FISHERY RESEARCH

DWORSHAK KOKANEE POPULATION AND ENTRAINMENT ASSESSMENT

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Prepared by:

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Dworshak Kokanee Population and Entrainment Assessment

Project Progress Report

2005 Annual Report

By

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ABSTRACT

During this contract, we continued testing underwater strobe lights to determine their effectiveness at repelling kokanee *Oncorhynchus nerka* away from Dworshak Dam. We tested one set of nine strobe lights flashing at a rate of 360 flashes/min in front of turbine 3 while operating at higher discharges than previously tested. The density and distribution of fish, (thought to be mostly kokanee), were monitored with a split-beam echo sounder. We then compared fish counts and densities during nights when the lights were flashing to counts and densities during adjacent nights without the lights on. On five nights between January 31 and February 28, 2006, when no lights were present, fish counts near turbine 3 averaged eight fish and densities averaged 91 fish/ha. When strobe lights were turned on during five adjacent nights during the same period, mean counts dropped to four fish and densities dropped to 35 fish/ha. The decline in counts (49%) was not statistically significant ($p = 0.182$), but decline in densities (62%) was significant ($p = 0.049$). There appeared to be no tendency for fish to habituate to the lights during the night. Test results indicated that strobe lights were able to reduce fish densities by at least 50% in front of turbines operating at higher discharges, which would be sufficient to improve sportfish harvest.

We also used split-beam hydroacoustics to monitor the kokanee population in Dworshak Reservoir during 2005. Estimated abundance of kokanee decreased from the 2004 population estimate. Based on hydroacoustic surveys, we estimated 3,011,626 kokanee (90% CI ± 15.2%) in Dworshak Reservoir, July 2005. This included 2,135,986 age-0 (90% CI ± 15.9%), 769,175 age-1 (90% CI ± 16.0%), and 107,465 age-2 (90% CI ± 15.2%). Poor survival of kokanee from age-1 to age-2 continued to keep age-2 densities below the management goal of 30-50 adults/ha.

Entrainment sampling was conducted with fixed-site split-beam hydroacoustics a minimum of two days per month for a continuous 24 h period when dam operations permitted. The highest fish detection rates from entrainment assessments were again found during nighttime periods and lowest during the day. Fish detection rates were low during high discharges throughout the spring and summer and highest during low discharges in September and November. High discharge during drawdowns for anadromous fish flows in July and August again resulted in low detection rates and susceptibility to entrainment.

Index counts of spawning kokanee in four tributary streams totaled 12,742 fish. This data fits the previously developed relationship between spawner counts and adult kokanee abundance in the reservoir.

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INTRODUCTION

Fisheries for kokanee *Oncorhynchus nerka* in the Pacific Northwest are very popular (Wydoski and Bennett 1981; Rieman and Myers 1992). Kokanee feed low on the food chain and may reach densities in excess of 150 harvestable-sized fish/ha even in relatively sterile waters (Maiolie et al. 1991). They also appear to be an ideal fish in fluctuating reservoirs since they inhabit the open pelagic zone and some strains spawn in tributary streams away from the potential impacts of water level fluctuations.

However, kokanee can exhibit behavioral tendencies to school and emigrate resulting in potentially large entrainment losses. Entrainment losses have been documented in Libby Reservoir in Montana (Skarr et al. 1996); Banks Lake, Washington (Stober et al. 1979); and Dworshak Reservoir (Maiolie and Elam 1998). At Dworshak Reservoir, it was estimated that 1.4 million kokanee (95% of the population) were lost through the dam in a period of 5 months in 1996 (Maiolie and Elam 1998).

Thus, entrainment loss of kokanee has been established as an important factor contributing to variability in the population. In 1996, losses of kokanee were severe enough that they strongly affected the angler's success in subsequent years, and years with high discharge have correlated with lower kokanee populations in the reservoir (Maiolie and Elam 1993). When densities are high, Dworshak Reservoir becomes one of the best kokanee fisheries in the state, accounting for a harvest of over 200,000 fish annually. When densities are low, catch rates, harvest, and fishing effort are sharply reduced (Mauser et. al. 1990).

Dworshak Reservoir has also become increasingly important for providing additional river flows to benefit salmon and steelhead. Each year during May, July, and August, large amounts of water are released to aid smolt migration and cool water temperatures in the Lower Snake River. Approximately 1.2 million acre feet of water stored in Dworshak Reservoir is discharged to implement summer flow augmentation for the Snake River identified in the 2000 FCRPS Biological Opinion (National Marine Fisheries Service 2000). This increase in discharge, however, has the potential to entrain additional fish during the summer.

Physically screening Dworshak Dam to prevent fish losses would be very difficult because of high discharge (800 m^3/s) and the large amounts of debris within the reservoir. Therefore, one major task of this project was to test behavioral avoidance devices to determine if kokanee and other fish can be deterred from the turbine intakes and effectively decrease entrainment.

Many previous studies have achieved good success at affecting the behavior of different species of fish with the use of strobe lights in a number of different conditions (Patrick 1982; Nemeth and Anderson 1992; Winchell et al. 1994; Ploskey and Johnson 1997, 2001). Strobe light testing for this project was first conducted offsite in 1997 in Spirit Lake and Lake Pend Oreille and again in 1998 on Lake Pend Oreille. In 1998, kokanee avoided the strobe lights throughout the night and remained 30 to 136 m away in the open water of Lake Pend Oreille (Maiolie et al. 2001a). Lights were found to be even more effective during winter (the season of the highest entrainment losses) when water clarity was highest.

Onsite strobe light testing was conducted in December 2001 and January 2002 in front of turbine 2. This testing showed an 88% mean decrease in fish densities from control samples with the lights off to test samples with the lights. The next phase in onsite testing involved evaluating the effectiveness of strobe lights to reduce kokanee densities near discharging reservoir outlets (ROs). Testing at this location was deemed important since the ROs are

smaller openings and, therefore, attain higher intake water velocities. Therefore, these areas could also present a bigger challenge to maintaining the position of strobe light systems. Results from strobe tests in front of ROs were also highly effective, reducing fish densities by 66% (Stark and Maiolie 2004). Testing continued in 2004, utilizing a strobe system each in front of simultaneously discharging turbines 1 and 2. These tests proved the most effective to date, with an 87% reduction in fish counts ($t = -4.417$, $n = 5$, $p = 0.012$) and a 90% reduction in fish densities ($t = -4.848$, $n = 5$, $p = 0.008$) with strobes flashing (Stark 2007).

This report describes ongoing strobe light testing at Dworshak Dam, entrainment sampling, and kokanee population monitoring. During this contract, we tested strobe lights in front of turbine 3 under high discharge rates. We also assessed the diel and seasonal susceptibility of kokanee to entrainment through turbine intakes under varying discharge, pool elevation, and water clarity. Lastly, mobile split-beam hydroacoustics were used to quantify abundance of kokanee. Angler caught kokanee were aged and measured to estimate mean age at length as a measure of the population size structure. Kokanee abundance in the reservoir was compared to previous estimates to determine the impacts of the current operation of the dam on the kokanee population relative previous operations.

OBJECTIVE

1. To maintain densities of 30 to 50 adult (age-2 and older) kokanee/ha in Dworshak Reservoir by reducing entrainment losses.

STUDY AREA

Dworshak Dam is located on the North Fork of the Clearwater River in northern Idaho. At 219 m tall, it is the tallest straight-axis concrete dam in the United States. It was built in 1971 by the U.S. Army Corps of Engineers (USACE) for power production and flood control. Three turbines within the dam have a total operating capacity of 450 megawatts. The dam can discharge up to 380 m^3/s (10,000 cfs) through the turbines and an additional 420 m^3/s (15,000 cfs) through reservoir outlets and the spillway.

Dworshak Reservoir is 86 km long at full pool (Figure 1). Maximum and mean depths are 194 m and 56 m, respectively. Surface area at full pool is 6,644 ha with 5,400 ha of kokanee habitat (defined as the area over 15 m deep). Drawdowns for flood control may lower the surface elevation 47 m and reduce surface area by as much as 52%. The reservoir has a mean hydraulic retention time of 10.2 months and a mean annual discharge of 162 m^3/s (Falter 1982). High releases from the reservoir occur during spring runoff, during the fall when the reservoir is lowered for flood control, and during late summer when water is released for anadromous fish flows.

Kokanee were first stocked into Dworshak Reservoir in 1972 (Horton 1981). Four sources of fish were initially used, but the early spawning strain from Anderson Ranch Reservoir, Idaho now populates the reservoir (Winans et al. 1996). These fish spawn during September in tributary streams as far as 140 km above the reservoir. They reach maturity primarily at age-2, although age-1 and age-3 spawners are occasionally found. Adults range in size from 200 to 400 mm in total length depending on the density of fish in the reservoir, but generally average 300 mm during spawning (Maiolie and Elam 1995).

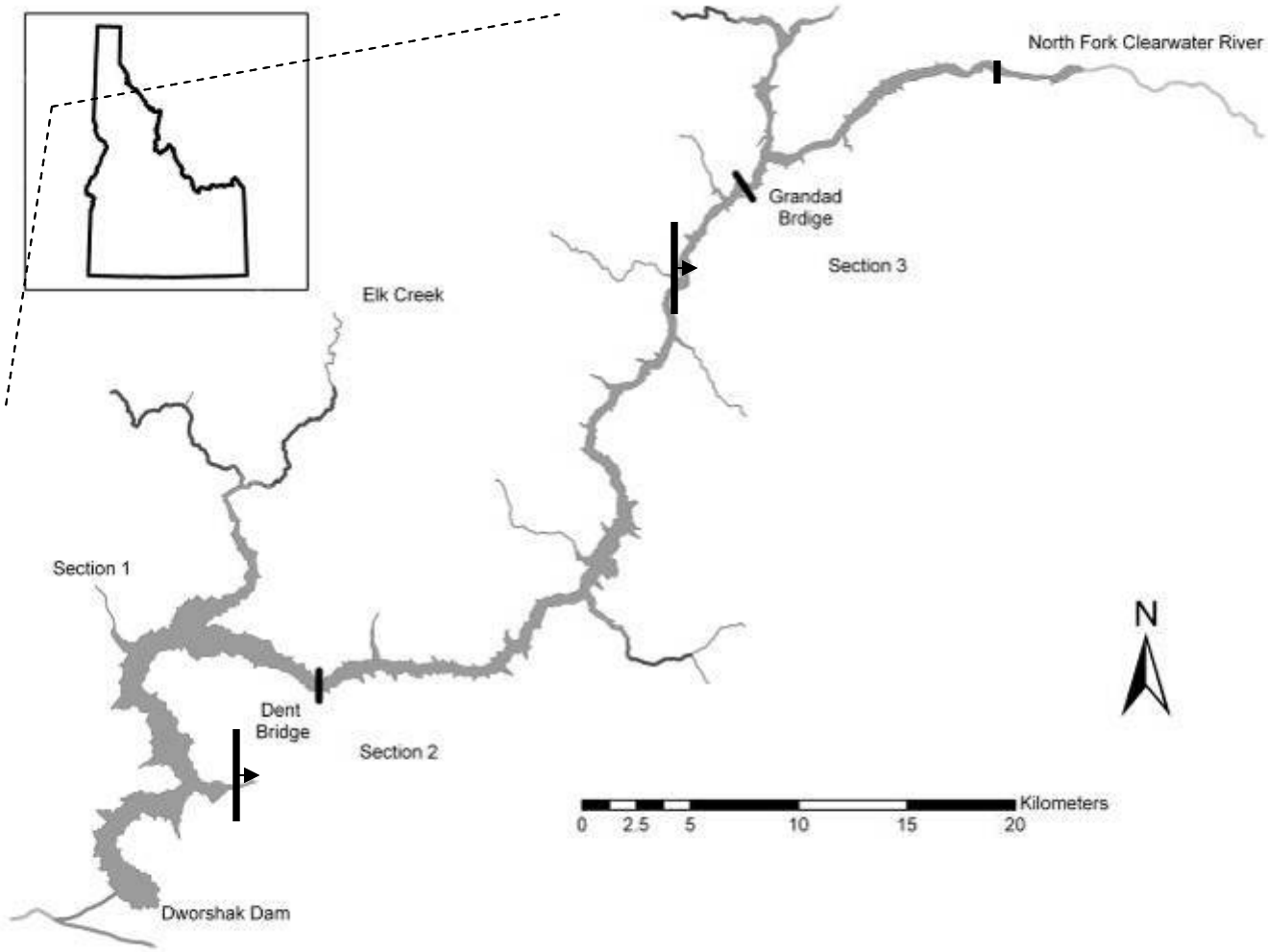

Figure 1. Map of Dworshak Reservoir and its major tributaries and reservoir sections, North Fork Clearwater River, Idaho.

METHODS

Strobe Light Testing

Strobe light tests were conducted on ten nights between January 30 and February 28, 2006 in front of turbine 3. Mean discharge through turbine 3 was 137 m^3/s during the tests but varied from 122 m^3/s to 164 m^3/s (Table 1). Turbine 3 is the largest of three turbines on Dworshak Dam with 220 MW of power production capacity. A paired replicate consisted of two consecutive nights: one test night and one control night. A random selection (coin flip) was used to determine which sample (test or control) occurred first for each paired replicate. Control samples were nights with no strobe lights flashing, and test samples were nights when strobe lights were deployed and flashing.

One strobe light system was used during these tests in front of turbine 3. The strobe system consisted of nine individual lights, with two whirls of four lights and a single light pointed directly downward from the lower whirl of lights. Lights in each whirl were pointed horizontally and were positioned 90° from each other. Lights were raised and lowered on a 6.4 mm steel cable using a 3600 kg vehicle winch.

All turbines were operated in undershot mode during this study, which means their selector gates were pulled up. Undershot mode allows water to enter straight into the penstock opening without going over the selector gate, which effectively creates a larger water intake opening or water withdrawal zone. Throughout the study the top whorl, bottom whorl, and down-pointing light were positioned at 27.4, 30.5, and 30.8 m deep, respectively. The top whorl was 4.2 m above the top, bottom whorl 3.2 m below the middle, and down-pointing light was 0.6 m below the bottom of the turbine opening, respectively. All lights flashed simultaneously at 360 flashes/min. During the study, the reservoir pool elevation ranged from 460.1 to 461.3 m above mean sea level (MSL).

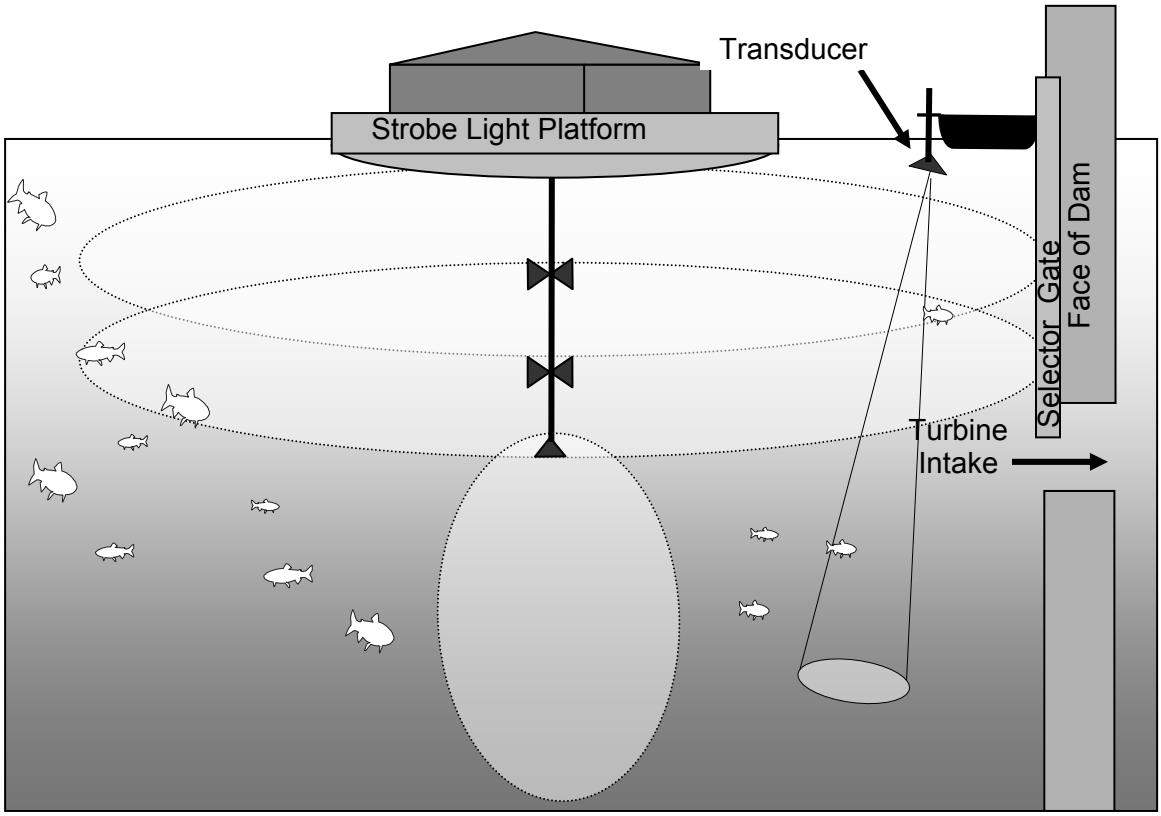

Figure 2. Diagram of strobe light and hydroacoustic equipment setup during testing to deter kokanee away from discharging turbine 3 of Dworshak Dam, Idaho.

During sampling, hydroacoustic survey transects were conducted parallel with the face of the dam, about 5-10 m out into the reservoir; each hour throughout the night from approximately 6:00 PM to 6:00 AM (Figure 2). Hydroacoustic surveys were conducted with a Simrad™, Inc. EY-500 split-beam scientific echo sounder with a 120 kHz transducer. We calibrated the echo sounder at the beginning of the year using a 23 mm copper calibration sphere with a target strength (TS) of -40.4 decibels (dB). We checked the calibration of the echo sounder prior to the start of the study and adjusted the transducer gains if needed. Boat speed during transects averaged 1.1 m/s. Secchi disc transparencies were also measured each day of the testing to relate strobe light effectiveness to water clarity.

We analyzed the data from each hydroacoustic transect to detect fish in an area from 2 to 60 m deep and 60 m wide (30 m on either side of the lights) directly upstream of the operating turbine. The number of fish detections and subsequent densities were calculated using SonarData Echoview™ 3.5 hydroacoustic analysis software. We configured the Echoview analysis settings so that only echoes meeting certain criteria would be considered as a fish, thereby eliminating turbine noise from the echograms and subsequent analyses. We used a minimum TS threshold of -45 dB, so only echoes larger than -45 dB in TS (a fish 97 mm total length based on Love [1971]) were included in the analyses. The maximum beam compensation was set at 6.0 dB, and we used Echoview minimum and maximum normalized pulse lengths of 0.3 and 1.8 respectively.

Table 1. Experimental design (replicates and treatments) and reservoir conditions during ten nights of strobe light research in front of Dworshak Dam, January 30—February 28, 2005.

Date	Replicate	Treatments	Mean Discharge (m^3/s) Turbine 1	2	3	Pool Elevation (m above MSL)	Secchi Transparency (m)
1/30/06	1	Test	0	29	122	469.4	5.5
1/31/06	1	Control	38	0	133	469.4	5.5
2/1/06	2	Control	65	0	141	469.3	5.4
2/2/06	2	Test	65	0	142	469.1	5.4
2/13/06	3	Test	0	65	161	467.0	4.8
2/14/06	3	Control	0	65	162	467.0	4.8
2/21/06	4	Test	47	18	147	465.2	4.3
2/22/06	4	Control	0	48	150	465.2	4.3
2/27/06	5	Test	0	21	152	464.8	4.1
2/28/06	5	Control	30	36	152	464.8	4.1
		Minimum	0	0	122	464.8	4.1
		Maximum	66	65	164	469.4	5.5
		Mean	17	28	137	467.1	4.8

In addition to the aforementioned echo criteria, we used the following track acceptance criteria. We required a minimum of three single target detections, a minimum of three pings, and a maximum of one missing ping per track to qualify targets as a fish track. Counting of fish tracks meeting both the echo and track criteria was conducted on each transect file again using Echoview™ 3.5 software. Echoes meeting the above criteria were counted as a single fish.

Estimates of both numbers of fish and fish densities (fish/ha) in hourly transects were averaged for the entire night to comprise one sample. We then used SYSTAT™ version 11.0 to run a paired *t*-test of control versus test samples to determine if differences in fish numbers and densities existed. We considered there to be statistically significant differences between control and test groups if $p < 0.05$. Strobe lights were deemed effective biologically if they were able to reduce fish entrainment by at least 50%. We also quantified the change in fish counts and densities by calculating 95% confidence intervals around the difference between control and test samples.

Lastly, the distance (m) from the strobe lights to the nearest fish in each of three directions, left or right (laterally) and below the lights, was calculated. Lateral distances were calculated by multiplying the number of pings between the fish and the strobe lights, times the ping rate in s/ping, and then multiplying by the boat speed for each transect. Again, we performed a paired *t*-test using SYSTAT to determine if there was a statistical difference in the distance fish were deterred in control transects versus test transects. Differences were considered significant if $p < 0.05$.

Kokanee Population Estimate

A standardized hydroacoustic survey was conducted to estimate kokanee abundance and density in Dworshak Reservoir on the evenings of July 11-13, 2005. The reservoir was stratified into three sections: from the dam to Dent Bridge, Dent Bridge to Granddad Bridge, and

Granddad Bridge to the slack water area (Figure 1), and a stratified systematic sampling scheme was used to estimate kokanee abundance and density for the population estimate. Survey transects were conducted in a zigzag fashion from one side of the reservoir to the other, with one transect starting where the previous transect ended, proceeding up the length of the reservoir. The angle between transects was never less than 90 degrees.

We used a BioSonics, Inc. DE-X™ split-beam scientific echo sounder with a 201 kHz transducer to document the abundance and distribution of kokanee. Boat speed was 1.5 to 2.1 m/s, and all surveys were conducted all night. The echo sounder was set to ping at 1.0 s intervals, with a pulse width of 0.3 milliseconds. Data were collected with a time varied gain constant of 20 log r (range). Echo sounder calibration and single trace criteria were performed and configured respectively as described previously in the strobe light testing methods.

Fish density estimates were calculated using BioSonics, Inc. Visual Analyzer™ software, version 4.2. Densities were estimated by echo integration techniques to account for fish within schools that could not be distinguished as single targets. We analyzed only the pelagic region of each echogram at depths from 10 m to 30 m.

Anglers were surveyed during routine field activities to obtain kokanee data. Scales from angler-caught kokanee were used to verify lengths of kokanee within each age class. Scales were collected dorsally to the lateral line and posterior to the dorsal fin using techniques described by Nielsen and Johnson (1985). Using a blunt knife, scales were loosened by scraping toward the head. Six to twelve scales were collected from each fish and sealed in a coin envelope labeled with total length (TL) and date collected. Scales were prepared by pressing them between two acetate slides. The slides were then viewed using a microfiche reader to examine patterns of growth from impressions of the scales on the slides. Areas of relatively slower growth signifying the end of one year's growth (annuli) were counted to determine age. These aging techniques are described by Nielsen and Johnson (1985).

Age-at-length information from angler-caught kokanee combined with hydroacoustic data were both utilized to define the age classes of acoustic targets. The total lengths of all angler-caught kokanee were transformed into TS (-dB) using Love's (1971) equation to approximate the acoustic TS range (-dB) of each age class. Then, using the age class TS ranges the proportion of acoustics targets in each range was estimated for each hydroacoustic transect. These age class proportions were subsequently used to apportion the total population estimate and density into abundance and density estimates for each age class.

During sampling, the reservoir elevation varied from 485.6 to 486.1 m (1,593 to 1,595 ft) and the midpoint of the kokanee layer was about 19.6 m deep (64.3 ft). Therefore, we calculated kokanee densities using an area of 5,231 ha of kokanee habitat corresponding to an elevation of 466.3 m (1,530 ft).

Mean density of each age class of kokanee in each reservoir section was calculated and multiplied by the area of that section to obtain abundance estimates per reservoir section. Abundance estimates for each reservoir section were totaled to obtain total age class population estimates and the age class estimates totaled to obtain total kokanee abundance in the entire reservoir. Ninety percent confidence intervals were calculated on the age-0, age-1, age-2, and total kokanee abundance estimates using a formula for stratified systematic designs (Scheaffer et al. 1990).

Entrainment

Entrainment sampling was conducted two days per month during most months (each for a continuous 24 h period) when the forebay area was accessible. This monitoring provided baseline information on time of day fish were susceptible to entrainment; detection rate immediately in front of each turbine and reservoir outlet; and the degree of variation in fish susceptibility that can be expected between the time of day, seasons, and discharge rate. Secchi disc transparencies were also measured during most hydroacoustic sample periods. These were used to relate water clarity to discharge rate and entrainment susceptibility.

A wooden dock was secured to the trash racks of the turbine to be sampled (Figure 3). The hydroacoustic equipment was set up under the protection of a tent, which was attached to the dock. The echo sounder's transducer was attached to a pole, which was secured to the dock and pointed between 1° and 5° from vertical, outward from the face of the dam. This angle was adjusted for each sampling period depending upon the pool elevation and selector gate mode and depth. The outward angle and distance from the face of the dam were set to maximize the echogram coverage of the turbine opening yet still ensure that return echoes from the face of the dam did not interfere with detecting fish targets.

During sample periods when turbines were discharging in 'overshot mode' (meaning the selector gate was lowered in front of the turbine opening and water flows over the top of the gate) only fish echoes in a zone from approximately 10.0 m above to 5.0 m below the selector gate's top (15.0 m tall zone) were counted. During sample periods when turbines were discharging in 'undershot mode', meaning the selector gate was raised allowing water to flow straight into the turbine opening, only fish echoes within the depths of the opening were counted. The intake openings for turbines 1 and 2 are located between 429.2 and 437.4 m above MSL, which results in an 8.2 m analysis zone when the turbines are operating in undershot. The opening for turbine 3 is located between 425.2 and 437.4 m above MSL, which results in a 12.2 m analysis zone when the turbine is operating in undershot mode. The center of the analysis zone was considered the depth of the selector gate if in overshot mode, or the center of the turbine opening (penstock) if in undershot mode.

We used the above echo sounder placement and sampling methods to estimate hourly rate of kokanee detection immediately in front of a single operating turbine or reservoir outlet. A BioSonics, Inc. DE-X™ split-beam scientific echo sounder with a 201 kHz transducer was used for all entrainment assessment sampling. The echo sounder was professionally calibrated by the manufacturer prior to the start of sampling in March 2004. Prior to each sample period, we checked the calibration of the echo sounder by measuring the TS of a 36 mm diameter standard calibration sphere, then compared the TS against the known TS of the sphere at the sample water temperature and adjusted the transducer gains if needed.

The echo sounder was set to ping at 5 pings per second with a pulse width of 0.3 milliseconds. The maximum beam compensation was set at 6.0 dB. In addition, the returned echo had to be greater than -45 dB (>100 mm) (Love 1971) to be counted as a valid fish echo. This minimum threshold was necessary to avoid detection of echoes returning from the face of the dam, which would interfere with detection of small fish.

Further criteria were applied and analysis of fish echoes was then conducted on each hydroacoustic file using SonarData Echoview™ 3.0 post-processing software. We used Echoview minimum and maximum normalized pulse lengths of 0.3 and 1.8, respectively. We

then manually counted fish echoes meeting the following track recognition criteria. We required a minimum of three single target detections, a minimum of three pings, and a maximum of one missing ping per track to qualify targets as a fish track. Fish tracks meeting these track criteria were counted as a single fish.

We divided the total number of fish detected by the number of hours sampled to estimate a detection rate (fish/h). This was determined for each of four time strata (dawn, day, dusk, and night). The diameter of the beam (B) at the depth of the center of the intake opening was also calculated with the following equation:

$$\text{Beam diameter (B)} = 2 \times R \times [\, \text{Tan}\,(\, \theta / 2\,)\,]$$

Where: R = range (depth of intake opening)
Tan = tangent of the angle
θ = the nominal beam width
(6.6 degrees for the 201 kHz transducer).

The portion (%) of the intake sampled was calculated by dividing the diameter of the beam (B) by the width of the turbine opening (I). The original detection estimates were then expanded based on the percent coverage of the acoustic beam during each sample period, respectively.

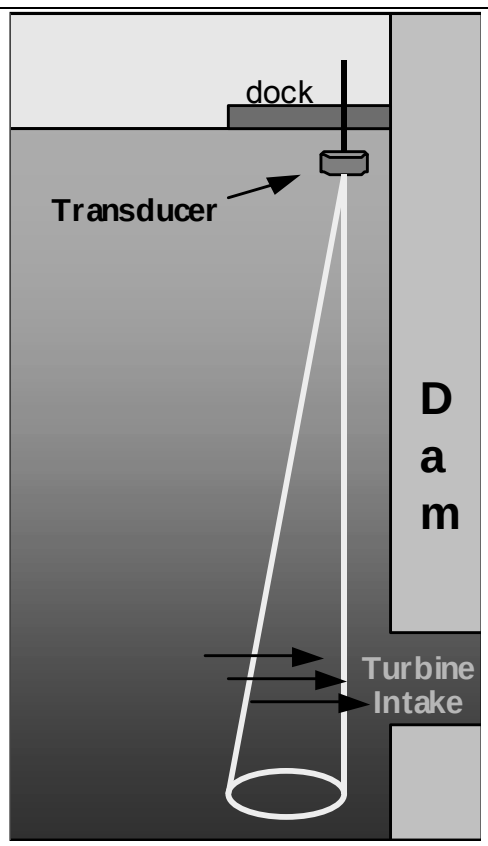

Figure 3. Location of the fixed-site echo sounding gear used to detect fish to determine their susceptibility to entrainment into turbines and reservoir outlets of Dworshak Dam, Idaho.

Discharge

Data on daily discharge, pool elevation, turbines operating, reservoir outlets in use, and spillway operation for the year were obtained from the USACE Dworshak Project Control Room. The timing and magnitude of discharge from Dworshak Dam was used to examine correlations between entrainment potential and population abundances. Discharge values were measured in cubic meters per second (m^3/s), and pool elevation measured as meters above MSL.

Spawner Counts

We counted kokanee in four tributaries to the North Fork of Clearwater upstream of Dworshak Reservoir on September 24 and 25, 2005. These spawner counts serve as an additional relative index of the adult population abundance. Spawning kokanee were counted in Isabella Creek, Dog Creek, Skull Creek, and Quartz Creek. Streams were walked from their mouths to the furthest upstream reaches utilized by kokanee. These index tributaries have been surveyed annually since 1981 on or near September 25, which was determined to be the peak of kokanee spawning (Horton 1980). Total lengths of available dead or near dead kokanee were also measured to obtain an adult spawner length distribution.

RESULTS

Strobe Light Testing

Fish distribution near turbine 3 was noticeably different on nights when the strobe lights were flashing versus nights without the lights on (Table 2). When the lights were off, kokanee were scattered from approximately 5.0 to 80.0 m deep near the face of the dam directly in front of the discharging turbines. On nights when the lights were on, kokanee in the area near the turbines were far fewer in number and nearly all were repelled in excess of 30 m in all directions. Secchi transparency values during testing ranged from 4.1 to 5.5 m and averaged 4.8 m (Table 1).

Fish counts near turbine 3 were highly variable between hourly samples of both control and test acoustic samples; yet counts were reduced when strobe lights were on compared to when turned off (Figure 4). Control samples had fish counts from zero up to 22 fish, whereas test samples ranged from zero to 17 fish. The mean nightly count of fish near turbine 3 was 8.2 for control samples and 4.4 fish for test samples (Figure 5). The difference between control and test samples was not statistically significant ($p = 0.182$ probability level, with $n = 5$) (Table 2). Strobe lights reduced the number of fish near discharging turbine three by 62% or 4.0 fish (90% CI ± 3.4).

Fish densities near turbine 3 were also highly variable between hourly samples of both control and test acoustic samples; but again fish densities were reduced when strobe lights were on compared to when turned off. Control samples had fish densities from zero up to 271 fish/ha, whereas test samples ranged from zero to 120 fish/ha (Figure 6). The mean nightly density of fish near turbine 3 was 90.6 fish/ha for control samples and 34.8 fish/ha for test samples (Figure 7). The difference between control and test samples (62%) was statistically significant at $p = 0.049$ probability level, with $n = 5$ (Table 2). Strobe lights reduced the density of fish near discharging turbine three by 62% or 53.1 fish/ha (90% CI ± 28.2).

In addition, the distance from the strobe lights to the nearest fish varied largely between hourly samples, yet this distance was greater when the lights were on (Figure 8). The distance to the nearest fish in control samples ranged from 4.8 m to 92.4 m, whereas test samples ranged from 12.1 m to 136.0 m. The mean distance to the first fish was 35.6 m for control samples and 47.8 m for test samples (Table 2). The difference between control and test samples was significant: p = 0.001, n = 2. Strobe lights deterred fish near away from discharging turbine three 12.2 m (90% CI ± 16.3).

Table 2. Mean number of fish, fish density, and distance fish were deterred from strobe lights in a 58 m by 60 m area directly upstream of the openings of turbine 3 of Dworshak Dam, Idaho on ten paired nights, January 30–February 28, 2005. All variables were measured with one set of nine strobe lights flashing at 360 flashes/min (test) and without the lights turned on (control).

		Mean Tracks (number of fish)			**Mean Density (fish/ha)**			**Mean Distance Deterred (m)**		
Sample Dates	**Replicate**	**Ctrl**	**Test**	**% Decrease**	**Ctrl**	**Test**	**% Decrease**	**Ctrl**	**Test**	**% Increase**
Jan 30-31	1	8.4	3.0	68%	93.3	25.7	72%	37.8	54.4	144%
Feb 1-2	2	13.0	1.1	92%	129.6	8.8	93%	22.5	73.6	327%
Feb 13-14	3	5.6	2.9	48%	70.7	30.6	57%	50.8	38.7	76%
Feb 21-22	4	6.4	4.9	23%	55.3	37.3	33%	29.4	41.1	140%
Feb 27-28	5	7.8	9.6	-24%	90.1	71.2	21%	37.0	30.9	83%
	Mean	**8.2**	**4.2**	**49%, p = 0.182**	87.8	34.7	**60%, p = 0.049**	35.5	47.7	**134%, p = 0.001**
		Difference		**4.0**			**53.1**			**12.2**
	90% CI on Difference			**3.4**			**28.2**			**16.3**

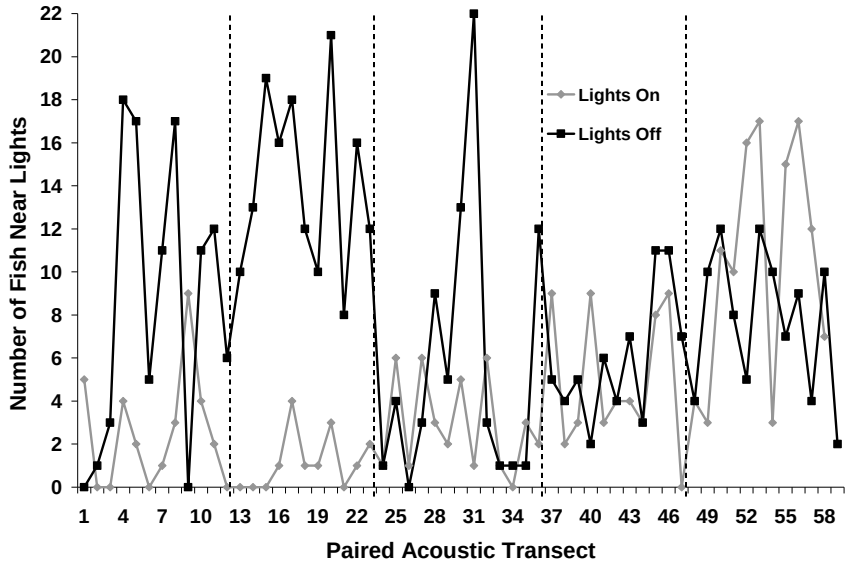

Figure 4. Number of fish in a 58 m by 60 m area directly upstream of turbine 3 during control (lights off) and test (lights on) mobile hydroacoustic transects in Dworshak Reservoir, Idaho. Hourly transects were conducted at night from 1800 to 0600 hours. The X-axis represents five nights each of control and test conditions with at least nine transects per night. Each replicate consisted of two consecutive nights, one control and one test. Replicates were conducted at least four days apart from each other except replicates one and two, which were consecutive nights.

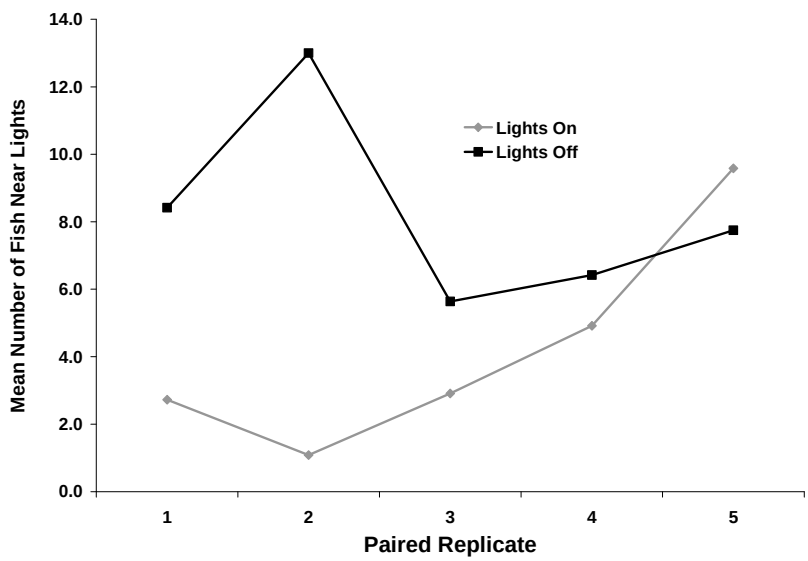

Figure 5. Mean number of fish in a 58 m by 60 m area directly upstream of turbine 3 during control (lights off) and test (lights on) mobile hydroacoustic transects in Dworshak Reservoir, Idaho. Hourly transects were conducted at night from 1800 to 0600 hours. The X-axis represents the mean of all transects for each of five nights for either control or test conditions. Each replicate consisted of two consecutive nights, one control and one test. Replicates were conducted at least four days apart from each other except replicates one and two, which were consecutive nights.

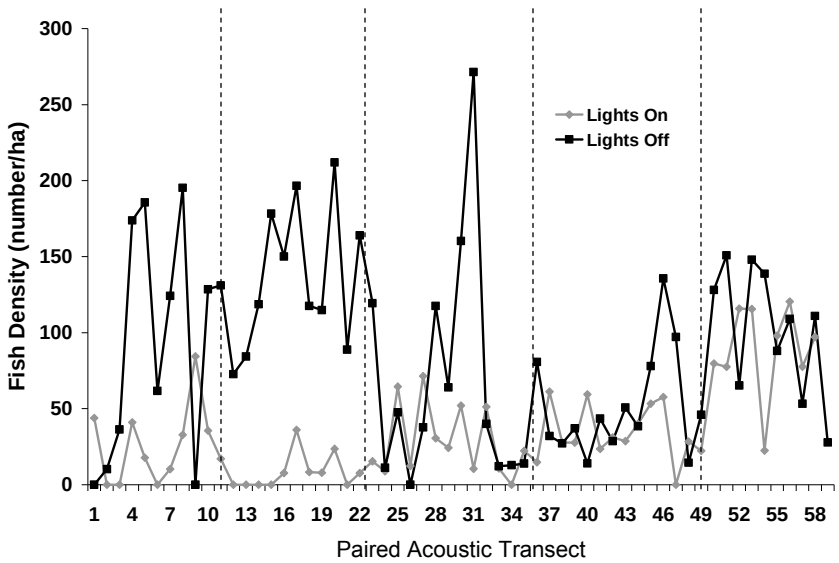

Figure 6. Fish density near turbine 3 during control (lights off) and test (lights on) mobile hydroacoustic transects in Dworshak Reservoir, Idaho. Hourly transects were conducted at night from 1800 to 0600 hours. The X-axis represents five nights each of control and test conditions with at least nine transects per night. Each replicate consisted of two consecutive nights, one control and one test. Replicates were conducted at least four days apart from each other except replicates one and two, which were consecutive nights.

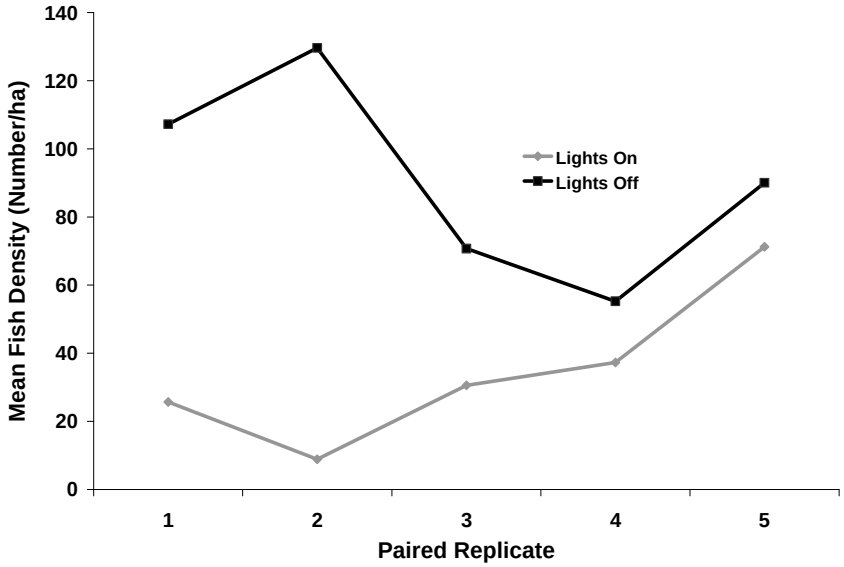

Figure 7. Mean fish density near turbine 3 during control (lights off) and test (lights on) mobile hydroacoustic transects in Dworshak Reservoir, Idaho. Hourly transects were conducted at night from 1800 to 0600 hours. The X-axis represents the mean of all transects for each of five nights each for control or test conditions. Each replicate consisted of two consecutive nights, one control and one test. Replicates were conducted at least four days apart from each other except replicates one and two, which were consecutive nights.

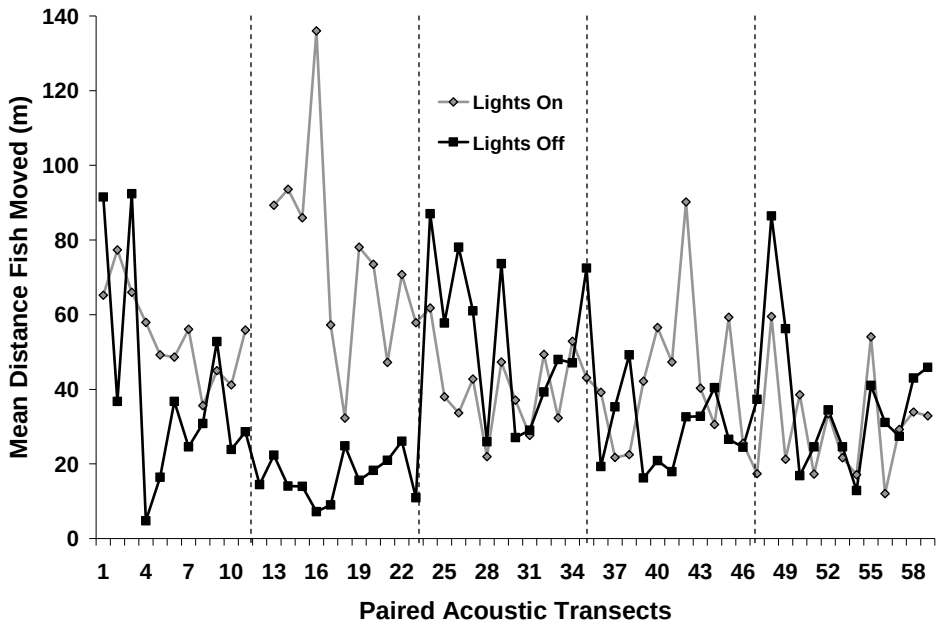

Figure 8. Mean distance fish moved from strobe lights near turbine 3 during control (lights off) and test (lights on) mobile hydroacoustic transects in Dworshak Reservoir, Idaho. Hourly transects were conducted at night from 1800 to 0600 hours. The X-axis represents five nights each of control and test conditions with at least nine transects per night. Each replicate consisted of two consecutive nights, one control and one test. Replicates were conducted at least four days apart from each other except replicates one and two, which were consecutive nights.

Kokanee Population Estimate

We estimated a total abundance of approximately 3,012,000 kokanee (90% CI ± 15.2%) in Dworshak Reservoir on July 2005; this included 2,135,000 age-0 (90% CI ± 15.9%), 769,000 age-1 (90% CI ± 16.0%), and 107,000 age-2 (90% CI ± 15.2%).

The total density of all kokanee was estimated at 576 fish/ha, with 408 age-0/ha, 147 age-1/ha, and 21 age-2/ha (Figure 10). The total abundance of kokanee was highest in section 2 (Figure 11), but total density was highest in section 3 (Figure 12). Abundance of age-1 and age-2 kokanee was highest in section 1; age-0 abundance was highest in section 2. Density of age-0 and age-2 kokanee was highest in section 3; age-1 density was highest in section 2.

Sixty-three kokanee were captured during creel surveys, with the largest measuring 312 mm (12.3 in) and smallest measuring 167 mm (6.6 in) (Figure 13). Angler caught kokanee were comprised of both age-1 and age-2 fish; no age-0 or age-3 kokanee were caught by anglers we sampled. Based on a length-at-age frequency distribution of angler caught fish, we estimated age-2 kokanee ranged from 200 to 369 mm TL (7.9 to 14.5 in) (Figure 9, 13).

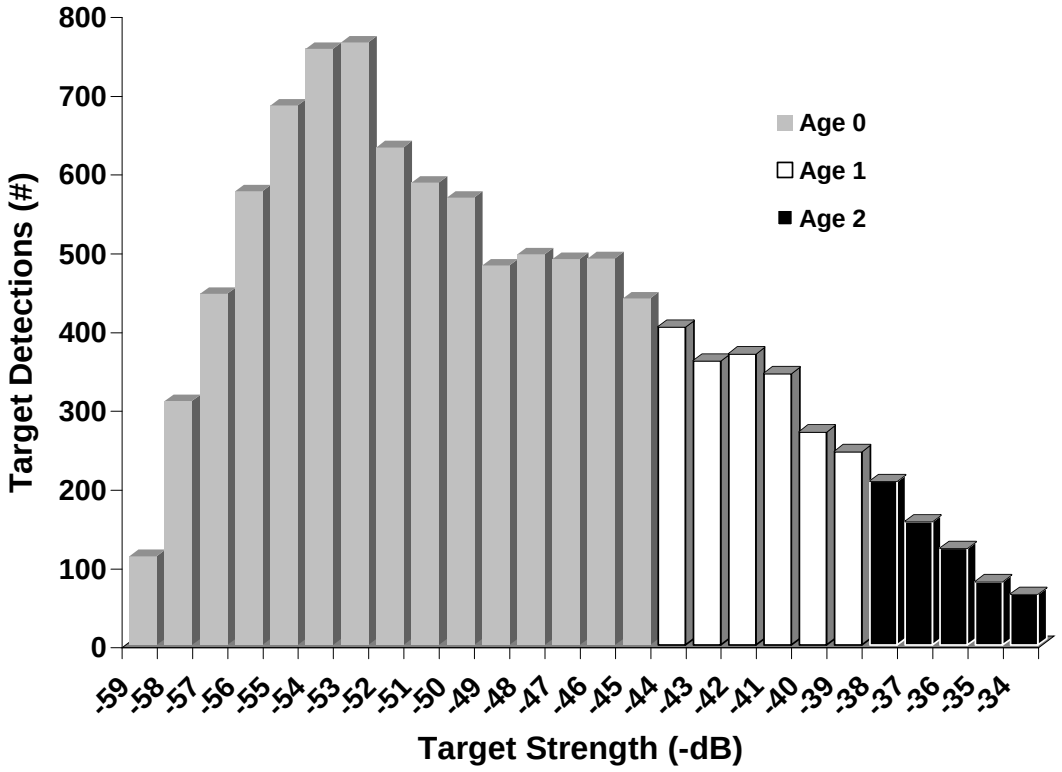

Figure 9. Dworshak Reservoir target strength (length) frequency from reservoir-wide hydroacoustic sampling, July 11-13, 2005.

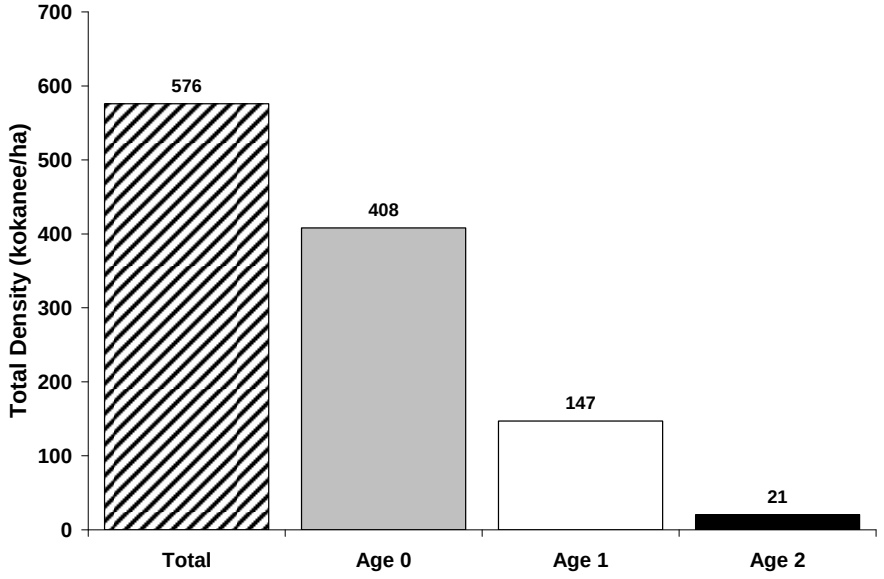

Figure 10. Density of age-0, age-1, age-2, and combined total density of kokanee in Dworshak Reservoir, July 11-13, 2005, obtained from hydroacoustics.

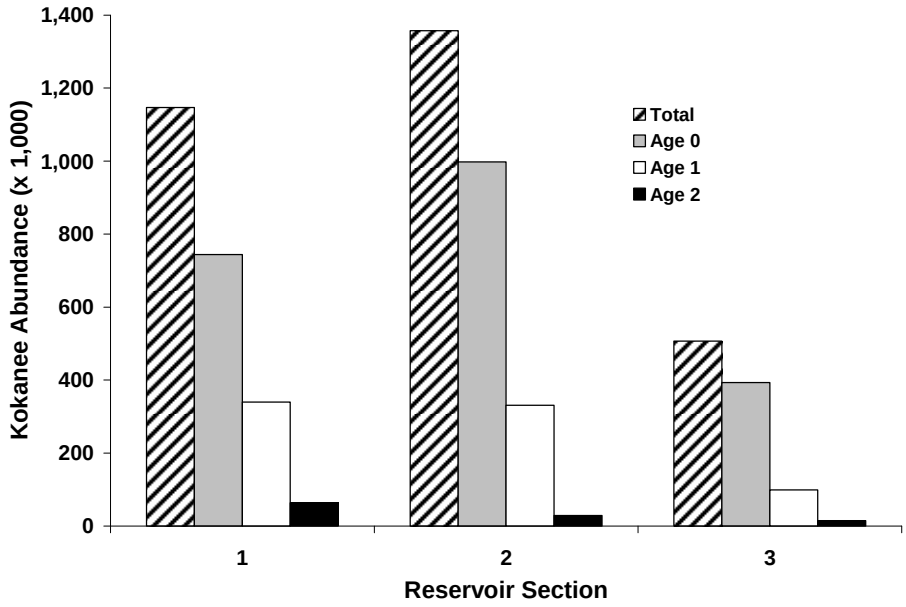

Figure 11. Abundance of age-0, age-1, age-2, and combined total abundance of kokanee by reservoir section in Dworshak Reservoir, July 11-13, 2005, obtained from hydroacoustics.

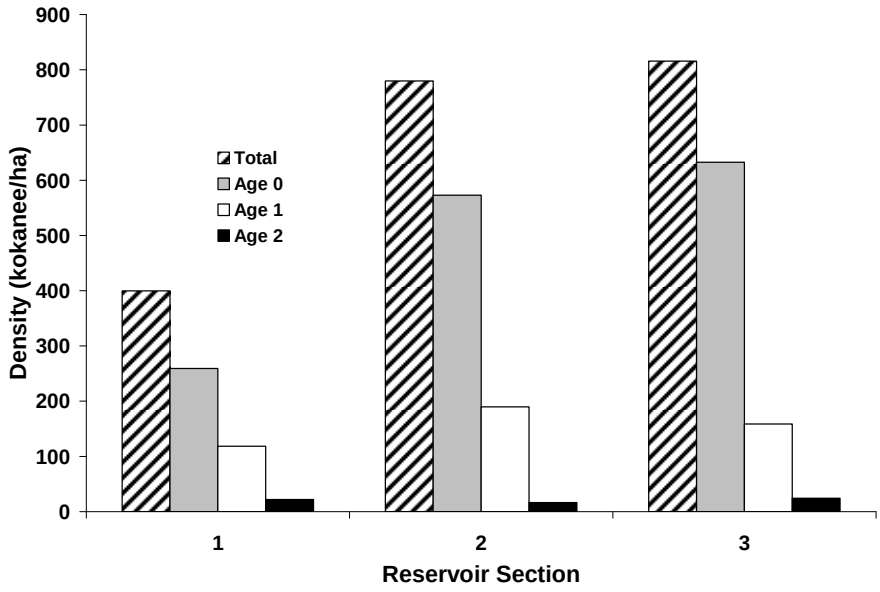

Figure 12. Density of age-0, age-1, age-2, and combined total density of kokanee by reservoir section in Dworshak Reservoir, July 11-13, 2005, obtained from hydroacoustics.

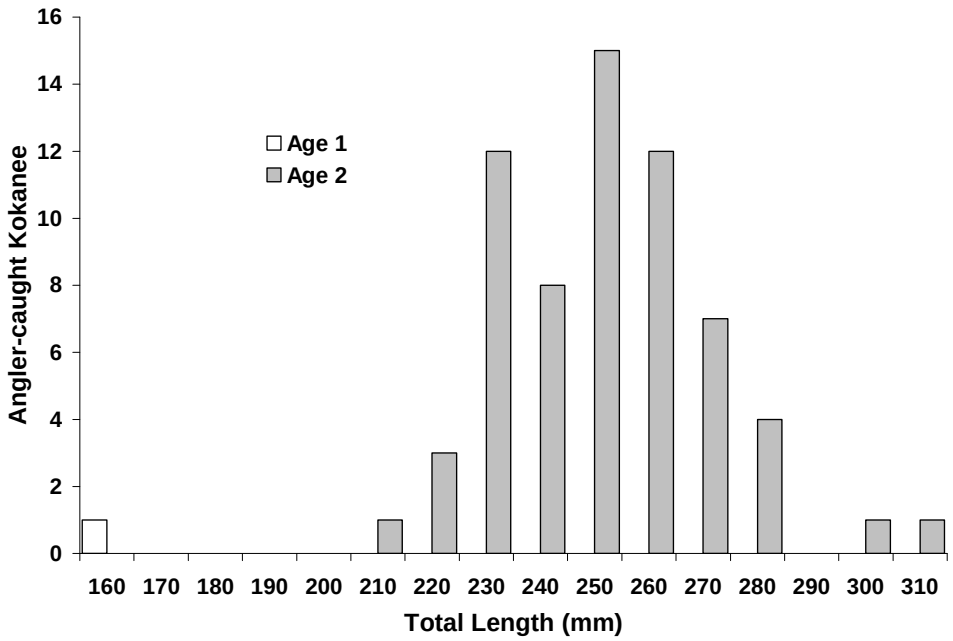

Figure 13. Length frequency of angler caught kokanee in Dworshak Reservoir, July 11-13, 2005. Based on these data, age 1 and age 2 kokanee were separated at 190 mm or -39.4 dB.

Entrainment

Fish detection rates during entrainment sampling in 2005 were quite variable. The highest 24 h fish detection rate (15.8 fish/h) was found at turbine 1 while discharging 42.5 m^3/s (Table 3) on November 8, 2005. Fish detection rates in general were low in front of all intakes from early spring through late summer then increased in the fall, particularly in September and November.

The highest mean fish detection rate among turbines was found in front of turbine 1 (4.2 fish/h) (Figure 14). Mean detection rate in front of turbine 2 was 4.0 fish/h, while the mean detection rate near turbine 3 was only 1.9 fish/h. Differences between detection rates in front of turbines were not statistically significant, in part due to high variances at each location (Figure 14). No real pattern was evident between fish detection rate and discharge (Figure 14), Secchi water transparency (Figure 16), or intake depth (Figure 17).

Fish were detected during all time-of-day periods in front of the turbines. The highest mean detection rate was found during night periods (6.7 fish/h), followed closely by the dawn period (6.0 fish/h). We found only 0.6 fish/h during both day and dusk periods, which was only one-tenth the mean detection rate observed during dawn and night periods (Figure 18).

Table 3. Sampling conditions and fish detection rate in front of operating turbines of Dworshak Dam. Fish detections were made using fixed location hydroacoustics between March 2005 and February 2006. Detection rates were expanded by the percent coverage to estimate potential entrainment across the entire turbine opening.

Date	Turbine	Discharge (m^3/s)	Intake Depth (m)	Secchi Transparency (m)	Detection Rate (fish/h)
3/21/2005	1	42.5	19.8	4.3	1.5
3/22/2005	1	42.5	19.8	4.3	3.1
4/26/2005	3	147.2	31.7	3.7	0.0
4/27/2005	3	147.2	31.7	3.7	0.0
5/23/2005	3	147.2	33.6	3.4	1.1
5/24/2005	2	59.5	27.5	3.4	3.6
5/25/2005	1	59.5	27.5	3.4	3.0
8/1/2005	3	154.3	31.4	3.4	0.7
8/2/2005	2	61.2	45.0	3.4	0.1
8/3/2005	1	61.7	44.7	3.4	0.1
8/29/2005	2	52.7	20.4	4.3	2.9
8/30/2005	2	52.7	20.4	4.3	2.8
9/12/2005	3	161.4	33.2	3.7	8.2
9/13/2005	2	38.2	17.7	3.7	12.9
9/14/2005	2	38.2	17.7	3.8	2.1
10/4/2005	1	42.5	29.7	6.2	2.8
10/11/2005	1	42.5	29.7	7.3	1.7
10/12/2005	1	42.5	29.7	7.3	2.0
11/7/2005	1	42.5	29.4	5.8	15.2
11/8/2005	1	42.5	29.4	5.8	15.8
11/29/2005	1	42.5	11.6	6.7	1.2
12/14/2005	1	42.5	11.6	5.8	0.7
1/17/2006	1	39.6	18.9	5.5	5.3
1/18/2006	1	39.6	18.9	5.5	3.8
1/24/2006	3	118.9	20.1	5.4	0.7
1/25/2006	3	118.9	20.1	5.4	4.2

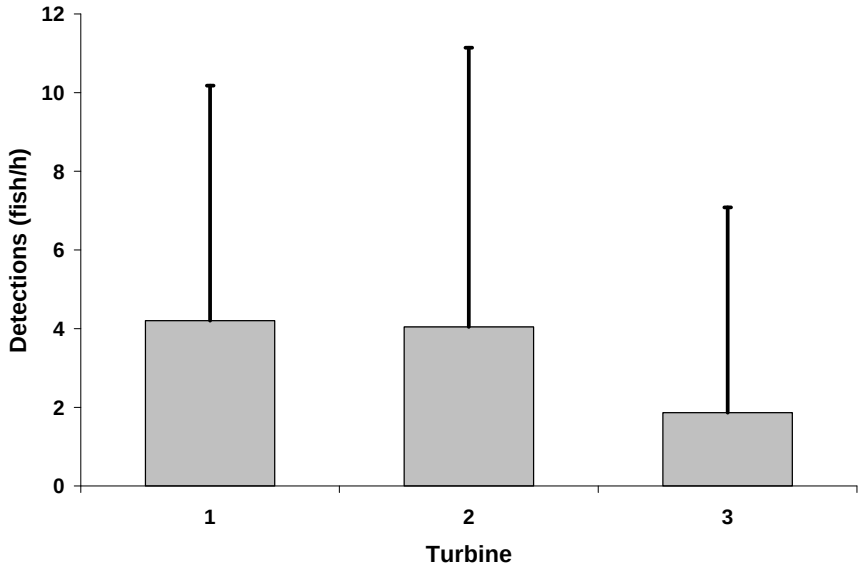

Figure 14. Mean fish detection rate in front of each of three turbines of Dworshak Dam, obtained from 24 h fixed-site hydroacoustic sampling, March 2005–February 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam. Vertical bar represents one standard deviation.

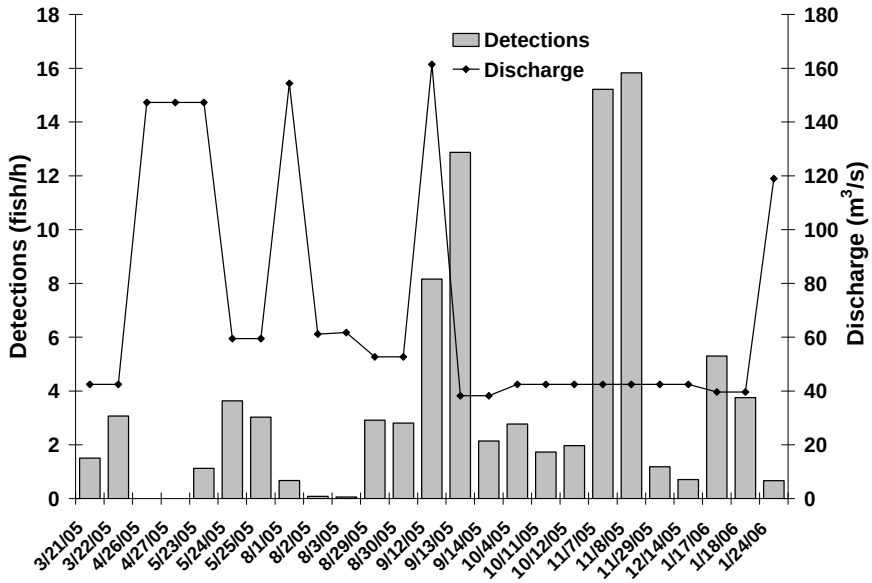

Figure 15. Mean fish detection rate in front of, and discharge rate of water through, the turbines of Dworshak Dam. Data were obtained from 24 h fixed-site hydroacoustic sampling, March 2005–February 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

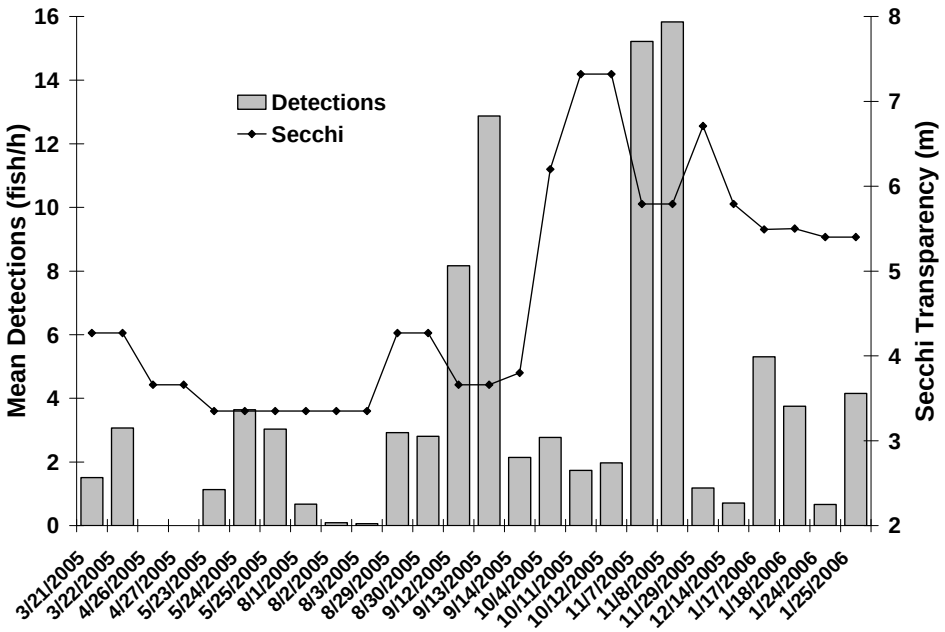

Figure 16. Mean fish detection rate in front of the turbines of Dworshak Dam and Secchi water transparency. Detection data were obtained from 24 h fixed-site hydroacoustic sampling, March 2005–February 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

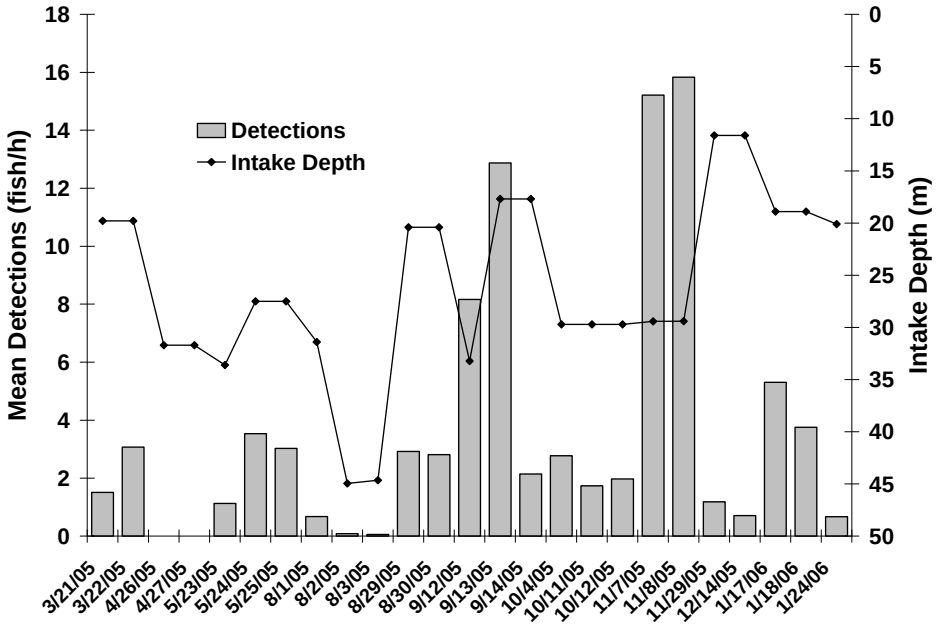

Figure 17. Mean fish detection rate and depth of water discharged through the turbines of Dworshak Dam. Data were obtained from 24 h fixed-site hydroacoustic sampling, March 2005–February 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

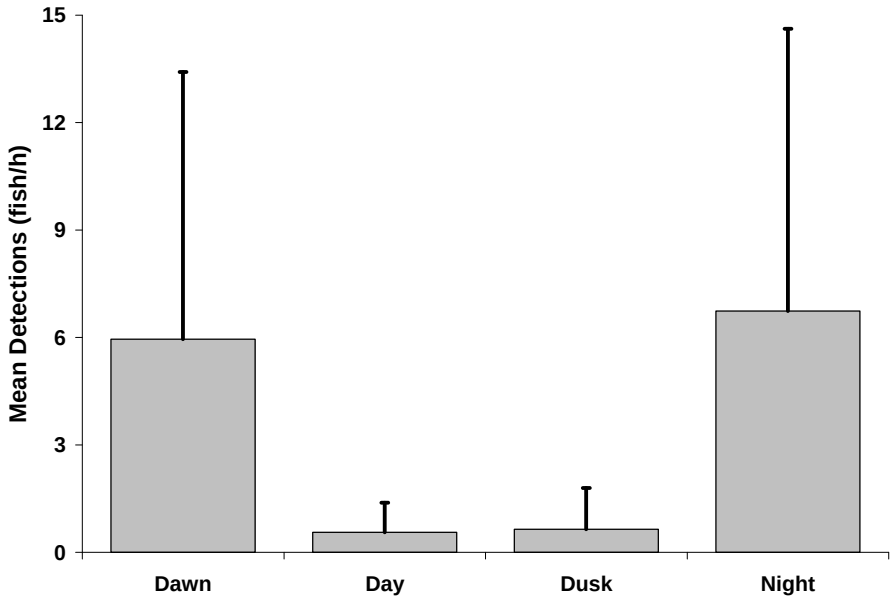

Figure 18. Mean fish detection rate in front of discharging turbines of Dworshak Dam for each of four time of day strata (dawn, day, dusk, and night). Data were obtained from 24 h fixed-site hydroacoustic sampling, March 2005–February 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam. Vertical bars represent one positive standard deviation of the mean detection rates.

Discharge

During this contract period, mean monthly discharge from Dworshak Dam varied from a low of 34.0 m^3/s on December 30, 2005 to a high of 283.2 m^3/s during mid August 2005 (Figure 19). Pool elevation varied with the amount of water discharged according to the USACE operational schedule (USACE 1986). Pool elevation varied from a low pool of 462.5 m in late October and again during mid December 2005 to a full pool of 487.6 m in late June and early July 2005 (Figure 20). Water releases during summer months ('Salmon Flows') in 2005 lasted from July 5 through September 14. These high discharge releases were intended to aid smolt migration and cool water temperatures in the Lower Snake River. Total discharge through Dworshak Dam was at or very near minimum discharge (36.8 m^3/s) for a total of 161 days. Secchi water transparencies generally decreased with greater discharge rates (Figure 21). Secchi transparency was lowest during August and highest in October.

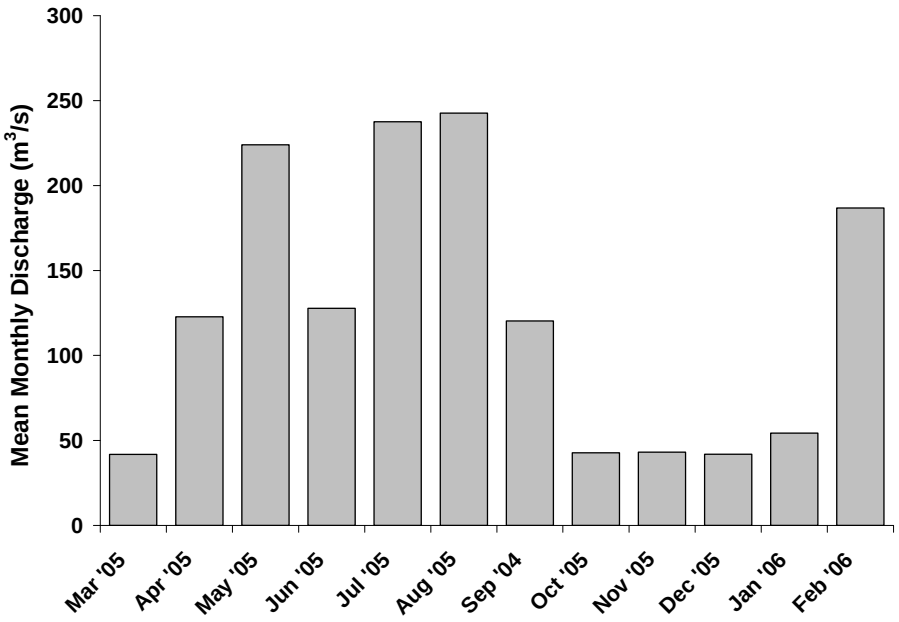

Figure 19. Mean monthly discharge through Dworshak Dam, March 2005–February 2006.

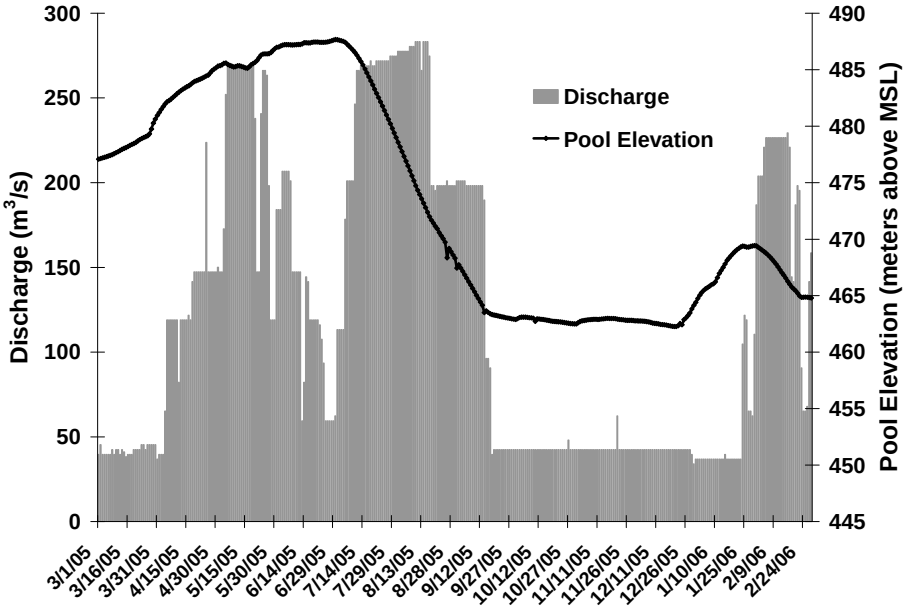

Figure 20. Total discharge through Dworshak Dam and Dworshak Reservoir pool elevation, March 2005–February 2006.

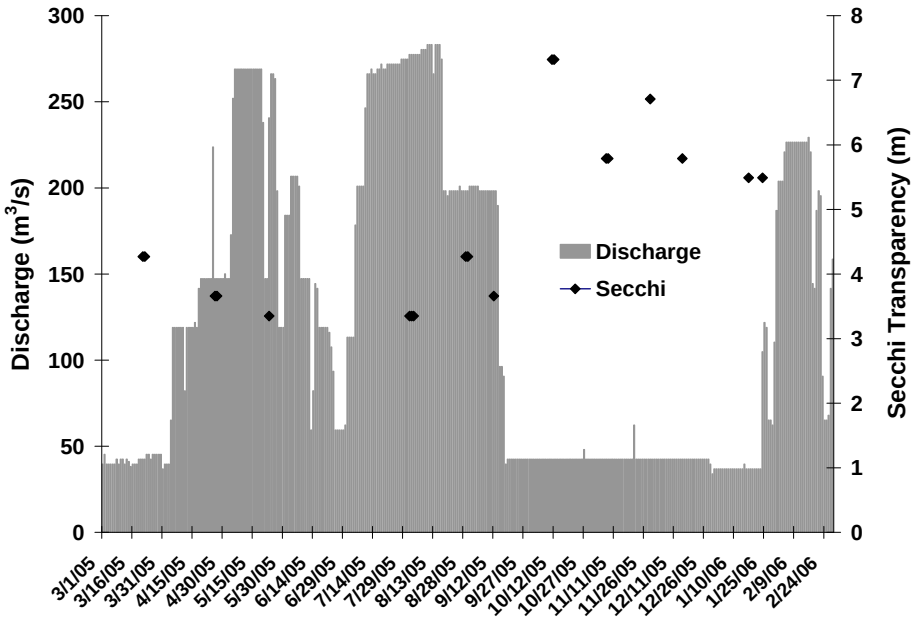

Figure 21. Total discharge through Dworshak Dam and Secchi water transparency, March 2005–February 2006.

Spawner Counts

We counted 12,742 spawning kokanee in three index streams (Table 4). This was roughly 1.6 times the number of kokanee counted in spawning tributaries in 2004 (7,992).

Kokanee distribution ended at 4.8, 2.1, 1.0, and 0.5 km upstream of the mouths of Isabella Creek, Skull Creek, Quartz Creek, and Dog Creek, respectively. The same rockslide barrier was present again this year in Quartz Creek, which prevented further upstream movement. A significant impediment to upstream migration was also found on Skull Creek near river kilometer (RK) 2.1. In Isabella Creek, spawners were observed up to RK 4.8. A subsample of 16 spawners was collected from the four tributaries during the counts. Fish ranged from 180 to 330 mm in length, with a mean of 248 mm (Figure 22).

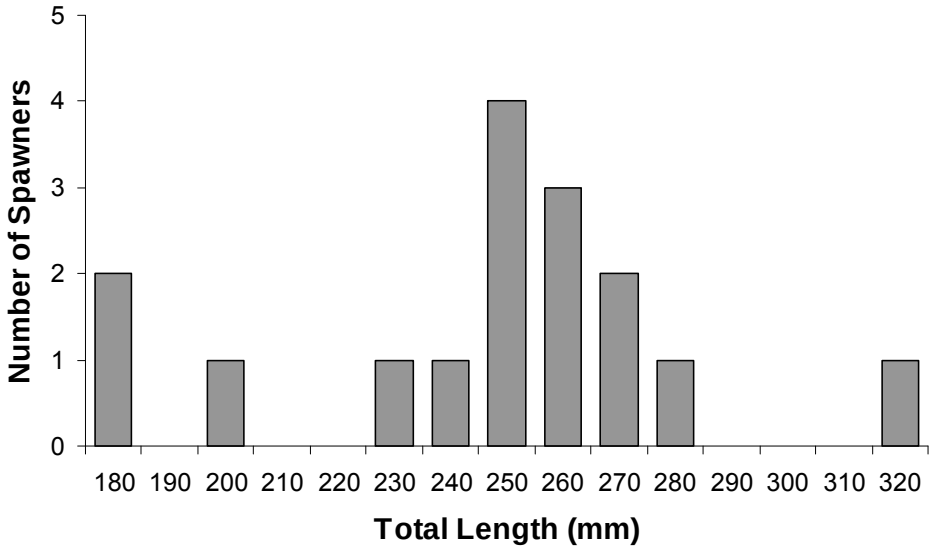

Figure 22. Length frequency distribution from a subsample of 16 kokanee spawners from Isabella, Quartz, and Skull Creeks, September 24–25, 2005.

Table 4. Number of kokanee spawners counted in selected tributaries to Dworshak Reservoir, Idaho during September 1987-2005.

Year	Isabella Creek	Skull Creek	Quartz Creek	Dog Creek	Total
2005	6,890	3,715	2,137	617	13,359
2004	6,922	2,094	450	1,474	10,940
2003	12,091	10,225	1,296	1,083	24,695
2002	15,933	7,065	2,016	1,367	26,381
2001	3,751	1,305	722	301	6,079
2000	3,939	402	124	565	5,030
1999	10,132	361	827	2,207	13,527
1998	627	20	13	18	678
1997	144	0	0	0	144
1996	2,552	4	13	82	2,651
1995	12,850		2,780	1,160	16,790
1994	14,613	12,310	4,501	1,878	33,302
1993	29,171	7,574	2,476	6,780	46,001
1992	7,085	4,299	1,808	1,120	14,312
1991	4,053	1,249	693	590	6,585
1990	10,535	3,219	1,702	1,875	17,331
1989	11,830	5,185	2,970	1,720	21,705
1988	10,960	5,780	5,080	1,720	23,540
1987	3,520	1,351	1,477	700	7,048

DISCUSSION

Strobe Light Testing

We observed a 62% reduction in densities near turbine 3 at high discharge while strobe lights were in use. This reduction was lower than previous tests in front of a single turbine at low discharge during December 2001 and January 2002 (Stark and Maiolie 2004). Despite reduced effectiveness at higher discharges, the lights still reduced kokanee densities near the discharging turbine. This measured effect was not statistically significant ($p = 0.182$ probability level, with $n = 5$), most likely due to the large variation in the data.

Several factors likely influenced the measured effectiveness of the strobe lights during these tests. One factor especially evident during repeated tests during January and February 2006 was kokanee densities and distribution during nights with the lights off (controls). Unlike during previous effectiveness testing, fish appeared to avoid the area in front of the turbine intake, especially within the analysis zone during controls. Thus, densities were very low and, therefore, likely influenced the measured effect of fish deterrence between tests and controls. In addition, the higher discharge during these tests likely influenced the effectiveness of the strobe lights.

As testing progressed, it appeared fish might have habituated to flashing strobe lights (Figure 5, 7); however, we did not feel this was likely. Although the number and density of fish in each replicate increased from replicates 2 through 5, there were 10, 6, and 4 days between replicates 2 and 3, replicates 3 and 4, and replicates 4 and 5, respectively. Therefore, it was unlikely that fish exposed to strobes during one replicate were the same fish as those in the next replicate. Additionally, previous offsite testing on Lake Pend Oreille and Spirit Lake did not find evidence of fish habituation (Maiolie et al. 2001b). Lastly, considering the low numbers and

densities of fish observed throughout the testing, a portion of fish could have been other species that were shown to be attracted to flashing strobes (Simmons et. al. 2005), such as rainbow trout and smallmouth bass.

All of this testing was conducted at night. Effectiveness of strobe lights during the daytime was not evaluated, but would likely be less effective due to the high levels of background lighting. In addition, though entrainment monitoring we found most losses occurred during the night (see entrainment discussion below). Thus, nighttime use of underwater strobe lights should provide sufficient deterrence of fish away from Dworshak Dam to effectively reduce entrainment on a population level.

One limitation of this work was that we only monitored the response of fish over -45 dB, which would be a kokanee of about 97 mm total length (Love 1971). Fish below this size were difficult to separate from the ambient noise near the dam and turbines.

Effectiveness testing of strobe lights proceeded in phases from offsite testing to increasingly greater discharge rates and number of turbines in onsite testing at Dworshak Dam. Offsite testing on Lake Pend Oreille and Spirit Lake proved strobe lights were highly effective in repelling kokanee (Maiolie et al. 2001b). The next phase progressed to testing in front of a single operating turbine on Dworshak Reservoir. Again, these tests demonstrated the lights reduced kokanee densities by 88% (Stark and Maiolie 2004). Onsite testing was needed to see if kokanee could be repelled even when there were water currents that could influence fish behavior and when kokanee could be actively attempting to move downstream (conditions that were not present in the offsite testing). These onsite tests demonstrated success in spite of these factors.

Strobe lights proved successful in front of two simultaneously discharging turbines and tests in front of discharging ROs indicated strobe lights might also be able to repel kokanee near these intakes (Stark and Maiolie 2004). The next phase is to develop a plan to permanently install this behavioral deterrent technology on Dworshak Dam. A conceptual design for the installation of strobe lights is provided in Appendix A.

The magnitude of reduction in abundance and density seen in both turbine (49-90%) and RO (66%) testing may be large enough to meet our objective of reducing fish entrainment by 50%. However, to date, testing has been quantified only through abundance and density measures. Nevertheless, in future testing we also recommend obtaining true measures of fish entrainment with newly installed hydroacoustic transducers inside the turbines. Comparison of control (lights off) versus test (lights on) entrainment rates (fish/h) would be a more definitive test of strobe light effectiveness.

Kokanee Population Estimate

Population estimates indicated kokanee abundance decreased from 3.9 million in 2004 to 3.0 million in 2005. Also, adult (age-2) density increased slightly from 14 adults/ha in 2004 to 21 adults/ha in 2005 (Table 5). It should be noted, though, that two different population estimation methods were used, trawling in 2004 and hydroacoustics in 2005, and therefore direct comparisons including calculation of survival rates were not estimated. Acoustic methods tend to overestimate and trawling to underestimate; therefore, despite differences in methods age 1 to age 2 survival between 2004 and 2005 was likely poor.

Several sources of annual mortality such as fishing mortality, natural mortality, and entrainment losses are likely contributing to the kokanee annual mortality. A population with little or no predation should have experienced 60% annual survival rate (Maiolie and Elam 1995). This suggested additional mortality other than natural mortality alone. Very high mortality due to entrainment was found in previous years, and entrainment likely continued to impact kokanee in 2005.

Table 5. Estimated abundance of kokanee age classes and density of adults (age-2) in Dworshak Reservoir, Idaho, 1988-2005.

Year	Sampling Method	Kokanee Abundance					Adult Density (fish/ha)
		Age-0	Age-1	Age-2	Age-3	Total	
2005	Hydroacoustic	2,134,986	769,663	107,466	0	3,011,626	21
2004	Trawling	3,136,892	692,348	90,715	0	3,919,956	14
2003	Hydroacoustic	439,580	434,586	276,055	0	1,150,222	42
2002	Hydroacoustic	1,246,959	1,101,232	127,933	0	2,476,124	24
2001	Hydroacoustic	1,962,000	781,000	405,000	0	3,150,000	75
2000	Hydroacoustic	1,894,857	303,680	199,155	0	2,397,691	37
1999	Hydroacoustic	1,143,634	363,250	38,464	0	1,545,347	7
1998	Hydroacoustic	537,000	73,000	39,000	0	649,000	7
1997	Trawling	65,000	0	0	0	65,000	0
1996	Hydroacoustic	231,000	43,000	29,000	0	303,000	5
1995[b]	Hydroacoustic	1,630,000	1,300,000	595,000	0	3,539,000	110
1994	Hydroacoustic	156,000	984,000	304,000	9,000	1,457,000	69
1993	Trawling	453,000	556,000	148,000	6,000	1,163,000	33
1992	Trawling	1,040,000	254,000	98,000	0	1,043,000	22
1991	Trawling	132,000	208,000	19,000	6,000	365,000	5
1990[a]	Trawling	978,000	161,000	11,000	3,000	1,153,000	3
1989[b]	Trawling	148,000	148,000	175,000	0	471,000	32
1988	Trawling	553,000	501,000	144,000	12,000	1,210,000	29

Although abundance of age-0 and age-2 kokanee declined in 2005 (Table 5), age-1 abundance increased. However, this increase can be attributed primarily to the record abundance of age-0 kokanee in 2004. Age-0 kokanee abundance in 2005 was extremely high again, suggesting very good adult spawning success and fry survival.

Average size of age-2 kokanee was substantially smaller in 2005 (257 mm, 10.1 in) than in 2004 when the mean total length was about 294 mm (11.6 in). Smaller average sizes suggest kokanee exhibited density dependent growth during 2005. High densities reduced the growth rate. We did not conduct trawling to obtain age-at-length data in 2005, but instead conducted angler checks to obtain this data.

Entrainment

Fish detection rates from entrainment assessment sampling were highly variable during 2005, with some similar findings to previous years but also a few different patterns observed. We again found the highest detection rate during nighttime periods (6.7 fish/h); however, unlike

2004 the rate of the next highest period, dawn (6.0 fish/h), was very close. The detection rate observed during the day (0.6 fish/h) (Figure 18), was less than one tenth that seen during the night or dawn. Through all entrainment sampling in 2005, nighttime detections comprised 82% of all detections. In fact, time of day was the only variable that has remained consistently predictable throughout all entrainment sampling over the years. These data support the belief that nighttime use of underwater strobe lights should provide sufficient deterrence of fish away from Dworshak Dam to effectively reduce entrainment on a population level.

However, several different patterns in fish detections were observed during 2005 than previous entrainment assessments in 2002-2004. Mean fish detection rates remained low throughout the spring high discharge period from April through June 2005 (Table 3), unlike previous years. We also found low fish detection rates throughout July and August sampling during high discharge periods unlike previous assessments (Figure 15). Conversely, low discharge during September and October resulted in our highest detection rates.

We found no clear relationship between detection rates and discharge (Figure 23). And unlike findings in 2002 (Stark and Maiolie 2004) and 2003 (Stark 2007), the highest fish detection rates occurred during low discharge periods (Figure 15). Like 2004, our highest fish detection rates also occurred during higher Secchi transparencies (Figure 16) (Stark and Stockner 2007).

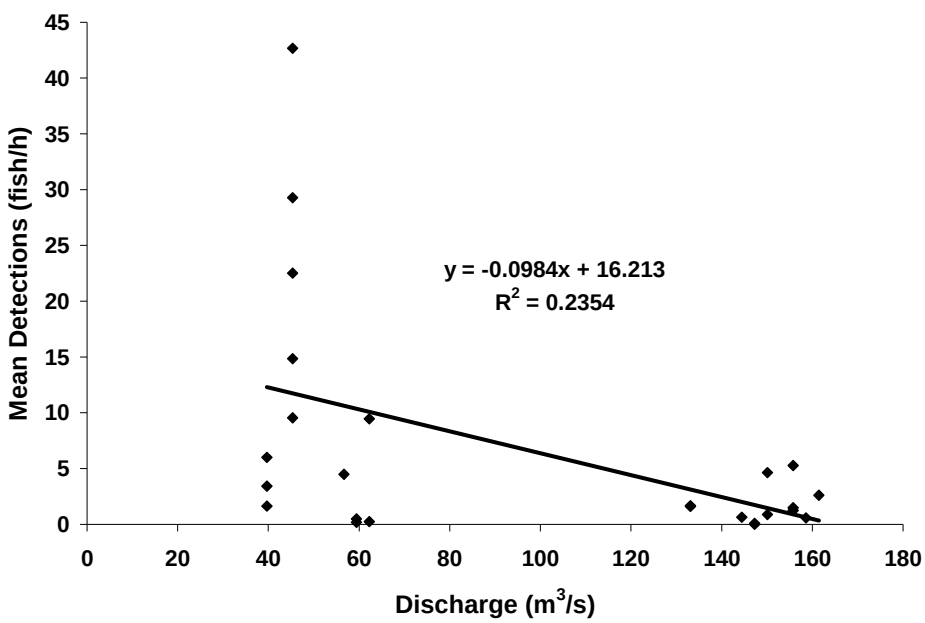

Figure 23. Relationship between fish detection rate and discharge rate of water through the turbines of Dworshak Dam obtained from 24 h fixed-site hydroacoustic sampling, March 2005–February 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

Maiolie and Elam (1998) documented movements of kokanee throughout the reservoir. They also found that kokanee densities near the dam were low during the August drawdowns largely because kokanee (mostly age-2 fish) were further up the reservoir. Thus, seasonal fish distribution and density of kokanee near the dam likely influenced entrainment potential, along with the influence of discharge rate.

Unlike 2002 and 2003, we detected more fish in front of turbine 1 than turbine 2, and more in front of turbine 2 than turbine 3 (Figure 14). However, turbine 3 was typically only operated during periods of high discharge in the spring and midsummer, as was turbine 2, although to a lesser extent. Turbine 1 was operated almost year-round and mostly at or near minimum discharge rate relative to its capacity. Thus, entrainment potential was not mutually exclusive of discharge rate through each turbine. In addition, comparisons between turbines were also likely influenced by the time of the year (season) turbines were operated. For instance, turbines 1 and 2 were more likely to be discharging during the spring. Lastly, the variation in the number of detections for each turbine was greater than the difference in detection rate between them; thus, their differences are not statistically significant.

Similar to 2004, we did not find a strong negative relationship between depth of intake and fish detection rate (Figure 24). But withdrawal depth again was not independent of discharge rate, season, or turbine. However, the sample periods with the highest detection rates all occurred while the depth of water withdrawal was about 30 m, which happens to be the typical depth of kokanee during the night (Maiolie and Elam 1998). Lastly, we did not find a relationship between detection rate (kokanee entrainment susceptibility) and Secchi transparency (water clarity). Again, water clarity was not independent of season and discharge rate.

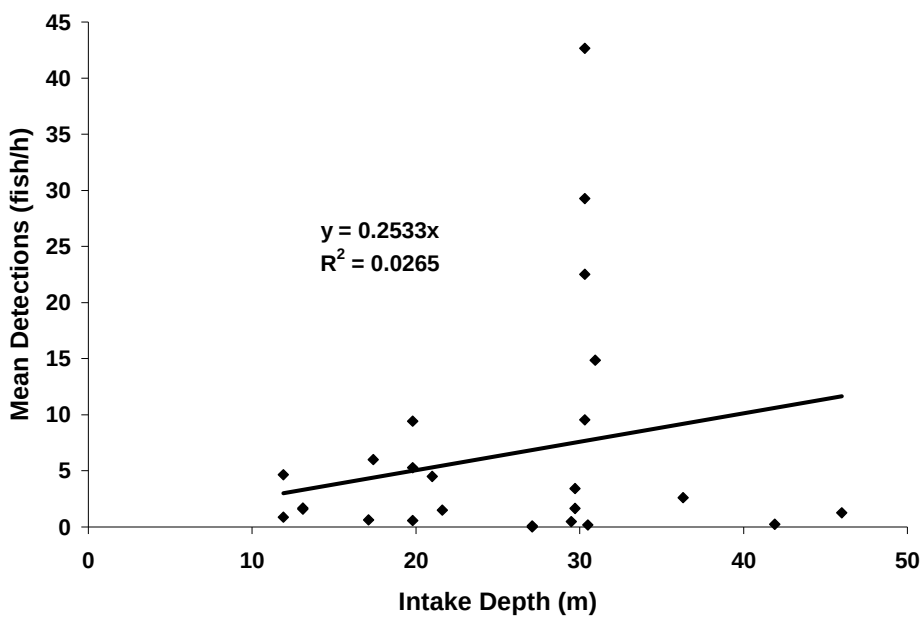

Figure 24. Relationship between fish detection rate and intake depth of water discharged through the turbines of Dworshak Dam obtained from 24 h fixed-site hydroacoustic sampling, March 2005–February 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

The percent of the turbine opening covered by our hydroacoustic sampling was highly variable (Table 6). Changes in depth of discharge through dam intakes, as affected by pool elevation and selector gate operation, changed our sampling efficiency. The fixed-site hydroacoustic transducer used for fish detection immediately in front of turbine intake openings had side lobes that detect the face of the dam. This detection resulted in severe noise intrusion into entrainment assessment echograms, especially within the 15-30 m depth range. More efficient coverage of the intakes was obtainable when the reservoir was closer to full pool since the intake depths were deeper, below the side-lobe noise band. Relatively noise free entrainment sampling was attainable when the intakes were quite shallow (<15 m deep) because the side lobes and the noise they incur were below the intake depth, but the acoustic coverage was drastically reduced since the acoustic beam was narrow near the surface.

An increase in sampling effort would allow us to obtain enough hours of fish detections (sample size) to allow for statistically valid tests of the effects of time of day, seasons, discharge rate, and depth of withdrawal. Sample sizes must be large enough to statistically test for the effects of one factor while controlling for the remaining factors.

Lastly, transducers installed inside the turbine intake monoliths (inside and downstream of the selector gates and trash racks) may be the best option to monitor entrainment since fish detected in this area have a much higher probability of being pulled into the turbine penstocks.

Table 6 Conditions, settings, acoustic beam coverage, and proximities to the turbines of Dworshak Dam during entrainment sampling, March 2005–February 2006. Beam diameter, portion of intake sampled, and distance from beam to dam were values at the center of the openings.

Date	Turbine	Intake Width (m)	Offset Angle (deg°)	Analysis Depths (m)	Beam Diameter (m)	Acoustic Beam Coverage (%)	Distance from Beam edge to Dam (m)
3/21/2005	1	0.3	4.0	14.8 - 24.8	2.3	62.5%	1.2
3/22/2005	1	0.3	4.0	14.8 - 24.8	2.3	62.5%	1.2
4/26/2005	3	0.9	10.0	26.7 - 36.7	3.7	60.0%	4.6
4/27/2005	3	0.9	10.0	26.7 - 36.7	3.7	60.0%	4.6
5/23/2005	3	0.9	6.0	28.6 - 38.6	3.9	63.7%	2.9
5/24/2005	2	0.6	6.0	22.5 - 32.5	3.2	87.0%	2.6
5/25/2005	1	0.3	5.0	22.5 - 32.5	3.2	87.0%	2.0
8/1/2005	3	0.9	5.0	26.4 - 36.4	3.6	59.4%	2.1
8/2/2005	2	0.6	5.0	40.8 - 49.1	5.2	141.7%	2.9
8/3/2005	1	0.3	5.0	40.5 - 48.8	5.1	140.8%	2.9
8/29/2005	2	0.6	5.0	15.4 - 25.4	2.4	100.0%	1.7
8/30/2005	2	0.6	5.0	15.4 - 25.4	2.4	64.4%	1.7
9/12/2005	3	0.9	4.0	27.1 - 39.3	3.8	62.8%	1.4
9/13/2005	2	0.6	5.0	12.7 - 22.7	2.0	55.7%	1.7
9/14/2005	2	0.6	5.0	12.7 - 22.7	2.0	55.7%	1.7
10/4/2005	1	0.3	5.0	25.6 - 33.8	3.4	93.7%	2.1
10/11/2005	1	0.3	5.0	25.6 - 33.8	3.4	93.7%	2.1
10/12/2005	1	0.3	5.0	25.6 - 33.8	3.4	93.7%	2.1
11/7/2005	1	0.3	5.0	25.3 - 33.5	3.4	92.7%	2.1
11/8/2005	1	0.3	5.0	25.3 - 33.5	3.4	92.7%	2.1
11/29/2005	1	0.3	5.0	6.6 - 16.6	1.3	36.5%	1.4
12/14/2005	1	0.3	5.0	6.6 - 16.6	1.3	36.5%	1.4
1/17/2006	1	0.3	5.0	13.9 - 23.9	2.2	59.6%	1.7
1/18/2006	1	0.3	4.5	13.9 - 23.9	2.2	59.6%	1.1
1/24/2006	3	0.9	5.0	15.1 - 25.1	2.3	38.1%	1.7
1/25/2006	3	0.9	5.0	15.1 - 25.2	2.3	38.1%	1.7

Discharge

The 2005 water year was about average when compared to 1999 though 2004 water years (Figure 25), with a mean annual discharge through Dworshak Dam of 124 m^3/s. However, the high discharge period was shorter in duration than in 2004 and peaked at a lower mean total discharge (Figure 26), very similar to the 2003 water year. The opportunity for large entrainment losses was lower during the spring of 2005 relative to previous years since discharge was lower during March and April. Despite lower discharges in 2005, entrainment sampling and population estimates suggest even low entrainment rates may have taken a large toll on kokanee abundance over time.

Discharge of water through Dworshak Dam during 2005 appeared to have adversely impacted kokanee abundance, since age-2 fish had particularly poor survival (Figure 27). However, entrainment assessments during July and August revealed high discharge 'Salmon Flows' were not likely impacting kokanee abundance severely since very few fish were detected (Figure 15). Similarly, few fish were detected during entrainment assessments during high discharges earlier in the spring. Unlike findings during 2002-2003 (Stark and Maiolie 2004; Stark 2007), 2005 results indicated the majority of fish losses likely occurred during low discharge periods primarily during the fall, particularly September and November, instead of high discharge periods during spring and summer.

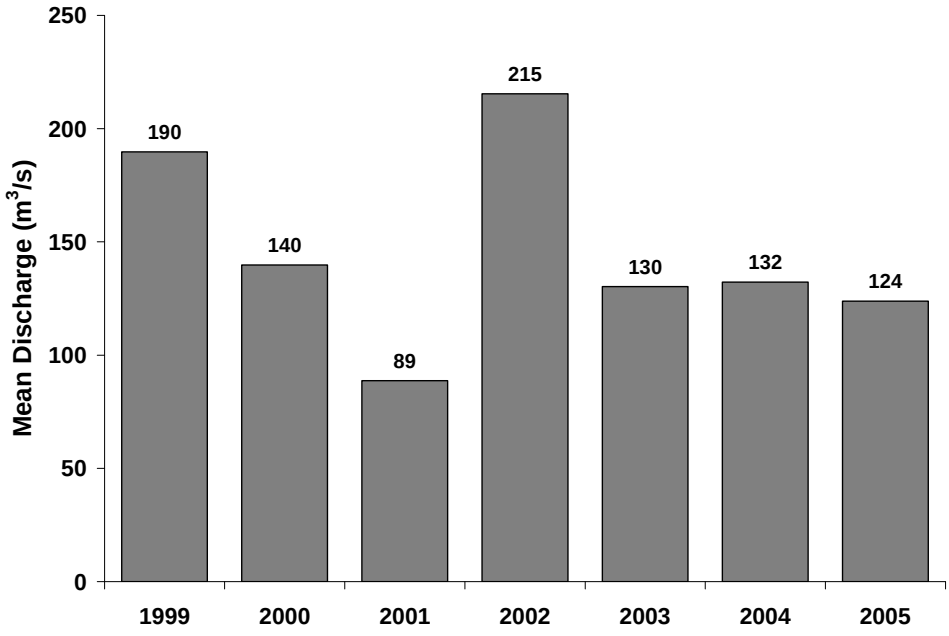

Figure 25. Mean annual discharge through Dworshak Dam, 1999-2005.

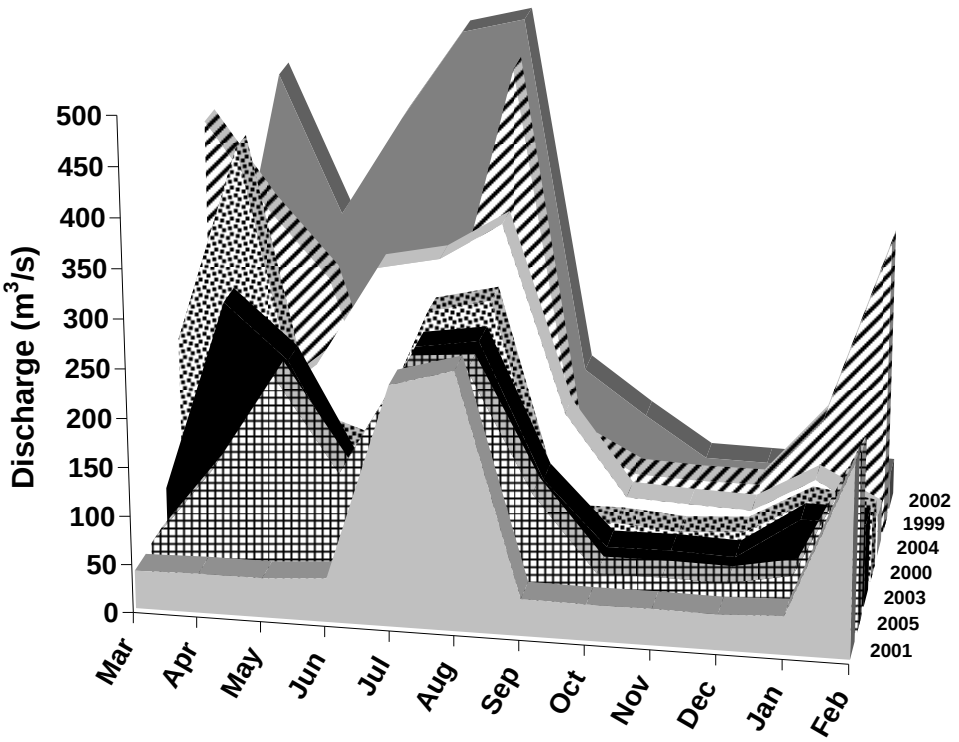

Figure 26. Mean monthly discharge through Dworshak Dam, 1999-2005.

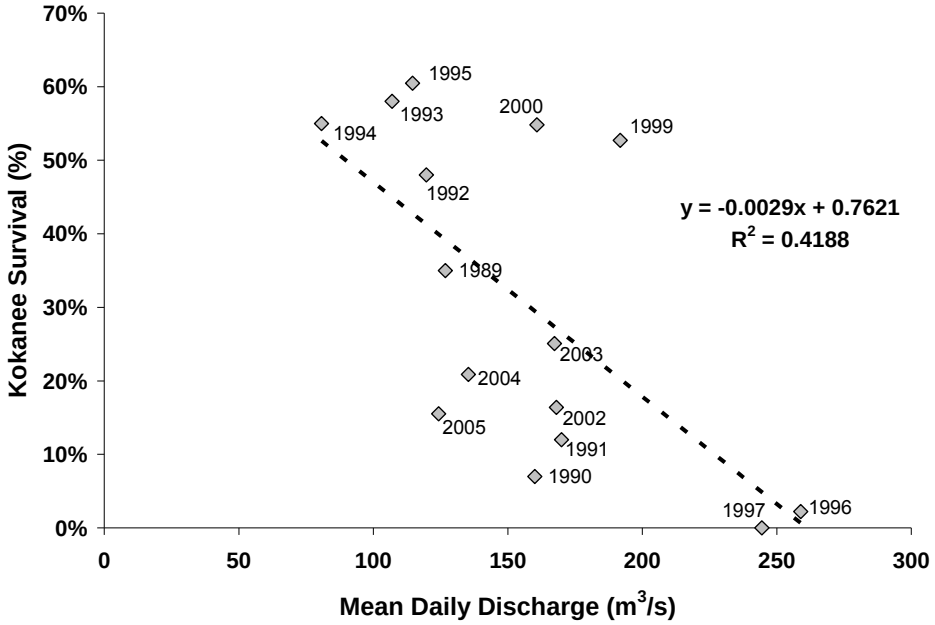

Figure 27. Relationship between the mean daily discharge through Dworshak Dam between July 1 and June 30 of the following year and the estimated kokanee survival rates from age-1 to age-2 based on July population estimation surveys, 1989-2005.

Spawner Counts

Counts of spawning kokanee in 2005 were slightly greater than 2004 counts (Table 4). The abundance of spawning fish appeared to closely match what we expected for the index tributaries based upon the 2005 acoustic population estimate (Table 5). This year's data closely fit the previous relationship between spawner counts and reservoir adult abundance (Figure 28).

Kokanee were not able to access as much prime spawning gravel during this year's survey because of lower than normal water levels. The previous barrier to upstream movement in Quartz Creek at river mile 0.8 appeared to have been obliterated since 2003. However, this year it appeared fish were impeded much lower by a logjam at river kilometer (RK) 1.0. Spawning fish migrated upstream as far as RK 4.8 and 2.1 on Isabella and Skull Creeks, respectively, but no migration barriers were evident at these locations. In Isabella Creek, spawning kokanee were observed up to 1.6 km farther than in 2004, but fish did not go as far in Skull and Quartz creeks compared to 2004. It was also evident that a few larger kokanee were able to migrate farther than the majority of smaller kokanee.

The variability in total length of adults was surprisingly broad, with several fish as small as 180 mm and one large fish at 320 mm, yet the majority of fish were between 230 and 280 mm in total length. Including outliers at either end of the frequency distribution, the mean spawner length was 60 mm smaller in 2005 than in 2004. The smaller spawners were likely early matured age-1 fish. Unfortunately, otoliths were not collected from the two 180 mm class fish, so fish ages could not be verified. If these were age-1 fish, the loss of them from the catchable population could have an appreciable impact on kokanee fishing in 2006. Because the mean size of adults was smaller in 2005, age-0 kokanee abundance in 2006 could be less than expected based upon spawning adult counts, since smaller adult fish likely produced fewer eggs.

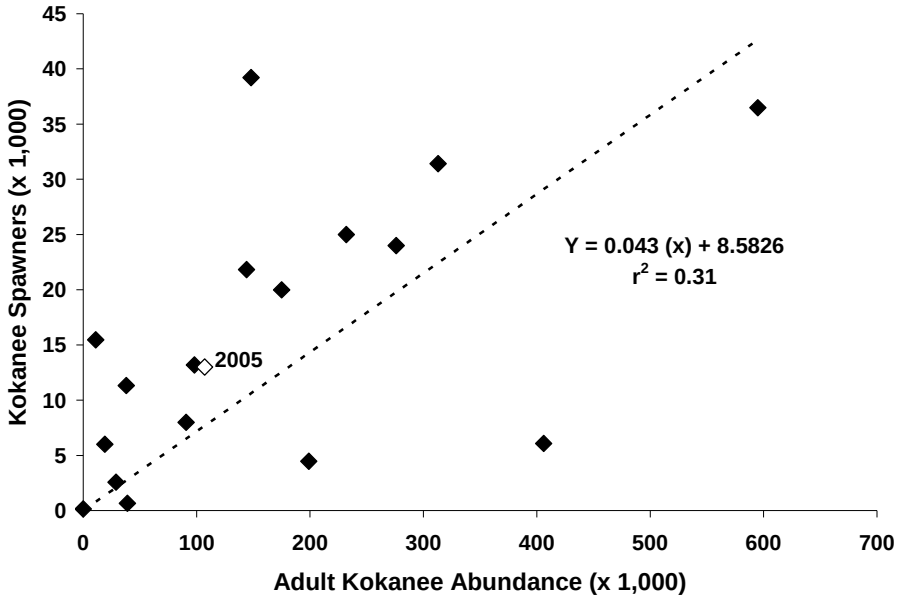

Figure 28. Relationship between adult kokanee abundance in Dworshak Reservoir and kokanee spawner abundance in tributaries to the North Fork Clearwater River, 1981–2005. The dotted trend line represents the linear regression equation for the relationship between adult and spawner abundances. The white diamond represents 2005 values.

CONCLUSIONS

Underwater strobe light tests in front of turbine 3 at high discharge were effective at repelling kokanee away from Dworshak Dam. Declines in densities (62%) were statistically significant ($p = 0.049$), but declines in counts of fish (49%) were not statistically significant at $p = 0.182$ probability level. Nonetheless, the measured effect was that strobe lights were able to reduce fish counts and densities by approximately 50% in front of turbines operating at higher discharges, which may be sufficient to keep populations within the management goal.

Dworshak Reservoir kokanee abundance decreased slightly from 2004 yet remained very high in 2005. However, densities of harvestable-size kokanee remained below Dworshak Reservoir management goals. Kokanee catch rates and yield would reach these goals if densities of harvestable kokanee doubled. Discharge of water through Dworshak Dam during 2005 appeared to have adversely impacted kokanee abundance, since age-1 to age-2 survival was very poor. Although 2005 mean monthly discharge was near the average for the last six years, low discharge periods appeared to affect the population.

The highest fish detection rates from entrainment assessments were again found during nighttime periods and lowest during the day. Unlike previous assessments, fish detection rates were low during high discharges throughout the spring and summer and highest during low discharges in September and November.

RECOMMENDATIONS

1. We recommend using strobe lights at night near operating turbines whenever kokanee densities in the forebay are high (Stark and Maiolie 2004) to lessen entrainment losses. This will help maintain adult kokanee densities between 30 to 50 fish/ha and improve the fishery.

2. We recommend monitoring fish entrainment rates with installed hydroacoustic transducers inside dam intakes throughout the year, which would provide an estimate of entrainment mortality with and without strobes operating.

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APPENDICES

Conceptual Design for Underwater Strobe Light Installation at Dworshak Dam

Final Report
October 27, 2006

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Project Background

Purpose

The Idaho Department of Fish and Game (IDFG) Dworshak Research Project determined that underwater strobe lights significantly reduced kokanee near discharging turbine intakes at Dworshak Dam. The results were based on several years of data collected using temporary research facilities that include a barge for structural support of the lighting system and a propane-powered generator for the power supply (Figure 1). With the effectiveness of the deterrent system established, a permanent installation was needed that provided greater energy efficiency, enhanced O&M conditions, and safety code compliance.

Figure 1. IDFG temporary research facilities in the Dworshak Dam forebay

IDFG retained HDR Engineering, Inc. (HDR|FishPro) to develop two conceptual design plans for a permanent strobe light installation. A major objective of the study was to identify design elements that interfaced with existing facilities at the Dworshak Dam, owned and operated by the US Army Corps of Engineers (Corps) Walla Walla District. Additionally, the study developed opinions of the probable construction cost for each design concept. The conceptual plans were expected to serve as an aid in the development of grant proposals for funding programs offered through various organizations.

Existing Conditions at Dworshak Dam

Dworshak Dam was built in 1971 for power production and flood control, at River Mile 1.9 of the North Fork Clearwater River. It is a straight concrete gravity dam with a structural height of 717 feet, and it is 3,287 feet long at the dam's crest elevation, 1613.49 feet above mean sea level (MSL). The dam was constructed as 51 distinct concrete monoliths, with Monolith 1 located at the south end of the dam, next to the left abutment. The outlet works for the dam are contained within Monoliths 18 to 26, near the center of the dam. The general plan and upstream elevation of the dam can be seen in Appendix C, along with other relevant drawings selected from the as-built set of construction drawings. Additional information regarding dam operations were obtained during a site reconnaissance on March 7, 2006, led by Dworshak Research Project personnel with assistance from staff of the Corps' Dworshak Dam project.

The annual streamflow of the North Fork Clearwater River at Dworshak Dam averages 5,727 cubic feet per second (cfs). In contrast, the standard winter and spring flood peaks

in the basin are 160,000 cfs and 120,000 cfs, respectively. The normal operating pool of Dworshak Reservoir ranges 155 feet, between the elevations of 1600 MSL and 1445 MSL. The maximum design pool is at elevation 1605 MSL.

Three Francis turbines were installed with the initial construction to provide a total production capacity of 400 megawatts. Turbines 1 and 2 have nameplate ratings of 90 megawatts, and Turbine 3 has a nameplate rating of 220 megawatts.

Discharges in excess of the power production discharges are released at the spillway or through three reservoir outlets located below the spillway (Figure 2). Spillway releases are controlled with two Tainter gates, each 50 feet wide by 56.4 feet high, at the crest elevation 1545 MSL. The gated reservoir outlets are 12 ft wide by 17 ft high with a centerline elevation of 1362 MSL.

Figure 2. View of Dworshak Dam spillway and turbine bays from the forebay, with IDFG temporary research facilities visible in the background

Turbine intake openings are located at the upstream face of the dam. Penstock openings of turbines 1 and 2 are 12 feet wide by 27 feet high, with the bottom edge of the bellmouth transition at elevation 1408 MSL. The opening for turbine 3 is 20 feet wide by 40 feet high, with the bellmouth bottom at elevation 1395 MSL. Upstream of the penstock openings, there is a concrete intake structure extending approximately 27 feet into the reservoir and spanning the width of the six intakes, that provides the support structure for multi-level selector gates and trash racks. Corbel walls extend from the dam face upstream past the selector gates to the trash racks, subdividing the intake structure into separate bays that are hydraulically segregated from each other. The selector gates and trash racks are constructed as panels with a 16-foot wide span. The bays for the smaller intakes (turbines 1 and 2) are constructed to accommodate two side-by-side panels, with a concrete pier located in the middle of the bay to provide continuity of the guides. Similarly, the larger bay for turbine 3 is sized to accommodate three panels, with concrete piers placed at the 1/3-points of the bay (Figure 3). These structural details were of special interest to the conceptual design, particularly the option 1 strobe light installation design.

a) b)

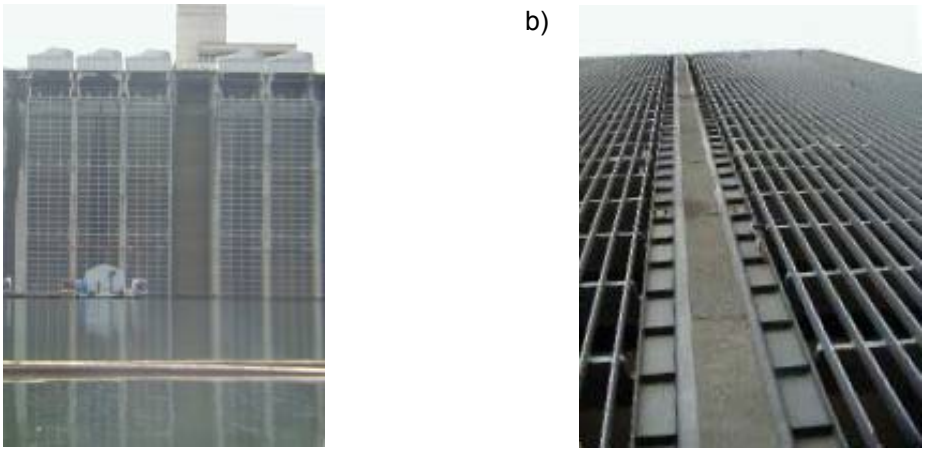


Figure 3. Dworshak dam turbine intake bay as seen from reservoir forebay, illustrating the three panel and two panel arrangements of turbines 3 and 2, respectively (a); and the face of a 2.6-foot wide concrete pier (b).

The multi-level selector gates can be positioned to allow water to enter the intake structure in either undershot mode or overshot mode. In the undershot mode, the gate is positioned high in the guides, and water enters the intake structure through an opening bounded on the bottom by a concrete sill at elevation 1395 MSL and on the top by the lower edge of the selector gate. In overshot mode, the selector gate is positioned low in the guides, and water enters the intake structure through a water column extending from the top edge of the selector gate up to the water surface. Overshot mode is used fall through spring, while undershot mode is typically used during summer months to provide cooler discharge temperatures as an aid to temperature regulation in the Lower Snake River.

A total of seven hoists, one mounted above each of the two gates for turbines 1 and 2 and the three gates for turbine 3 (Figure 4a), are used to position selector gates. The deck area surrounding the hoists may provide space for mounting strobe light equipment. An 11 ft wide by 14 ft deep area of the deck is open between turbines 1 and 2. Between turbines 2 and 3, a deck area 15 ft wide by 19 ft deep is open, which was originally used as a visitor viewing platform (Figure 4b). A concrete parapet separates the deck above the intake structure from the main deck area holding the crane rail. An open area approximately 8 feet deep exists between the parapet and the hoists, with the exception of two grated areas approximately 18 feet wide by 8 feet deep that provide access to storage areas for selector gate leafs and trash rack panels (Figure 4c). The upstream face of the hoists are recessed back from the front plane of the intake structure, to accommodate the trash racks and an access walkway located below the top deck at EL 1603 (Figure 4d).

a) Hoists above turbine 1 (left), turbine 2 and turbine 3.

b) Visitor viewing area between turbines 2 and 3.

c) Area between crane rail and hoists at turbines 1 and 2. Note cover of gate leaf and trash rack storage area.

d) View across turbine 2 hoist towards visitor viewing area. Note walkway behind trash rack (at EL 1603).

Figure 4. Views of hoists and available deck space above turbines 1 to 3

Strobe Light System Requirements

Permanent installation of a strobe light system on Dworshak Dam will place strobe lights in front of turbines 1 through 3. The conceptual design plan consists of two design options. Option 1 employs a floating structure to hold strobe lights out in front of the turbine intake openings and thereby allow positioning of strobes in the appropriate upstream/downstream axis with changes in water clarity. Option 2 utilizes a simpler superstructure attached directly to the face of the dam, thereby not allowing for changes in the position of the strobes along the upstream/ downstream axis. Both options allow for variable positioning of strobes along the vertical axis, to enable placement anywhere between the limits of the undershot and overshot modes of gate operations.

A general configuration for the strobe light spacing was developed based on test results. Two gridwork arrays of strobe lights will be utilized, one for turbine 3, and a second that spans the smaller turbines 1 and 2. The vertical grid will be 32 feet high, with 3 strobes positioned 16 feet apart. Since option 2 is attached directly to the dam, the horizontal grid is dictated by the spacing of the concrete piers supporting the trash racks. Consequently, turbine 3 will have a horizontal array of 4 strobes, one at each outer edge and one on each on the two intermediate piers. The combined grid for turbines 1 and 2 will have 5 lights on each horizontal array. Therefore, installation will utilize a total of 27 strobe lights, 12 for turbine 3 and 15 for turbines 1 and 2. Flash Technology located in Franklin, Tennessee manufactured the strobe lights and controller equipment used during testing, from which this design is based upon (Appendix A).

Electrical power for the lights and the system support facilities shall be drawn from an appropriate and available panel of the existing Dworshak Dam utility power system. Electrical wiring to individual strobe lights and the associated superstructure must be able to function with the water level fluctuations of the reservoir. All elements of the two design options must meet both safety guidelines and construction standards of the U.S. Army Corps of Engineers.

The strobe light installation must withstand the water velocities encountered immediately upstream of discharging turbine intakes. Tests conducted by Dworshak Research Project personnel measured water velocities upstream of the turbine intakes when the units were operating near the maximum discharge capacity. Sampling conducted at turbine 3, while discharging 5,800 cfs, revealed water velocities up to 1.7 ft/sec at 10 feet from the dam in the middle of the intake opening. Results also showed the velocities drop off quickly with distance from the intake opening, with all measurements being less than 1.0 ft/sec at distances greater than 10 feet from the dam. Similar results were obtained at turbine 2 while discharging 2,100 cfs. The maximum water velocity measurement was 1.2 ft/sec at 5 feet in front of the intake.

Electrical Design Considerations

Power must be supplied for the 27 strobe lights while integrating with existing Corps operations at Dworshak Dam. Additionally, the frequency of strobe replacement must be considered in project feasibility. These two issues are common to both design option 1 and option 2, and therefore addressed in the following subsections, prior to descriptions of the unique aspects of the structural support options.

Supply and Control

Breaker #1G in Panel DCQ1, located in the 1603 Gallery at Monolith 17, was identified as spare breaker nearest the visitor viewing area. Based on the estimated power demand of the strobe lights and associated support facilities, this breaker provides an acceptable source of power for the strobe light system installation. The voltage of the panel is 480 volt and will be sized at 75 amps. From the panel to the visitor viewing area, the feeder will consist of a 1-1/2-inch rigid galvanize steel conduit and three #4 conductors with a ground. In the case of option 2, the feeder will then transition to the same conductors and ground enclosed in a marine cable. The feeder will terminate in a wall mounted 75 amp circuit breaker and feed a 45 kva dry type transformer. The transformer will then feed two 200 amp 120/208 volt distribution panels mounted on the wall. The distribution panels will have a dedicated circuit breaker for two strobe light power units. The power units will be fed by 2 #12 conductors with a ground. This equipment will be housed in a prefabricated building, located at the visitor viewing deck in the case of Option 1, and on the barge in the case of Option 2. The power units will feed the flashhead by a water proof cable supplied with the lighting system. A one-line diagram of the required electrical installation is shown in Figure 5.

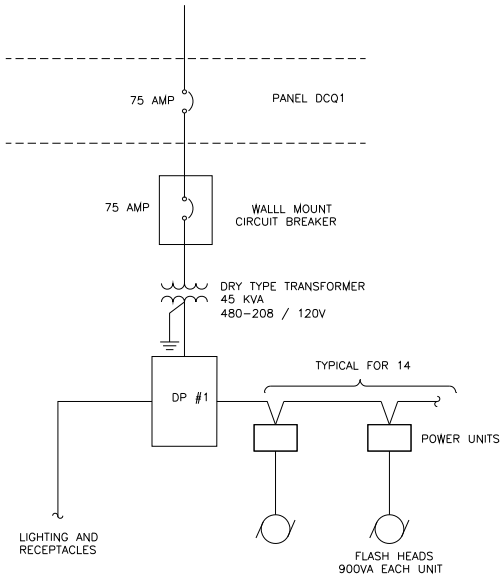


Figure 5. Electrical one-line diagram

The lighting system will also include a controller which will monitor and control the sequence of the flashing. If a unit fails, the controller will be able to generate an alarm. The controller will be connected to the site control system to monitor this alarm.

Bulb Replacement

The manufactures literature lists the bulb life as 30,000,000 flashes. IDFG has indicated that the strobes would only be in use during the night and while the powerhouse is generating. Assuming an average of 8 hours of operation per day at a flash rate of 360 flashes per minute, this translates to bulb replacement every 6 months (30M flashes / 360 fpm = 83,333 minutes = 5.7 months @ 8 hours per days). During further discussions with Flash Technology, however, their staff indicated that they have, in laboratory condition, gotten "years" of operation from a bulb (although no flash rate was indicated). Once the strobe system has been in operation for a year or two, an actual bulb life and replacement schedule should be established. The control system will indicate when a bulb is no longer working. Logistics will likely necessitate that all bulbs will be replaced at one time, rather than as individual bulbs fail.

Option 1 – Floating Structure for Strobe Support

Option 1 will employ a floating structure to hold strobe lights out in front of the turbine intake openings, thereby allowing the positioning of strobes to be adjusted along the upstream/downstream axis, depending on the findings of system effectiveness or changes in water clarity. A minimum safe distance from the intakes will need to be established during final design that takes into account the intake velocity sampling results in conjunction with estimated drag forces on the structure due to potential debris loading. The following subsections describe the option design, installation, operation, and estimate of probable construction cost.

Design

A floating structure for positioning of the strobe light arrays would be staged off one or possibly two barges tethered to the dam, shoreline, and possibly anchored within the reservoir. Two separate supporting arrays would be fabricated as rigid frames, one for turbines 1 & 2, and the second for turbine 3. The frame for turbines 1 & 2 would be approximately 70 ft wide by 36 ft tall and the frame for turbine 3 approximately 55 ft wide by 36 ft tall. In order to lift the frames clear of the water for bulb replacement, an overhead hoist structure, approximately 40 ft tall will be required (Figure 6).

A number of options are available for the barge itself depending on the projected lifespan of the project and the amount of maintenance expected. For the purposes of this report, a 50-year lifespan is assumed. One barge option is a series of flat-deck utility barges (e.g. Flexi Float) arranged in a rectangle with an opening in the middle. Most other options consist of custom built steel or pontoon barges which would be fabricated on-site. Regardless of the barge type, periodic maintenance will be required, mostly consisting of hauling out, cleaning and painting.

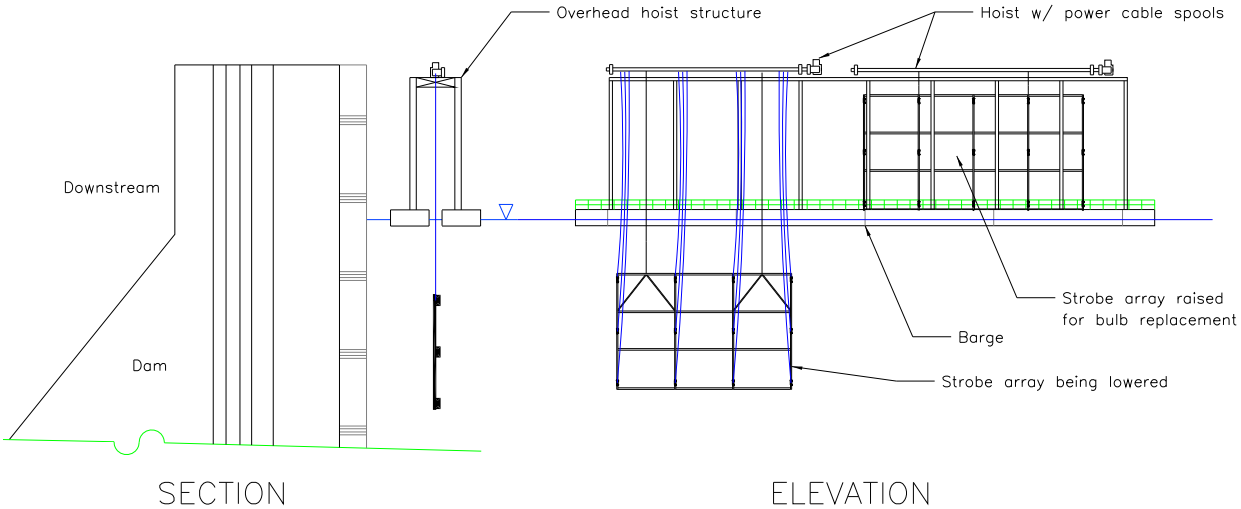


Figure 6. Option 1 section and elevation

The barge must be approximately 180 ft long by 40 ft wide in order to allow space for the overhead hoist and torque tube structure, a prefabricated building for controls and electrical equipment, and an opening large enough for the frames to be lifted out of the water (Figure 7). Power to the barge will be supplied by the 480 volt feeder enclosed in a marine cable, addressing the fluctuating barge elevation with a configuration similar to the power system supplying the Clearwater Hatchery floating intake, also located in the Dworshak Dam forebay. A retractable spool will be mounted on the barge to take up any slack in the feeder cable, and the feeder will terminate in the control building.

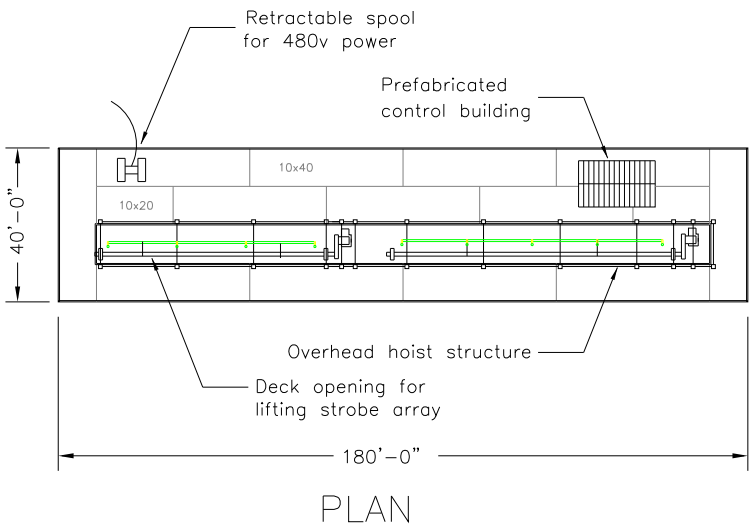


Figure 7. Option 1 barge plan

Installation

A floating structure will require very little installation on the dam and deck and none underwater. A single 480 volt line will be spooled from the dam deck above the barges allowing their elevation to vary with the reservoir. The flashhead controls, hoists, and hoist controls will all be located on the barge.

Operation

A separate hoist and torque tube arrangement is assumed for each array of strobes. The hoists will be used for vertical positioning as well as lifting the entire array above the water surface for bulb changes.

Estimate of Probable Construction Cost

The conceptual-level construction cost for Option 1, which uses a floating structure for strobe support, is estimated at $2.68 million.

Mobilization	$406,000
Electrical	$483,000
Barge	$867,000
Structural	$220,000
Mechanical	$256,000
Project Subtotal	$2,232,000
Contingency (20%)	$447,000
Total Estimated Project Cost	$2,679,000

This estimate includes all fabrications, installation, start-up, and required construction bonds, and it includes a 20% contingency due to the preliminary nature of the design. The estimate is in 2006 dollars. A more detailed breakdown of construction materials and estimated quantities is presented in Appendix B.

Option 2 – Dam Face Structure for Strobe Support

Option 2 will utilize a simpler support superstructure attached directly to the face of the dam. The following subsections describe the option design, installation, operation, and estimate of probable construction cost.

Design

A dam face support structure for the strobes will require nine vertical grids for the strobe light array: four for turbine 3, and five for a combined array at turbines 1 and 2. The design concept proposes that nine independent vertical tracks be mounted to the dam face, and that nine independent strobe sleds be used to position the lights (Figure 8).

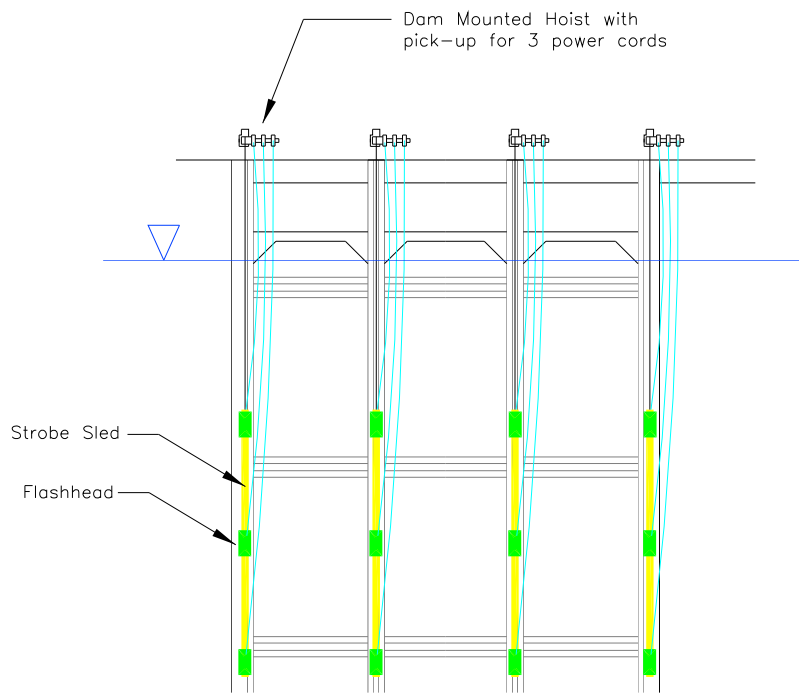


Figure 8. Strobe light installation plan, option 2 partial elevation detailing four of nine vertical tracks and sleds

We recommend smaller independent vertical tracks and sleds, rather than large frames, be used for the following reasons:

- For moving underwater structures, the likelihood of racking and jamming is greatly reduced with the high aspect ratio created by a vertical sled arrangement. (The aspect ratio is approximately 200:1 for individual sleds and tracks, as compared to 1.5:1 for a 54-foot by 36-foot frame.)
- There is very little room on the deck of the dam for a 40-foot to 60-foot long torque tube. A torque tube would be required to synchronize the lifting cables and spooling of the power cables at 4 or 5 locations.

- A 36 ft by 70 ft frame (for turbines 1 and 2) or a 36 ft by 55 ft frame (for turbine 3) would be very unwieldy if it was ever required to be removed. If the frame is made stiff enough to easily handle, the weight and hoist size increases.
- In the event of a problem, individual sleds could be easily removed.

The tracks are proposed to be fabricated from commonly available 3 in diameter, 0.25 in walled thickness, 304 stainless steel pipe. The tracks will be secured to the dam face at 20 ft intervals with "T" shaped brackets drilled and mechanically fastened to the concrete between the intake screens. The sleds will be approximately 36 ft tall with flashheads spaced at 16 ft. The sleds will be fabricated from 4 in diameter, 0.25 in walled thickness, 304 stainless steel pipes, and plates (Figure 9).

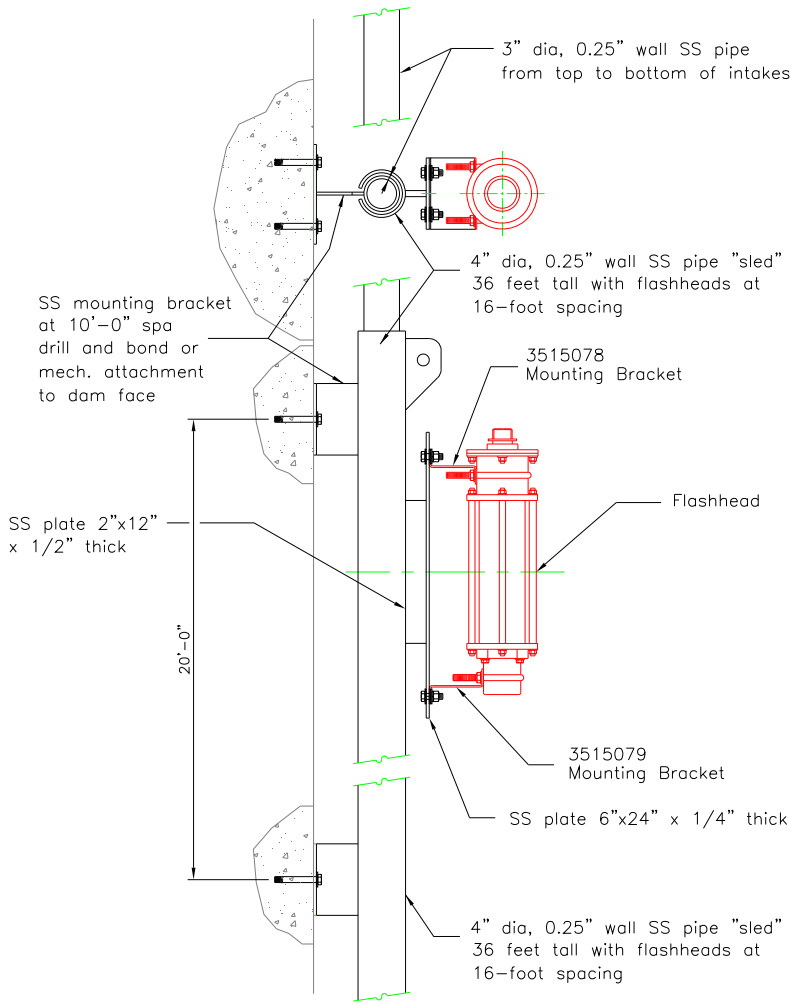


Figure 9. Strobe light installation plan, option 2 section and elevation of track and flashhead sled

Installation

Depending on the reservoir elevation at the time of installation, up to 190 ft of vertical track may need to be installed underwater.

Operation

Nine small, individual hoists are proposed for each of the vertical tracks and sleds, rather than having two hoist and torque tube arrangements (one each for the arrays at turbines 1&2 and turbine 3). Each individual flashhead sled will weigh approximately 1,000 lbs. Although individually lifted, the hoist motor controls can be synchronized such that all sleds maintain the same elevation. The individual lifting spools will be approximately 12 in diameter (assuming 0.5 in SS cable); significantly smaller that what would be required to lift an entire array.

Estimate of Probable Construction Cost

The conceptual-level construction cost for option 2, which uses a dam mounted structure for strobe support, is estimated at $1.41 million.

Mobilization	$214,000
Electrical	$483,000
Track	$410,000
Sled	$55,000
Mechanical	$16,000
Project Subtotal	$1,178,000
Contingency (20%)	$236,000
Total Estimated Project Cost	$1,414,000

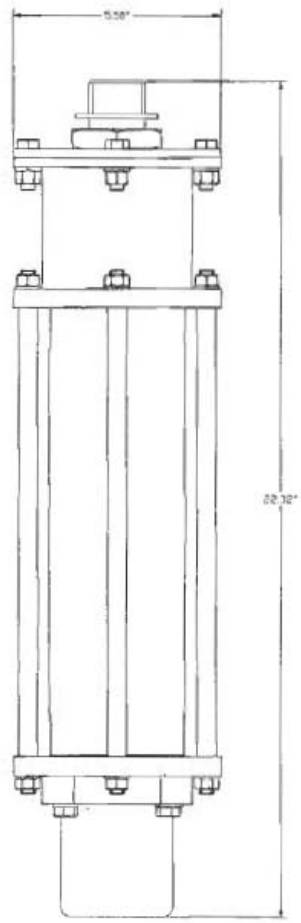
This estimate includes all fabrications, installation, start-up, and required construction bonds, and it includes a 20% contingency due to the preliminary nature of the design. The estimate is in 2006 dollars. A more detailed breakdown of construction materials and estimated quantities is presented in Appendix B.

Appendix A
Aquatic Guidance Lighting, Manufactures Technical Data

FLASH TECHNOLOGY

FH 920

Aquatic Guidance Lighting
Omni-Directional Strobe Light Flashhead



The FH 920 is an omni-directional strobe light flashhead for underwater applications.

Features

- Watertight to 200 feet.
- Easy change linear flashtube cartridge.
- Bottom-weighted to ensure proper orientation.
- Quick release connector.
- Multiple mounting options.
- Salt or fresh water applications.
- Negatively buoyant (15 lbs).

Specifications

- Height: 22.32 inches.
- Width: 5.50 inches.
- Weight: 31 lbs.
- Tube Life: 30 million flashes.

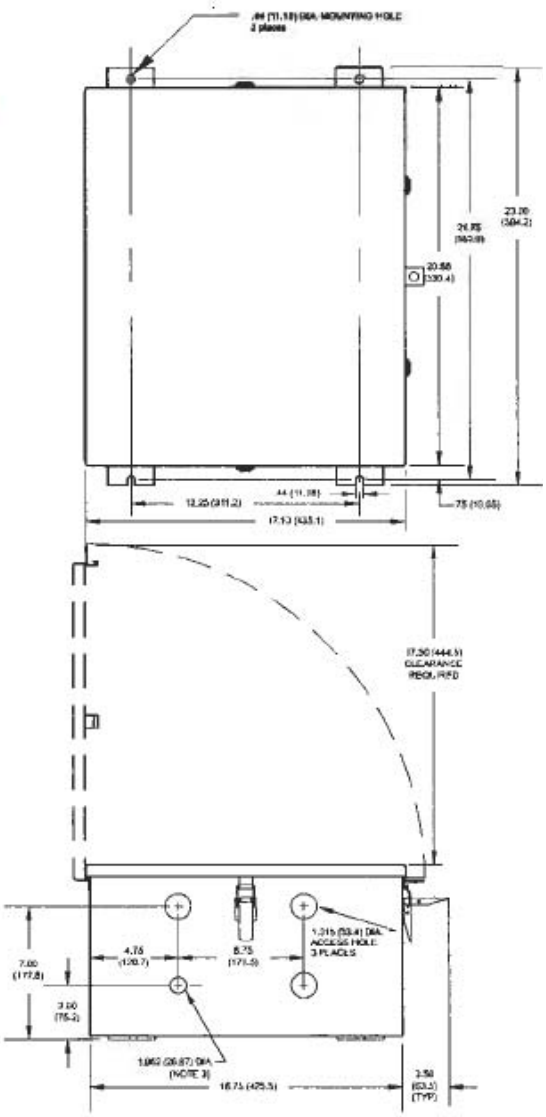
U.S. Patent No. 5,850,806

Flash Technology, 332 Nichol Mill Lane, Franklin, TN 37067
Phone: (615) 261-2000 Fax: (615) 261-2600
www.flashtechnology.com

FLASH TECHNOLOGY

PC 920

Aquatic Guidance Lighting Strobe Light Power Converter



The PC 920 provides power and triggering for the FH 920 strobe light. The unit can be operated stand-alone or as part of a multiple light system using the FTC 190 controller.

Features

- Capable of 120, 300 and 360 flashes per minute.
- Manual flashrate switch.
- RS-485 communication.

Specifications

- 120VAC, 60Hz
- 840VA @ 300 FPM
- 888VA @ 360 FPM
- 23"H x 17.13"W X 9.44"D
- NEMA 4X, 70 lbs.

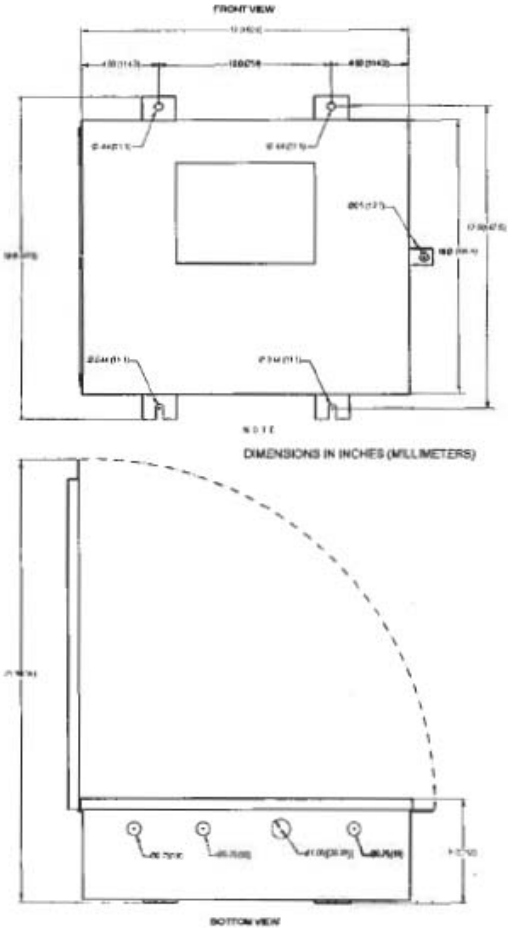
U.S. Patent No. 5,850,806

Flash Technology, 332 Nichol Mill Lane, Franklin, TN 37067
Phone: (615) 261-2000 Fax: (615) 261-2600
www.flashtechnology.com

FTC 190

Aquatic Guidance Lighting System Controller

The FTC 190 provides control, monitoring and synchronization of up to 32 PC 920 strobe light power converters. The interface is a 6" color touch-screen display. The controller can be monitored remotely via Ethernet or an optional modem card and software.



Features

- User friendly interface via a 6" color touch screen display.
- Controls up to 32 PC 920 strobe light power converters.
- Remote monitoring by Ethernet or using an optional modem card and software.
- Additional I/O with up to 3 expansion cards.
- Available expansion cards: Analog input, dry-contact input and relay output.

Specifications

- 120VAC, 60Hz
- 60 Watts
- 16"H x 19"W x 6"D
- NEMA 4X, 31 lbs

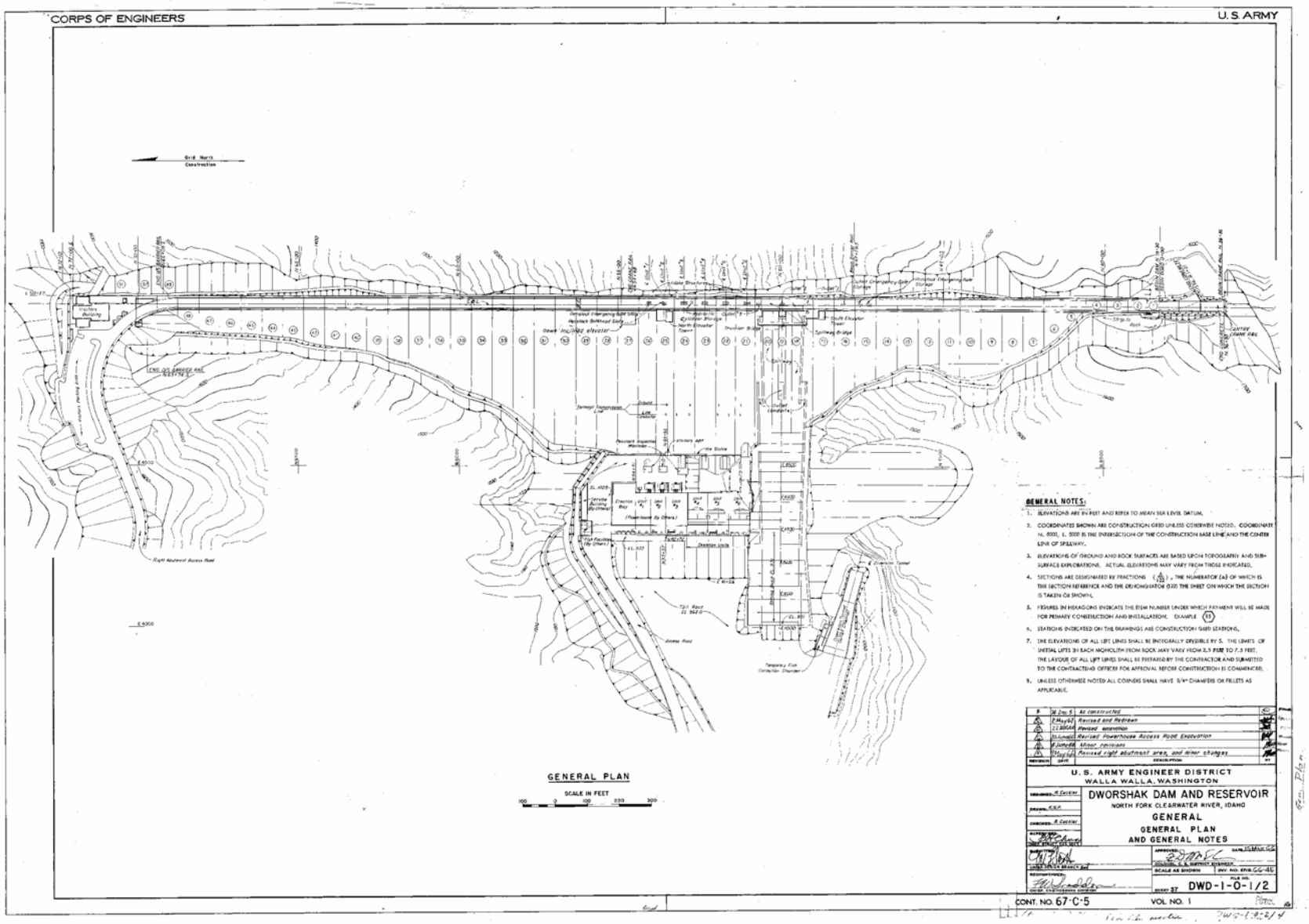
Flash Technology, 332 Nichol Mill Lane, Franklin, TN 37067
Phone: (615) 261-2000 Fax: (615) 261-2600
www.flashtechnology.com

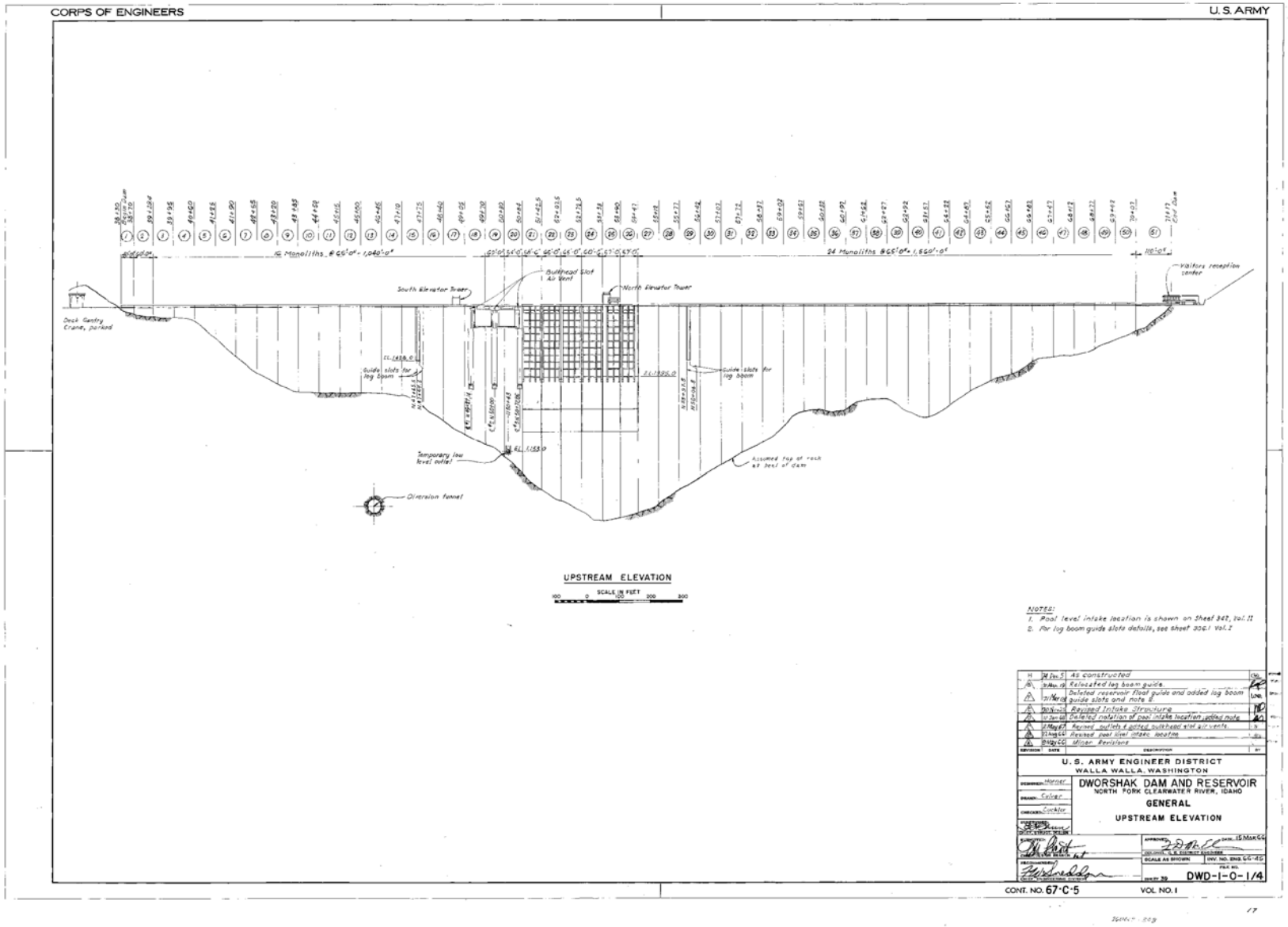
Appendix B
Detailed Estimate of Probable Cost

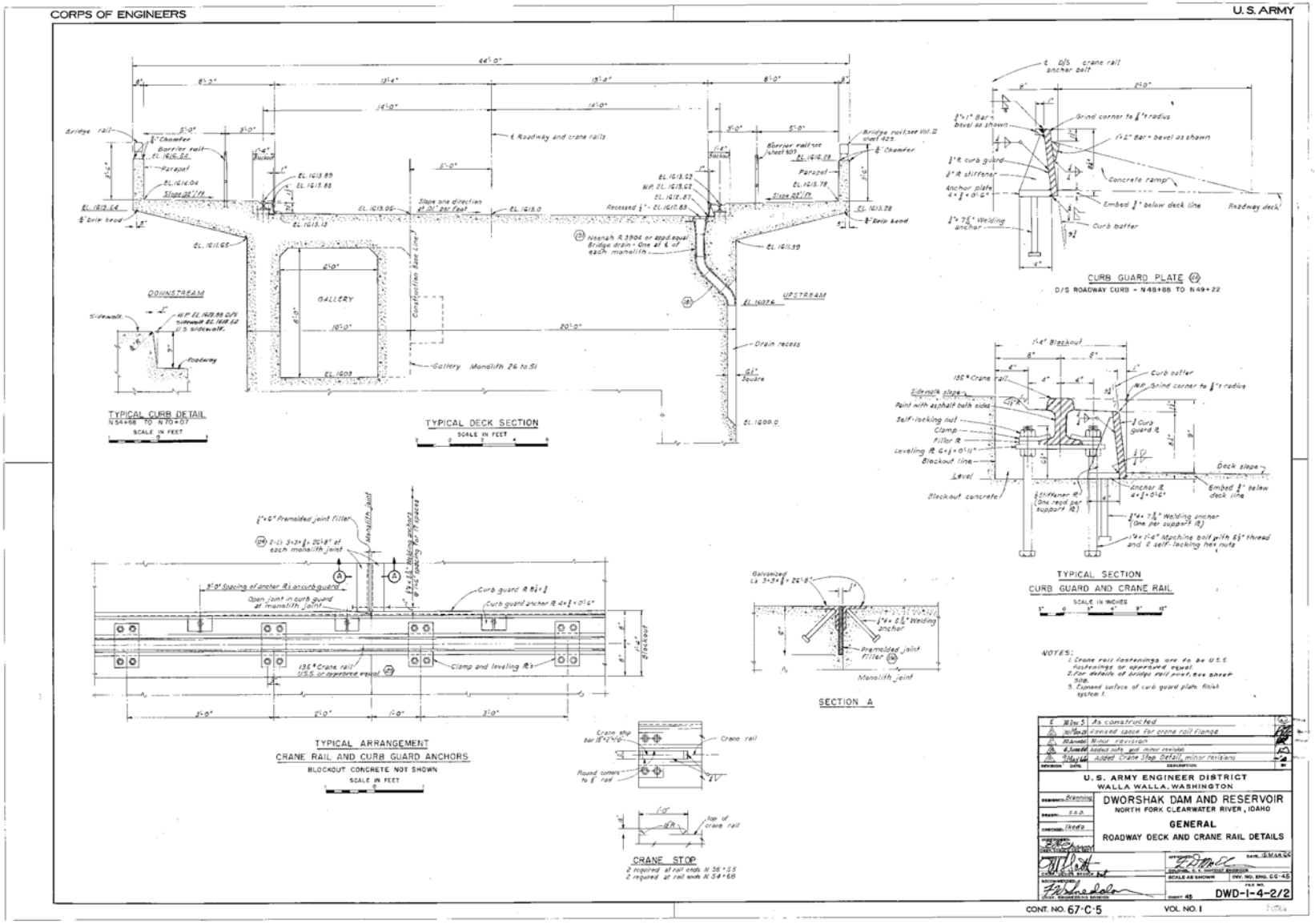
Conceptual Design for Underwater Strobe Light Installation at Dworshak Dam
Detailed Estimate of Probable Cost

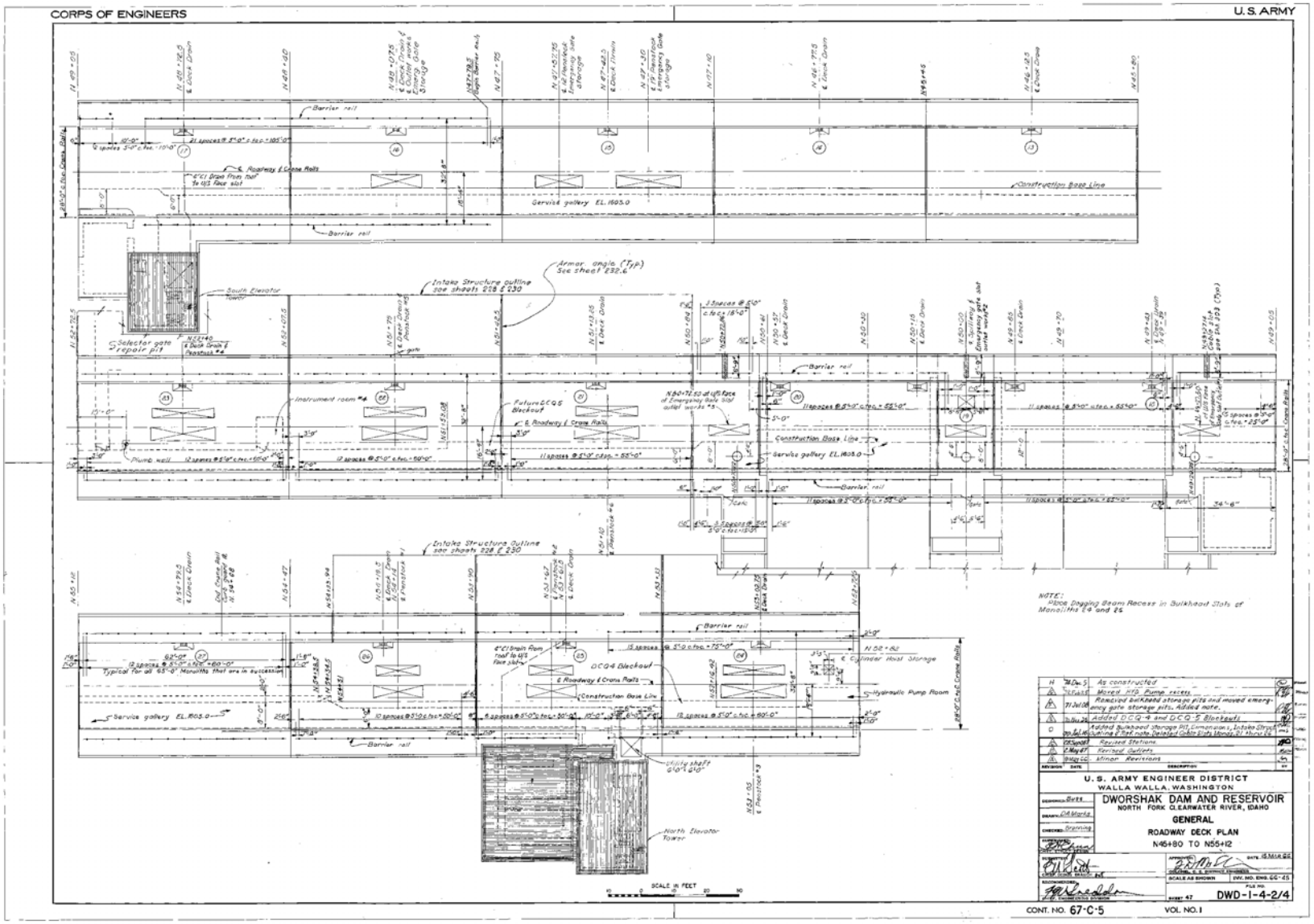
	Option 1						Option 2					
	Quantity	Units	Equip Cost	Install Cost	Unit Cost	TOTAL COST	Quantity	Units	Equip Cost	Install Cost	Unit Cost	TOTAL COST
MOBILIZATION												
Mobilization and Demobilization 15%						$328,000						$173,000
Insurance and Bonds						$77,500						$40,900
ELECTRICAL												
FTV 920 Aquatic Lighting System	27	EA	$14,950	$1,500	$16,450	$444,150	27	EA	$14,950	$1,500	$16,450	$444,150
(includes power unit, flash head, mounting						$0						$0
and 251 feet of cable)												
75 amp 480 circuit breaker in MCC	1	EA	$750	$2,600	$3,350	$3,350	1	EA	$750	$2,600	$3,350	$3,350
1 1/2 ' RGS conduit	600	LF	$7	$9	$16	$9,510	600	LF	$7	$9	$16	$9,510
1 ' RGS conduit	600	LF	$4	$5	$9	$5,640	600	LF	$4	$5	$9	$5,640
3/4 ' RGS conduit	100	LF	$2	$4	$6	$640	100	LF	$2	$4	$6	$640
Conductor - Size #4	20	CLF	$41	$62	$102	$2,040	20	CLF	$41	$62	$102	$2,040
Conductor - Size #12	5	CLF	$7	$65	$72	$360	5	CLF	$7	$65	$72	$360
Conductor - control	5	CLF	$4	$45	$49	$245	5	CLF	$4	$45	$49	$245
Wall mounted 75 amp circuit breaker	1	EA	$750	$500	$1,250	$1,250	1	EA	$750	$500	$1,250	$1,250
45 kva dry transformer	1	EA	$1,700	$1,814	$3,514	$3,514	1	EA	$1,700	$1,814	$3,514	$3,514
200 amp power panel	1	EA	$1,225	$1,835	$3,060	$3,060	1	EA	$1,225	$1,835	$3,060	$3,060
20 amp circuit breaker	20	EA	$30	$20	$50	$1,000	20	EA	$30	$20	$50	$1,000
Cat 5 cable	6	CLF	$3	$58	$61	$366	6	CLF	$3	$58	$61	$366
Control Building	1	EA	$5,000	$2,000	$7,000	$7,000	1	EA	$5,000	$2,000	$7,000	$7,000
						$0						$0
						$0						$0
OPTION 1						$0						$0
BARGE						$0						$0
10x40x5 Units	13	EA	$36,000	$1,000	$37,000	$481,000						$0
10x20x5 Units	2	EA	$22,000	$1,000	$23,000	$46,000						$0
Overhead Frame	40,000	LB	$8		$8	$320,000						$0
Spool for 480kv	1	EA	$2,000		$2,000	$2,000						$0
Railing - Aluminum	240	LF	$50		$50	$12,000						$0
Misc Lighting & Electrical	1	EA	$2,000		$2,000	$2,000						$0
Thethers	4	EA	$1,000		$1,000	$4,000						$0
						$0						$0
STRUCTURAL						$0						$0
32x68 SS Frame	11,000	LB	$11		$11	$121,000						$0
32x54 SS Frame	9,000	LB	$11		$11	$99,000						$0
						$0						$0
MECHANICAL						$0						$0
68' Hoist, Torque Tube & Spools	1	EA	$130,000		$130,000	$130,000						$0
54' Hoist, Torque Tube & Spools	1	EA	$120,000		$120,000	$120,000						$0
Controls	2	EA	3,000		$3,000	$6,000						$0
						$0						$0
						$0						$0
						$0						$0
						$0						$0
OPTION 2						$0						$0
TRACK						$0						$0
Stainless Steel Track & Supports						$0	14,501	LB	11		$159,511	$159,511
Underwater Track Installation						$0				$250,000		$250,000
SLED						$0						$0
Stainless Steel Fab						$0	5,000	LB	11		$55,000	$55,000
						$0						$0
MECHANICAL						$0						$0
Hoist and Power Spool						$0	9	EA	10,000	$2,000	$12,000	$14,000
Controls						$0	1	EA	1,500		$1,500	$1,500
						$0						$0
						$0						$0
Project Subtotal						**$2,230,625**						**$1,176,036**
Contingency					**20%**	**$446,125**					**20%**	**$235,207**
TOTAL ESTIMATED PROJECT COST						**$2,676,749**						**$1,411,243**

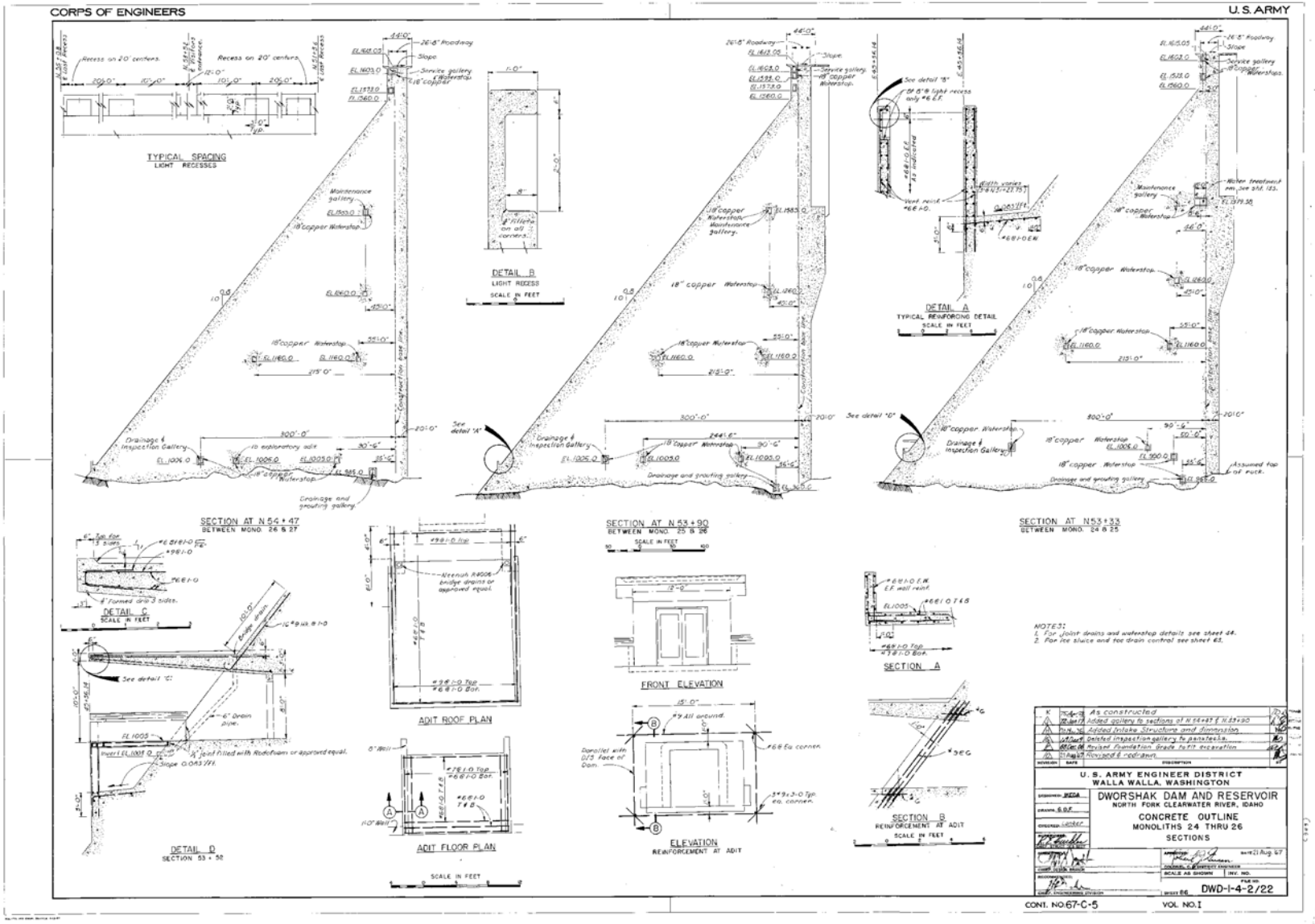
Appendix C
Dworshak Dam Select As-Built Construction Drawings

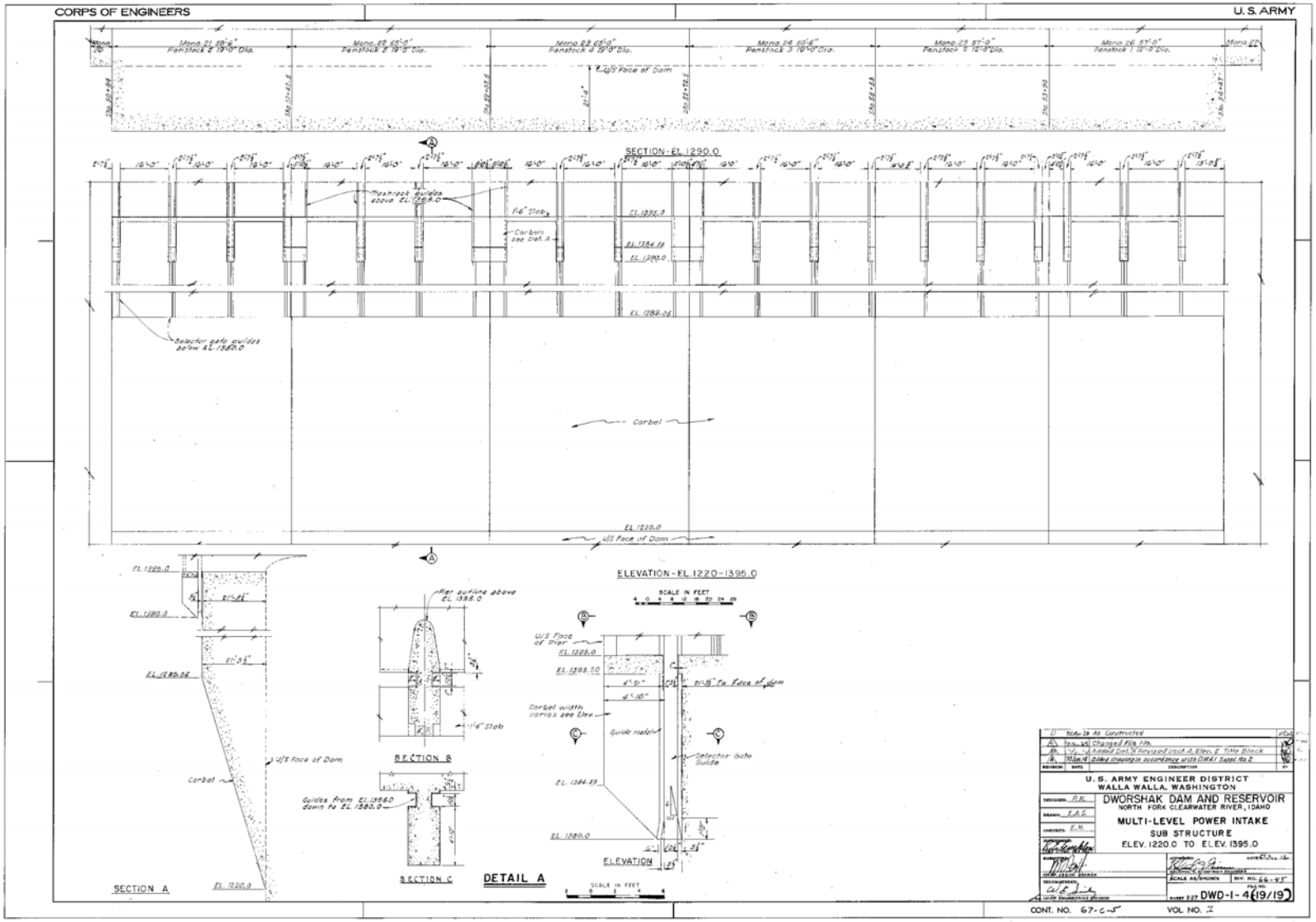

CORPS OF ENGINEERS
U.S. ARMY
GENERAL PLAN
SCALE IN FEET
GENERAL NOTES:
U. S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
DWORSHAK DAM AND RESERVOIR
NORTH FORK CLEARWATER RIVER, IDAHO
GENERAL
GENERAL PLAN
AND GENERAL NOTES
DWD-1-0-1/2
CONT. NO. 67-C-5
VOL. NO. 1

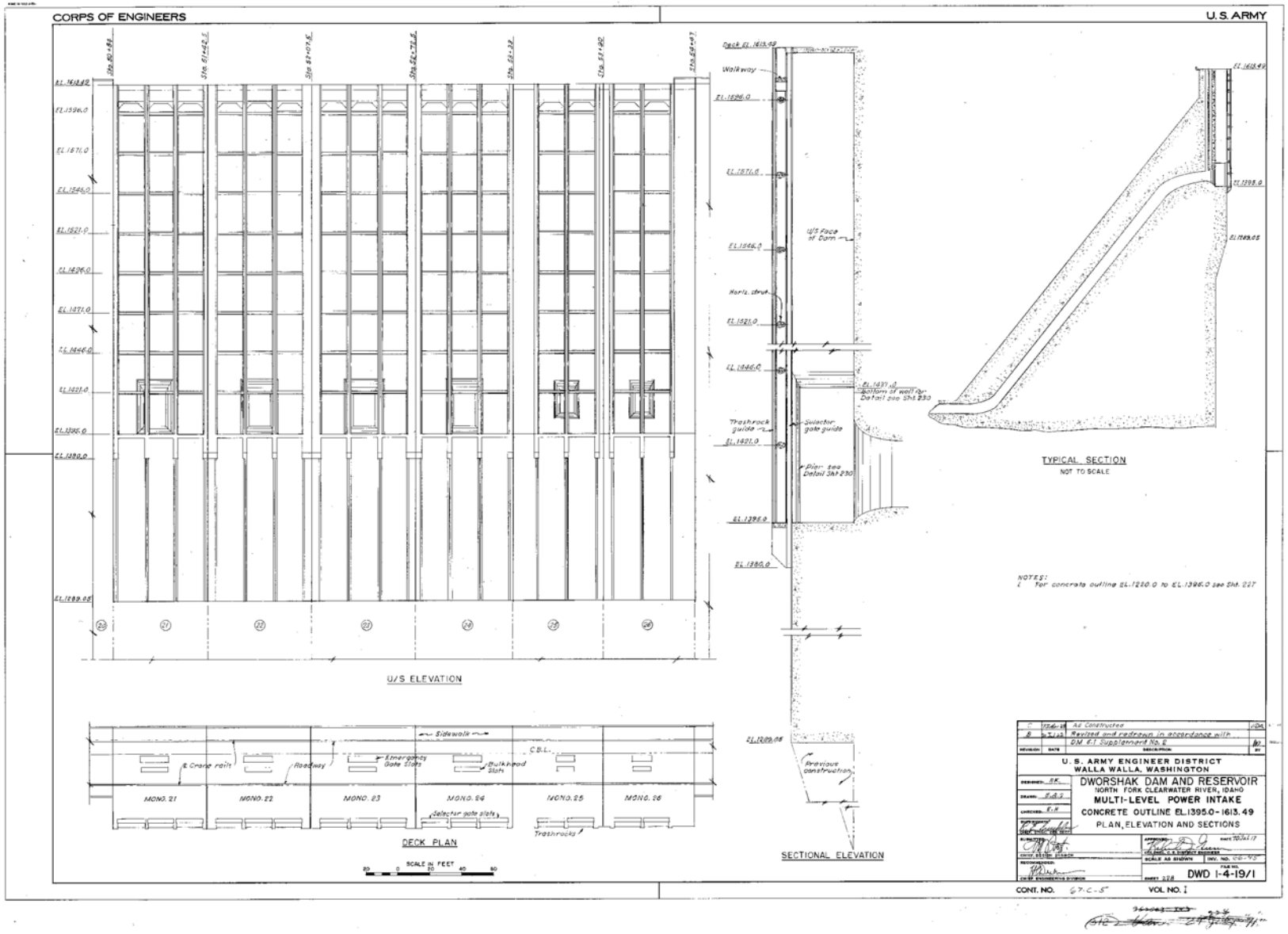

CORPS OF ENGINEERS
U. S. ARMY
South Elevator Tower
North Elevator Tower
Bulkhead Slot & Vent
Visitors reception center
Deck Gantry Crane, parked
Guide slots for log boom
Temporary low level outlet
Diversion tunnel
Assumed top of rock at base of dam
UPSTREAM ELEVATION
SCALE IN FEET
NOTES:
1. Pool level intake location is shown on Sheet 342, Vol. II
2. For log boom guide slots details, see sheet 306.1 Vol. I
U. S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
DWORSHAK DAM AND RESERVOIR
NORTH FORK CLEARWATER RIVER, IDAHO
GENERAL
UPSTREAM ELEVATION
DWD-1-0-1/4
CONT. NO. 67-C-5
VOL. NO. I

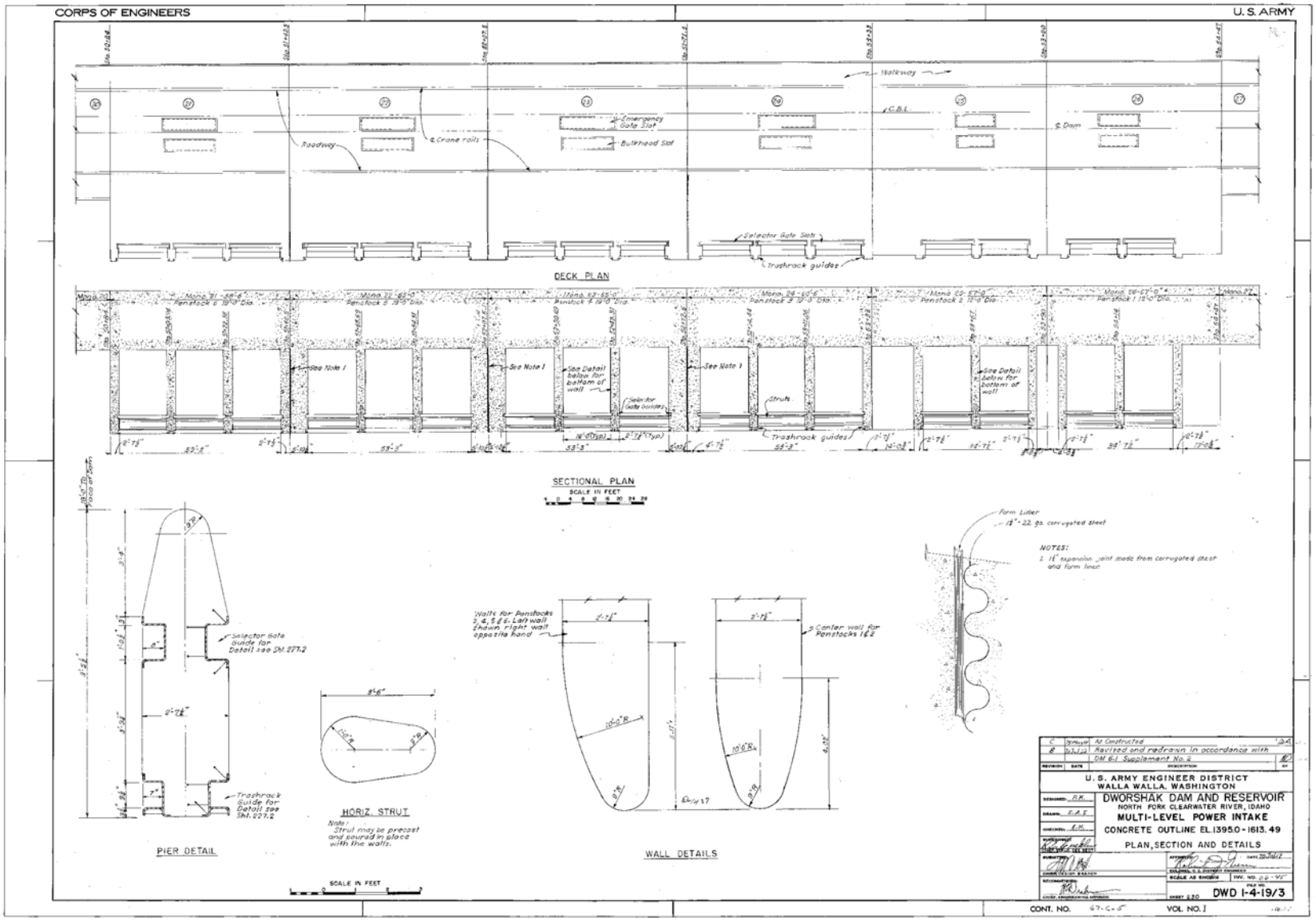

CORPS OF ENGINEERS
U.S. ARMY
TYPICAL CURB DETAIL
TYPICAL DECK SECTION
GALLERY
DOWNSTREAM
UPSTREAM
CURB GUARD PLATE
D/S ROADWAY CURB - N48+88 TO N49+22
TYPICAL SECTION
CURB GUARD AND CRANE RAIL
TYPICAL ARRANGEMENT
CRANE RAIL AND CURB GUARD ANCHORS
BLOCKOUT CONCRETE NOT SHOWN
SECTION A
CRANE STOP
NOTES:
U.S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
DWORSHAK DAM AND RESERVOIR
NORTH FORK CLEARWATER RIVER, IDAHO
GENERAL
ROADWAY DECK AND CRANE RAIL DETAILS
DWD-I-4-2/2
CONT. NO. 67-C-5
VOL. NO. I

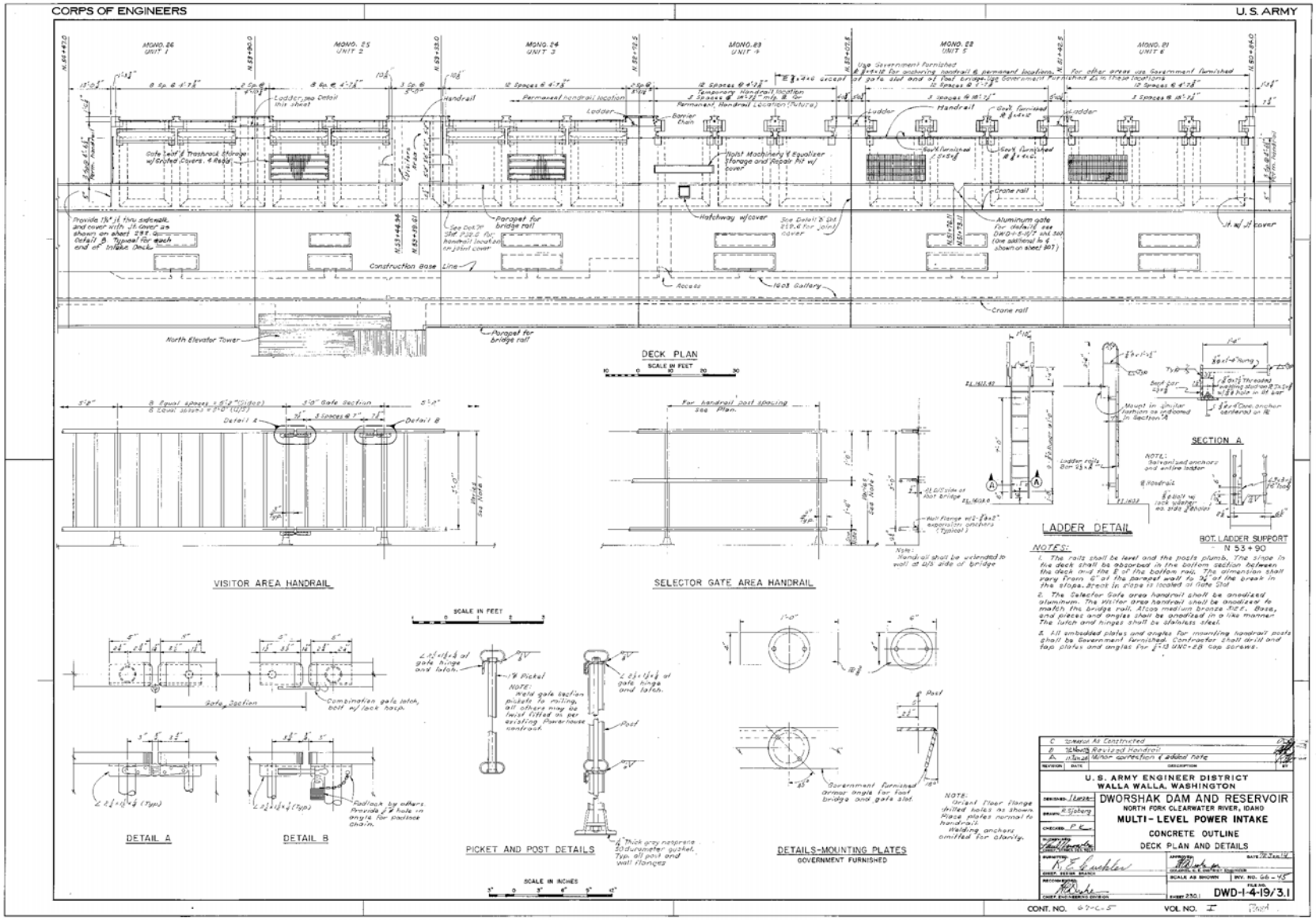

CORPS OF ENGINEERS
U.S. ARMY
U.S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
DWORSHAK DAM AND RESERVOIR
NORTH FORK CLEARWATER RIVER, IDAHO
GENERAL
ROADWAY DECK PLAN
N46+80 TO N55+12
DWD-1-4-2/4
CONT. NO. 67-C-5
VOL. NO. 1

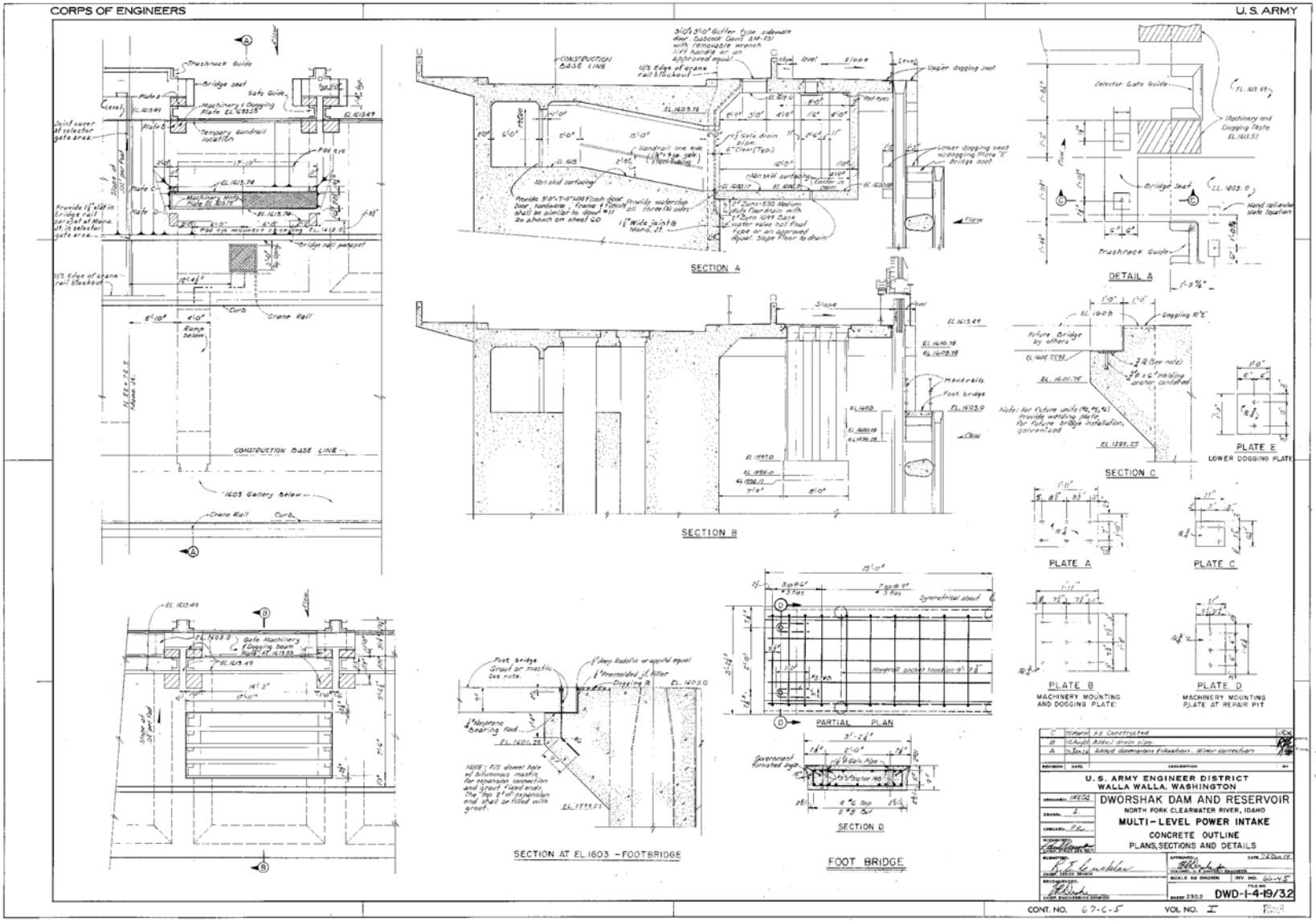

CORPS OF ENGINEERS
U.S. ARMY
TYPICAL SPACING
LIGHT RECESSES
DETAIL B
LIGHT RECESS
SCALE IN FEET
DETAIL A
TYPICAL REINFORCING DETAIL
SCALE IN FEET
SECTION AT N 54+47
BETWEEN MONO. 26 & 27
SECTION AT N 53+90
BETWEEN MONO. 25 & 26
SECTION AT N 53+33
BETWEEN MONO. 24 & 25
DETAIL C
SCALE IN FEET
DETAIL D
SECTION 53 + 50
ADIT ROOF PLAN
ADIT FLOOR PLAN
FRONT ELEVATION
ELEVATION
REINFORCEMENT AT ADIT
SECTION A
SECTION B
REINFORCEMENT AT ADIT
SCALE IN FEET
NOTES:
1. For joint drains and waterstop details see sheet 44.
2. For ice sluice and toe drain control see sheet 63.
U.S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
DWORSHAK DAM AND RESERVOIR
NORTH FORK CLEARWATER RIVER, IDAHO
CONCRETE OUTLINE
MONOLITHS 24 THRU 26
SECTIONS
DWD-I-4-2/22
CONT. NO.67-C-5
VOL. NO.I

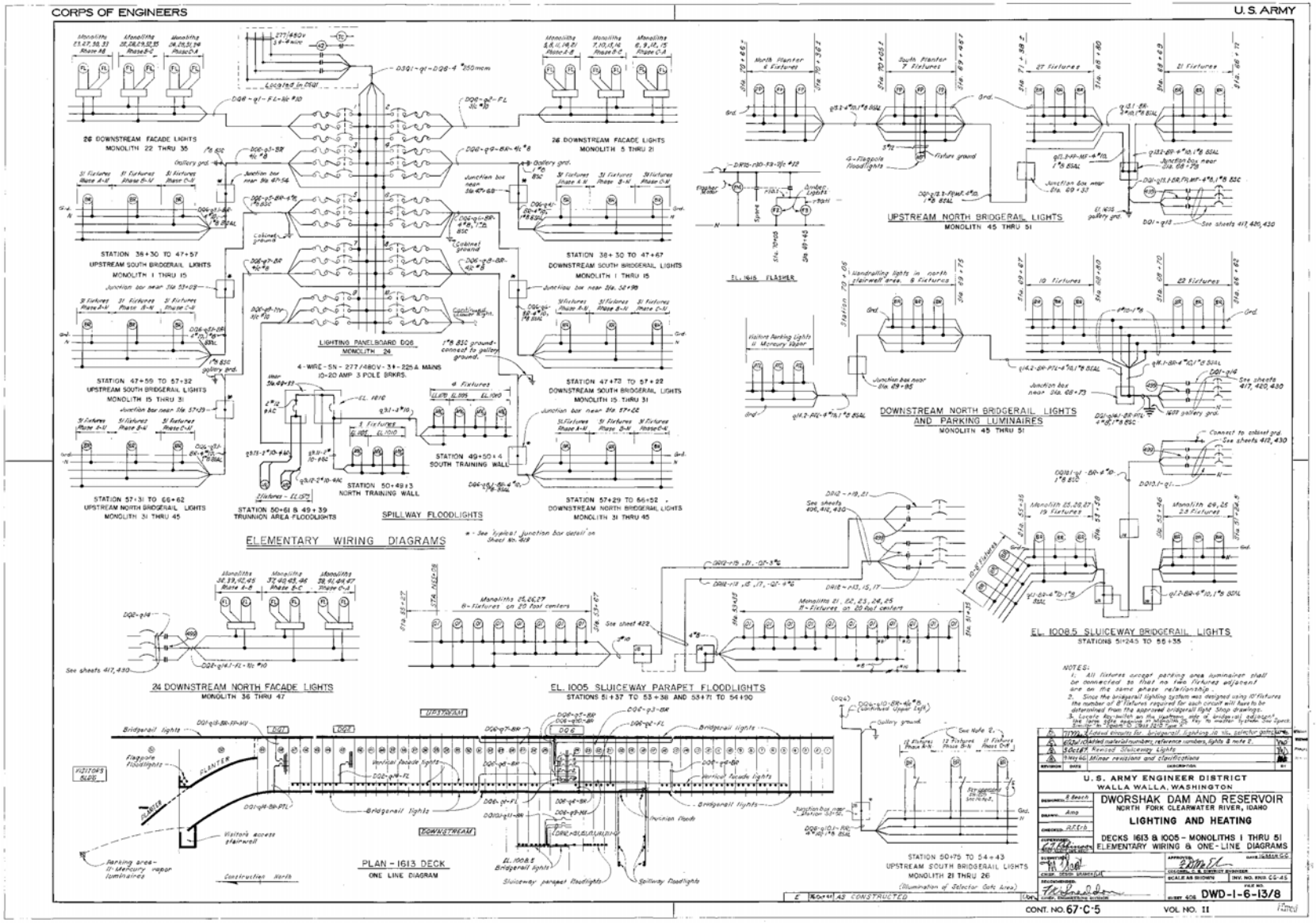

CORPS OF ENGINEERS
U. S. ARMY
SECTION - EL. 1290.0
ELEVATION - EL. 1220 - 1395.0
SECTION A
SECTION B
SECTION C
DETAIL A
ELEVATION
U.S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
DWORSHAK DAM AND RESERVOIR
NORTH FORK CLEARWATER RIVER, IDAHO
MULTI-LEVEL POWER INTAKE
SUB STRUCTURE
ELEV. 1220.0 TO ELEV. 1395.0
DWD-I-4(19/19)
CONT. NO. 67-C-5
VOL. NO. I
262063 343

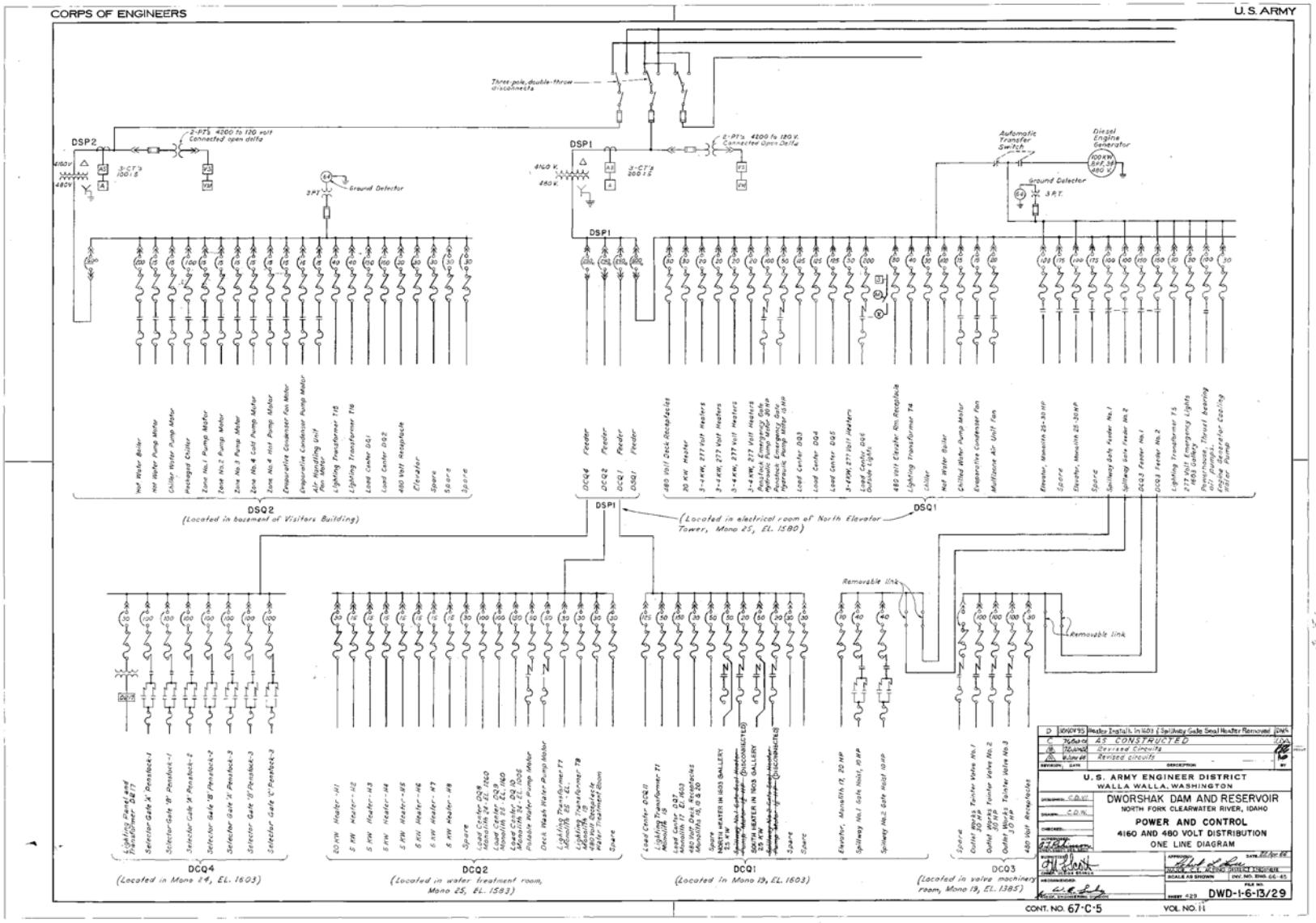

CORPS OF ENGINEERS
U.S. ARMY
U/S ELEVATION
DECK PLAN
SECTIONAL ELEVATION
TYPICAL SECTION
NOT TO SCALE
NOTES:
1. For concrete outline EL.1220.0 to EL.1395.0 see Sht. 227
U. S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
DWORSHAK DAM AND RESERVOIR
NORTH FORK CLEARWATER RIVER, IDAHO
MULTI-LEVEL POWER INTAKE
CONCRETE OUTLINE EL.1395.0-1613.49
PLAN, ELEVATION AND SECTIONS
DWD 1-4-19/1
CONT. NO. 67-C-5
VOL. NO. I


CORPS OF ENGINEERS
U. S. ARMY
DECK PLAN
SECTIONAL PLAN
PIER DETAIL
HORIZ. STRUT
WALL DETAILS
U. S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
DWORSHAK DAM AND RESERVOIR
NORTH FORK CLEARWATER RIVER, IDAHO
MULTI-LEVEL POWER INTAKE
CONCRETE OUTLINE EL.1395.0-1613.49
PLAN, SECTION AND DETAILS
DWD I-4-19/3
CONT. NO. 67-C-5
VOL. NO. I


CORPS OF ENGINEERS
U.S. ARMY
DECK PLAN
SCALE IN FEET
VISITOR AREA HANDRAIL
SELECTOR GATE AREA HANDRAIL
LADDER DETAIL
SECTION A
BOT. LADDER SUPPORT
NOTES:
DETAIL A
DETAIL B
PICKET AND POST DETAILS
DETAILS-MOUNTING PLATES
GOVERNMENT FURNISHED
SCALE IN INCHES
U.S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
DWORSHAK DAM AND RESERVOIR
NORTH FORK CLEARWATER RIVER, IDAHO
MULTI-LEVEL POWER INTAKE
CONCRETE OUTLINE
DECK PLAN AND DETAILS
DWD-1-4-19/3.1
CONT. NO.
VOL. NO.


CORPS OF ENGINEERS
U.S. ARMY
SECTION A
SECTION B
DETAIL A
SECTION C
PLATE A
PLATE B
PLATE C
PLATE D
PLATE E
LOWER DOGGING PLATE
MACHINERY MOUNTING AND DOGGING PLATE
MACHINERY MOUNTING PLATE AT REPAIR PIT
PARTIAL PLAN
SECTION D
FOOT BRIDGE
SECTION AT EL 1603 - FOOTBRIDGE
U.S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
DWORSHAK DAM AND RESERVOIR
NORTH FORK CLEARWATER RIVER, IDAHO
MULTI-LEVEL POWER INTAKE
CONCRETE OUTLINE
PLANS, SECTIONS AND DETAILS
DWD-1-4-19/3.2
CONT. NO. 67-C-5
VOL NO. I


CORPS OF ENGINEERS
U.S. ARMY
ELEMENTARY WIRING DIAGRAMS
26 DOWNSTREAM FACADE LIGHTS
MONOLITH 22 THRU 35
STATION 38+30 TO 47+57
UPSTREAM SOUTH BRIDGERAIL LIGHTS
MONOLITH 1 THRU 15
STATION 47+59 TO 57+32
UPSTREAM SOUTH BRIDGERAIL LIGHTS
MONOLITH 15 THRU 31
STATION 57+31 TO 66+62
UPSTREAM NORTH BRIDGERAIL LIGHTS
MONOLITH 31 THRU 45
LIGHTING PANELBOARD DQ6
MONOLITH 24
4-WIRE-SN-277/480V-3Φ-225A MAINS
10-20 AMP 3 POLE BRKRS.
STATION 50+61 & 49+39
TRUNNION AREA FLOODLIGHTS
STATION 50+49±3
NORTH TRAINING WALL
STATION 49+50±4
SOUTH TRAINING WALL
SPILLWAY FLOODLIGHTS
26 DOWNSTREAM FACADE LIGHTS
MONOLITH 5 THRU 21
STATION 38+30 TO 47+67
DOWNSTREAM SOUTH BRIDGERAIL LIGHTS
MONOLITH 1 THRU 15
STATION 47+73 TO 57+22
DOWNSTREAM SOUTH BRIDGERAIL LIGHTS
MONOLITH 15 THRU 31
STATION 57+29 TO 66+52
DOWNSTREAM NORTH BRIDGERAIL LIGHTS
MONOLITH 31 THRU 45
UPSTREAM NORTH BRIDGERAIL LIGHTS
MONOLITH 45 THRU 51
DOWNSTREAM NORTH BRIDGERAIL LIGHTS
AND PARKING LUMINAIRES
MONOLITH 45 THRU 51
EL. 1616 FLASHER
24 DOWNSTREAM NORTH FACADE LIGHTS
MONOLITH 36 THRU 47
EL. 1005 SLUICEWAY PARAPET FLOODLIGHTS
STATIONS 51+37 TO 53+38 AND 53+71 TO 54+90
EL. 1008.5 SLUICEWAY BRIDGERAIL LIGHTS
STATIONS 51+245 TO 56+35
PLAN - 1613 DECK
ONE LINE DIAGRAM
STATION 50+75 TO 54+43
UPSTREAM SOUTH BRIDGERAIL LIGHTS
MONOLITH 21 THRU 26
NOTES:
1. All fixtures except parking area luminaires shall be connected so that no two fixtures adjacent are on the same phase relationship.
2. Since the bridgerail lighting system was designed using 10' fixtures the number of 8' fixtures required for each circuit will have to be determined from the approved bridgerail light Shop drawings.
3. Locate Key-switch on the upstream side of bridgerail adjacent the light. Place another switch on the key on weather tightness. See Specs. Sheet 1 of 2 Sheets
U.S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
DWORSHAK DAM AND RESERVOIR
NORTH FORK CLEARWATER RIVER, IDAHO
LIGHTING AND HEATING
DECKS 1613 & 1005 - MONOLITHS 1 THRU 51
ELEMENTARY WIRING & ONE-LINE DIAGRAMS
DWD-1-6-13/8
CONT. NO. 67-C-5
VOL. NO. II


CORPS OF ENGINEERS
U.S. ARMY
DSP2
DSP1
DSQ2
(Located in basement of Visitors Building)
DSQ1
(Located in electrical room of North Elevator Tower, Mono 25, EL. 1580)
DCQ4
(Located in Mono 24, EL. 1603)
DCQ2
(Located in water treatment room, Mono 25, EL. 1583)
DCQ1
(Located in Mono 19, EL. 1603)
DCQ3
(Located in valve machinery room, Mono 19, EL. 1385)
Removable link
AS CONSTRUCTED
Revised Circuits
U.S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
DWORSHAK DAM AND RESERVOIR
NORTH FORK CLEARWATER RIVER, IDAHO
POWER AND CONTROL
4160 AND 480 VOLT DISTRIBUTION
ONE LINE DIAGRAM
DWD-I-6-13/29
CONT. NO. 67-C-5
VOL. NO. 11

Prepared by:

Eric J. Stark
Sr. Fishery Research Biologist

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

_____
Steve Yundt, Chief
Bureau of Fisheries

_____
Daniel J. Schill
Fisheries Research Manager