

**MERRIMACK STATION
THERMAL DISCHARGE EFFECTS
ON DOWNSTREAM SALMON SMOLT MIGRATION**

DECEMBER 2006

**MERRIMACK STATION
THERMAL EFFLUENT EFFECTS
ON DOWNSTREAM SALMON SMOLT MIGRATION**

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1.0 INTRODUCTION

Public Service Company of New Hampshire's (PSNH's) Merrimack Station in Bow, New Hampshire (the Station) is seeking a renewal of its existing variance under Section 316(a) of the Clean Water Act (CWA), 33 U.S.C. §1326(a), as part of its renewal of its existing National Pollutant Discharge Elimination System (NPDES) permit (NPDES Permit NH0001465). The United States Environmental Protection Agency (EPA), in collaboration with the New Hampshire Fish and Game Department (NHFG) and the United States Fish and Wildlife Service (USFW), has indicated its intent to propose new thermal criteria that are more stringent than the §316(a) variance-based alternative thermal criteria presently contained in the Station's NPDES permit. According to EPA, these thermal discharge criteria are primarily intended to address its and USFW and NHFG's concerns about the potential impacts of the Station's discharge on migratory species – in particular, Atlantic salmon, American shad and river herring (alewife and blueback herring) – during spring and fall migration periods.

Normandeau Associates, Inc. (Normandeau) assessed the effects of Merrimack Station's thermal discharge on the downstream migration of Atlantic salmon smolts using radio telemetry during the springs of 2003 and 2005. The purpose of the two-year study was to evaluate the downstream passage available to Atlantic salmon smolts migrating past the Station's cooling canal discharge. The study results demonstrate that the Station's thermal discharge neither delayed nor created a barrier to the downstream migration of Atlantic salmon smolts. The salmon smolts released as part of this study behaved as is typical for the species, moving downstream during the typical New England smolt migration period of late April through early June (Whalen et al. 1999). Their downstream migrations took place during the nocturnal hours, as has been observed in other temperate populations of Atlantic salmon (Hesthagen and Garnas 1986; McCormick et al. 1998; Moore et al. 1998); and as with smolts in other studies (Hesthagen and Garnas 1986; Davidsen et al. 2005), the released smolts traveled in the deeper, high flow portion of the channel, with the majority avoiding the shallow, low-flow, western section of the channel as they moved past Merrimack Station.

2.0 METHODS

Study methods were the same in both 2003 and 2005, except as described below. Age 1+ Atlantic salmon smolts were obtained from the USFWS Green Lake Fish Hatchery in Ellsworth, Maine and were kept in a holding tank using a flow-through water system of Merrimack River water. These smolts ranged in total length from 193 mm to 240 mm in 2003 and from 170 mm to 229 mm in 2005. Fish were radio-tagged by removing them from the holding tank using a small seine, and placing them in a bath containing a 5% solution of buffered MS-222 (tricaine methanesulfonate). After each fish was sufficiently anesthetized, a glycerin-coated radio tag was gently inserted in its stomach via the esophagus while the fish was submerged. The fish was then removed from the bath, quickly measured to the nearest millimeter, and placed in a recovery tank for at least 24 hours prior to release to document any handling mortality or regurgitated radio tag transmitters.

A total of 49 radio-tagged Atlantic salmon smolts were released during five sampling events that took place between May 21 and June 5, 2003. Similarly, a total of 60 radio-tagged Atlantic salmon smolts were released during five sampling events that took place between May 11 and May 26, 2005. For each sampling event, fish were transported by truck, then boat, in an aerated fish cooler filled with Merrimack River water, to the release point (Release Site). The Release Site was located two miles upstream of the monitoring station located at the Discharge Station (Discharge Station) (Figure 2-1). The radio-tagged smolts were released at the mid-channel point of the river, which is the deepest portion of the Release Site area. Atlantic salmon smolts have been shown to select the mid-channel when migrating downstream (Hesthagen and Garnas 1986; Davidsen et al. 2005). The ten releases during the two-year study were conducted during the evening hours (1800 to 2030). Nocturnal migration of downstream migrating smolts has regularly been observed in the temperate areas of the Atlantic salmon range (Hesthagen and Garnas 1986; McCormick et al. 1998; Moore et al. 1998).

Following release, the downstream movement of the salmon smolts was monitored by two stationary telemetry monitoring (STM) stations. Radio telemetry has routinely been utilized in studies evaluating the downstream movement of Atlantic salmon smolts (Stier and Kynard 1986; Scruton et al. 2003). One STM station was located at the Discharge Station discharge, and the other STM station was installed 0.5 miles downstream of the Discharge Station, at Monitoring Station S4 (Figure 2-1). Each STM station was composed of a Lotek Engineering SRX 400 W32 telemetry receiver/data logger connected to a directional Yagi antenna, and was fully operational for the duration of the telemetry study.

In addition to the stationary telemetry receivers, salmon smolts were tracked manually as they migrated past the Discharge Station. This was accomplished by boat using a Lotek Engineering SRX 400 W32 telemetry receiver connected to a directional Yagi antenna. During this process, the tracker identified the tag number and location of the tag by orienting the directional antenna towards the strongest signal. Radio tag numbers transmitted from the tag were able to be identified up to 100-200 feet (depending on fish depth) from the boat. As the tagged smolt passed the Discharge Station, the tracker identified the approximate location of the tag relative to five marker buoys (A, B, C, D, E) that were located along a transect running east-west across the river channel just downstream of the Discharge Station (Figure 3-3). These marker buoys were oriented with A being furthest west and E being furthest east. During 2003, one manual tracking boat was used. That was increased to two manual tracking boats during the 2005 season.

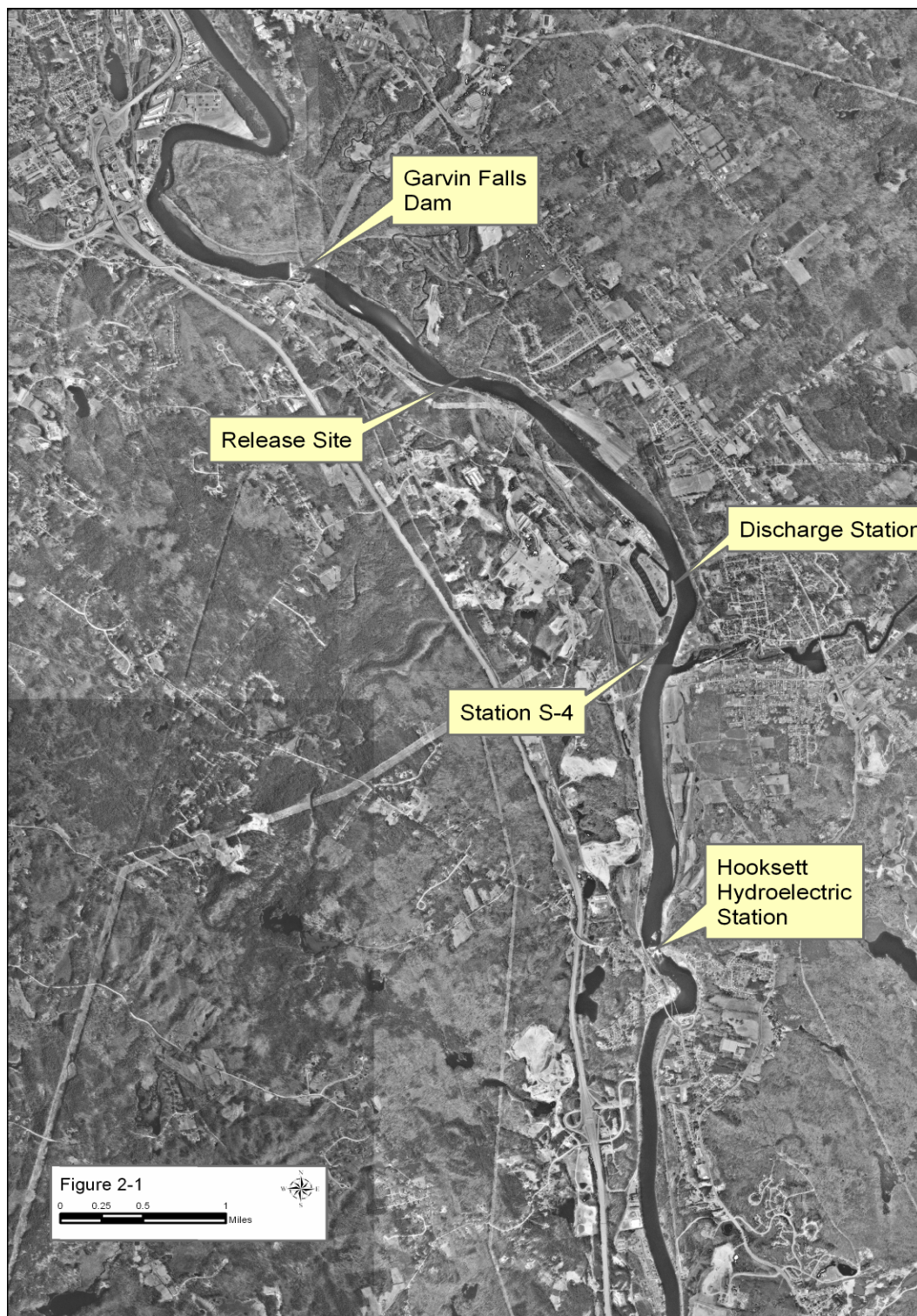


Figure 2-1. Merrimack River fish release and monitoring stations for the Merrimack Station downstream Atlantic salmon smolt migration study, Spring 2003 and Spring 2005.

Merrimack Station Salmon Smolt Migration

Water quality measurements were recorded for each release by water quality stations established at each of the five marker buoys used for the manual tracking effort. During 2003, temperature and dissolved oxygen (DO) were recorded at the surface, mid-depth (as determined by fathometer reading), and bottom. During 2005, temperature and DO were recorded in one-foot intervals for the entire water column. Temperature and DO were also recorded at the Release Site in both 2003 and 2005. The measured Release Site temperature for each release was used as the “ambient” water temperature for that release, as the river water in this area was upstream of Merrimack Station and any potential influences.

3.0 RESULTS

During the two years of this study, a total of 109 Atlantic salmon smolts were radio-tagged and released at the Release Site. Of these, only three were unable to be tracked by the stationary and manual radio-telemetry efforts. One radio tag transmitter (#44 from Release 5 in 2003) remained stationary at the Release Site for the duration of the battery life. This transmitter was most likely regurgitated by the smolt upon its release into the system. Although regurgitation rates of wild salmon are difficult to assess, a study with adult Atlantic salmon estimated the rate at 14.8% (+/- 1.2%) (Smith et al. 1998). In addition, two transmitters (#72 from Release 2 in 2005 and #107 from Release 5 in 2005) went undetected by both the stationary receivers and manual efforts to locate the fish. The most likely explanation is transmitter failure, as searches upstream and downstream of the study area on the nights of the releases did not locate these fish or their transmitters. Of the 106 smolts carrying functioning transmitters that moved downstream and past Merrimack Station, all were detected by the stationary telemetry receivers, the manual tracking receivers or both. Eleven transmitters that went undetected by the manual tracking effort were recorded by the stationary receivers. Nine of these transmitted fish moved past the Station after the field crews had concluded sampling for the night. One transmitter went undetected by both stationary telemetry receivers but was detected by the manual tracking receiver onboard an NAI boat.

Table 3-1 provides river water temperature (°C) and DO (mg/l) at the five water quality sampling stations set up across the river channel, the migration route of each fish, and the travel times from the Release Site to the Discharge Station and from the Discharge Station to Station S4 for each fish tracked. Table 3-2 provides the equivalent data for 2005. Figures 3-1 and 3-2 present thermal cross-sections of the river along the water quality transect with values based on the difference between the ambient temperature and the temperatures measured at each water quality station (A, B, C, D, E). The temperature values in these figures are color-coded to graphically show water temperatures within 0.5°C of ambient water temperature (as measured at the Release Site)(black), between 0.5 - 1.0°C above ambient (blue), and greater than 1.0 °C (green) above ambient, to indicate the potential area available to migrating salmon smolts for downstream passage.

Release 1 during 2003 occurred on May 21. On this release date, there was a 41% probability that the measured average daily temperature (as measured at Monitoring Station N10) would have exceeded the observed ambient temperature and an 83% probability that calculated river flow would have exceeded observed river flow. Ambient conditions during this release could be classified as having above average temperature and low flow conditions for that date (Normandeau 2006). Ambient river water temperature (as measured at the Release Site) during this release was 15.8 °C. Water temperatures throughout the water column at Stations B, C, D, and E were within 0.1 °C of ambient river temperature (Table 3-1). Based on temperature measurements during the first release, 87% of the river provided a zone of passage for the salmon that was within 0.1 °C of ambient river water (Figure 3-1). Only water temperatures at Station A surface (Δ 4.3 °C) and mid-depth (Δ 2.1 °C) were greater than one degree above ambient. One unit at Merrimack Station was in operation during this release.

During the first release, a total of ten radio-tagged Atlantic salmon smolts were released. Smolts from Release 1 took an average of 123 minutes (range 97 – 166) to travel from the Release Site downstream to the Discharge Station and an average of 39 minutes (range 29 – 66) to travel from the Discharge Station to Station S4 (Table 3-1). The majority of smolts (70%) migrated downstream in

Merrimack Station Salmon Smolt Migration

Table 3-1. River temperature profiles at Water Quality Stations A through E, and radio-tagged Atlantic salmon smolt migration routes and travel times past the Discharge Station during Spring 2003.

Release 1- 1 Unit operating

Date: 5/21/2003

Release Time: 2009

Ambient Temp: 15.8°C

| | | A | B | C | D | E |
|----------------|-----------|----------|----------|----------|----------|----------|
| SURFACE | TEMP (°C) | 20.1 | 15.8 | 15.9 | 15.8 | 15.8 |
| | DO (mg/l) | 8.1 | 9.0 | 9.1 | 9.5 | 9.1 |
| MIDDLE | TEMP (°C) | 17.9 | 15.8 | 15.8 | 15.8 | 15.8 |
| | DO (mg/l) | 8.4 | 8.8 | 9.1 | 8.9 | 9.1 |
| BOTTOM | TEMP (°C) | 15.9 | 15.8 | 15.7 | 15.8 | 15.8 |
| | DO (mg/l) | 9.1 | 8.8 | 9.0 | 8.9 | 9.1 |
| MEAN | TEMP (°C) | 18.0 | 15.8 | 15.8 | 15.8 | 15.8 |
| MEAN | DO (mg/l) | 8.5 | 8.9 | 9.1 | 9.1 | 9.1 |

| TAG NO. | ARRIVAL TIME AT DISCHARGE STATION | MIGRATION ROUTE | TRAVEL TIME RELEASE SITE TO DISCHARGE STATION (minutes) | TRAVEL TIME DISCHARGE STATION TO S4 (minutes) |
|----------------------|--|----------------------------|--|--|
| 18 | 2147 | WEST BANK | 98 | 66 |
| 17 | 2150 | B | 101 | 40 |
| 23 | 2207 | D/E | 118 | 32 |
| 13 | 2207 | C/D | 118 | 33 |
| 21 | 2208 | C/D | 119 | 38 |
| 22 | 2208 | C/D | 119 | 40 |
| 19 | 2146 | C/D | 97 | 31 |
| 14 | 2230 | C/D | 141 | 46 |
| 20 | 2241 | A/WEST BANK | 152 | 33 |
| 16 | 2255 | D/E | 166 | 29 |
| Mean (min) | | | 123 | 39 |
| Avg. Velocity | | | 1.0 mph | 0.8 mph |

(continued)

Merrimack Station Salmon Smolt Migration

Table 3-1 (continued)

Release 2- 1 Unit operating

Date: 5/23/2003

Release Time: 2000

Ambient Temp: 15.1°C

| | | A | B | C | D | E |
|----------------|-----------|----------|----------|----------|----------|----------|
| SURFACE | TEMP (°C) | 17.7 | 17.9 | 15.2 | 15.2 | 15.1 |
| | DO (mg/l) | 8.5 | 7.7 | 9.2 | 8.9 | 8.6 |
| MIDDLE | TEMP (°C) | 17.0 | 17.6 | 15.2 | 15.2 | 15.1 |
| | DO (mg/l) | 8.8 | 8.1 | 8.9 | 8.6 | 8.9 |
| BOTTOM | TEMP (°C) | 15.3 | 16.5 | 15.2 | 15.2 | 15.1 |
| | DO (mg/l) | 9.3 | 8.3 | 9.1 | 9.2 | 9.1 |
| MEAN | TEMP (°C) | 16.7 | 17.3 | 15.2 | 15.2 | 15.1 |
| MEAN | DO (mg/l) | 8.8 | 8.0 | 9.1 | 8.9 | 8.8 |

| TAG NO. | ARRIVAL TIME AT DISCHARGE STATION | MIGRATION ROUTE | TRAVEL TIME RELEASE SITE TO DISCHARGE STATION (minutes) | TRAVEL TIME DISCHARGE STATION TO S4 (minutes) |
|----------------------|--|----------------------------|--|--|
| 6 | 2156 | D/E | 75 | 35 |
| 3 | 2129 | D/E | 89 | 40 |
| 11 | 2131 | D/E | 91 | 105 |
| 2 | 2129 | D/E | 89 | 38 |
| 4 | 2132 | C/D | 92 | 363 |
| 5 | 2140 | B/C | 100 | 110 |
| 7 | 2225 | D/E | 145 | 26 |
| 24 | 2227 | D/E | 147 | 29 |
| 1 | 24 May – 0027 | C | 267 | 27 |
| 8 | 24 May – 0143 | C | 343 | 30 |
| Mean (min) | | | 144 | 80 |
| Avg. Velocity | | | 1.1 mph | 0.7 mph |

(Continued)

Merrimack Station Salmon Smolt Migration

Table 3-1 (continued)

Release 3- 2 Units operating

Date: 5/25/2003

Release Time: 1950

Ambient Temp: 14.3 °C

| | | A | B | C | D | E |
|----------------|-----------|----------|----------|----------|----------|----------|
| SURFACE | TEMP (°C) | 18.8 | 21.2 | 21.6 | 14.4 | 14.3 |
| | DO (mg/l) | 8.5 | 7.5 | 7.9 | 9.6 | 9.6 |
| MIDDLE | TEMP (°C) | 18.5 | 15.0 | 14.6 | 14.4 | 14.3 |
| | DO (mg/l) | 7.8 | 9.4 | 9.1 | 9.2 | 9.3 |
| BOTTOM | TEMP (°C) | 17.6 | 14.8 | 14.4 | 14.4 | 14.3 |
| | DO (mg/l) | 8.4 | 9.1 | 9.1 | 9.4 | 9.4 |
| MEAN | TEMP (°C) | 18.3 | 17.0 | 16.9 | 14.4 | 14.3 |
| MEAN | DO (mg/l) | 8.3 | 8.7 | 8.7 | 9.4 | 9.5 |

| TAG NO. | ARRIVAL TIME AT DISCHARGE STATION | MIGRATION ROUTE | TRAVEL TIME RELEASE SITE TO DISCHARGE STATION (minutes) | TRAVEL TIME DISCHARGE STATION TO S4 (minutes) |
|----------------------|--|----------------------------|--|--|
| 25 | 2100 | E | 70 | 25 |
| 33 | 2114 | D/E | 84 | 26 |
| 9 | 2124 | E | 94 | 36 |
| 31 | 2129 | D/E | 99 | 43 |
| 28 | 2134 | C/D | 104 | 35 |
| 27 | 2133 | C/D | 103 | 37 |
| 30 | 2137 | D/E | 107 | 35 |
| 29 | 2138 | C/D | 108 | 75 |
| 26 | 2306 | D/E | 196 | 37 |
| 32 | 26 May - 2026 | D/E | 1476 | 31 |
| Mean (min) | | | 244 | 38 |
| Avg. Velocity | | | 1.1 mph | 0.9 mph |

(continued)

Merrimack Station Salmon Smolt Migration

Table 3-1 (continued)

Release 4- 2 Units operating

Date: 6/3/2003

Release Time: 2000

Ambient Temp: 16.2°C

| | | A | B | C | D | E |
|---------|-----------|----------|----------|----------|----------|----------|
| SURFACE | TEMP (°C) | 20.3 | 23.2 | 22.1 | 16.3 | 16.2 |
| | DO (mg/l) | 8.7 | 8.4 | 8.8 | 9.6 | 9.6 |
| MIDDLE | TEMP (°C) | 19.1 | 22.2 | 16.5 | 16.3 | 16.2 |
| | DO (mg/l) | 8.9 | 8.2 | 9.6 | 9.6 | 9.6 |
| BOTTOM | TEMP (°C) | 18.6 | 18.8 | 16.3 | 16.3 | 16.2 |
| | DO (mg/l) | 8.5 | 9.1 | 9.7 | 9.4 | 9.6 |
| MEAN | TEMP (°C) | 19.3 | 21.4 | 18.3 | 16.3 | 16.2 |
| MEAN | DO (mg/l) | 8.7 | 8.6 | 9.4 | 9.5 | 9.6 |

| TAG NO. | ARRIVAL TIME AT DISCHARGE STATION | MIGRATION ROUTE | TRAVEL TIME RELEASE SITE TO DISCHARGE STATION (minutes) | TRAVEL TIME DISCHARGE STATION TO S4 (minutes) |
|----------------------|--|----------------------------|--|--|
| 39 | 2058 | E | 58 | 21 |
| 40 | 2110 | D/E | 70 | 30 |
| 42 | 2106 | E/BANK | 66 | 25 |
| 15 | 2107 | D/E | 67 | * |
| 38 | 2112 | D/E | 72 | 24 |
| 41 | 2117 | C/D | 77 | 31 |
| 36 | 2132 | E/BANK | 92 | 25 |
| 35 | 2130 | C/D | 90 | 35 |
| 34 | 2130 | C/D | 90 | 26 |
| 37 | 2254 | C/D | 174 | 91 |
| Mean (min) | | | 86 | 34 |
| Avg. Velocity | | | 1.5 mph | 1.0 mph |

* No travel time discharge station to S4 due to tag 15 undetected by stationary receiver at S4

(continued)

Merrimack Station Salmon Smolt Migration

Table 3-1 (continued)

Release 5- 2 Units operating

Date: 6/5/2003

Release Time: 1955

Ambient Temp: 16.2°C

| | | A | B | C | D | E |
|----------------|-----------|----------|----------|----------|----------|----------|
| SURFACE | TEMP (°C) | 20.3 | 23.7 | 24.8 | 20.1 | 16.4 |
| | DO (mg/l) | 7.6 | 7.9 | 7.3 | 7.8 | 9.4 |
| MIDDLE | TEMP (°C) | 19.8 | 23.4 | 18.9 | 16.5 | 16.3 |
| | DO (mg/l) | 8.1 | 8.0 | 8.3 | 8.6 | 9.4 |
| BOTTOM | TEMP (°C) | 19.4 | 17.6 | 16.4 | 16.3 | 16.2 |
| | DO (mg/l) | 8.5 | 8.9 | 9.2 | 9.1 | 9.3 |
| MEAN | TEMP (°C) | 19.8 | 21.6 | 20.0 | 17.6 | 16.3 |
| MEAN | DO (mg/l) | 8.0 | 8.3 | 8.3 | 8.5 | 9.4 |

| TAG NO. | ARRIVAL TIME AT DISCHARGE STATION | MIGRATION ROUTE | TRAVEL TIME RELEASE SITE TO DISCHARGE STATION (minutes) | TRAVEL TIME DISCHARGE STATION TO S4 (minutes) |
|----------------------|--|----------------------------|--|--|
| 50 | 2107 | C/D | 67 | 33 |
| 46 | 2108 | D/E | 68 | 26 |
| 48 | 2110 | E | 70 | 223 |
| 45 | 2118 | D/E | 78 | 32 |
| 43 | 2123 | C/D | 83 | 53 |
| 12 | 2123 | D/E | 83 | 31 |
| 10 | 2137 | C/D | 97 | 65 |
| 47 | 2116 | D/E | 136 | 165 |
| 44 | * | ----- | ----- | ----- |
| Mean (min) | | | 85 | 79 |
| Avg. Velocity | | | 1.5 mph | 0.7 mph |

* Tag 44 remained stationary at Release Site

Merrimack Station Salmon Smolt Migration

Table 3-2. River temperature profiles at Water Quality Stations A through E, and radio-tagged Atlantic salmon smolt migration routes and travel times past the Discharge Station during Spring 2005.

Release 1- 1 Unit operating

Date: 5/11/2005

Release Time: 2010

Ambient Temp: 13.7 °C

| Depth (ft) | | Condition | A | B | C | D | E |
|------------|--|-----------|------|------|------|------|------|
| 1 | | TEMP (°C) | 16.7 | 13.5 | 13.5 | 13.7 | 13.9 |
| | | DO (mg/l) | 8.8 | 9.5 | 9.6 | 9.5 | 9.3 |
| 2 | | TEMP (°C) | 15.8 | 13.5 | 13.5 | 13.6 | 13.9 |
| | | DO (mg/l) | 8.9 | 9.4 | 9.4 | 9.6 | 9.7 |
| 3 | | TEMP (°C) | 15.5 | 13.5 | 13.5 | 13.7 | 13.8 |
| | | DO (mg/l) | 9.2 | 9.3 | 9.3 | 9.3 | 9.5 |
| 4 | | TEMP (°C) | 14.5 | 13.5 | 13.5 | 13.6 | 13.8 |
| | | DO (mg/l) | 9.2 | 9.3 | 9.3 | 9.4 | 9.5 |
| 5 | | TEMP (°C) | 14.3 | 13.5 | 13.5 | 13.6 | 13.8 |
| | | DO (mg/l) | 9.3 | 9.3 | 9.2 | 9.4 | 9.4 |
| 6 | | TEMP (°C) | 14.4 | 13.5 | 13.5 | 13.6 | 13.8 |
| | | DO (mg/l) | 9.2 | 9.4 | 9.3 | 9.3 | 9.4 |
| 7 | | TEMP (°C) | 14.3 | 13.5 | 13.5 | 13.6 | 13.8 |
| | | DO (mg/l) | 9.1 | 9.4 | 9.3 | 9.3 | 9.2 |
| 8 | | TEMP (°C) | 14.3 | 13.5 | 13.5 | 13.6 | 13.8 |
| | | DO (mg/l) | 9.1 | 9.5 | 9.3 | 9.2 | 9.1 |
| 9 | | TEMP (°C) | | 13.5 | 13.5 | 13.6 | 13.8 |
| | | DO (mg/l) | | 9.4 | 9.5 | 9.3 | 9.4 |
| 10 | | TEMP (°C) | | | 13.5 | 13.6 | 13.8 |
| | | DO (mg/l) | | | 9.5 | 9.4 | 9.5 |
| 11 | | TEMP (°C) | | | | 13.6 | 13.8 |
| | | DO (mg/l) | | | | 9.5 | 9.5 |
| 12 | | TEMP (°C) | | | | | 13.7 |
| | | DO (mg/l) | | | | | 9.4 |
| MEAN | | TEMP (°C) | 15.0 | 13.5 | 13.5 | 13.6 | 13.8 |
| | | DO (mg/l) | 9.1 | 9.4 | 9.4 | 9.4 | 9.4 |

| TAG NO. | ARRIVAL TIME AT DISCHARGE STATION | MIGRATION ROUTE | TRAVEL TIME RELEASE SITE TO DISCHARGE STATION (minutes) | TRAVEL TIME DISCHARGE STATION TO S4 (minutes) |
|----------------------|--------------------------------------|--------------------|---|---|
| 78 | 2114 | C/D | 64 | 18 |
| 81 | 12 May - 1959 | E | 1429 | 44 |
| 86 | 2115 | C/D | 65 | 18 |
| 76 | 2126 | C | 76 | 16 |
| 71 | 2125 | D/E | 75 | 20 |
| 66 | 2130 | C/D | 80 | 62 |
| 63 | 2125 | D/E | 75 | 17 |
| 62 | 2116 | C/D | 66 | 18 |
| 61 | 2116 | C/D | 66 | 17 |
| 91* | 12 May - 0033 | E | 263 | 3086 |
| Mean (min) | | | 226 | 332 |
| Avg. Velocity | | | 1.4 mph | 1.3 mph |

(continued)

* Fish 91 remained in area between Discharge Station and S4 before resuming normal downstream pattern and being confirmed as passing the downstream hydroelectric project.

Merrimack Station Salmon Smolt Migration

Table 3.2 (continued)

Release 2- 1 Unit operating

Date: 5/17/2005

Release Time: 2015

Ambient Temp: 13.4 °C

| Depth (ft) | | Condition | A | B | C | D | E |
|------------|--|-----------|------|------|------|------|------|
| 1 | | TEMP (°C) | 16.0 | 13.2 | 13.2 | 13.2 | 13.6 |
| | | DO (mg/l) | 9.3 | 10.1 | 10.3 | 10.2 | 9.9 |
| 2 | | TEMP (°C) | 16.0 | 13.2 | 13.2 | 13.2 | 13.6 |
| | | DO (mg/l) | 9.2 | 10.1 | 10.0 | 10.2 | 9.6 |
| 3 | | TEMP (°C) | 15.0 | 13.2 | 13.2 | 13.2 | 13.5 |
| | | DO (mg/l) | 9.3 | 10.1 | 9.9 | 10.0 | 9.7 |
| 4 | | TEMP (°C) | 14.1 | 13.2 | 13.2 | 13.2 | 13.4 |
| | | DO (mg/l) | 9.1 | 10.0 | 9.8 | 9.7 | 9.1 |
| 5 | | TEMP (°C) | 14.1 | 13.2 | 13.2 | 13.2 | 13.4 |
| | | DO (mg/l) | 9.6 | 9.9 | 9.9 | 9.4 | 9.3 |
| 6 | | TEMP (°C) | 14.1 | 13.2 | 13.2 | 13.2 | 13.4 |
| | | DO (mg/l) | 9.7 | 9.8 | 9.9 | 9.6 | 9.4 |
| 7 | | TEMP (°C) | | 13.2 | 13.2 | 13.2 | 13.4 |
| | | DO (mg/l) | | 9.9 | 10.0 | 9.8 | 9.5 |
| 8 | | TEMP (°C) | | 13.2 | 13.2 | 13.2 | 13.4 |
| | | DO (mg/l) | | 9.9 | 10.0 | 10.1 | 9.9 |
| 9 | | TEMP (°C) | | | | 13.2 | 13.4 |
| | | DO (mg/l) | | | | 10.1 | 10.0 |
| 10 | | TEMP (°C) | | | | 13.2 | 13.4 |
| | | DO (mg/l) | | | | 10.1 | 10.0 |
| MEAN | | TEMP (°C) | 14.9 | 13.2 | 13.2 | 13.2 | 13.5 |
| | | DO (mg/l) | 9.4 | 10.0 | 10.0 | 9.9 | 9.6 |

| TAG NO. | ARRIVAL TIME AT DISCHARGE STATION | MIGRATION ROUTE | TRAVEL TIME RELEASE SITE TO DISCHARGE STATION (minutes) | TRAVEL TIME DISCHARGE STATION TO S4 (minutes) |
|----------------------|---|--------------------|--|--|
| 82 | 2142 | D/E | 87 | 19 |
| 83 | 2218 | D/E | 117 | 29 |
| 68 | 2145 | D | 90 | 22 |
| 64 | 2219 | D | 118 | 29 |
| 72 | undetected | | | |
| 87 | 2152 | D/E | 97 | 19 |
| 92 | 2153 | D/E | 98 | 18 |
| 65 | 2219 | D/E | 118 | 29 |
| 73 | 2218 | D | 117 | 28 |
| 84 | 0144 | C/D | 329 | * |
| Mean (min) | | | 130 | 24 |
| Avg. Velocity | | | 1.1 mph | 1.3 mph |

(continued)

Merrimack Station Salmon Smolt Migration

Table 3-2 (continued)

Release 3- 1 Unit operating

Date: 5/19/2005

Release Time: 2032

Ambient Temp: 13.1 °C

| Depth (ft) | | Condition | A | B | C | D | E |
|------------|--|-----------|------|------|------|------|------|
| 1 | | TEMP (°C) | 17.5 | 13.3 | 13.0 | 13.0 | 13.0 |
| | | DO (mg/l) | 8.2 | 9.5 | 9.6 | 9.7 | 9.7 |
| 2 | | TEMP (°C) | 14.1 | 13.2 | 13.1 | 13.1 | 13.1 |
| | | DO (mg/l) | 9.3 | 9.6 | 9.6 | 9.6 | 9.6 |
| 3 | | TEMP (°C) | 13.9 | 13.1 | 13.1 | 13.1 | 13.1 |
| | | DO (mg/l) | 9.0 | 9.6 | 9.5 | 9.6 | 9.5 |
| 4 | | TEMP (°C) | 14.1 | 13.1 | 13.1 | 13.1 | 13.1 |
| | | DO (mg/l) | 9.2 | 9.2 | 9.4 | 9.6 | 9.5 |
| 5 | | TEMP (°C) | 14.2 | 13.1 | 13.1 | 13.1 | 13.1 |
| | | DO (mg/l) | 9.1 | 9.3 | 9.3 | 9.4 | 9.5 |
| 6 | | TEMP (°C) | 14.2 | 13.1 | 13.1 | 13.1 | 13.1 |
| | | DO (mg/l) | 9.1 | 9.4 | 9.3 | 9.3 | 9.5 |
| 7 | | TEMP (°C) | 14.1 | 13.1 | 13.1 | 13.1 | 13.1 |
| | | DO (mg/l) | 9.0 | 9.3 | 9.3 | 9.4 | 9.3 |
| 8 | | TEMP (°C) | 14.0 | 13.1 | 13.1 | 13.1 | 13.1 |
| | | DO (mg/l) | 9.2 | 9.4 | 9.3 | 9.4 | 9.4 |
| 9 | | TEMP (°C) | | | | 13.1 | 13.1 |
| | | DO (mg/l) | | | | 9.4 | 9.4 |
| 10 | | TEMP (°C) | | | | 13.1 | 13.1 |
| | | DO (mg/l) | | | | 9.3 | 9.4 |
| 11 | | TEMP (°C) | | | | | 13.1 |
| | | DO (mg/l) | | | | | 9.4 |
| 12 | | TEMP (°C) | | | | | 13.1 |
| | | DO (mg/l) | | | | | 9.4 |
| MEAN | | TEMP (°C) | 14.5 | 13.1 | 13.1 | 13.1 | 13.1 |
| | | DO (mg/l) | 9.0 | 9.4 | 9.4 | 9.5 | 9.5 |

| TAG NO. | ARRIVAL TIME AT DISCHARGE STATION | MIGRATION ROUTE | TRAVEL TIME RELEASE SITE TO DISCHARGE STATION (minutes) | TRAVEL TIME DISCHARGE STATION TO S4 (minutes) |
|---------------|---|--------------------|--|--|
| 74 | 2339 | E | 190 | 33 |
| 70 | 2204 | E | 92 | 25 |
| 67 | 0124 | D/E | 292 | 26 |
| 94 | 2335 | E | 186 | 22 |
| 79 | 0412 | B/C | 460 | 43 |
| 77 | 0133 | E | 301 | 33 |
| 89 | 2206 | C | 94 | 20 |
| 88 | 2213 | D | 102 | 27 |
| 93 | 2201 | E | 89 | 24 |
| 69 | 0050 | D | 258 | 25 |
| Mean (min) | | | 206 | 28 |
| Avg. Velocity | | | 0.8 mph | 1.1 mph |

(continued)

Merrimack Station Salmon Smolt Migration

Table 3-2 (continued)

Release 4- 1 Unit operating

Date: 5/24/2005

Release Time: 1835

Ambient Temp: 11.7 °C

| Depth (ft) | | Condition | A | B | C | D | E |
|------------|--|-----------|------|------|------|------|-------|
| 1 | | TEMP (°C) | 13.7 | 11.7 | 11.6 | 11.6 | 11.6 |
| | | DO (mg/l) | 9.6 | 10.1 | 10.2 | 10.2 | 10.4 |
| 2 | | TEMP (°C) | 13.6 | 11.7 | 11.6 | 11.6 | 11.6 |
| | | DO (mg/l) | 9.3 | 9.9 | 10.0 | 10.0 | 10.2 |
| 3 | | TEMP (°C) | 12.6 | 11.7 | 11.6 | 11.6 | 11.6 |
| | | DO (mg/l) | 9.3 | 10.0 | 9.9 | 10.0 | 10.0 |
| 4 | | TEMP (°C) | 12.4 | 11.7 | 11.7 | 11.6 | 11.6 |
| | | DO (mg/l) | 9.8 | 10.1 | 9.9 | 9.9 | 10.1 |
| 5 | | TEMP (°C) | 12.4 | 11.7 | 11.6 | 11.7 | 11.6 |
| | | DO (mg/l) | 9.9 | 10.1 | 9.8 | 10.0 | 10.1 |
| 6 | | TEMP (°C) | 12.1 | 11.7 | 11.6 | 11.6 | 11.6 |
| | | DO (mg/l) | 9.9 | 10.2 | 9.8 | 10.1 | 10.1 |
| 7 | | TEMP (°C) | 12.0 | 11.7 | 11.7 | 11.7 | 11.6 |
| | | DO (mg/l) | 10.1 | 10.2 | 9.8 | 10.1 | 10.14 |
| 8 | | TEMP (°C) | | 11.7 | 11.6 | 11.7 | 11.6 |
| | | DO (mg/l) | | 10.2 | 9.9 | 10.2 | 10.1 |
| 9 | | TEMP (°C) | | 11.7 | 11.7 | 11.7 | 11.6 |
| | | DO (mg/l) | | 10.2 | 10.0 | 10.2 | 10.1 |
| 10 | | TEMP (°C) | | | 11.7 | 11.7 | 11.6 |
| | | DO (mg/l) | | | 10.2 | 10.2 | 10.0 |
| 11 | | TEMP (°C) | | | | 11.7 | 11.5 |
| | | DO (mg/l) | | | | 10.2 | 10.1 |
| 12 | | TEMP (°C) | | | | | 11.5 |
| | | DO (mg/l) | | | | | 10.2 |
| MEAN | | TEMP (°C) | 12.7 | 11.7 | 11.6 | 11.7 | 11.6 |
| | | DO (mg/l) | 9.7 | 10.1 | 10.0 | 10.1 | 10.1 |

| TAG NO. | ARRIVAL TIME AT DISCHARGE STATION | MIGRATION ROUTE | TRAVEL TIME RELEASE SITE TO DISCHARGE STATION (minutes) | TRAVEL TIME DISCHARGE STATION TO S4 (minutes) |
|---------------|---|--------------------|--|--|
| 85 | 1950 | D/E | 75 | 18 |
| 97 | 1949 | D/E | 74 | 18 |
| 90 | 1950 | D/E | 75 | 17 |
| 80 | 1953 | D | 78 | 19 |
| 99 | 1958 | C/D | 83 | 16 |
| 98 | 1959 | D/E | 84 | 17 |
| 75 | 2003 | E | 88 | 22 |
| 96 | 2011 | D/E | 96 | 19 |
| 100 | 2014 | C/D | 99 | 18 |
| 95 | 2043 | D/E | 132 | 187 |
| Mean (min) | | | 88 | 35 |
| Avg. Velocity | | | 1.4 mph | 1.5 mph |

(continued)

Merrimack Station Salmon Smolt Migration

Table 3-2 (continued)

Release 5- 1 Unit operating

Date: 5/26/05

Release Time: 1812

Ambient Temp: 10.2 °C

| Depth (ft) | | Condition | A | B | C | D | E |
|------------|--|-----------|------|------|------|------|------|
| 1 | | TEMP (°C) | 10.2 | 10.1 | 10.1 | 10.0 | 10.0 |
| | | DO (mg/l) | 11.8 | 11.6 | 11.5 | 11.5 | 11.0 |
| 2 | | TEMP (°C) | 10.2 | 10.1 | 10.1 | 10.0 | 10.0 |
| | | DO (mg/l) | 11.7 | 11.5 | 11.5 | 11.5 | 10.9 |
| 3 | | TEMP (°C) | 10.2 | 10.1 | 10.1 | 10.0 | 10.0 |
| | | DO (mg/l) | 11.6 | 11.5 | 11.5 | 11.4 | 11.1 |
| 4 | | TEMP (°C) | 10.2 | 10.1 | 10.1 | 10.0 | 10.0 |
| | | DO (mg/l) | 11.5 | 11.4 | 11.4 | 11.4 | 11.0 |
| 5 | | TEMP (°C) | 10.1 | 10.1 | 10.1 | 10.0 | 10.0 |
| | | DO (mg/l) | 11.4 | 11.3 | 11.3 | 11.3 | 10.8 |
| 6 | | TEMP (°C) | 10.1 | 10.1 | 10.0 | 10.0 | 10.0 |
| | | DO (mg/l) | 11.2 | 11.3 | 11.2 | 11.4 | 10.8 |
| 7 | | TEMP (°C) | 10.1 | 10.1 | 10.0 | 10.0 | 10.0 |
| | | DO (mg/l) | 11.1 | 11.4 | 11.2 | 11.2 | 11.2 |
| 8 | | TEMP (°C) | 10.1 | 10.1 | 10.1 | 10.0 | 10.0 |
| | | DO (mg/l) | 11.2 | 11.4 | 11.3 | 11.2 | 11.1 |
| 9 | | TEMP (°C) | 10.1 | 10.1 | 10.1 | 10.0 | 10.0 |
| | | DO (mg/l) | 11.4 | 11.3 | 11.3 | 11.1 | 11.2 |
| 10 | | TEMP (°C) | 10.1 | 10.1 | 10.1 | 10.0 | 10.0 |
| | | DO (mg/l) | 11.4 | 11.4 | 11.4 | 11.1 | 11.2 |
| 11 | | TEMP (°C) | | 10.1 | 10.0 | 10.0 | 10.0 |
| | | DO (mg/l) | | 11.6 | 11.5 | 11.3 | 11.5 |
| 12 | | TEMP (°C) | | | 10.1 | 10.0 | 10.0 |
| | | DO (mg/l) | | | 11.5 | 11.4 | 11.5 |
| 13 | | TEMP (°C) | | | | 10.0 | 10.0 |
| | | DO (mg/l) | | | | 11.5 | 11.4 |
| 14 | | TEMP (°C) | | | | 10.0 | 10.0 |
| | | DO (mg/l) | | | | 11.6 | 11.4 |
| MEAN | | TEMP (°C) | 10.1 | 10.1 | 10.1 | 10.0 | 10.0 |
| | | DO (mg/l) | 11.4 | 11.4 | 11.4 | 11.4 | 11.2 |

(continued)

Merrimack Station Salmon Smolt Migration

Table 3-2 (continued)

| TAG NO. | ARRIVAL TIME AT DISCHARGE STATION | MIGRATION ROUTE | TRAVEL TIME RELEASE SITE TO DISCHARGE STATION (minutes) | TRAVEL TIME DISCHARGE STATION TO S4 (minutes) |
|----------------------|--|----------------------------|--|--|
| 7 | 1928 | D | 76 | 15 |
| 8 | 2035 | D/E | 143 | 17 |
| 3 | 1941 | C/D | 89 | 18 |
| 4 | 1925 | D/E | 73 | 15 |
| 14 | 1929 | D | 77 | 14 |
| 19 | 1909 | D/E | 57 | 11 |
| 27 | 1939 | D/E | 87 | 15 |
| 31 | 1925 | D/E | 73 | 13 |
| 33 | 2020 | C/D | 128 | 18 |
| 34 | 1920 | C/D | 68 | 14 |
| 101 | 1928 | C/D | 76 | 16 |
| 102 | 1907 | C/D | 55 | 20 |
| 103 | 1922 | D/E | 70 | 16 |
| 104 | 1941 | D/E | 89 | 12 |
| 105 | 1940 | D/E | 88 | 20 |
| 106 | 1916 | D/E | 64 | 13 |
| 107 | undetected | | | |
| 108 | 1928 | D | 76 | 15 |
| 109 | 1908 | D/E | 56 | 12 |
| 110 | 1944 | D | 92 | 14 |
| Mean (min) | | | 81 | 15 |
| Avg. Velocity | | | 1.6 mph | 2.0 mph |

Merrimack Station Salmon Smolt Migration

| Depth (ft) | STATION | | | | |
|------------|---------|-------|-------|-------|-------|
| | A | B | C | D | E |
| 1 | Green | Black | Black | Black | Black |
| 2 | White | White | White | White | White |
| 3 | Green | White | White | White | White |
| 4 | White | Black | Black | White | White |
| 5 | White | White | White | Black | White |
| 6 | Black | White | White | White | Black |
| 7 | White | Black | Black | White | White |
| 8 | White | White | White | White | White |
| 9 | White | White | White | Black | White |
| 10 | White | White | White | White | White |
| 11 | White | White | White | White | Black |

Release 1, 2003

| Depth (ft) | STATION | | | | |
|------------|---------|-------|-------|-------|-------|
| | A | B | C | D | E |
| 1 | Green | Green | Green | Black | Black |
| 2 | White | White | White | White | White |
| 3 | Green | White | White | White | White |
| 4 | White | Green | Black | White | White |
| 5 | White | White | White | Black | White |
| 6 | Green | White | White | White | Black |
| 7 | White | Green | Black | White | White |
| 8 | White | White | White | White | White |
| 9 | White | White | White | Black | White |
| 10 | White | White | White | White | White |
| 11 | White | White | White | White | Black |

Release 4, 2003

| Depth (ft) | STATION | | | | |
|------------|---------|-------|-------|-------|-------|
| | A | B | C | D | E |
| 1 | Green | Green | Black | Black | Black |
| 2 | White | White | White | White | White |
| 3 | Green | White | White | White | White |
| 4 | White | Green | Black | White | White |
| 5 | White | White | White | Black | White |
| 6 | Black | White | White | White | Black |
| 7 | White | Green | Black | White | White |
| 8 | White | White | White | White | White |
| 9 | White | White | White | Black | White |
| 10 | White | White | White | White | White |
| 11 | White | White | White | White | Black |

Release 2, 2003

| Depth (ft) | STATION | | | | |
|------------|---------|-------|-------|-------|-------|
| | A | B | C | D | E |
| 1 | Green | Green | Green | Green | Black |
| 2 | White | White | White | White | White |
| 3 | Green | White | White | White | White |
| 4 | White | Green | Green | White | White |
| 5 | White | White | White | Black | White |
| 6 | Green | White | White | White | Black |
| 7 | White | Green | Black | White | White |
| 8 | White | White | White | White | White |
| 9 | White | White | White | Black | White |
| 10 | White | White | White | White | White |
| 11 | White | White | White | White | Black |

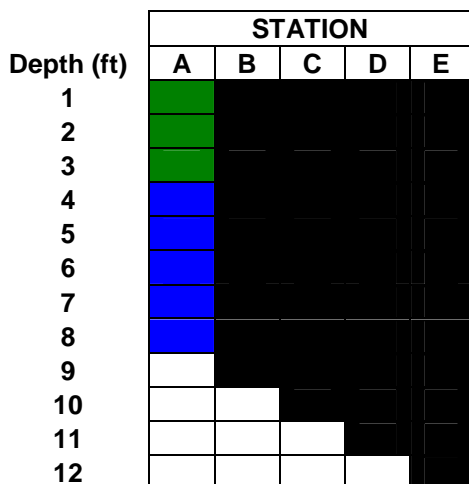
Release 5, 2003

| Depth (ft) | STATION | | | | |
|------------|---------|-------|-------|-------|-------|
| | A | B | C | D | E |
| 1 | Green | Green | Green | Black | Black |
| 2 | White | White | White | White | White |
| 3 | Green | White | White | White | White |
| 4 | White | Blue | Black | White | White |
| 5 | White | White | White | Black | White |
| 6 | Green | White | White | White | Black |
| 7 | White | Blue | Black | White | White |
| 8 | White | White | White | White | White |
| 9 | White | White | White | Black | White |
| 10 | White | White | White | White | White |
| 11 | White | White | White | White | Black |

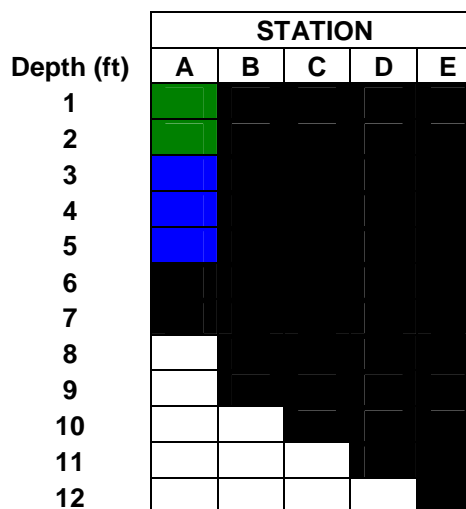
Release 3, 2003

Figure 3-1. River temperature profiles at Water Quality Stations A through E relative to ambient river water temperature for 2003 Atlantic salmon smolt releases.

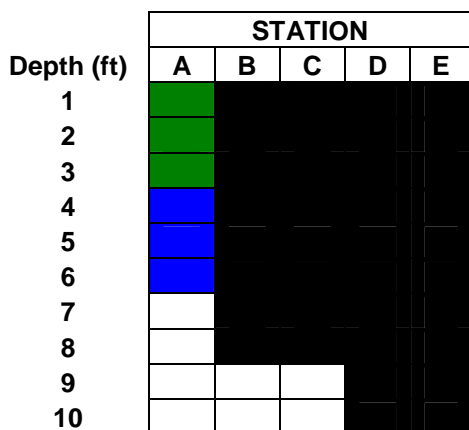
Note: Black box denotes that temperature measurement was within 0.5 °C of ambient water temperature, blue box denotes temperature was within 0.5 – 1.0 °C of ambient, and green box denotes that temperature was greater than 1.0 °C above ambient.



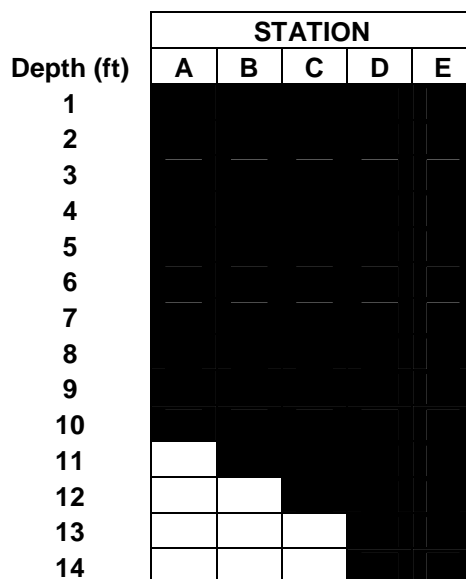
Release 1, 2005



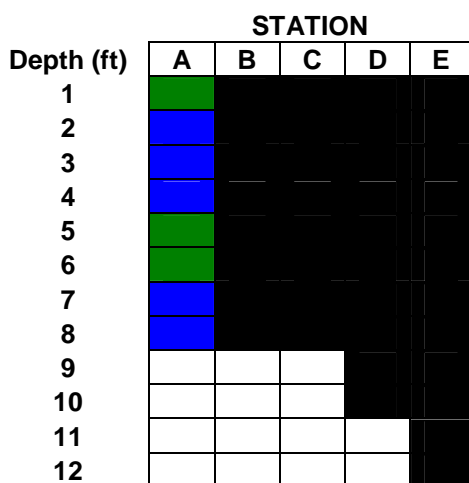
Release 4, 2005



Release 2, 2005



Release 5, 2005



Release 3, 2005

Figure 3-2. River temperature profiles at Water Quality Stations A through E relative to ambient river water temperature for 2005 Atlantic salmon smolt releases.

Note: Black box denotes that temperature measurement was within 0.5 °C of ambient water temperature, blue box denotes temperature was within 0.5 – 1.0 °C of ambient, and green box denotes that temperature was greater than 1.0 °C above ambient.

the eastern half of the river (Figure 3-3). Of those fish, five passed between Stations C and D and two passed between Stations D and E. Two fish moved past the Discharge Station between the western bank and Station A and the tenth fish passed over Station B. Migration routes for nine of the ten fish were determined through manual tracking. One fish (#19) was not detected manually. Its position was later estimated using signal strength after examination of the data collected by the stationary receivers. (Making use of the signal strengths, numbers of hits, and the known migration routes of the other fish released, a migration route for smolt #19 could be assigned.)

Mean travel speed from the Release Site to the Discharge Station for all Release 1 fish was 1.0 mile per hour (mph), and mean travel speed from the Discharge Station to Station S4 was 0.8 mph (Table 3-1). River discharge during this release decreased from 3119 to 3045 cubic feet per second (cfs) between 2000 and 2100, a decrease of 74 cfs, but remained constant at 3045 cfs until 0300 the next morning (22 May).

Release 2 during 2003 occurred on May 23. On this release date, there was a 58% probability that the measured average daily temperature (as measured at Monitoring Station N10) would have exceeded the observed ambient temperature and a 77% probability that calculated river flow would have exceeded observed river flow. Ambient conditions during this release could be classified as having average temperature and low flow conditions for that date. Ambient river water temperature (as measured at the Release Site) during this release was 15.1 °C. Water temperatures throughout the water column at Stations C, D, and E were within 0.1 °C of ambient river temperature (Table 3-1). Based on temperature measurements during the second release, approximately 67% of the river provided a zone of passage for the salmon that was within 0.2 °C of ambient river water (Figure 3-1). Water temperatures at Station A surface (Δ 2.6 °C), mid-depth (Δ 1.9 °C), and Station B surface (Δ 2.8 °C), mid-depth (Δ 2.5 °C), and bottom (Δ 1.4 °C) were greater than one degree above ambient. One unit at Merrimack Station was in operation during this release.

During the second release, a total of ten radio-tagged Atlantic salmon smolts were released. Smolts from Release 2 took an average of 144 minutes (range 75 – 343) to travel from the Release Site downstream to the Discharge Station and an average of 80 minutes (range 26 – 363) to travel from the Discharge Station to Station S4 (Table 3-1). The majority of smolts (60%) migrated downstream in the eastern third of the river, east of Station D (Figure 3-4). One fish moved past the Discharge Station in the vicinity of Station D, two fish moved downstream in the vicinity of Station C and one fish passed in the western half of the river, between Stations B and C. Migration routes for eight of the ten fish were determined through manual tracking. Two fish (#1 and #8) were not detected manually. Similar to the fish from the first release, their migration routes were later determined after examination of the data collected by the stationary receivers. Mean travel speed from the Release Site to the Discharge Station for all Release 2 fish was 1.1 mph, and mean travel speed from the Discharge Station to Station S4 was 0.7 mph (Table 3-1). River discharge during this release decreased from 3144 to 3069 cfs (Δ 75 cfs) between 1900 and 2000, one hour prior to release, but remained constant at 3069 cfs until 0200 the next morning (24 May).

Release 3 during 2003 occurred on May 25. On this release date, there was a 74% probability that the measured average daily temperature (as measured at Monitoring Station N10) would have exceeded the observed ambient temperature and a 74% probability that calculated river flow would have exceeded observed river flow. Ambient conditions during this release could be classified as having low temperature and flow conditions for that date. Ambient river water temperature (as measured at



Figure 3-3. Migration routes of radio-tagged Atlantic salmon smolts past the Discharge Station during Release 1, 2003.



Figure 3-4. Migration routes of radio-tagged Atlantic salmon smolts past the Discharge Station during Release 2, 2003.

the Release Site) during this release was 14.3 °C. Water temperatures throughout the water column at Stations D, and E were within 0.1 °C of ambient river temperature (Table 3-1). Based on temperature measurements during the third release, approximately 53% of the river provided a zone of passage for the salmon that was within 0.3 °C of ambient river water (Figure 3-1). Water temperatures at Station A (surface (Δ 4.5 °C), mid-depth (Δ 4.2 °C), bottom (Δ 3.3 °C)), Station B (surface (Δ 6.9 °C)), and Station C (surface (Δ 7.3 °C)) were greater than one degree above ambient. Water temperatures at Station B mid-depth (Δ 0.7 °C) and bottom (Δ 0.5 °C) were between 0.5 °C and 1.0 °C degrees above ambient. Two units at Merrimack Station were in operation during this release.

During the third release, a total of ten radio-tagged Atlantic salmon smolts were released. Smolts from Release 3 took an average of 244 minutes (range 70 – 1476) to travel from the Release Site downstream to the Discharge Station and an average of 38 minutes (range 25 – 75) to travel from the Discharge Station to Station S4 (Table 3-1). During Release 3, all ten smolts migrated past the Discharge Station in the eastern half of the river (Figure 3-5). Two fish moved past the Discharge Station in the vicinity of Station E, five fish moved downstream between Stations D and E, and three fish passed between Stations C and D. Migration routes for eight of the ten fish were determined through manual tracking. Two fish (#26 and #32) were not detected manually. Similar to the fish from the first two releases, their migration routes were later determined after examination of the data collected by the stationary receivers. Mean travel speed from the Release Site to the Discharge Station for all Release 3 fish was 1.1 mph, and mean travel speed from the Discharge Station to Station S4 was 0.9 mph (Table 3-1). River discharge during this release decreased from 3094 to 2995 cfs between 2100 and 2200, a decrease of 99 cfs, but remained constant at 2995 cfs until 0200 the next morning (26 May).

Release 4 during 2003 occurred on June 3. On this release date, there was a 67% probability that the measured average daily temperature (as measured at Monitoring Station N10) would have exceeded the observed ambient temperature and a 37% probability that calculated river flow would have exceeded observed river flow. Ambient conditions during this release could be classified as having low temperature and above average flow conditions for that date. Ambient river water temperature (as measured at the Release Site) during this release was 16.2 °C. Water temperatures throughout the water column at Stations D, and E were within 0.1 °C of ambient river temperature (Table 3-1). Based on temperature measurements during the fourth release, approximately 53% of the river provided a zone of passage for salmon that was within 0.3 °C of ambient river water (Figure 3-1). Water temperatures at Station A (surface (Δ 4.1 °C), mid-depth (Δ 2.9 °C), bottom (Δ 2.4 °C)), Station B (surface (Δ 7.0 °C), mid-depth (Δ 6.0 °C), bottom (Δ 2.6 °C)), and Station C (surface (Δ 5.9 °C)) were greater than one degree above ambient. Two units at Merrimack Station were in operation during this release.

During the fourth release, a total of ten radio-tagged Atlantic salmon smolts were released. Smolts from Release 4 took an average of 86 minutes (range 58 – 174) to travel from the Release Site downstream to the Discharge Station and an average of 34 minutes (range 21 – 91) to travel from the Discharge Station to Station S4 (Table 3-1). During Release 4, all ten smolts migrated past the Discharge Station in the eastern half of the river (Figure 3-6). Two fish moved past the Discharge Station between Station E and the eastern shore, one fish moved downstream in the vicinity of Station E, three fish moved downstream between Stations D and E, and four fish passed between Stations C

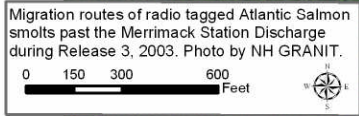




Figure 3-6. Migration routes of radio-tagged Atlantic salmon smolts past the Discharge Station during Release 4, 2003.

and D. Migration routes for all ten fish were determined through manual tracking and confirmed through analysis of the stationary telemetry data. Mean travel speed from the Release Site to the Discharge Station for all Release 4 fish was 1.5 mph, and mean travel speed from the Discharge Station to Station S4 was 1.0 mph (Table 3-1). River discharge during this release increased from 4257 to 4332 cfs between 2100 and 2200, an increase of 75 cfs, but remained constant at 4332 cfs until 0800 the next morning (4 June).

Release 5 during 2003 occurred on June 5. On this release date, there was a 70% probability that the measured average daily temperature (as measured at Monitoring Station N10) would have exceeded the observed ambient temperature and a 46% probability that calculated river flow would have exceeded observed river flow. Ambient conditions on this release date could be classified as having low temperature and average flow conditions for that date. Ambient river water temperature (as measured at the Release Site) during this release was 16.2 °C. Water temperatures throughout the water column at Station E were within 0.2 °C of ambient river temperature (Table 3-1). Based on temperature measurements during the fifth release, approximately 40% of the river provided a zone of passage for salmon that was within 0.3 °C of ambient river water (Figure 3-1). Water temperatures at Station A (surface (Δ 4.1 °C), mid-depth (Δ 3.6 °C), bottom (Δ 3.2 °C)), Station B (surface (Δ 7.5 °C), mid-depth (Δ 7.2 °C), bottom (Δ 1.4 °C)), Station C (surface (Δ 8.6 °C), mid-depth (Δ 2.7 °C)) and Station D (surface (Δ 3.9 °C)) were greater than one degree above ambient. Two units at Merrimack Station were in operation during this release.

During the fifth release, a total of nine radio-tagged Atlantic salmon smolts were released. Of the nine smolts, one regurgitated its transmitter immediately upon release and was dropped from the study. Smolts from Release 5 took an average of 85 minutes (range 37 – 136) to travel from the Release Site downstream to the Discharge Station and an average of 79 minutes (range 26 – 223) to travel from the Discharge Station to Station S4 (Table 3-1). During Release 5, all eight smolts migrated past the Discharge Station in the eastern half of the river (Figure 3-7). One fish moved downstream in the vicinity of Station E, four fish moved downstream between Stations D and E, and three fish passed between Stations C and D. Migration routes for all eight fish were determined through manual tracking and confirmed through analysis of the stationary telemetry data. Mean travel speed from the Release Site to the Discharge Station for all Release 4 fish was 1.5 mph, and mean travel speed from the Discharge Station to Station S4 was 0.7 mph (Table 3-1). River discharge during this release decreased from 3441 to 3391 cfs (50 cfs) between 1900 and 2000, one hour prior to release, but remained constant at 3391 cfs until 0400 the next morning (6 June).

Release 1 during 2005 occurred on May 11. On this release date, there was a 30% probability that the measured average daily temperature (as measured at Monitoring Station N10) would have exceeded the observed ambient temperature and a 50% probability that calculated river flow would have exceeded observed river flow. Ambient conditions on this release date could be classified as having above average temperature and average flow conditions for that date. Ambient river water temperature (as measured at the Release Site) during this release was 13.7 °C. Water temperatures throughout the water column at Stations B, C, D, and E were within 0.2 °C of ambient river temperature (Table 3-2). Based on temperature measurements during the first release, 84% of the river provided a zone of passage for the salmon that was within 0.2 °C of ambient river water (Figure 3-2). Water temperatures in the top three feet at Station A (Δ 3.0 °C, Δ 2.1 °C, and Δ 1.8 °C respectively) were greater than one degree above ambient. Water temperatures in the lower five feet



Figure 3-7. Migration routes of radio-tagged Atlantic salmon smolts past the Discharge Station during Release 5, 2003.

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at station A were between 0.6 °C and 0.8 °C greater than ambient. One unit at Merrimack Station was in operation during this release.

During the first release of 2005, a total of ten transmitted Atlantic salmon smolts were released. Smolts from Release 1 took an average of 226 minutes (range 64 – 1429) to travel from the Release Site downstream to the Discharge Station and an average of 332 minutes (range 16 – 3086) to travel from the Discharge Station to Station S4 (Table 3-2). The smolts migrated past the Discharge Station from the midpoint of the river channel towards the eastern shore (Figure 3-8). One salmon smolt passed in the vicinity of Station C, five passed between Stations C and D, two passed between Stations D and E, and one passed in the vicinity of Station E. Migration routes for eight of the ten fish were determined through manual tracking. Two fish (#81 and #91) were not detected manually. Their migration routes were later determined after examination of the data collected by the stationary receivers. Fish #91 moved past the discharge station along the eastern bank of the river at 0033 on May 12. This fish remained in the area between the Discharge Station and Station S-4 for approximately 28 hours. During this time, it was documented as moving in and out of the field of detection at Station S4. This fish was last detected at Station S-4 at 0359 on May 14 and was confirmed as moving past the downstream hydroelectric facility at 0539 (approximately 2 miles). Water quality conditions during fish #91's time of residence between the Discharge Station and Station S-4 were within 0.2°C of ambient throughout 85% of the river channel. Mean travel speed from the Release Site to the Discharge Station for all Release 1 fish was 1.4 mile per hour (mph), and mean travel speed from the Discharge Station to Station S4 was 1.3 mph (Table 3-2). River discharge during this release remained constant at 4233 cfs from 2000 to 2300 before decreasing slightly to 4158 cfs at 0000 on the morning of May 12.

Release 2 during 2005 occurred on May 17. On this release date, there was a 60% probability that the measured average daily temperature (as measured at Monitoring Station N10) would have exceeded the observed ambient temperature and a 67% probability that calculated river flow would have exceeded observed river flow. Ambient conditions on this release date could be classified as having average temperature and low flow conditions for that date. Ambient river water temperature (as measured at the Release Site) during this release was 13.4 °C. Water temperatures throughout the water column at Stations B, C, D, and E were within 0.2°C of ambient river temperature (Table 3-2). Based on temperature measurements during the first release, 86% of the river provided a zone of passage for the salmon that was within 0.2 °C of ambient river water (Figure 3-2). Water temperatures in the top three feet at Station A (Δ 2.6 °C, Δ 2.6 °C, and Δ 1.6 °C respectively) were greater than one degree above ambient. Water temperatures in the lower three feet at Station A were 0.7 °C greater than ambient. One unit at Merrimack Station was in operation during this release.

During the second release, a total of ten radio-tagged Atlantic salmon smolts were released. Due to a transmitter malfunction, one smolt from this release was dropped from the study. Smolts from Release 2 took an average of 130 minutes (range 97 – 329) to travel from the Release Site downstream to the Discharge Station and an average of 24 minutes (range 18 – 29) to travel from the Discharge Station to Station S4 (Table 3-2). Eight of the nine smolts migrated past the Discharge Station in the eastern third of the river (Figure 3-9). One salmon smolt passed between Stations C and D, three passed in the vicinity of Station D, and five passed between Stations D and E. Migration routes for eight of the nine fish were determined through manual tracking. The migration route for tag #84 was later determined after examination of the data collected by the stationary receivers. Mean travel speed from the Release Site to the Discharge Station for all Release 2 fish was 1.1 mile



Figure 3-8. Migration routes of radio-tagged Atlantic salmon smolts past the Discharge Station during Release 1, 2005.



Figure 3-9. Migration routes of radio-tagged Atlantic salmon smolts past the Discharge Station during Release 2, 2005.

per hour (mph), and mean travel speed from the Discharge Station to Station S4 was 1.3 mph (Table 3-2). River discharge during this release decreased from 4725 to 4555 cubic feet per second (cfs) between 2000 and 2100, a decrease of 170 cfs. Flows continued to decrease before they leveled off at 4455 cfs between 0200 and 0400 on May 18.

Release 3 during 2005 occurred on May 19. On this release date, there was a 66% probability that the measured average daily temperature (as measured at Monitoring Station N10) would have exceeded the observed ambient temperature and a 71% probability that calculated river flow would have exceeded observed river flow. Ambient conditions on this release date could be classified as having low temperature and flow conditions for that date. Ambient river water temperature (as measured at the Release Site) during this release was 13.1 °C. Water temperatures throughout the water column at Stations B, C, D, and E were within 0.2 °C of ambient river temperature (Table 3-2). Based on temperature measurements during the third release, approximately 83% of the river provided a zone of passage for the salmon that was within 0.2 °C of ambient river water (Figure 3-2). Water temperatures in the top foot and fifth and sixth feet at Station A (Δ 4.4 °C, Δ 1.1 °C, and Δ 1.1 °C respectively) were greater than one degree above ambient. Water temperatures in feet two through four and seven and eight at Station A were between 0.8 °C and 1.0 °C greater than ambient. One unit at Merrimack Station was in operation during this release.

During the third release, a total of ten radio-tagged Atlantic salmon smolts were released. Smolts from Release 3 took an average of 206 minutes (range 89 – 460) to travel from the Release Site downstream to the Discharge Station and an average of 38 minutes (range 25 – 75) to travel from the Discharge Station to Station S4 (Table 3-2). During Release 3, smolts moved past the Discharge Station throughout the eastern two-thirds of the river (Figure 3-10). One fish moved past the Discharge Station between Stations B and C, one fish moved past the Discharge Station in the vicinity of Station C, two fish moved downstream in the vicinity of Station D, one fish between Stations D and E and five fish in the vicinity of Station E. Migration routes for eight of the ten fish were determined through manual tracking. Two fish (#67 and #79) were not detected manually and their migration routes were later determined after examination of the data collected by the stationary receivers. Mean travel speed from the Release Site to the Discharge Station for all Release 3 fish was 0.8 mph, and mean travel speed from the Discharge Station to Station S4 was 1.1 mph (Table 3-2). River discharge during this release decreased from 3665 to 3515 cfs between 2000 and 2300, a decrease of 150 cfs.

Release 4 during 2005 occurred on May 24. On this release date, there was a 90% probability that the measured average daily temperature (as measured at Monitoring Station N10) would have exceeded the observed ambient temperature and a 41% probability that calculated river flow would have exceeded observed river flow. Ambient conditions on this release date could be classified as having low temperature and average flow conditions for that date. Ambient river water temperature (as measured at the Release Site) during this release was 11.7 °C. Water temperatures throughout the water column at Stations B, C, D, and E were within 0.2 °C of ambient river temperature (Table 3-2). Based on temperature measurements during the fourth release, approximately 90% of the river provided a zone of passage for the salmon that was within 0.2 °C of ambient river water (Figure 3-2). Water temperatures in the top two feet at Station A (Δ 2.0 °C and Δ 1.9 °C respectively) were greater than one degree above ambient. Water temperatures in feet three through five at Station A were between 0.9 °C and 0.7 °C greater than ambient. The lowest two feet at Station A had water



Figure 3-10. Migration routes of radio-tagged Atlantic salmon smolts past the Discharge Station during Release 3, 2005.

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temperatures that were 0.4 °C and 0.3 °C greater than ambient. One unit at Merrimack Station was in operation during this release.

During the fourth release, a total of ten radio-tagged Atlantic salmon smolts were released. Smolts from Release 4 took an average of 88 minutes (range 74 – 132) to travel from the Release Site downstream to the Discharge Station and an average of 35 minutes (range 16 – 187) to travel from the Discharge Station to Station S4 (Table 3-2). During Release 4, eight of the ten smolts moved past the Discharge Station in the eastern third of the river (Figure 3-11). Two fish moved past the Discharge Station between Stations C and D, one fish moved past the Discharge Station in the vicinity of Station D, six fish between Stations D and E and one fish in the vicinity of Station E. Migration routes for all ten fish were determined through manual tracking and confirmed through analysis of the stationary telemetry data. Mean travel speed from the Release Site to the Discharge Station for all Release 4 fish was 1.4 mph, and mean travel speed from the Discharge Station to Station S4 was 1.5 mph (Table 3-2). River discharge during this release increased from 4828 to 5000 cfs between 1800 and 2200, an increase of 172 cfs.

Release 5 during 2005 occurred on May 26. On this release date, there was a 99% probability that the measured average daily temperature (as measured at Monitoring Station N10) would have exceeded the observed ambient temperature and a 4% probability that calculated river flow would have exceeded observed river flow. Ambient conditions on this release date could be classified as having low temperature and high flow conditions for that date. Ambient river water temperature (as measured at the Release Site) during this release was 10.2 °C. Water temperatures throughout the water column at Stations A, B, C, D, and E were within 0.2 °C of ambient river temperature (Table 3-2). Based on temperature measurements during the third release, approximately 90% of the river provided a zone of passage for salmon that was within 0.2 °C of ambient river water (Figure 3-2). Water temperatures in the top two feet at Station A (Δ 2.0 °C and Δ 1.9 °C respectively) were greater than one degree above ambient. Water temperatures in feet three through five at Station A were between 0.9 °C and 0.7 °C greater than ambient. The lowest two feet at Station A had water temperatures that were 0.4 °C and 0.3 °C greater than ambient. One unit at Merrimack Station was in operation during this release.

During the fifth release, a total of twenty radio-tagged Atlantic salmon smolts were released. Due to a transmitter malfunction, one smolt from this release was dropped from the study. Smolts from Release 5 took an average of 81 (range 55 – 143) minutes to travel from the Release Site downstream to the Discharge Station and an average of 15 minutes (range 11 – 20) to travel from the Discharge Station to Station S4 (Table 3-2). During Release 5, fourteen of the nineteen smolts moved past the Discharge Station in the eastern third of the river (Figure 3-12). Five fish moved past the Discharge Station between Stations C and D, four fish moved past the Discharge Station in the vicinity of Station D, and ten fish between Stations D and E. Migration routes for all nineteen fish were determined through manual tracking and confirmed through analysis of the stationary telemetry data. Mean travel speed from the Release Site to the Discharge Station for all Release 5 fish was 1.6 mph, and mean travel speed from the Discharge Station to Station S4 was 2.0 mph (Table 3-2). River discharge during this release fluctuated between 4802 and 4826 cfs between 1800 and 2300 before increasing during the early morning hours of May 27.

Migration routes past the Discharge Station were recorded for 106 of the 109 (97 %) of the radio-tagged salmon smolts released upstream of the discharge. Figure 3-13 provides the percentage of smolts that selected each potential zone of passage during the two years of the study. The majority of



Figure 3-11. Migration routes of radio-tagged Atlantic salmon smolts past the Discharge Station during Release 4, 2005.



Figure 3-12. Migration routes of radio-tagged Atlantic salmon smolts past the Discharge Station during Release 5, 2005.

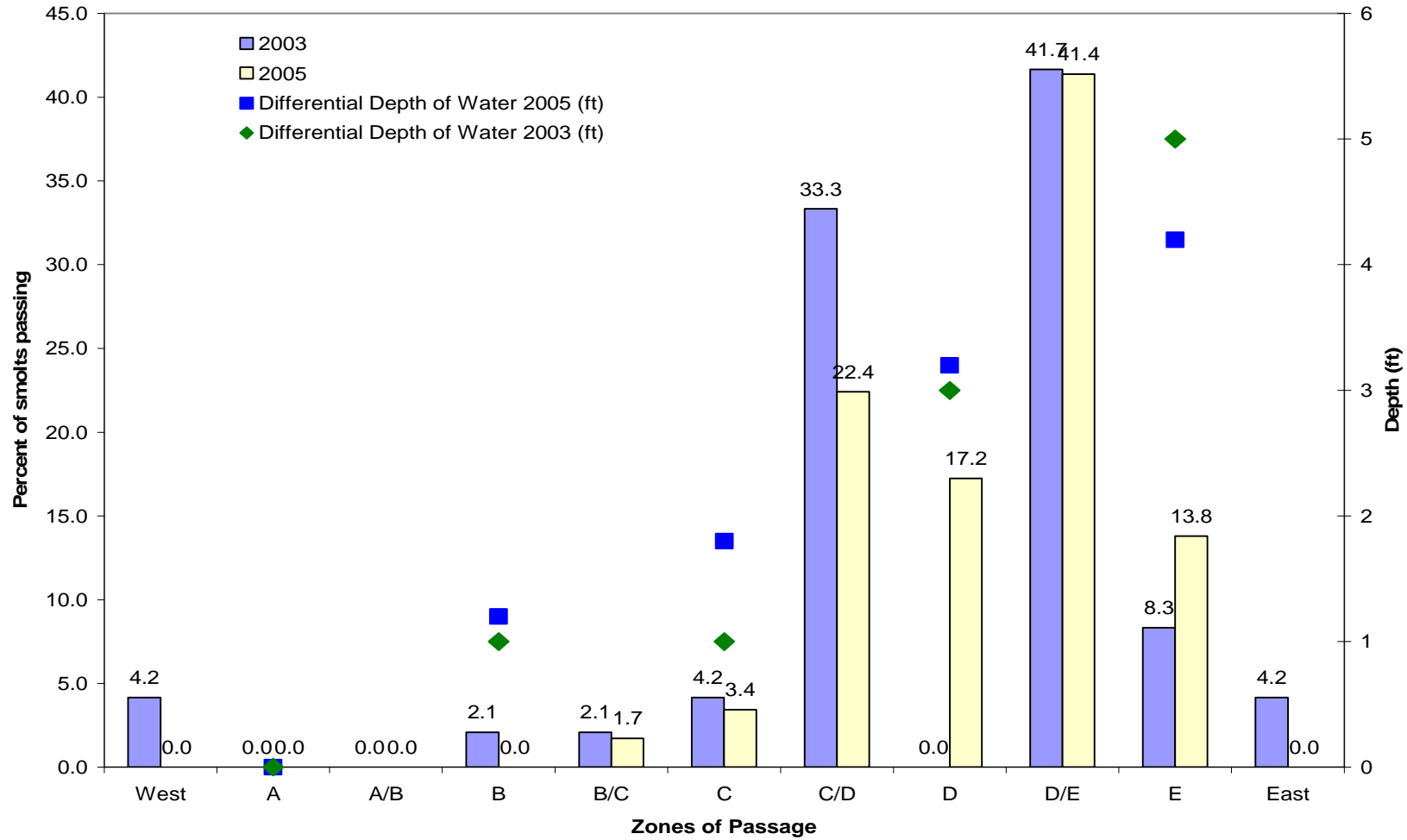


Figure 3-13. Percentage of smolt passage by zone for 2003 and 2005 Atlantic salmon smolts released during Merrimack Station study.

smolts (91.5%) migrated downstream past the Discharge Station in the eastern half of the river during both years of the study. The difference in mean water depths as recorded at the five water quality stations is also shown in Figure 3-13. During the two years of the study, water depths were an average of four to five feet deeper at Station E, which is located in the eastern portion of the river channel. Overall depths sloped from shallowest in the western section of the river (closest to the discharge) to deepest in the eastern section of the river. The average percentage of the river providing a zone of passage for the salmon within 0.3 °C of ambient river water was 73%. This ranged between 67 and 90% for releases that occurred when one unit was running, and between 40 and 53% for releases that occurred when both units were running.

For all releases combined, the mean travel time from the Release Site to the Discharge Station, a distance of 2.0 miles, was 137 minutes (1.3 mph) and from the Discharge Station to Station S4 (0.5 miles) was 67 minutes (1.2 mph) (Table 3-3). Since the passage times for individual smolts varied widely, high standard deviations were associated with the average travel times calculated between the Release Site and Discharge Station and the Discharge Station and Station S4. Median travel times were also calculated and are presented in Table 3-3. This was done to avoid the influence of smolts that took an extreme amount of time to move downriver and out of the study zone. For all releases combined, the median time for smolts to move from the Release Site to the Discharge Station was 91 minutes and from the Discharge Station to Station S4 was 26 minutes. Median times for smolts released during 2003 were 97 minutes from the Release Site to the Discharge Station and 35 minutes from the Discharge Station to Station S4. Median times for smolts released during 2005 were 88 minutes from the Release Site to the Discharge Station and 18 minutes from the Discharge Station to Station S4. There were no significant differences between 2003 and 2005 in the average travel time for smolts traveling between the Release Site and Discharge Station ($p = 0.479$) and between the Discharge Station and Station S4 ($p = 0.329$).

For all releases combined, the median speed (mph) for smolts moving from the Release Site to the Discharge Station was 1.3 mph and from the Discharge Station to Station S4 was 1.2 mph. The median speed for smolts released during 2003 was 1.2 mph from the Release Site to the Discharge Station and 0.9 mph from the Discharge Station to Station S4. The median speed for smolts released during 2005 was 1.4 mph from the Release Site to the Discharge Station and 1.7 mph from the Discharge Station to Station S4. There were no significant differences between 2003 and 2005 in the average travel speed for smolts moving between the Release Site and Discharge Station ($p = 0.178$). During 2005, smolts moved significantly faster between the Discharge Station and Station S4 than was observed in 2003 ($p = > 0.001$). However, the average river flow at the time of release was greater during the 2005 releases than during the 2003 releases (Appendix 1). There was no significant difference in the average travel speed of fish from both years when they were upstream or downstream of the Discharge Station ($p = 0.278$).

Three of the ten releases were conducted while Merrimack Station had both of its electrical power generating units in operation. During these releases, the median time for smolts to move from the Release Site to the Discharge Station was 87 minutes and from the Discharge Station to Station S4 was 33 minutes. The median times for smolts released while one unit was in operation was 92 minutes from the Release Site to the Discharge Station and 22 minutes from the Discharge Station to Station S4. There were no significant differences between average travel times for smolts traveling between the Release Site and Discharge Station ($p = 0.479$) and between the Discharge Station and Station S4 ($p = 0.329$) during the conditions associated with one-unit or two-unit operation. During

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one-unit operation, the median speed for smolts moving from the Release Site to the Discharge Station was 1.3 mph and from the Discharge Station to Station S4 was 1.4 mph. The median speed for smolts released while two units were in operation was 1.4 mph from the Release Site to the Discharge Station and 0.9 mph from the Discharge Station to Station S4. There were no significant differences in the average travel speed for smolts moving between the Release Site and Discharge Station ($p = 0.110$) associated with one-unit or two-unit operation. Smolts moved significantly faster between the Discharge Station and Station S4 during periods of one-unit operation than periods of two-unit operation ($p = > 0.001$). However, average river flow was also greater during the release events where one unit was operating than those where two units were operating (Appendix 1). It has been suggested that smolts migrate more quickly at high water flow than low (Youngson et al. 1983).

Table 3-3. Downstream travel times and speeds for Atlantic salmon smolts released during 2003 and 2005, Merrimack Station.

| | Travel Times (minutes) | | Travel Speeds (mph) | |
|------------------------|------------------------------|-------------------------|------------------------------|-------------------------|
| | Release to Discharge Station | Discharge Station to S4 | Release to Discharge Station | Discharge Station to S4 |
| All Fish | | | | |
| Mean | 137 | 67 | 1.3 | 1.2 |
| St. Dev. | 195 | 302 | 0.04 | 0.06 |
| Median | 91 | 26 | 1.3 | 1.2 |
| 2003 | | | | |
| Mean | 138 | 53 | 1.2 | 0.8 |
| St. Dev. | 203 | 59 | 0.06 | 0.05 |
| Median | 97 | 35 | 1.2 | 0.9 |
| 2005 | | | | |
| Mean | 136 | 78 | 1.3 | 1.6 |
| St. Dev. | 189 | 406 | 0.06 | 0.07 |
| Median | 88 | 18 | 1.4 | 1.7 |
| 1 Unit running | | | | |
| Mean | 136 | 73 | 1.2 | 1.3 |
| St. Dev. | 166 | 351 | 0.05 | 0.07 |
| Median | 92 | 22 | 1.3 | 1.4 |
| 2 Units running | | | | |
| Mean | 142 | 49 | 1.4 | 0.9 |
| St. Dev. | 263 | 46 | 0.08 | 0.06 |
| Median | 87 | 33 | 1.4 | 0.9 |

4.0 DISCUSSION

Radio telemetry data show that Atlantic salmon smolt migration past the Discharge Station was not impaired when either one or both of Merrimack Station's electric power generating units were in operation. Under both operating scenarios, released smolts' migratory routes were more prevalent in the eastern half of the river. In fact, 88% of the smolts released during one-unit operation passed the Discharge Station by traveling in the eastern half of the river, while 100% of the smolts released during two-unit operation passed the Discharge Station by traveling in the eastern half of the river. Water depths on the eastern side of the river in the vicinity of the Discharge Station were deeper than those on the western side of the river during both years of the study. Atlantic salmon smolts have been found to migrate within the middle part of a channel, where the highest water velocities are found (Ruggles 1980; Davidsen et al. 2005). In addition, smolts will actively move into the main current of a river to avoid being caught in backwater and slough areas (Hansen and Jonsson 1985). Atlantic salmon smolts moving past Merrimack Station may be naturally shifting their migration routes to the eastern half of the Merrimack River to remain in the deeper water and avoid being caught in the shallower areas associated with the west bank.

There were no significant differences in the migration rates of smolts upstream or downstream of the Discharge Station. Migration rates between the Release Site and the Discharge Station did not differ between 2003 and 2005 or when one or two units were in operation. Smolts moved significantly faster between the Discharge Station and Station S4 during 2005 than they did during 2003. However, the average river flow at the time of release was greater during the 2005 releases than during the 2003 releases (Appendix 1). Average speeds of smolts traveling between the Discharge Station and Station S4 were significantly greater when one unit was running than when two units were running. However, average river flow was also greater during the release events where one unit was operating than those where two units were operating (Appendix 1). It has been suggested that smolts migrate more quickly at high water flow than low (Youngson et al. 1983). Ruggles (1980) and Spicer et al. (1995) have both reported ranges for the net ground speed of migrating Atlantic salmon smolts (0.1 – 0.72 mph and 0.01 – 0.41 mph, respectively). Smolts in this study ranged in travel speeds from 0.01 to 2.72 mph with an average speed of 1.24 mph.

The thermal effluent discharged from Merrimack Station did not create a barrier to the downstream migration of Atlantic salmon smolts, nor did it delay their downstream migration. Salmon smolts released as part of this study behaved as is typical for the species, moving downstream during the typical smolt migration period in New England of late April through early June (Whalen et al. 1999). Downstream migrations took place during the nocturnal hours as has been observed in other temperate populations of Atlantic salmon (Hesthagen and Garnas 1986; McCormick et al. 1998; Moore et al. 1998). As with smolts from other studies (Hesthagen and Garnas 1986; Davidsen et al. 2005), the released smolts moved past Merrimack Station in the deeper, high flow portion of the channel with the majority of fish avoiding the shallow, low-flow, western section of the channel.

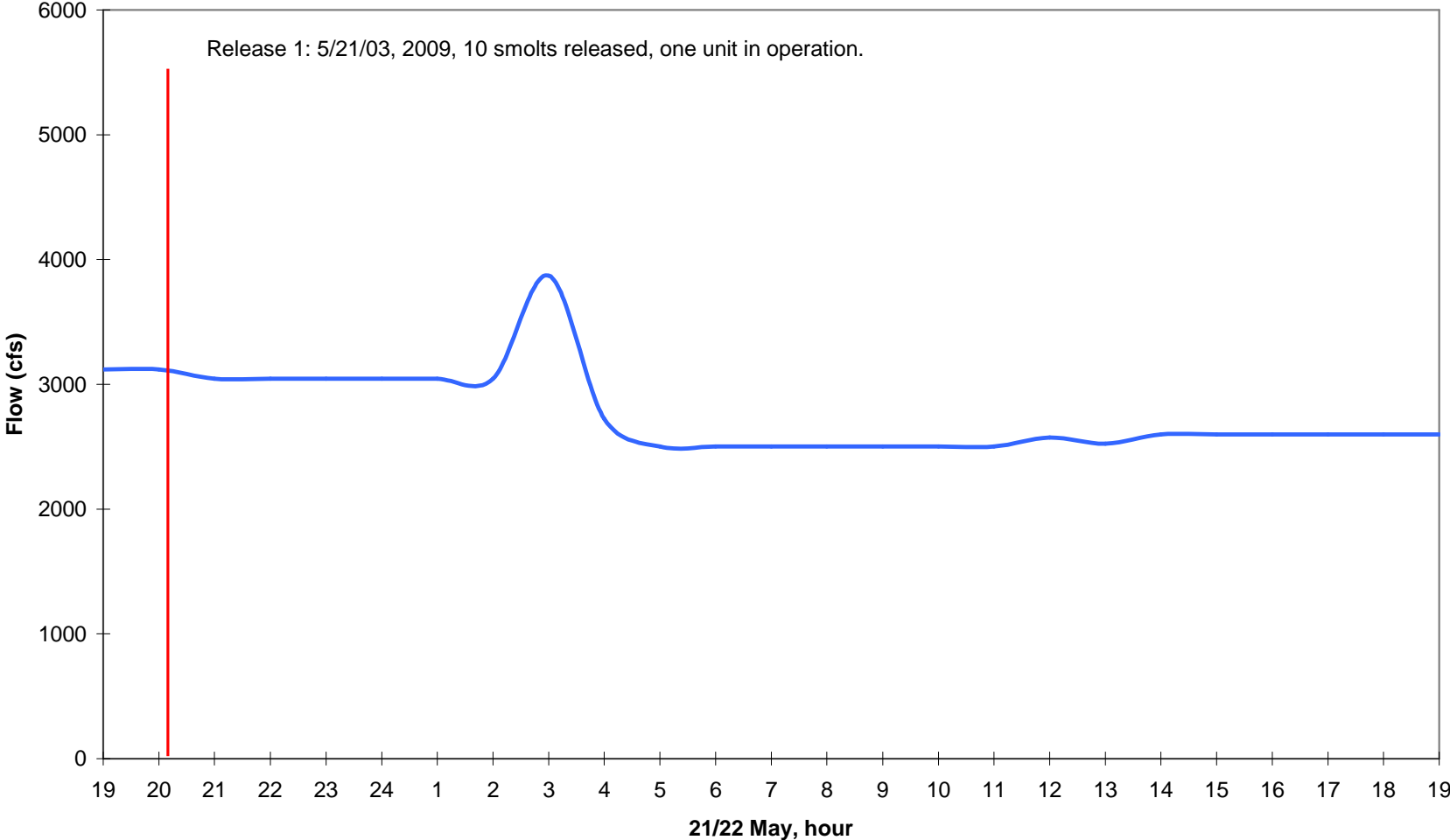
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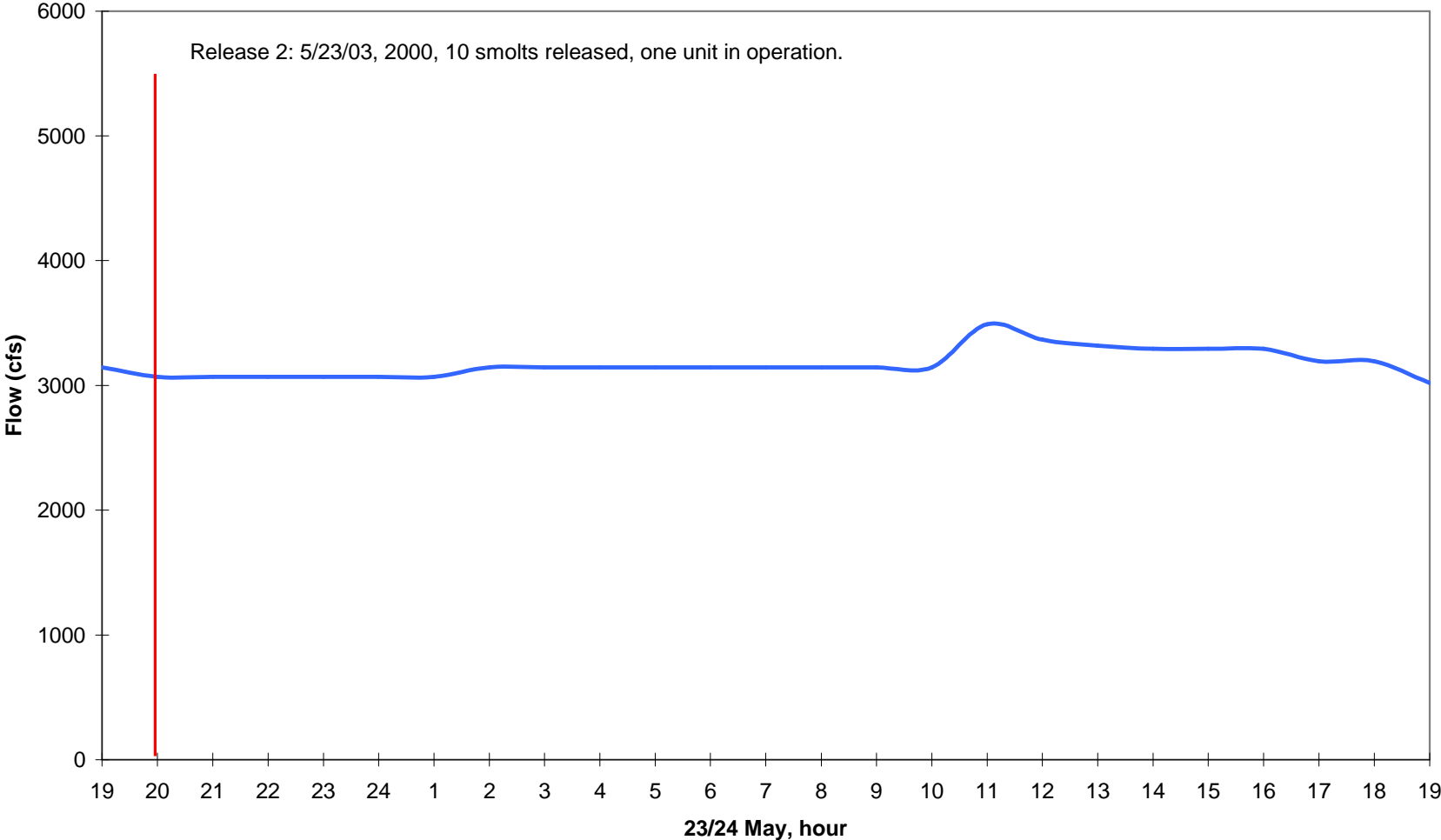
APPENDIX A

River Discharge During Fish Releases

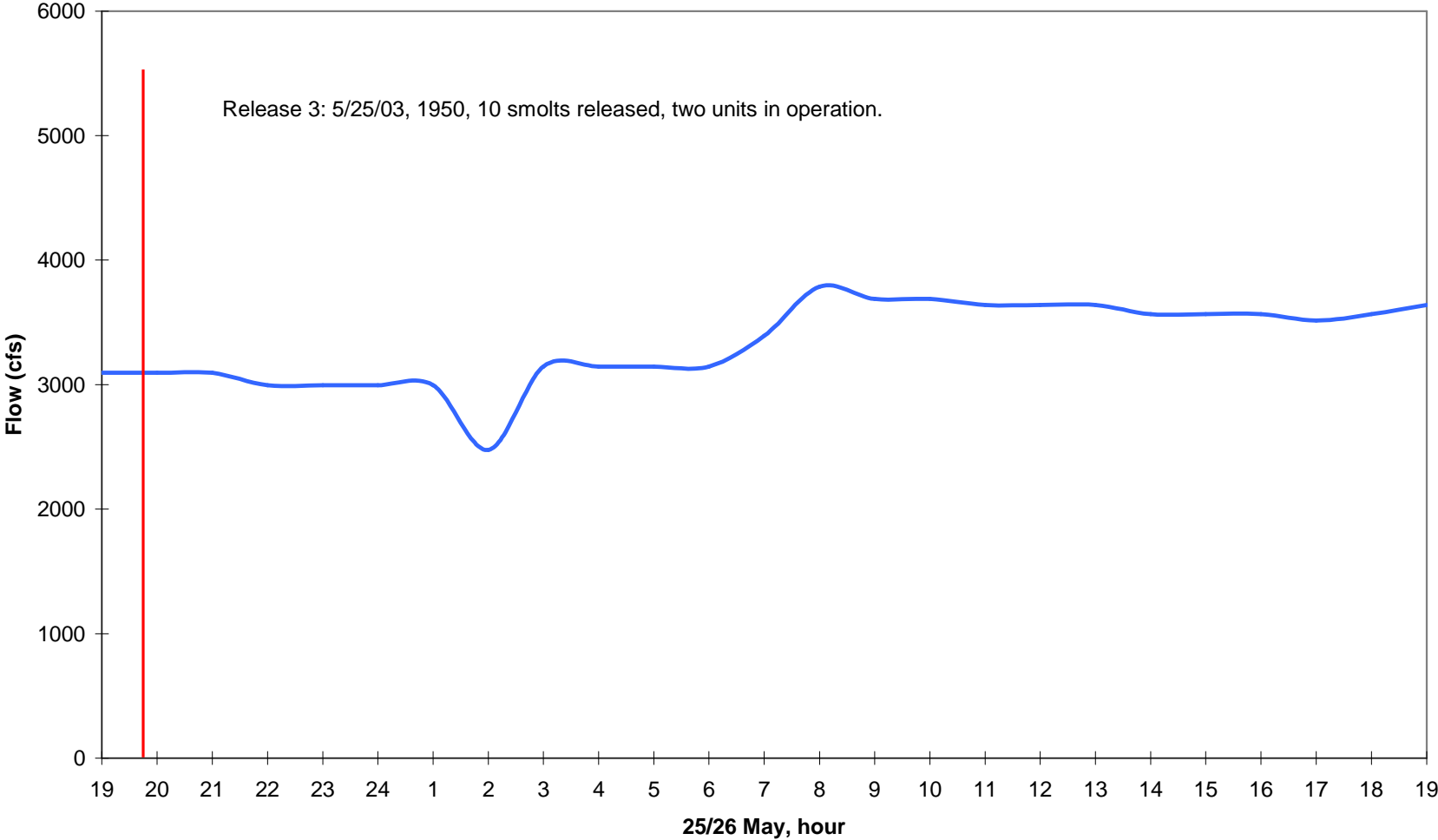
Appendix A. Hourly River Discharge during Release 1. Merrimack Station
Downstream Smolt Passage, 2003.



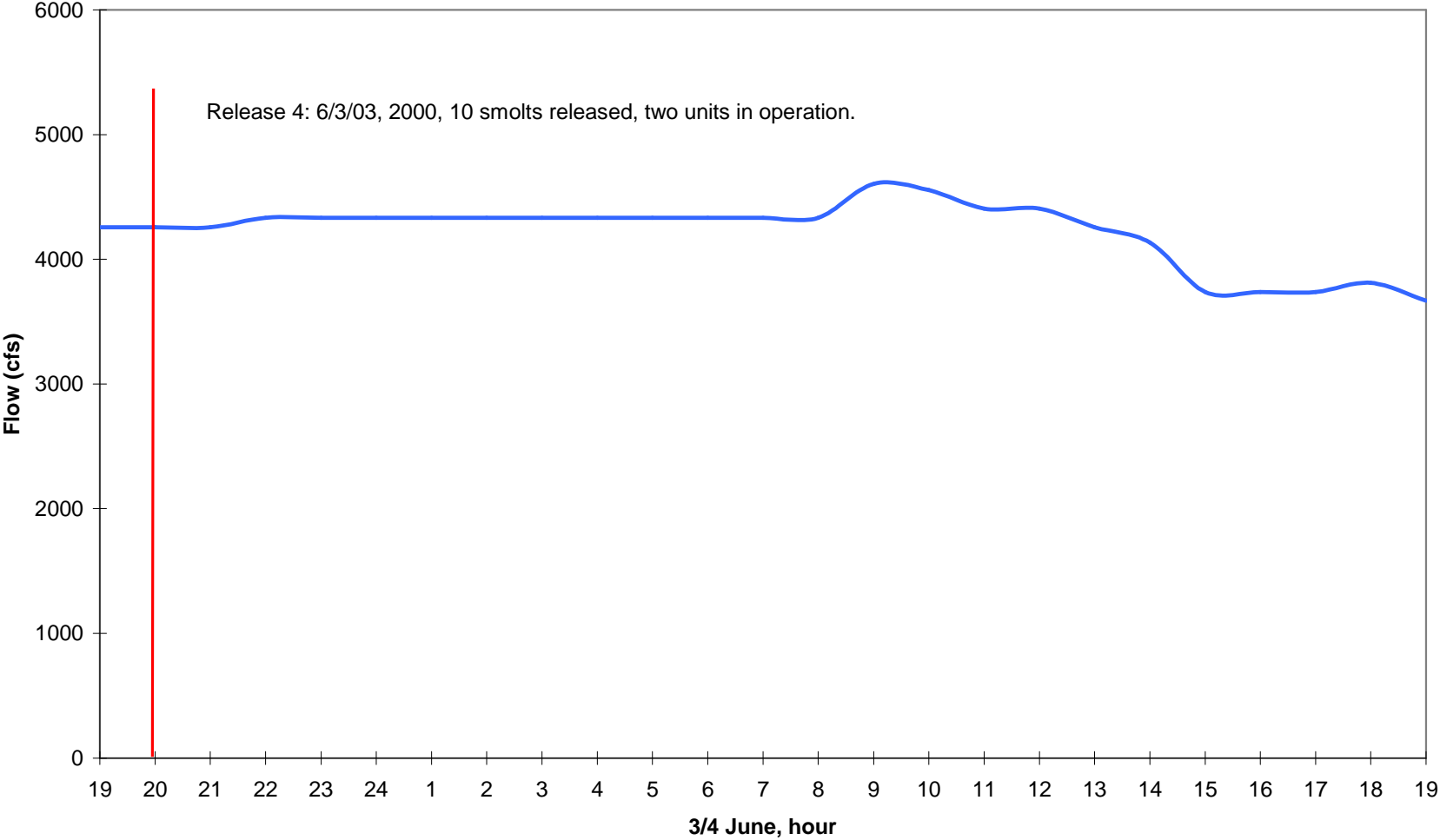
Appendix A (continued). Hourly River Discharge during Release 2. Merrimack Station
Downstream Smolt Passage, 2003.



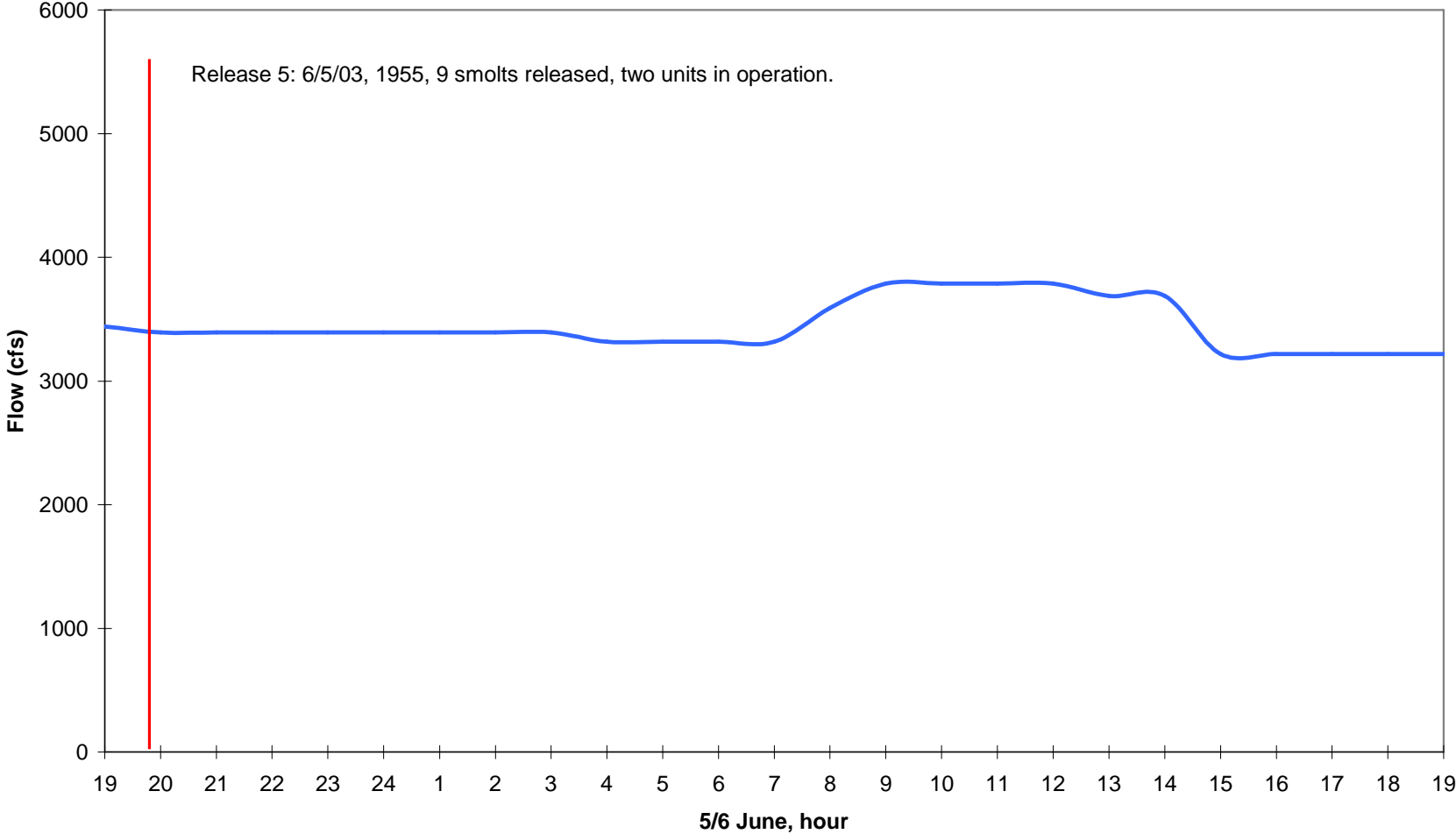
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Downstream Smolt Passage, 2003.



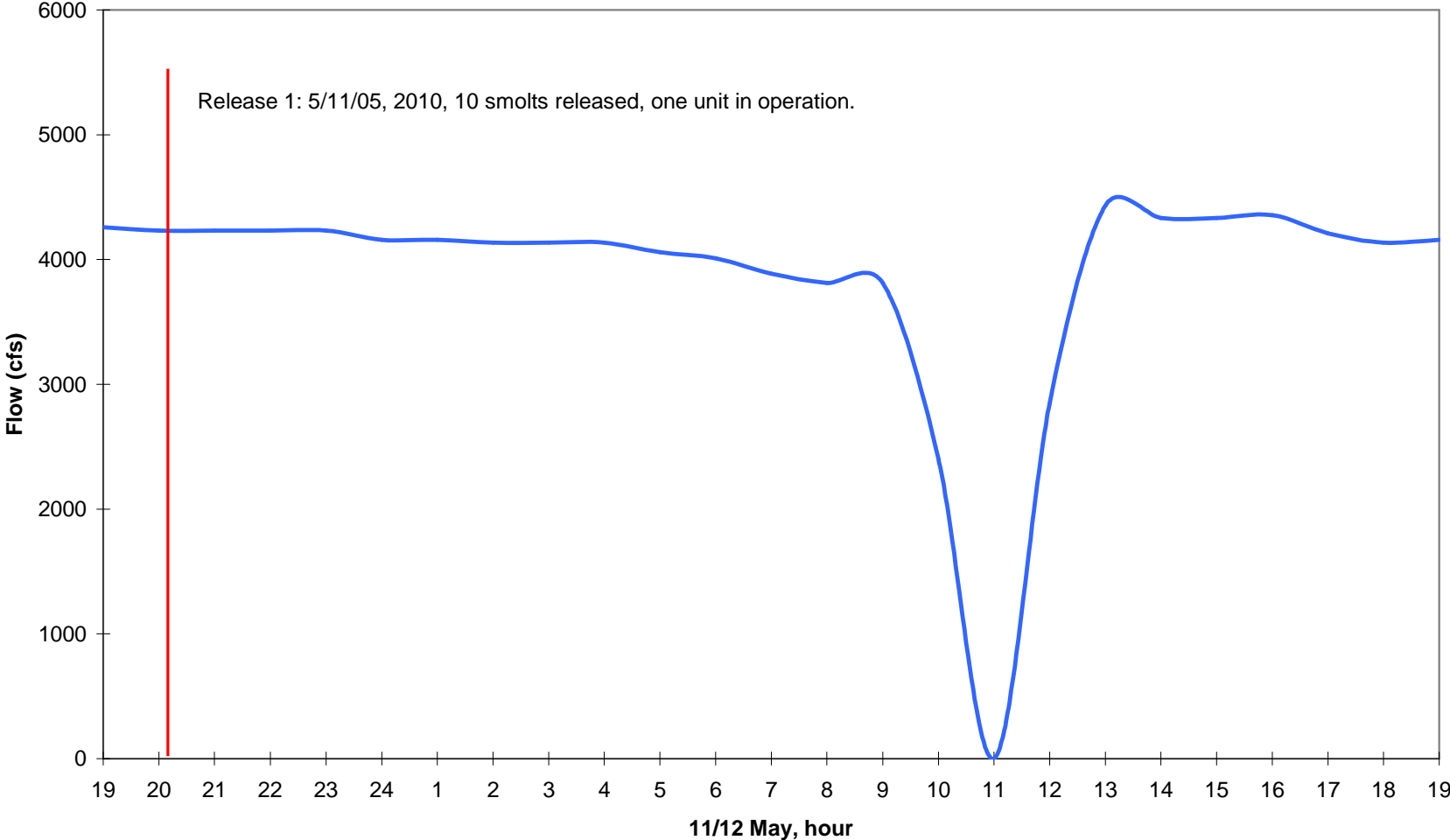
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Downstream Smolt Passage, 2003.



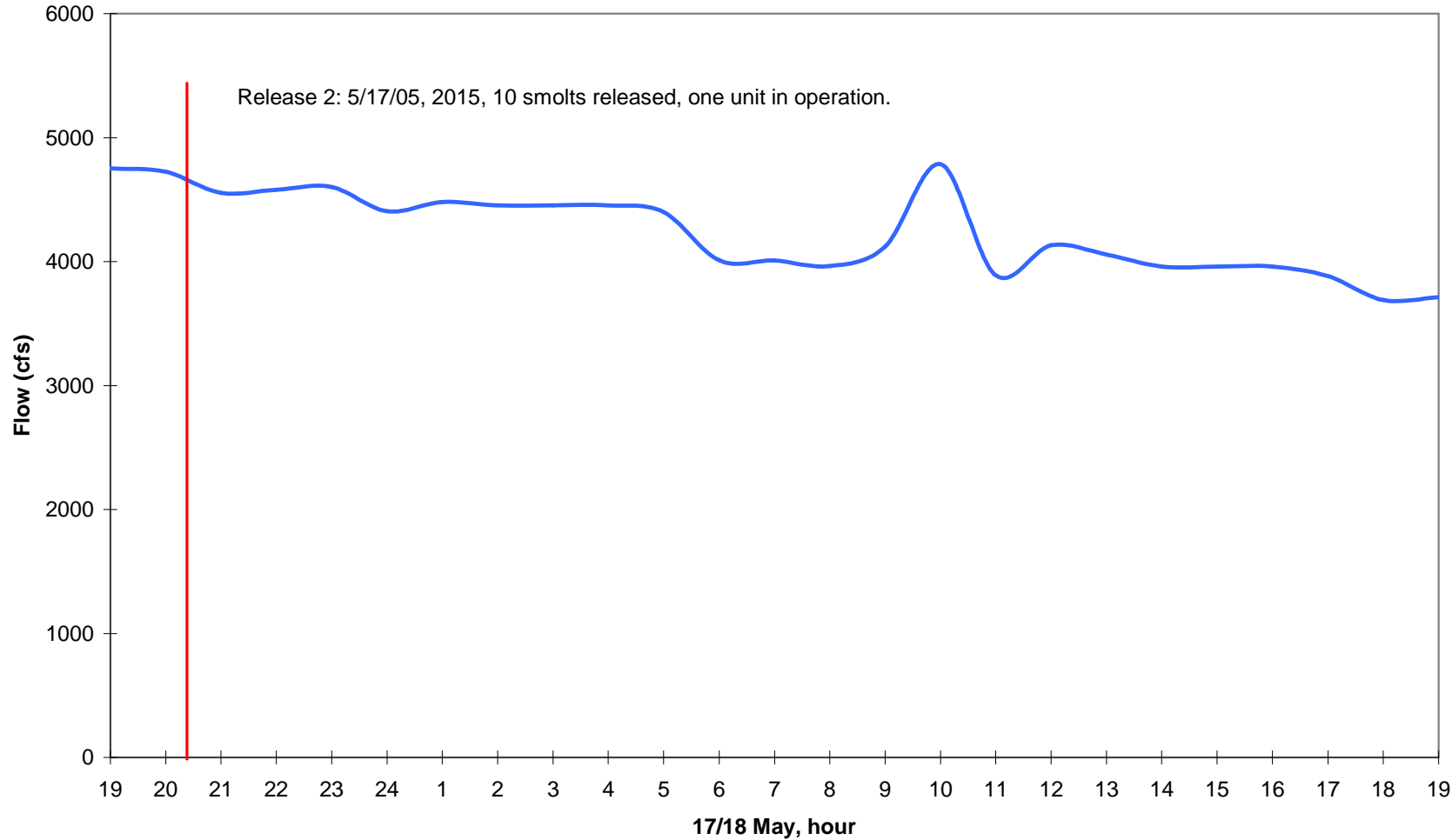
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Downstream Smolt Passage, 2003.



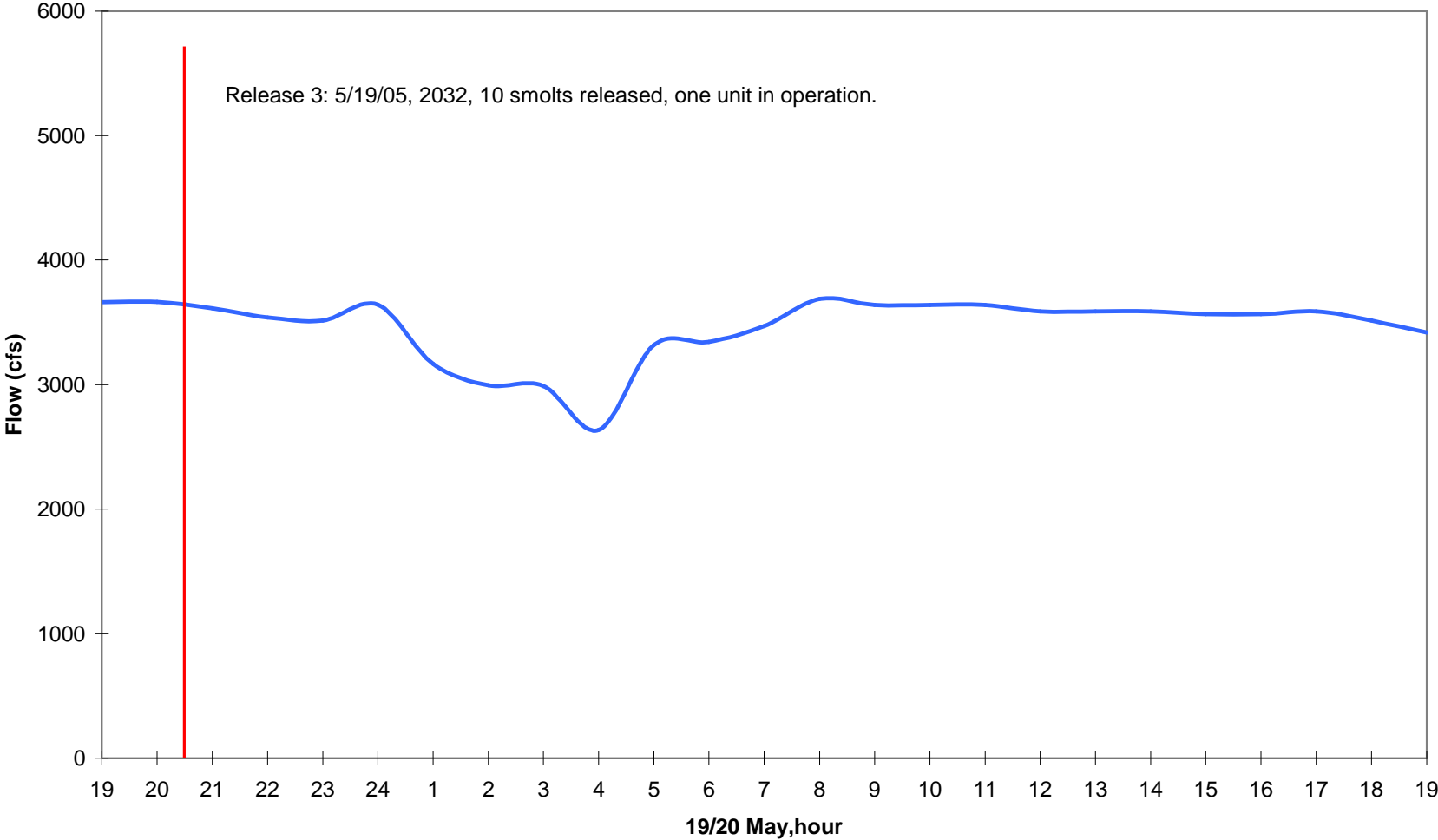
Appendix A (continued). Hourly River Discharge during Release 1. Merrimack Station
Downstream Smolt Passage, 2005.



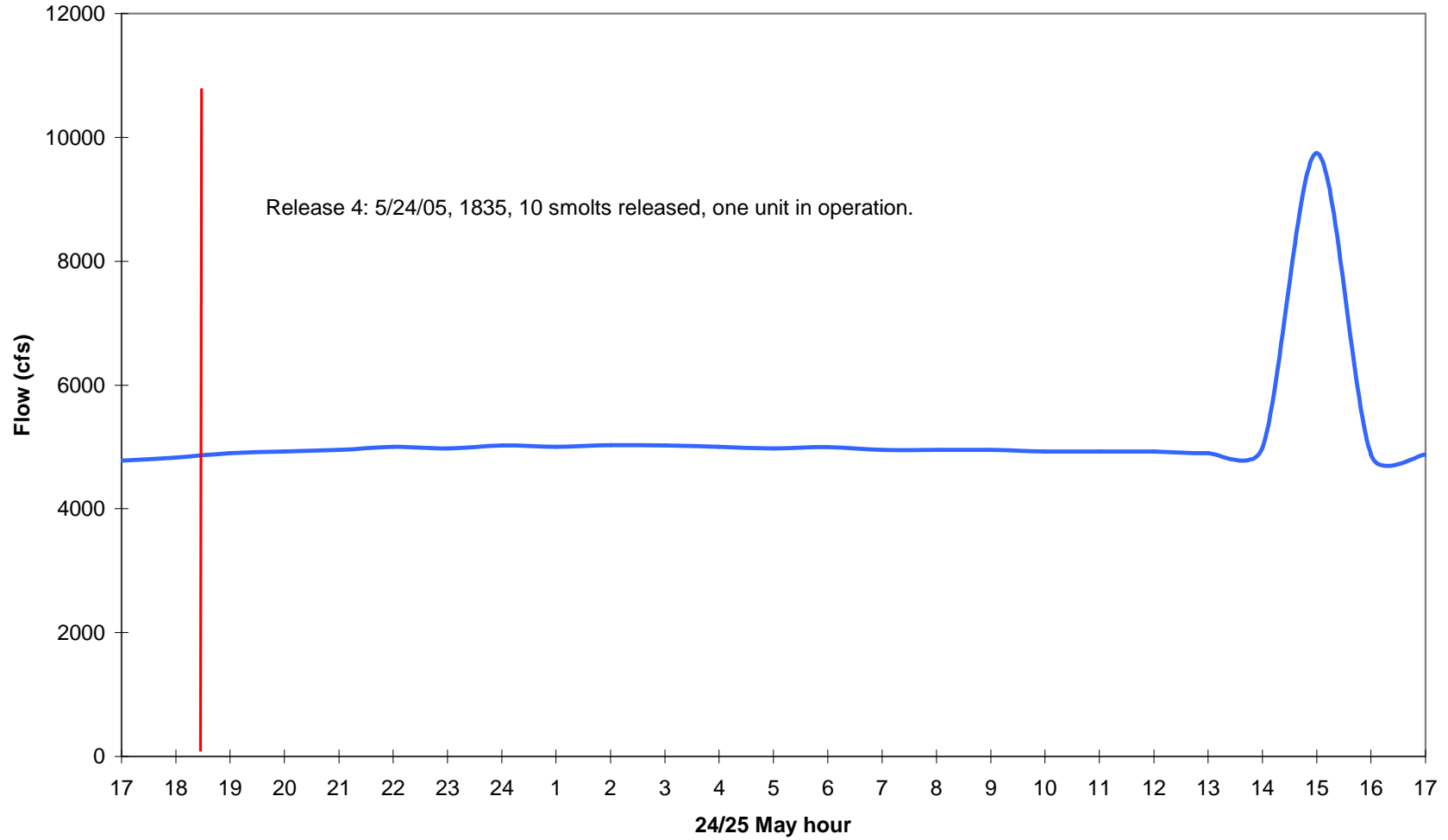
Appendix A (continued). Hourly River Discharge during Release 2. Merrimack Station
Downstream Smolt Passage, 2005.



Appendix A (continued). Hourly River Discharge during Release 3. Merrimack Station
Downstream Smolt Passage, 2005



**Appendix A (continued). Hourly River Discharge during Release 4. Merrimack Station
Downstream Smolt Passage, 2005.**



Appendix A (continued). Hourly River Discharge during Release 5. Merrimack Station
Downstream Smolt Passage, 2005.

