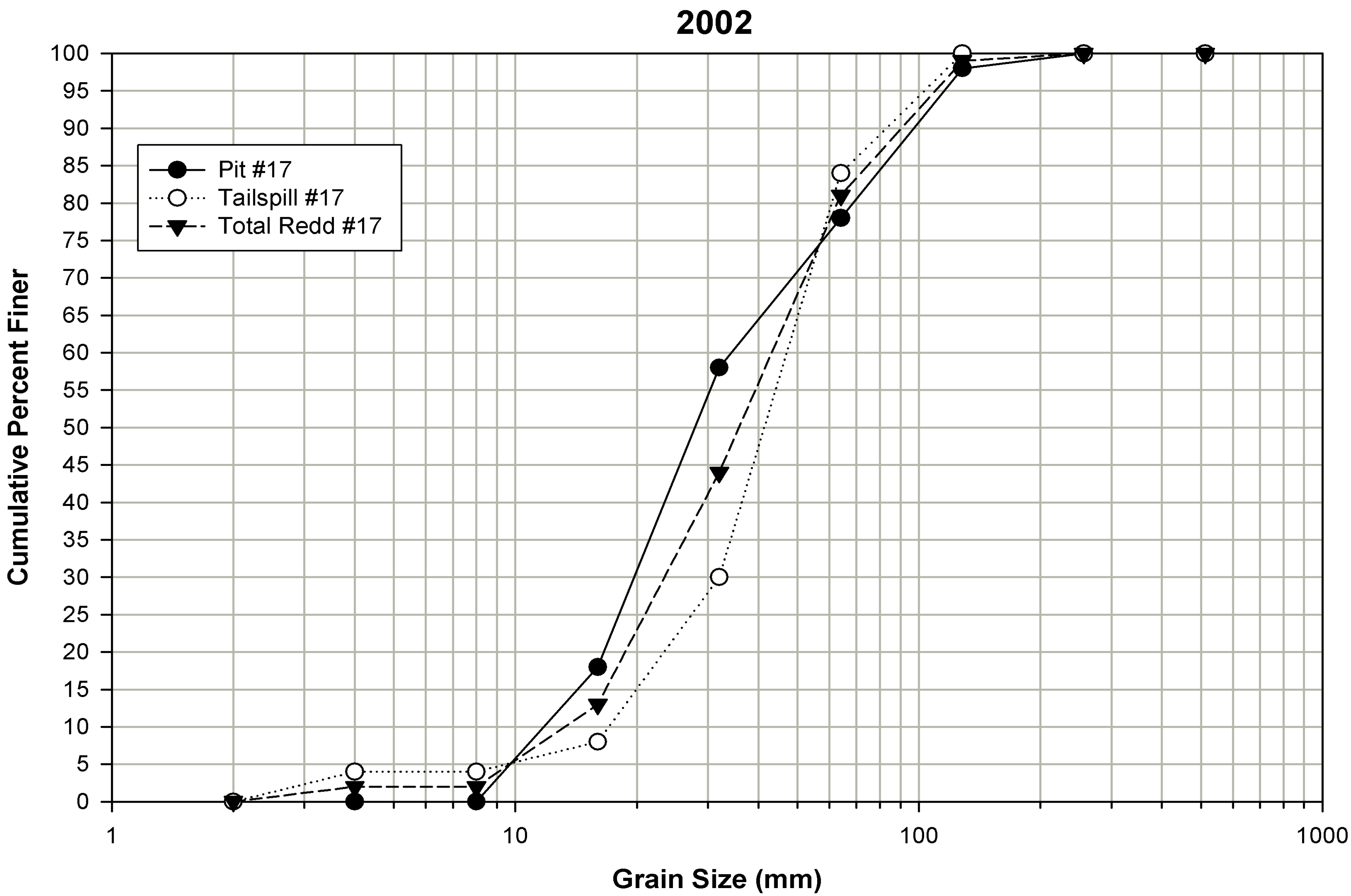

FIGURE A17.—Cumulative particle size distribution for Pebble Count No. 17 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2002.

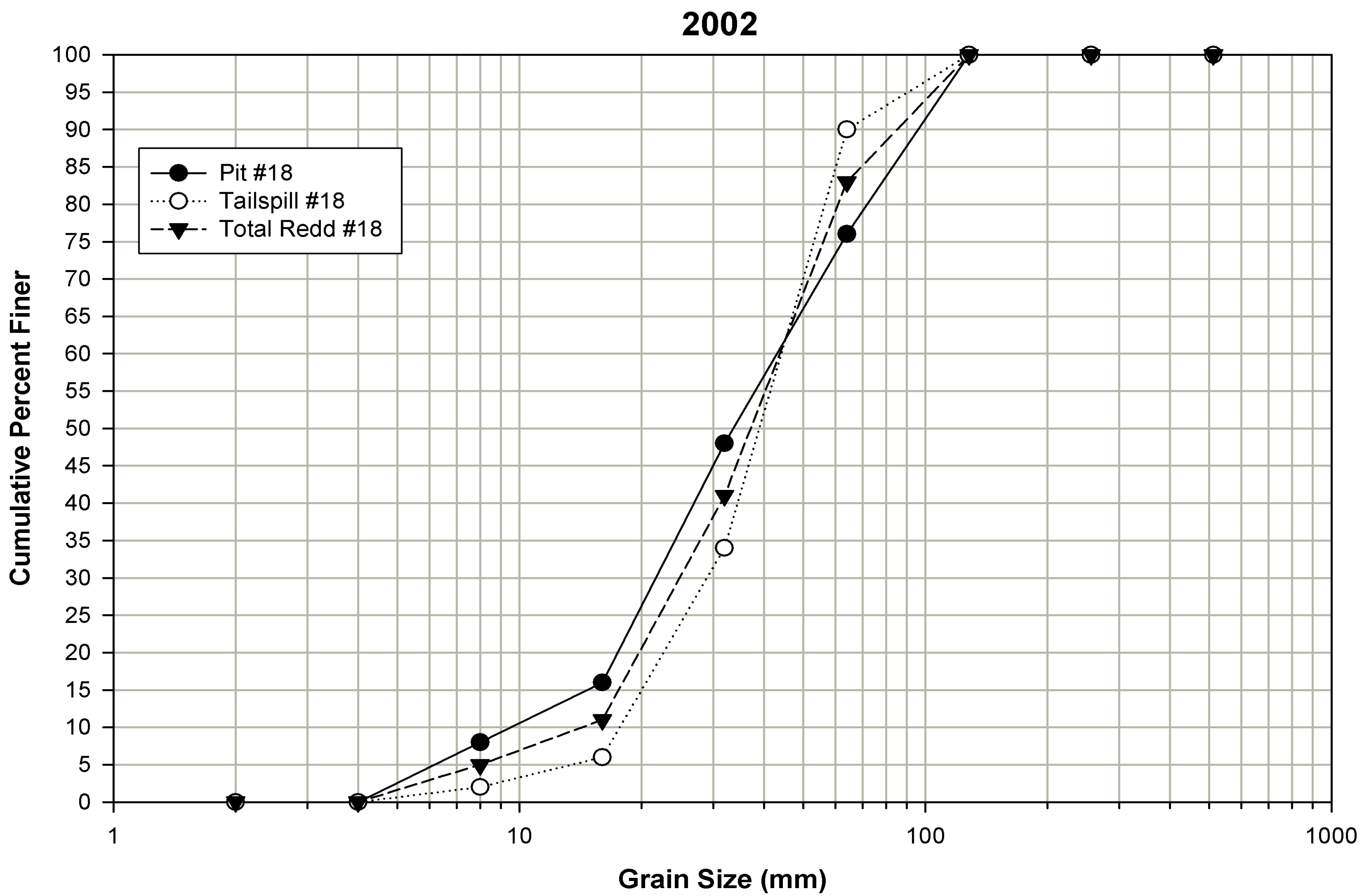

FIGURE A18.—Cumulative particle size distribution for Pebble Count No. 18 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2002.

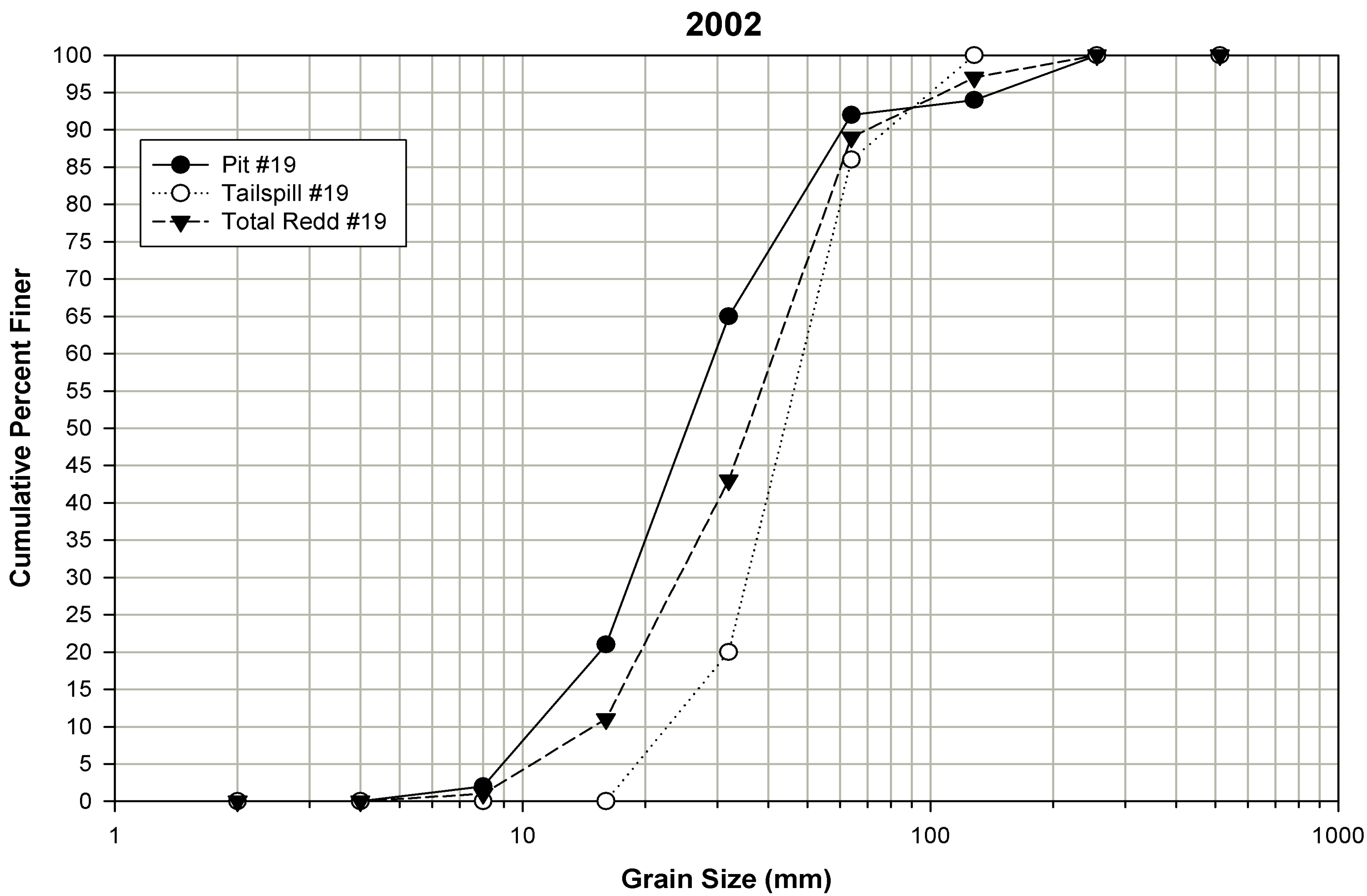

FIGURE A19.—Cumulative particle size distribution for Pebble Count No. 19 (Tables A6 and A7) performed in a spring Chinook redd on Clear Creek in 2002.