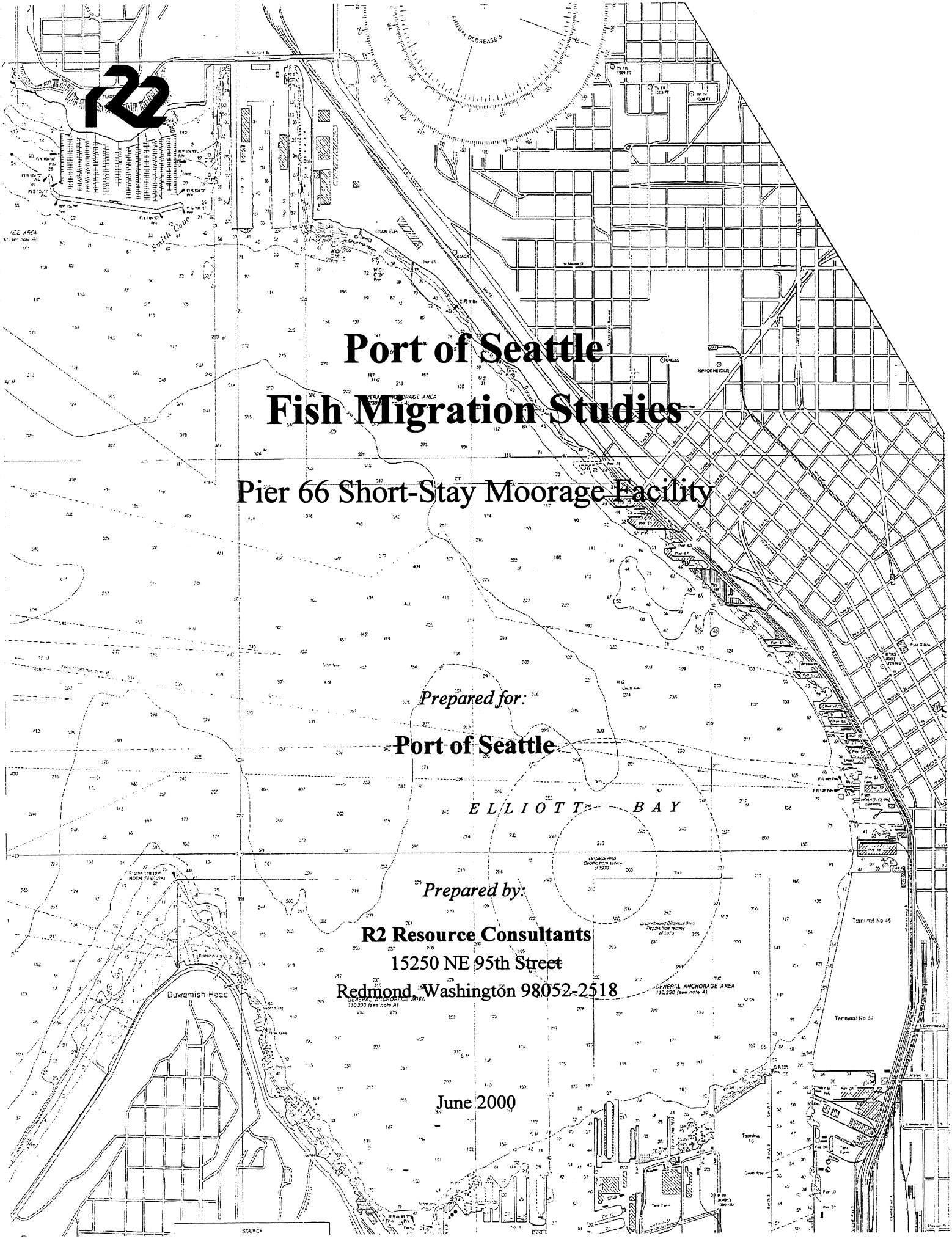

Port of Seattle
Fish Migration Studies

Pier 66 Short-Stay Moorage Facility

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Port of Seattle

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JUVENILE SALMONID MIGRATION STUDIES

1. INTRODUCTION

As part of the Port of Seattle's moorage monitoring studies, Beak Consultants was retained to assess how successfully juvenile salmonids negotiate the new short-stay moorage facility at Bell Street Pier 66 during their 1996 outmigration. This moorage facility includes a pile-supported wave board to attenuate waves in lieu of a traditional riprap fill breakwater. To provide adequate wave protection for the moorage, however, the wave board nearly meets the shoreline, potentially blocking the migration path of juvenile salmonids. During project design, the area where the wave board approached the shoreline was re-designed in consultation with resource agencies and tribes (primarily Randy Carmen, WDFW) to allow uninterrupted migration of juvenile fish along the shoreline.

The revised fish passage design elements include a "fish opening" or a gap between the shore and the wave board and openings in the deck above the fish opening and along the intertidal area north of the opening. The fish opening varies in width from 20 feet at mean lower low water (MLLW, El + 0.0 feet) to approximately 43 feet at mean higher high water (MHHW, El +12.0 feet). Other design considerations include: 1) two additional 8 feet wide openings at the base of the wave boards (P1 and P2) adjacent to the main shore opening, offering various levels of water depth for fish passage depending upon tidal elevation (Figure 1), and 2) surface openings in the pier deck in the vicinity of the fish opening and immediately north to allow light to penetrate beneath the pier (Figure 2). The objective of the deck openings is to illuminate the water so fish can readily locate and pass through wave board openings to shoreline areas beyond. Also immediately northward of the "fish opening" was an bench constructed in the shoreline slope at elevation 0.0 MLLW, for the enhanced production of epibenthic fauna preferred as juvenile salmonid food items (Figure 2).

Regardless of design features, successful fish passage was in question due to the lack of information on juvenile salmonid behavior around structures combined with narrow openings and partial overwater coverage. Subsequent concerns related to predation would arise is fish do not quickly negotiate the facility. As a result, the Port in consultation with WDFW prepared a monitoring program and contingency actions that would provide evaluation of fish passage and implementation of corrective actions as appropriate (Parametrix 1993).

Monitoring objectives of the program include the following:

1) Do juvenile salmonids successfully negotiate the public short-stay moorage?

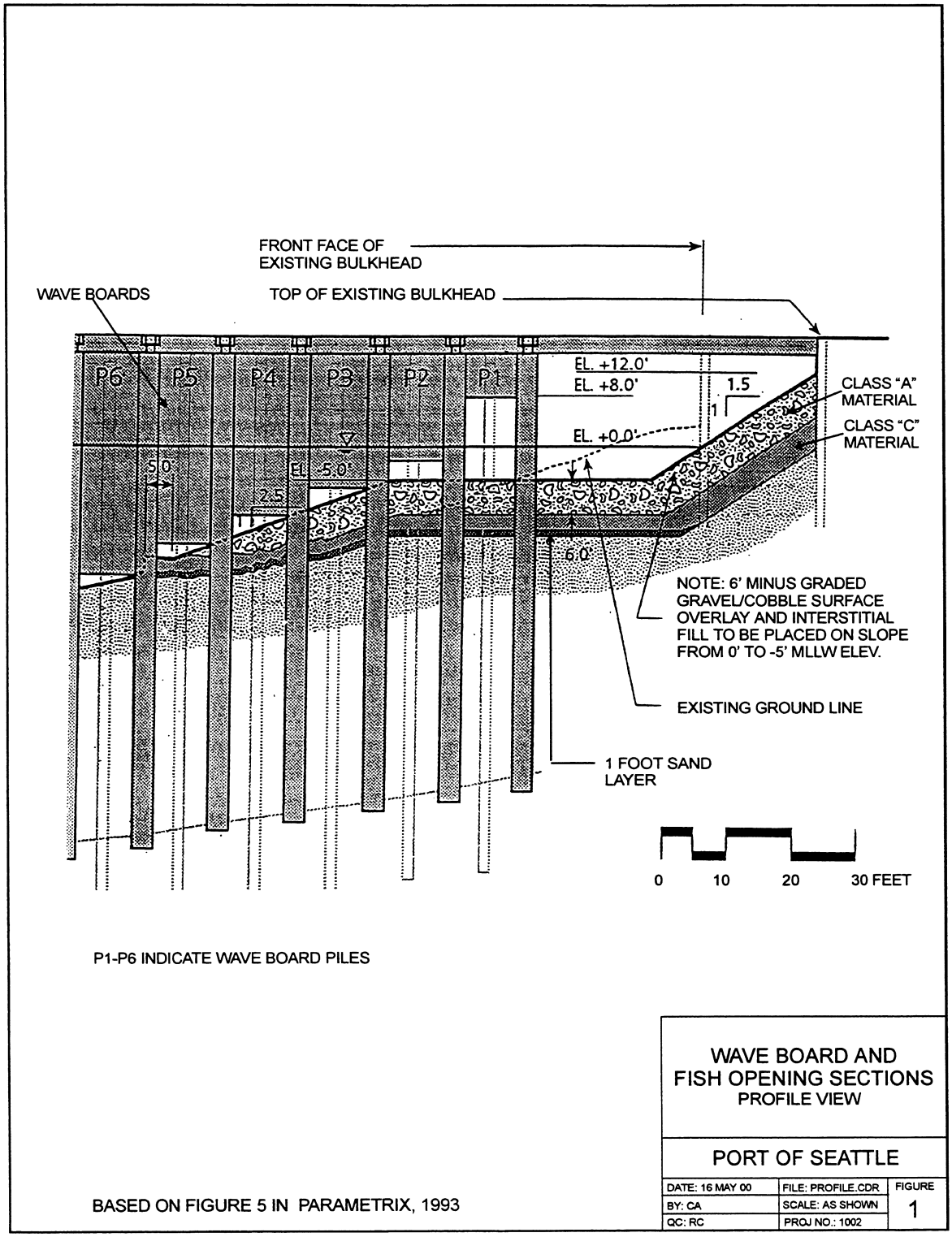

Figure 1. Fish opening sections.

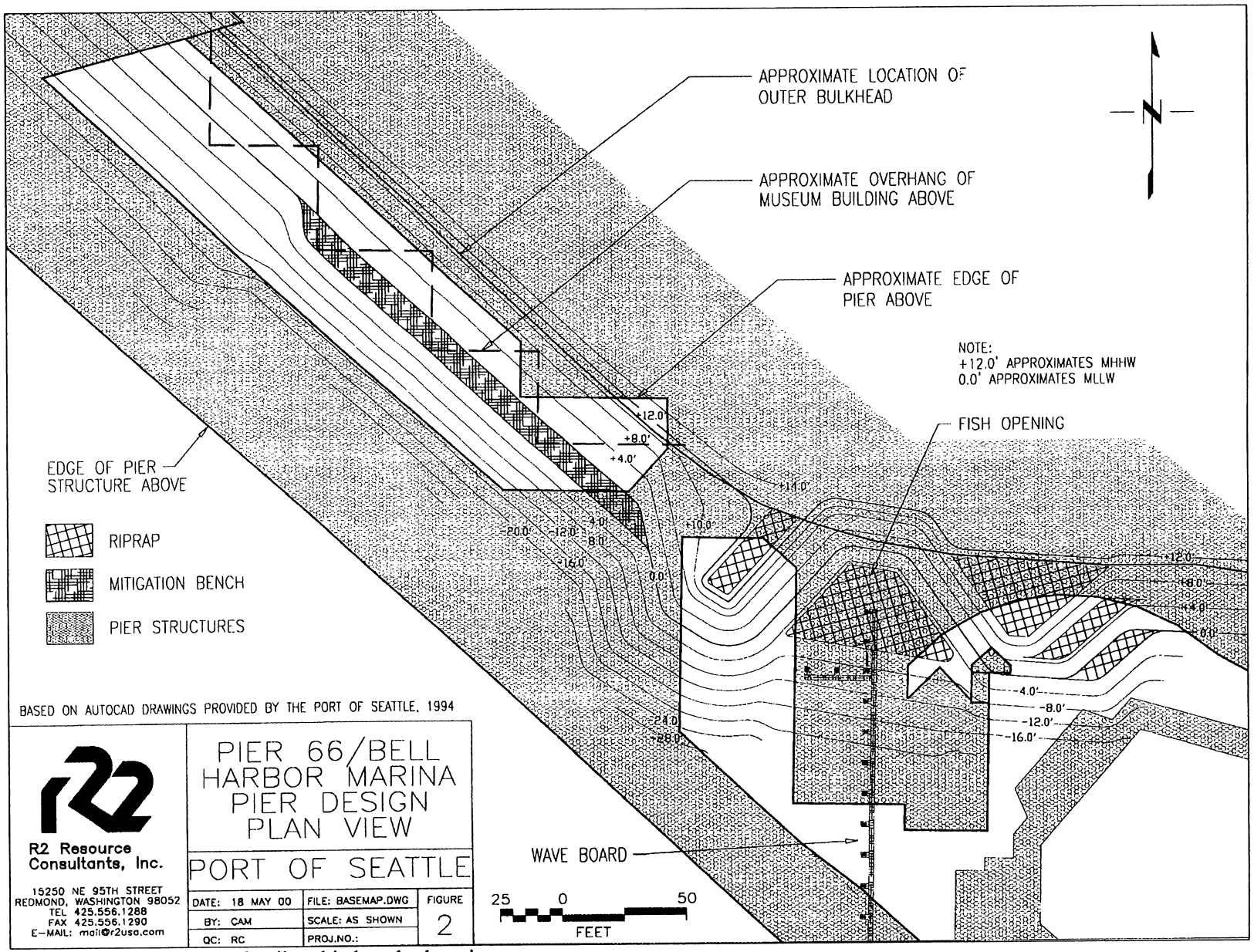

Figure 2. Fish opening and epibenthic bench plan view.

2) Do juvenile salmonids use the fish opening at the northern end of the wave board?

3) Are avian predators especially abundant in the vicinity of the fish opening?

The consensus study plan outlined two tasks to address the objectives; a juvenile salmonid mark and recapture study and a qualitative fish and predator observation program. The methodology for these two studies is described in Parametrix (1993) and summarized herein as Section 2.

Performance standards to meet, prior to implementing any Port proposed contingency plans, include:

1) Juvenile salmonids are observed to pass through the fish opening; or

2) Mark and recapture studies indicate fish pass the moorage facility from south to north (the assumed prevailing migration pattern along the shoreline); and

3) There are no unusual concentrations of predatory birds in the vicinity of the fish opening.

The results of the monitoring study for the 1996 outmigration period and an assessment of the performance standards are reported herein as Sections 3 and 4, respectively.

2. METHODOLOGY

2.1 MARK AND RECAPTURE STUDY

The purpose of the mark and recapture study was to release marked fish south of the moorage facility and to subsequently recapture them along the shoreline of Elliott Bay to determine if they successfully negotiate the moorage facility based on their point of capture. Distance traveled by recaptured salmonids and the time between release and recapture was used to calculate migration direction and speed of migration along the waterfront.

2.1.1 Target Fish and Period of Abundance

The abundance and migration patterns of juvenile chum and chinook salmon along the Seattle waterfront led to their selection as the target species. The mark and recapture study was performed between 9 and 31 May 1996, which coincided with the peak outmigration of juvenile chum and chinook from the Duwamish River estuary (Figure 3). This period was selected to

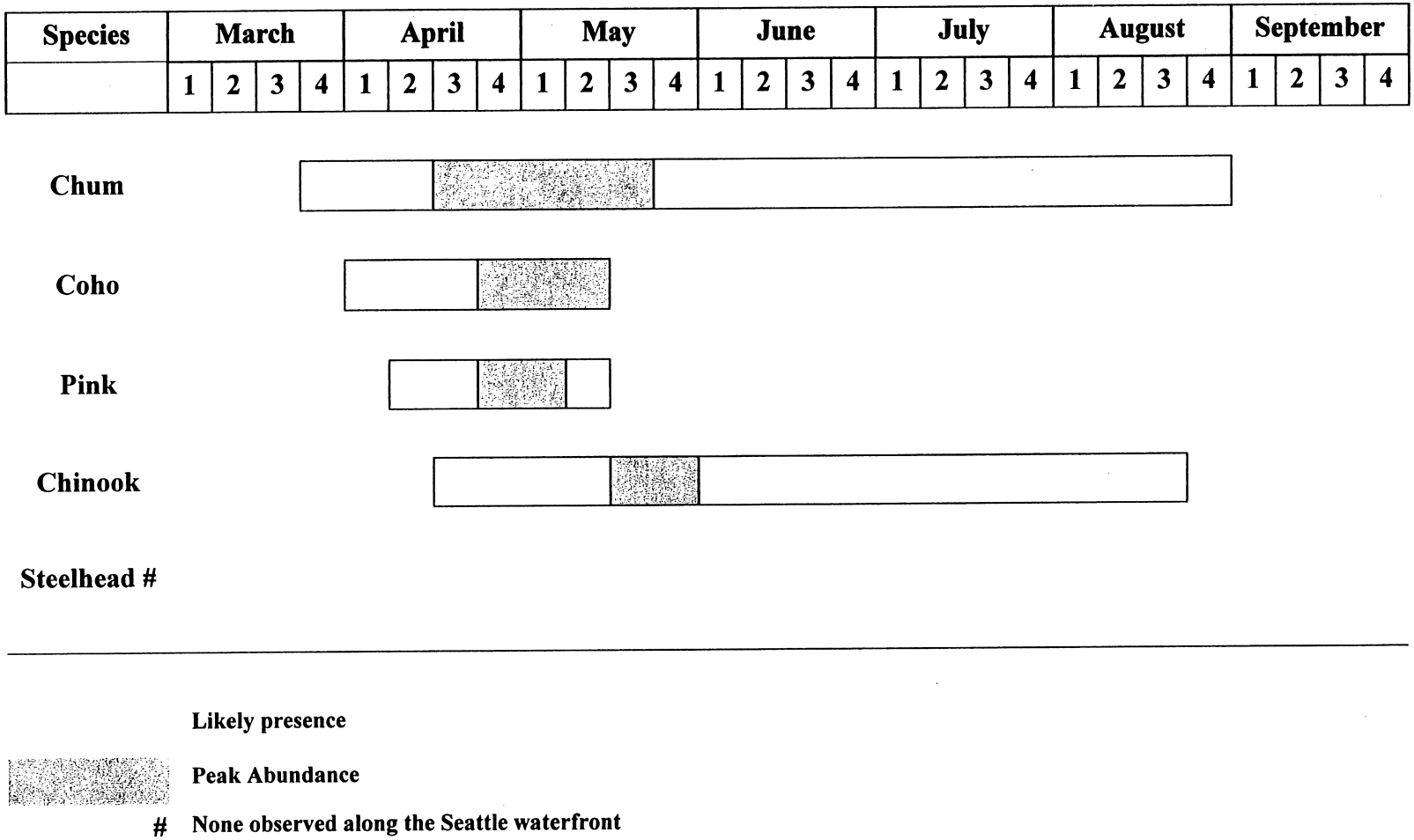

Figure 3. Summary of annual appearance and peak abundance data for juvenile salmonid fishes from previous surveys along the Elliott Bay shoreline.

increase the likelihood of capturing the target species for marking. In addition, both the Seattle Aquarium and the Muckleshoot Indian Tribe offered chum salmon for marking and release during the normal liberation dates for these species from their respective facilities. Approximately 5,000 marked chum (384/lb; at the mean size of 53 mm) of Keta Creek Hatchery origin were released at 1300 hours on 3 May 1996 in the lower Duwamish River near Kellogg Island at approximate River Mile 1.3. Estimated travel time to the short-stay moorage facility was estimated to be between 8 and 10 days according to prior travel time estimates of 1,200 to 1,500 feet per day for chum salmon along the Seattle waterfront (Parametrix 1980; Meyer et al. 1981; Weitkamp and Schadt 1982). Approximately 9,000 marked chum salmon (108/lb; at the mean size of 81 mm) were released at 2000 hours from the Seattle Aquarium at Pier 59 immediately south of the moorage basin on 8 May 1996. The estimated travel time to the moorage facility was estimated to be 2 to 3 days. The aquarium fish were especially large relative to other hatchery plants of chum salmon during the spring of 1996 (Table 1) and were nearly twice as large as native juvenile chum typically found along the Seattle waterfront during this time period.

Currents in Elliott Bay are very weak and dominated by semi-diurnal tides and the freshwater outflow from the Duwamish River. The average currents suggest a counter-clockwise gyre exists in the inner bay sweeping water northwesterly along the Seattle waterfront. The Duwamish River plume appears on the north side of the bay regardless of the tidal stage (Sillcox et al. 1981). The residence time for water in the inner bay is inferred to range from 1 to 10 days (Sillcox et al. 1981). It is assumed juvenile salmonids outmigrate past the waterfront in accordance to the prevailing current pattern.

2.1.2 Marking Techniques

Florescent Spray Marking

Prior to field sampling, juvenile chum salmon were marked with florescent pigments of various colors as per Phinney et al. (1967). A total of 14,000 juvenile chum (5,000 from Keta Creek Hatchery, 9,000 from the Seattle Aquarium) were marked with yellow and red pigments, respectively.

Freeze Branding

A portion of the largest size classes (generally greater than 50 mm) of juvenile salmon captured during field sampling (Section 2.1.3) were marked with freeze brands. Each day, juvenile

Table 1. Duwamish and Elliott Bay hatchery releases: Spring 1996.

Date	Source	Species	Numbers Liberated	Weight	Estimated Size	Release Site	Marking	Available for Research
3-18 to 4-1-96	Muckleshoot	Chinook	572,000	~200/lb	60 mm	Above Howard Hansen Dam	70% Adipose clip/CWT	
3-27-26	Muckelshoot	Chum	212,400	397/lb	55 mm	Keta Creek	None	
4-11-26	Muckelshoot	Chum	72,100	398/lb	55 mm	Keta Creek	None	
4-11-26	Muckelshoot	Chum	200,000	398/lb	55 mm	Keta Creek	None	
4-24-96	Muckelshoot	Chum	180,400	396/lb	55 mm	Keta Creek	None	
5-01-96	Muckelshoot	Chum	176,100	384/lb	55 mm	Keta Creek	None	5,000 Yellow
5-08-96	Aquarium	Chum	56,000	108/lb	81 mm	Elliott Bay/P59	None	9,000 Red
Mid-May to Mid-June	WDFW	Chinook	3,200,000	~80/lb	78 mm	Soos Creek	6% Adipose clip/CWT	
Mid-June	Aquarium	Coho				Elliott Bay/P59		
Mid-June	Suquamish	Coho	200,000	20/lb	125 mm	Elliott Bay/P86	None	
Mid July	Aquarium	Chinook				Elliott Bay/P59		

salmon were branded with a different mark or in a different spot on the body above the lateral line. The following numbers of fish were marked during the field sampling effort:

chinook salmon	270
chum salmon	153
coho salmon	151
pink salmon	9
Total	583

Mark Retention and Handling Mortality Estimates

Approximately 400 marked juvenile chum were returned to the Bioassay Laboratory of Beak Consultants in Kirkland, Washington. The marked fish were held in the cold room for mark retention confirmation and handling mortality estimates.

2.1.3 Fish Collection

Juvenile salmonids along the waterfront in Elliott Bay were collected by two methods; a surface townet and a beach seine.

Trawl Net. A Kvichak trawl net (Figure 3) was used to sample the top portion of the water column in offshore areas around the wave board and piers located north and south of the moorage facility (Figure 4). The trawl net, made of 3/16 inch stretch mesh, was floated with two large pontoons positioned above each spreader bar. A lead weight was attached to the bottom of each spreader bar. The mouth of the trawl net was 9 ft^2 (0.8 m^2).

The Kvichak trawl net was pulled behind one or two boats. Tow speeds when one boat was used ranged from 1.5 to 1.9 knots. Tow speeds when two boats were used ranged from 2.6 to 3.6 knots.

Beach Seine. A 100-foot long by 10-feet deep beach seine made of 1/4-inch stretch mesh was used to sample nearshore areas within the moorage facility and at available beach sites north and south of the moorage facility (Figure 5). Beach seine site #1 (BS1) was located in the SE corner of the Canadian Ferry Terminal P-48. It consisted of a shallow sandy beach available for seining at mid-to low tidal elevations. Due to excessive water depths, this beach was not available to seining at high tides. Beach seine site #2 (BS2) was located along the east shoreline near the

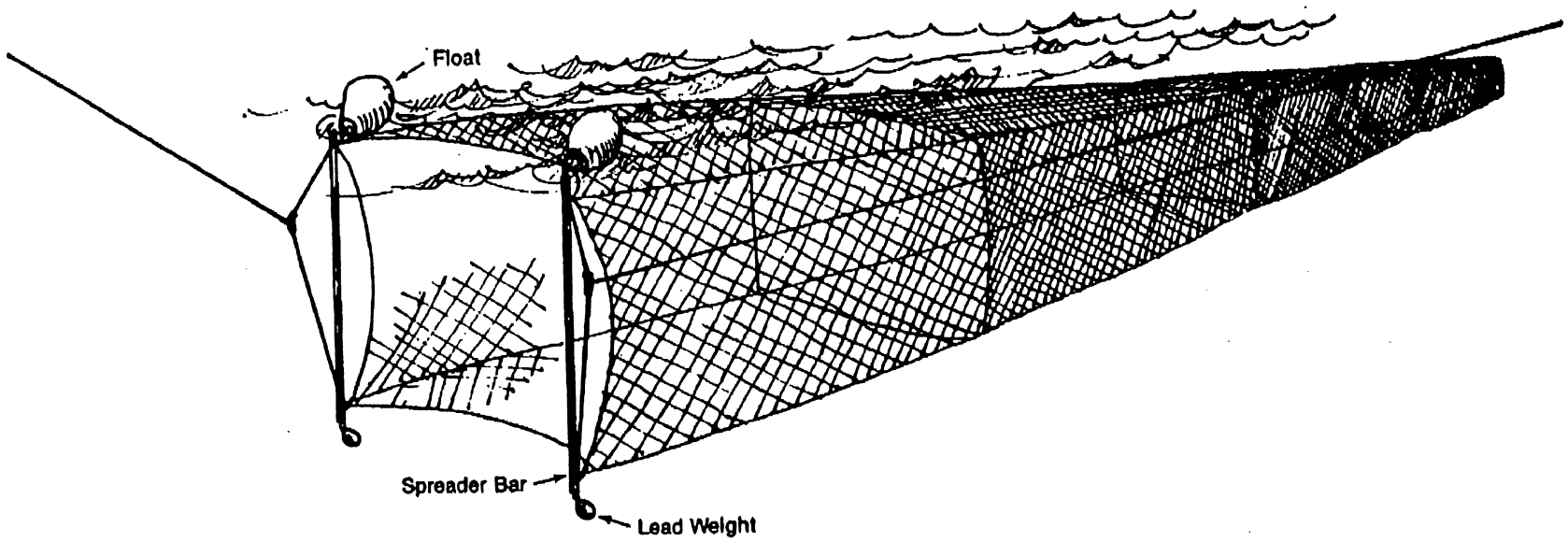

Figure 4. Kvichak trawl net (After Weitkamp and Schadt 1982).

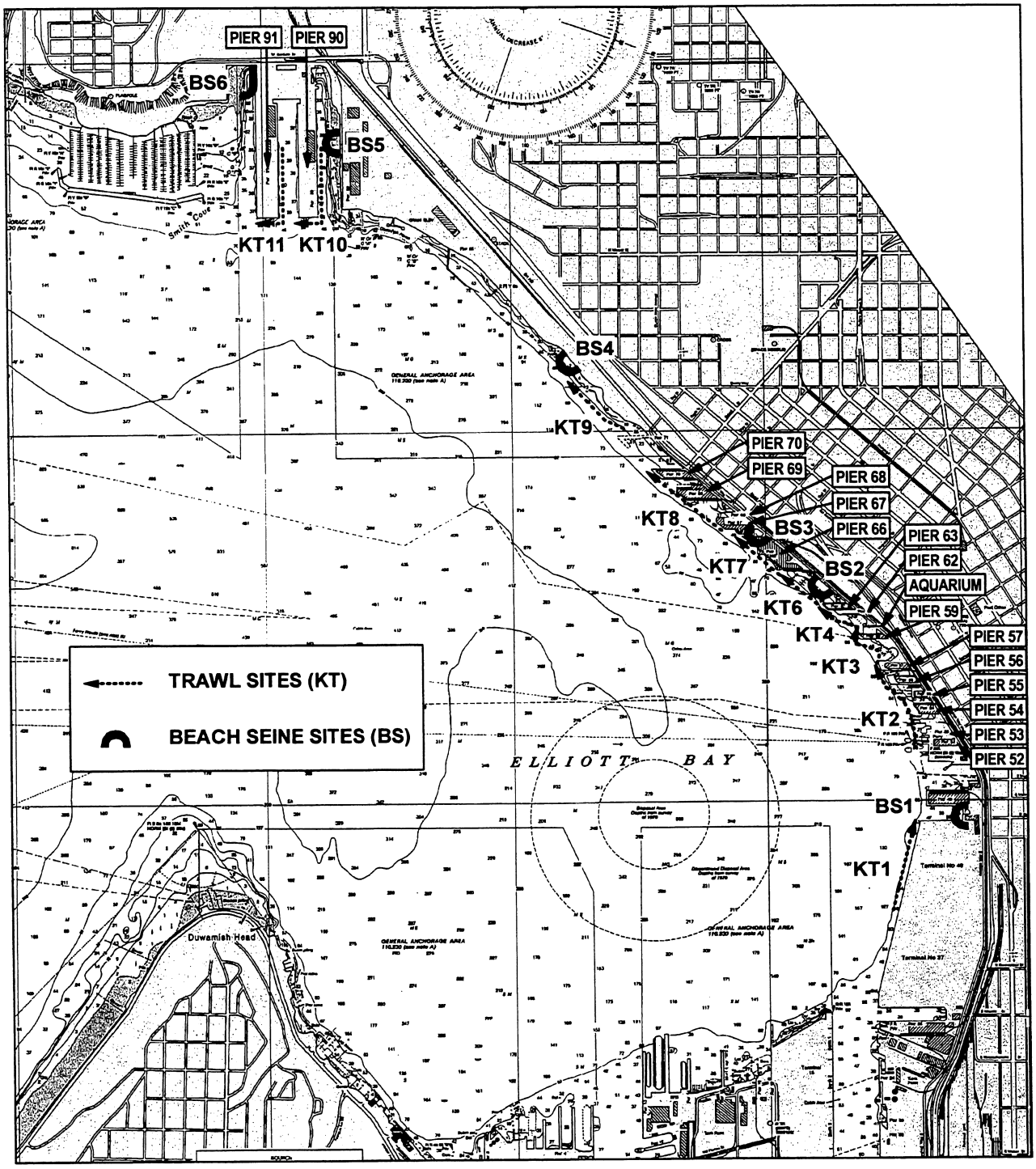

Figure 5. Elliott Bay, Seattle, Washington, showing beach seining and townet stations sampled during the fish migration study for the Pier 66 short-stay moorage facility.

entrance of the moorage basin (Pier 64/65). This site was steep riprap that offered difficult seining conditions. This sampling location was deleted prior to the 9 May start-up date due to the routine loss of fish during net retrieval during preliminary testing. Beach Seine site #3 (BS3) was also on the east shore in the moorage basin (Pier 66). It was located south of the wave board opening adjacent to the Tribal dock. Although the shoreline substrate also consisted of riprap at this site, the gradient was less steep than BS2, allowing for improved capture rates of juvenile salmonids. Beach seine site #4 (BS4) was located along the waterfront near Myrtle Beach Park at the Metro CSO site. This site offered coarse sand and cobble substrate that was readily available to seining techniques. Beach seine site #5 (BS5) was located mid-way down the eastern shore of Pier 89. It was a shallow muddy sand beach that offered good seining opportunities. Beach seine site #6 (BS6) was located in the NE corner of Smith Cove along Pier 91. The substrate at this site was primarily sand, but consisted of small gravel at higher tidal elevations. Accumulations of algae and macrophytes occasionally hindered fish processing during seines at low tides. Since the study objective was simply to recapture marked fish and not to quantitatively compare collections at the various sites, differences in sampling efficiency or substrate conditions between sampling locations was not considered an adverse situation. The straight-line distances between the beach seining sites and the two points where marked fish were released is shown in Table 2.

Table 2. Distance between beach seining sites and the two points where marked juvenile chum salmon were released into Elliott Bay.

Station	Distance North from Kellogg Island (ft)	Distance North from Pier 59 (ft)
B1 – Canadian Ferry Terminal – P46	16,896	--
B3 – Moorage Facility – P66	21,648	1,584
B4 – Myrtle Edwards Beach/Metro CSO	26,928	6,864
B5 – Pier 89	31,680	11,616
B6 – Smith Cover – Pier 91	34,848	14,784

The beach seine was deployed along shore from a boat by two biologists. All captured salmonids were held in livewells and aerated with battery-powered aerators. At the time of capture, sampling location and beach seine set time were recorded to allow calculation of migration rates for any recaptured fish. The fish were transported to Pier 66 where two biologists examined the fish. The fish were anesthetized with MS-222 and subsequently identified, enumerated, measured to the nearest mm (FL), and inspected for marks. A UV (black light) apparatus was used to recognize individuals marked with florescent pigments. A portion

of the unmarked fish was subsequently freeze-branded to increase the numbers of marked salmonids available to the study (Section 2.1.2). After examination, fish were allowed to recover in a live cage floating in the marina. At the end of the day, freeze-branded fish were transported by boat to an area south of the moorage facility (near Pier 59) where they were released. Captured fish previously marked with the fluorescent dye were released outside of the study area (north of Pier 91) to ensure they were not recaptured.

2.2 QUALITATIVE FISH AND PREDATOR OBSERVATION PROGRAM

The purpose of this qualitative observation program was to directly observe small schools of fish in the moorage facility and to describe their behavior and position relative to the fish opening, within the moorage facility, along the Alaskan Way seawall at the south (open) end of the facility, and along the outer edge of the wave board. The specific objectives of the study were: 1) to determine if juvenile salmonids were successfully negotiating and migrating past the moorage facility; and 2) to census bird predators (gulls, cormorants, grebes, herons, king fishers, mergansers, etc.) and describe their behavior coincident with the period of fish observations.

A two-person crew was used to document the presence and behavior of juvenile salmonids and avian predators. One person remained on the dock and was responsible for dockside salmonid and avian predator observations. A second person snorkeled and was responsible for all underwater observations. The underwater observer documented fish behavior. To ensure the greatest opportunity for fish observation, sampling was conducted during the outmigration period of the most abundant species. The program was originally scheduled to occur from April through June to target juvenile chum and chinook salmon. However, due to the peak in juvenile chinook abundance on 26 June, surveys were extended to 29 July 1996. Observations were performed over a variety of conditions (i.e., extremes in tidal stages, during periods of use and non-use at the moorage facility). Observations were performed once every two weeks, encompassing both spring and neap tidal conditions. Each observation period was approximately 2.5 hours in length during a morning and an afternoon survey to cover low and high water passage conditions (Table 3). A total of 14 snorkel and 14 dockside observations were completed over the four month sampling period. The marina was opened for vessel traffic on 11 June 1996, so nearly half of the observations covered a period of operative use.

Whenever the snorkeler observed schools of salmonid fishes, the following data were recorded: 1) species; 2) approximate number in school; 3) activity (feeding/resting/migratory behavior) 4) position in the water column; 5) position of school relative to the shoreline or any moorage structures (e.g., pilings, floating docks, the wave board) and 6) negotiation of the facility. The

snorkeler also estimated the migratory speed of juvenile fish along the shoreline. Parameters estimated for avian predators included species presence, location within the moorage facility and behavior (feeding, roosting, or resting).

Table 3. Qualitative fish observation sampling dates during 1996 outmigration season.

Date	Time (hrs)	Tidal Height	Stage
April 8th	1415	0.0'	Low
April 28th	1423	8.1'	High
April 30th	0957	1.9'	Low
May 9th	0936	9.0'	High
May 9th	1626	0.0'	Low
May 24th	0952	7.6'	High
May 24th	1625	1.8'	Low
June 7th	0935	8.6'	High
June 7th	1602	1.5'	Low
June 26th	1445	8.5'	High
June 26th	0756	1.1'	Low
July 9th	0719	1.0'	Low
July 9th	1409	8.6'	High
July 29th	1035	-2.4'	Low

3. RESULTS

3.1 MARK RETENTION AND HANDLING MORTALITY ESTIMATES

Mark retention for the spray-marked fish over a two-month period was estimated at 100 percent. Insufficient numbers of freeze-branded fish were held for mark retention estimates but freeze brand deterioration is typically slow. Studies have shown that freeze brand mark retention ranges from at least five weeks to one year (Cane 1981; Mighel 1969; and Piggins 1972) so it is likely the freeze brands were identifiable during this study period.

Over the first 72 hours (3 days), 31 percent of the Keta Creek Hatchery fish retained in the laboratory perished. It was unclear if this mortality was related to marking, handling, transportation, or holding conditions in the Bioassay Lab. Adequate levels of dissolved oxygen were maintained at all times during transportation and holding and did not appear to be a factor in the mortalities. Mortalities began almost immediately and continued throughout the 72-hour holding period. Handling mortalities were also apparent for the Seattle Aquarium hatchery fish, however, due to a power outage in the lab all the fish expired making an estimate of handling, marking, or transportation mortality impossible to estimate.

3.2 FISH COLLECTION

3.2.1 Beach Seining

A summary of juvenile salmonid collection results at each of the five beach seining sites is presented in Table 4. The table includes the date, number of salmonids captured, location, number of spray-marked juvenile chum that were collected (recaptures) and the number of collected chinook juveniles that were freeze-branded and released. A complete record of the fish captures including size class increments by sampling date are incorporated into Appendix A.

A total of 2,044 juvenile chinook, coho, chum, and pink salmon were captured during beach seining. A subsample of 583 of these fish were marked with a freeze-brand and then released. Only 7 of the spray-marked juvenile chum salmon were recaptured (0.07% recapture rate). Of these fish, six were from the Seattle Aquarium and one was from the Keta Creek Hatchery. No freeze-brand marked salmon were recaptured.

The large Seattle Aquarium fish that were recaptured on 9 May and 10 May 1996 migrated along the Seattle waterfront at a rate of 8,448 and 8,654 feet/day, respectively (Table 5). This rate is 5.6 to 7.0 times faster than the approximate range of migration rates (1,200-1,500 feet/day) for chum salmon along the Seattle waterfront estimated by Parametrix (1980), Meyer et al. (1981), and Weitkamp and Schadt (1982). It is possible that the Seattle Aquarium fish recaptured on 9 May and 10 May were larger (69, 72, 77, and 85 mm) than the fish in the previous studies and may be migrating along the waterfront at a faster rate. The migration rate of these juveniles was approximately twice the speed of the smaller Keta Creek Hatchery fish (55 mm, 4,905 feet/day) and the Seattle Aquarium fish (49 mm, 3,245 feet/day) that were recaptured on 10 and 13 May, respectively. A single Seattle Aquarium fish (73 mm) recaptured on 24 May milled around the waterfront for 16 days with an overall net travel speed of 100 feet/day.

Table 4. Juvenile salmon collected in Elliott Bay during beach seining surveys conducted in May 1996 as part of the Port of Seattle fish marking and recovery study.

Date	Number of Salmonids Caught	Freeze Mark	Beach Seine Station	Recaptures
08 May 1996	31	6	BS1	0
09 May 1996	0	0	BS1	0
	2	0	BS3	0
	30	30	BS4	3A
	5	1	BS5	0
	11	4	BS6	0
10 May 1996	0	0	BS1	0
	200	4	BS3	0
	15	15	BS4	0
	26	0	BS5	0
	280	20	BS6	1H, 1A
13 May 1996	0	0	BS1	0
	38	2	BS3	0
	0	0	BS4	0
	30	4	BS5	0
	43	43	BS6	1A
15 May 1996	17	0	BS1	0
	2	1	BS3	0
	3	3	BS4	0
	72	27	BS5	0
	16	16	BS6	0
17 May 1996	31	31	BS1	0
	0	0	BS3	0
	76	76	BS4	0
	8	8	BS5	0
	29	21	BS6	0
20 May 1996	5	0	BS1	0
	96	54	BS3	0
	7	7	BS4	0
	4	4	BS5	0
	6	1	BS6	0
23 May 1996	10	10	BS1	0

Table 4. Juvenile salmon collected in Elliott Bay during beach seining surveys conducted in May 1996 as part of the Port of Seattle fish marking and recovery study.

Date	Number of Salmonids Caught	Freeze Mark	Beach Seine Station	Recaptures
	85	13	BS3	0
	0	0	BS4	0
	7	7	BS5	0
	3	2	BS6	0
24 May 1996	10	10	BS1	0
	643	20	BS3	1A
	0	0	BS4	0
	0	0	BS5	0
	3	3	BS6	0
29 May 1996	67	67	BS1	0
	85	80	BS3	0
	2	2	BS4	0
	0	0	BS5	0
	1	1	BS6	0
31 May 1996	1	NA	BS1	0
	32	NA	BS3	0
	19	NA	BS4	0
	1	NA	BS5	0
	2	NA	BS6	0
Totals	2,044	583		7

Key:

A Fish released from the Seattle Aquarium on 8 May 1996 at 2000 hours.

H Keta Creek Hatchery Fish released at Kellogg Island on 3 May 1996 at 1300 hours.

Table 5. Recapture summary of marked juvenile chum salmon, distance traveled and their migration rates along the Seattle waterfront.

Date of Recapture	Number of Recaptures	Size (mm)	Distance Traveled since Release (ft)	Time Between Release and Capture (hours)	Net Migration Rate (ft/day)
09 May 1996	3	69, 72, 77	6.864	19.5	8,448
10 May 1996	1	55	34,848	170.5	4,905
10 May 1996	1	85	14,784	41	8,654
13 May 1996	1	49	14,784	110	3,245
24 May 1996	1	73	1,584	382	100

At an average speed of 8,550 feet/day, the larger of the marked Seattle Aquarium fish left the sampling area in less than 2 days. At an average speed of 4,075 feet/day, the majority of the small Seattle Aquarium and Keta Creek Hatchery marked fish passed through the sampling area after approximately 4 and 8 days, respectively, depending upon the release site. The data imply most of the marked fish were unavailable to collection following 13 May 1996. Only one marked fish was recaptured more than 8 days after release. It is possible the unexpected rapid migration rate enabled the juvenile chum to leave the sampling area before the collection effort had been completed.

It is assumed all of the large chum size class ($\geq$ 65 mm) collected in early May were of Aquarium hatchery origin. A pulse of the large size class fish was tracked northward along Elliott Bay waterfront. These fish were present at Myrtle Edwards Beach in 19.5 hours. They first reached Pier 91 approximately 41 hours after release, and the numbers of the large size chum peaked there 110 hours after release. They apparently passed completely out of the study area approximately two weeks of the release date. The resulting migration rate of the large chum size class up to Pier 91 ranged from 937 to 8,654 ft/day with a weighted mean of 2,662 ft/day. The results suggest the large chum from the Seattle Aquarium do not spend much time rearing along the waterfront, but move rapidly through the system. The mean migration rate of this size class was slightly slower than the weighted mean migration time to Myrtle Edwards Park of 3,916 ft/day, suggesting their migration rates may slow where shallow nearshore areas are available to the fish along the northern shores of Elliott Bay.

The small size class (< 65 mm) of chum salmon migrated at approximately half the speed of the larger size class. Nevertheless, their net migration was relatively rapidly compared to previous

estimates of their migration speed along the waterfront. The slowest migration rate observed for chum past Pier 91 of 2,300 ft/day was substantially faster than historic estimates of 1,200 to 1,500 ft/day. Their migration speed was also quite fast compared to chinook salmon juveniles that tended to actively feed and frequently held in specific locations during their emigration (Appendix B).

Seven of the spray-marked chum salmon were recaptured at beach seining stations north of Pier 66. Such data indicate these juvenile salmonids successfully negotiated the short-stay marina. It is also interesting to note that two adipose clipped juvenile chinook salmon were collected along the waterfront at BS4, north of the wave board. As shown in Table 1, both WDFW Soos Creek Hatchery and the Muckleshoot Indian Tribe Keta Creek Hatchery release adipose clipped chinook salmon juveniles in the Duwamish/Green River Basin. It is possible this information also indirectly confirms passage of juvenile salmonids past the moorage basin.

3.2.2 Trawl Netting

No juvenile salmonids were collected during the trawl surveys. At tow speeds up to 3.6 knots, salmonid fishes were able to avoid capture. Juvenile salmonids were observed in deep water offshore of the moorage basin during trawling and during qualitative diver observations (Appendix B). Failure to capture juvenile salmonids in offshore habitats using townets is relatively common. Townet sampling in Possession Sound during periods of peak outmigration in the Snohomish River system also failed to capture juvenile salmonids (R.W. Beck and Associates 1986).

3.3 QUALITATIVE FISH AND PREDATOR OBSERVATION PROGRAM

Chinook, coho, and chum salmon were observed during the qualitative fish observations in and around the short-stay moorage facility (Appendix B). Total juvenile salmonid abundance peaked during mid- to late-May. Chum salmon were relatively more common than chinook or coho salmon. Chum salmon abundance was greatest in May, while chinook abundance peaked in June (Appendix B).

Chum salmon were observed exclusively in large schools of 25 to 500 individuals. The schools swam at an estimated rate of approximately 25 feet in 20 seconds (1.25 feet/second). Observed localized swimming speed and net migration speeds calculated during mark and recapture studies may vary considerably due to the actual swimming distance fish experience versus straight line distance assumed in calculating the net migration speed.

The schools were usually orientated within 10 feet of the water surface and near the shoreline or other moorage facility structure. Chinook and coho salmon were usually found swimming alone or in small schools (10-50 individuals). Chinook salmon were usually found in deeper water than the chum salmon.

Chinook, coho, and chum salmon were observed to successfully negotiate the short-stay marina (Appendix B). Chinook and coho juveniles were seen actively passing through the wave board opening. Chum salmon were not directly observed passing through the opening, but the presence of chum salmon schools north of the fish opening provided indirect evidence that chum juveniles were migrating past the moorage facility (Appendix B).

Western grebes, belted kingfishers, cormorants, gulls, and common or red-breasted mergansers were observed during the predator observation program. Predatory birds were not observed during the peak period of total juvenile salmonid abundance in May 1996. Peak predatory bird abundance was reported in April, late June, and July. Kingfisher abundance was greatest in June and July (Appendix B). Western grebes and mergansers were observed diving and catching fish within the moorage facility in April. These birds were the only two avian species observed catching fish.

4. SUMMARY

The Port's monitoring program to evaluate fish passage at the Bell-Street Pier, Short-Stay Moorage Facility consisted of three objectives with specific performance criteria for each objective as follows:

Objective 1 Do juvenile salmonid fishes successfully negotiate the public short-stay facility?

Criteria 1) Mark and Recapture studies indicate fish pass the moorage facility from south to north (the assumed prevailing migration pattern along the shoreline).

Objective 2 Do juvenile salmonid fishes use the fish opening at the northern end of the wave board?

Criteria 2) Juvenile salmonid fishes are observed to pass through the fish opening.

Objective 3 Are avian predators especially abundant in the vicinity of the fish opening?

Criteria 3) There are no unusual concentrations of predatory birds in the vicinity of the fish opening.

Both the mark and recapture study and the direct underwater observation program determined that juvenile salmonids successfully migrated past the short-stay marina. Juvenile chinook and coho salmon were seen actively passing through the fish opening. Juvenile chinook salmon were usually found in the vicinity of the fish opening, displaying both feeding and holding behavior. Individual chinook salmon would frequently pass back and forth through the fish opening several times within a few minutes. Although chum salmon were not directly observed passing through the opening, they were observed on both sides of the wave board in the vicinity of the fish opening. Divers inferred chum passage was likely unhindered.

Mark and recapture results indicate fish released south of the moorage facility were subsequently collected north of the facility indicating successful passage either nearshore through the fish opening or offshore on the outside of the wave board. Both studies confirm a net south to north migration pattern of juvenile salmonids along the Elliott Bay waterfront. Although the recapture numbers are relative small, the data imply the migration rates along the waterfront are rapid, especially for chum salmon. Data indicate chum salmon migration rates slow somewhat north of Myrtle Edwards Park, suggesting chum move rapidly past the developed Seattle waterfront and slow slightly along the north shore of Elliott Bay where more shallow nearshore areas are available to the fish.

Qualitative avian predator observations indicate there was no unusual concentrations of predacious birds in the vicinity of the moorage facility. Western grebes, belted kingfishers, common and red-breasted mergansers, double-crested cormorants and various species of gulls were encountered in the Short-Stay Facility. These species are typically or commonly observed along the entire Elliott Bay shoreline and there was no indication of enhanced feeding rates in the facility. Only mergansers and grebes were observed catching fish. Other bird species were either consuming alternative prey items, roosting or performing other non-feeding activities. It is interesting to note that predatory birds were present during the beginning and end of the study period, but they were not observed in the moorage facility during the peak of the juvenile salmon outmigration period in May and early June.

Other pelagic fish species were observed in the moorage facility including pile perch and an abundance of herring. One large cottid sp. was seen amongst the ripraped eastern shoreline. No unusual concentrations of piscivorous fishes were recorded in the facility that would pose a threat to migrating juvenile salmonids.

The monitoring results indicate the moorage facility, as designed and operated, successfully passed the established performance standards related to the spring migration of juvenile salmonid fishes. Fish collection and qualitative fish observations determined that juvenile salmonids successfully migrated past the short-stay marina. Qualitative fish observations found that salmonids were actively passing through the fish opening in the wave board near the shoreline. Qualitative avian predator observations documented that avian predators were not especially abundant and peak abundance in the vicinity of the short-stay marina did not coincide with peak juvenile salmonid abundance.

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APPENDIX A

Juvenile Salmonid Mark and Recapture Collection Data

CHINOOK SALMON

Chinook Salmon Caught at SE Corner of Canadian Ferry Terminal 46/47 (Beach Seine Site #1)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
50-59												0
60-69												0
70-79										4		4
80-89						1				25		26
90-99						2				15	1	18
100-109						4				5		9
110-119						3			2	3		8
120-129						2			3	4		9
130-139												0
TOTAL	0	0	0	0	0	12	0	0	5	56	1	74

Chinook Salmon Caught at Pier 66 (Beach Seine Site #3)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
50-59												0
60-69												0
70-79												0
80-89							1			1	1	3
90-99							1			5	3	9
100-109							5		1	4	2	12
110-119							8			13	3	24
120-129							3		3	27	9	42
130-139							2		1	8	5	16
140-149							1			6		7
150-159									1			1
TOTAL	0	0	0	0	0	0	21	0	6	64	23	114

Chinook Salmon Caught at Myrtle Beach Park (Beach Seine Site #4)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
50-59												0
60-69												0
70-79		2										2
80-89		1	2								2	5
90-99			5			1				1	2	9
100-109		3	2				1					6
110-119			1			10						11
120-129		1				7						8
130-139		1				1						2
140-149						1						1
150-159												0
160-169												0
170-179												0
180-189												0
190-199												0
200-209						1						1
210-219						2						2
220-229						4						4
230-239						2						2
TOTAL	0	8	10	0	0	29	1	0	0	1	4	53

Chinook Salmon Caught at Pier 89 (Beach Seine Site #5)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
50-59												0
60-69												0
70-79												0
80-89												0
90-99					1						1	2
100-109								1				1
110-119							3					3
120-129								2				2
130-139												0
TOTAL	0	0	0	0	1	0	3	3	0	0	1	8

Chinook Salmon Caught at Pier 91 (Beach Seine Site #6)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
50-59		1	1									2
60-69												0
70-79				1								1
80-89		1	1	4		1					2	9
90-99		1	1	12					1	1		16
100-109				2				1				3
110-119				6			1	1				8
120-129				3					1			4
130-139				1								1
TOTAL	0	3	3	29	0	1	1	2	2	1	2	44

CHUM SALMON

Chum Salmon Caught at SE Corner of Canadian Ferry Terminal 46/47 (Beach Seine Site #1)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
30-39	30				6		1					37
40-49	1				11		4					16
50-59												0
60-64												0
65-69												0
70-79												0
80-89						2			1	4		7
90-99						1						1
>=100												0
TOTAL	31	0	0	0	17	3	5	0	1	4	0	61

Chum Salmon Caught at Pier 66 (Beach Seine Site #3)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
30-39		2	11	7	1		4	5				30
40-49			17	32			37	70	16			172
50-59			7				6	10	11			34
60-64									8			8
65-69									2			2
70-79									6*			0
80-89												0
90-99											1	1
>=100												0
TOTAL	0	2	35	39	1	0	47	85	43	0	1	253

Chum Salmon Caught at Myrtle Park Beach (Beach Seine Site #4)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
30-39												0
40-49											1	1
50-59		4										4
60-64		5									2	7
65-69		6**	1								2	3
70-79		5*	3		3						4	10
80-89		1	1								2	4
90-99												0
>=100						6						6
TOTAL	0	21	5	0	3	6	0	0	0	0	11	46

Chum Salmon Caught at Pier 89 (Beach Seine Site #5)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
30-39			9		3							12
40-49		4	17	25	48							94
50-59				5	21							26
60-64												0
65-69												0
70-79												0
80-89							1					1
90-99								2				2
>=100						1		1				2
TOTAL	0	4	26	30	72	1	1	3	0	0	0	137

Chum Salmon Caught at Pier 91 (Beach Seine Site #6)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
30-39		1	1			3						5
40-49		8	16	2*		12						36
50-59		2	11*	3		7						12
60-64			2									2
65-69												0
70-79				1			2					3
80-89			1*	5	2		3					10
90-99				4	1			1	1			7
>=100												0
TOTAL	0	11	31	15	3	22	5	1	1	0	0	89

* - Size of recaptures

COHO SALMON

Coho Salmon Caught at SE Corner of Canadian Ferry Terminal 46/47 (Beach Seine Site #1)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
60-69												0
70-79										1		1
80-89									2			2
90-99						2			1			3
100-109						1				2		3
110-119						7				3		10
120-129						6						6
130-139												0
140-149												0
150-159												0
160-169												0
170-179												0
180-189										1		1
TOTAL	0	0	0	0	0	16	0	0	3	7	0	26

Coho Salmon Caught at Pier 66 (Beach Seine Site #3)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
60-69											1	1
70-79											2	2
80-89												0
90-99												0
100-109							2			2	2	6
110-119							11		4	1	1	17
120-129							8		3	3		14
130-139							4		2	8	1	15
140-149							2			1		3
150-159					1						1	2
TOTAL	0	0	0	0	1	0	27	0	9	15	8	60

Coho Salmon Caught at Myrtle Park Beach (Beach Seine Site #4)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
60-69		1				1						2
70-79												0
80-89						3						3
90-99												0
100-109						6					1	7
110-119						7	1					8
120-129						14	2					16
130-139						3	1					4
140-149						5						5
150-159						1						1
160-169						2						2
170-179							1					1
180-189												0
190-199												0
200-209												0
210-219												0
220-229												0
230-239												0
240-249												0
250-259												0
260-269												0
270-279												0
280-289												0
290-299							1					1
TOTAL	0	1	0	0	0	42	6	0	0	0	1	50

Coho Salmon Caught at Pier 89 (Beach Seine Site #5)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
60-69												0
70-79												0
80-89		1	1		1							3
90-99			3		3							6
100-109			1		1							2
110-119			1		1	3						5
120-129						1						1
130-139												0
140-149												0
150-159						3						3
TOTAL	0	1	6	0	6	7	0	0	0	0	0	20

Coho Salmon Caught at Pier 91 (Beach Seine Site #6)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
60-69												0
70-79												0
80-89						4						4
90-99					2	2						4
100-109					3							3
110-119					2							2
120-129					6							6
130-139												0
TOTAL	0	0	0	0	13	6	0	0	0	0	0	19

PINK SALMON

Pink Salmon Caught at SE Corner of Canadian Ferry Terminal 46/47 (Beach Seine Site #1)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
30-39												0
40-49												0
50-59												0
60-69									1			1
70-79												0
80-89												0
90-99												0
>=100												0
TOTAL	0	0	0	0	0	0	0	0	1	0	0	1

Pink Salmon Caught at Pier 66 (Beach Seine Site #3)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
30-39												0
40-49												0
50-59												0
60-69												0
70-79												0
80-89												0
90-99												0
100-109										2		2
110-119										1		1
120-129										2		2
130-139										1		1
TOTAL	0	0	0	0	0	0	0	0	0	6	0	6

Pink Salmon Caught at Myrtle Park Beach (Beach Seine Site #4)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
30-39												0
40-49												0
50-59												0
60-69											2	2
70-79											1	1
80-89										1		1
90-99												0
>=100												0
TOTAL	0	0	0	0	0	0	0	0	0	1	3	4

Pink Salmon Caught at Pier 89 (Beach Seine Site #5)

	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
30-39												0
40-49												0
50-59												0
60-69								1				1
70-79												0
80-89												0
90-99												0
>=100												0
TOTAL	0	0	0	0	0	0	0	1	0	0	0	1

Pink Salmon Caught at Pier 91 (Beach Seine Site #6)

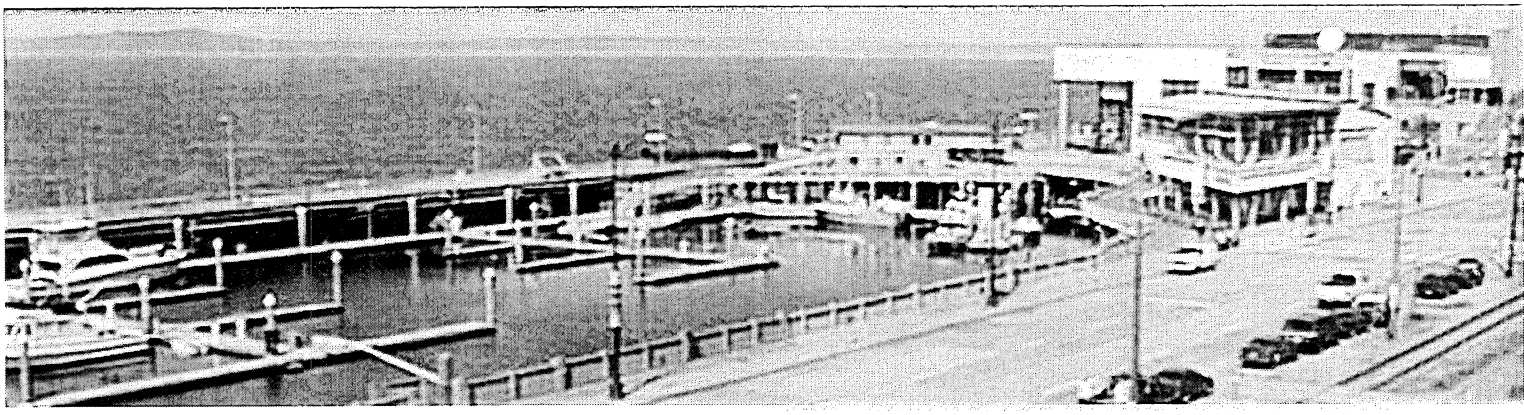
	5/8/96	5/9/96	5/10/96	5/13/96	5/15/96	5/17/96	5/20/96	5/23/96	5/24/96	5/29/96	5/31/96	TOTAL
30-39												0
40-49												0
50-59												0
60-69												0
70-79												0
80-89												0
90-99												0
>=100												0
TOTAL	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX B

Qualitative Fish and Avian Predator Observations Taylor and Willey (1997)

PORT OF SEATTLE
FISH MIGRATION STUDIES

PIER 64/65 SHORT-STAY MOORAGE FACILITY



Qualitative Fish and Avian Predator Observations

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FINAL REPORT

INTRODUCTION

The development of the Seattle waterfront and Elliott Bay shoreline over the past century has raised concerns as to the environmental impacts of this development on the aquatic resources found in Elliott Bay. As a result of this widespread environmental concern, the recent re-construction and development of Pier 64/65 for use as a short-stay public moorage facility along the Elliott Bay shoreline has triggered several environmental studies concerning potential impacts from the Pier's development (Figure 1). As part of these environmental studies related to the re-construction and development of Pier 64/65 a monitoring program to determine effects of this development on juvenile salmonid migratory passage and behavior along the Elliott Bay shoreline was implemented by the Port of Seattle (POS) during the summer of 1996. This monitoring program consisted of a juvenile salmonid mark and recapture study and a qualitative fish and avian predator observation study. This report documents the results of the later of these studies.

Beak Consultants Incorporated were selected to conduct these studies for the POS Fish Migration Studies monitoring program. Beak Consultants conducted the mark and recapture study along the Elliott Bay shoreline while the qualitative fish and predator observation study was performed by Taylor Associates as sub-consultants to Beak Consultants Inc. The qualitative fish and avian predator observation study was conducted within and around the newly constructed Pier 64/65 moorage facility over a four month period in the summer of 1996. The four months chosen for the study (April through July, 1996) coincided with the juvenile salmonid outmigration period typically observed along the Elliott Bay shoreline.

The purpose of the qualitative fish and avian predator observation study was to observe small schools of fish and avian predators within and around the newly constructed short-stay moorage facility to describe their behavior, location, and relative numbers. The specific objectives of the study were, 1) to determine if juvenile salmonids were successfully negotiating and migrating past the Pier 64/65 moorage facility through a constructed fish opening in the facilities outer waveboard and, 2) to determine whether avian predators were concentrating and feeding/roosting within the Pier 64/65 moorage facility as a result of its construction.

METHODS

The qualitative fish and avian predator observations were conducted simultaneously during each survey period to more efficiently utilize available time. The observations were conducted prior to and at the beginning of public operation of the facility, so typically no or few boats were present in the docks during any of the observations. At least two people were involved with study observations during each survey; an in-water snorkel observer who was responsible for all underwater fish observations, and a dock-side observer responsible for dock-side fish observations and avian predator observations. The dock-side observer also acted in a support role to

ensure the safety of the snorkel observer while in the water, and to record notes and fish observations for the snorkel observer.

Qualitative Fish Migration Observations

To determine whether outmigrating juvenile salmonids were successfully negotiating the Pier 64/65 short-stay moorage facility, snorkel and dockside observations were conducted throughout the moorage facility during each survey period. The Pier 64/65 facility was separated into four main areas, each of which were observed by the in-water snorkel surveyor and the dock-side observer. These four areas included, 1) the fish opening, 2) the south end of the facility, 3) along the outer edge of the waveboard, and 4) within the moorage float system (Figure 2). Particular attention was paid to the expected shoreline migration routes typically used by outmigrating salmonids. These included the south end of the facility along the shoreline and the fish opening. The approximate time of observation was two hours around low and high tide.

Snorkel surveys were conducted at approximately two-week intervals throughout the four month study period to more accurately cover the entire outmigration period and to determine temporal differences in fish abundance. Snorkel and dockside observation surveys were also conducted over a variety of conditions, such as during extremes in tidal stages and during periods of use and non-use of the short-stay moorage facility. Surveys were not conducted at night, consequently no information on diel differences in juvenile outmigration were collected.

The qualitative fish observation study design was to observe salmonid fish schools within the Pier 64/65 moorage facility every two-weeks, two-times per day, once during high-tide and again during low-tide. The surveys were conducted on days which offered satisfactory high and low tides which occurred at convienient times in the course of one day. Seven days were selected for conducting fish observation surveys during the four month study period, accounting for 14 individual snorkel and dock-side observations (see Table 1 for dates surveyed and survey conditions during those dates). The snorkel and dock-side observers would typically conduct a survey in the morning, then return for the second survey in the afternoon or evening.

The in-water snorkel surveyor used a dry-suit and cold water snorkel gear as protection during the prolonged exposure to cold water during each snorkel observation event. The snorkel observer would begin at the north end of the float system and work his way through the moorage facility to observe migrating salmonids in the four survey areas. Although all four target areas were surveyed during each observation event the snorkel route changed from snorkel to snorkel. Whenever fish schools were located the snorkel observer would note species present, approximate number in the school, fish activity, depth in the water column, and location of the school next to any moorage facility structures such as the shoreline, pilings, floating moorage docks, waveboard etc. The snorkel observer would then relay this information to the dock-side observer who would subsequently transcribe this information onto pre-printed field survey forms and maps.

Whenever possible, the snorkel observer would attempt to snorkel in a north to south direction through the moorage facility. This was done to swim against the predominant salmonid migration route of south to north along the Elliott Bay shoreline. In effect, the snorkel observer would swim in a direction which allowed the fish to swim to him. On several occasions the snorkel observer would hold on to a stationary object and monitor fish schools as they swam past his position. This not only avoided startling the fish, but also allowed him to monitor their migration speed past his fixed location. This was especially done at the fish opening. For a short period of time during each snorkel observation survey the snorkel observer would position himself near the fish opening and simply observe fish activity at the fish opening.

The dock-side observer would also survey the four target areas within the Pier 64/65 moorage facility by walking along-side of or away from the snorkel observer. The dock-side observer would look for surface oriented fish schools and record species observed, approximate number of fish in the school and fish activity as stated by the diver. The dock-side observer would also photograph and videotape salmonid fish schools observed, on some occasions.

Avian Predator Observations

The dock-side observer would identify any predatory bird species located within or around the Pier 64/65 short-stay moorage facility during each observation survey period. The dock-side observer would watch the bird(s) and record species and number, their location within the moorage facility, and predator activity (floating, actively feeding, or roosting). The dock-side observer would photograph and videotape bird activity on some occasions.

RESULTS

Qualitative Fish Observations

Results of the qualitative snorkel observations indicate that chum (*Oncorhynchus keta*), chinook (*O. tshawytscha*), and coho (*O. kisutch*) salmon all migrate to some degree through the Pier 64/65 short-stay moorage facility. Although all salmon species were observed throughout the moorage facility, only chinook and coho juveniles were observed actively passing through the fish opening. Chum salmon were never observed passing through this opening. Indirect evidence, however, does exist for chum salmon passage success through or around the facility by their presence north and on the outside edge of the fish opening. The fish observed on the north side of the waveboard's fish opening, either passed through the fish opening or swam around the outside edge of the waveboard. In any case, these fish are successfully passing beyond the Pier 64/65 moorage facility during their outmigration from the mouth of the Duwamish River.

All fish observations which were recorded onto field data sheets during the snorkel and avian predator observation surveys were subsequently entered into a spreadsheet tabular format and then graphically represented. These tables and figures are provided as Tables 2-8 and as Figures 2a & 2b - 8a & 8b. Note that Table 2 presents the data for Snorkel Number 2 and that the graphical representation of the data is presented in Figures 2a & 2b, Table 3 presents the data for Snorkel Number 3 which is graphically represented as Figure 3a & 3b, etc. Also please note that while the Snorkel Number 1 was conducted during low tide in a similar manner as the remaining trips, the data from Snorkel Number 1 was not presented either in tabular form or graphically because no salmonids or avian predators were encountered during that preliminary survey.

From these tables and figures one can readily see the rapid increase in total numbers of fish schools observed and total abundance of fish during the May 9th and 24th, qualitative fish observation events (Snorkel Numbers 3 and 4). One can further see how the number of fish schools slowly tends to decrease as the summer progresses. The increase in the number of fish schools observed in May is the result of the rapid outmigration of chum salmon. The subsequent decline in the number of fish schools observed as the summer progresses is the result of a decline in chum salmon migrants in June through July, and a concurrent but smaller increase in chinook salmon.

Chum salmon were the most frequently observed salmon species by numbers, followed by chinook salmon and finally coho salmon. Table 9 shows the numbers of chum and chinook salmon observed for each of the study survey dates segregated by both high and low tides and total fish observed. Figures 9, 10, and 11 graphically represent the data presented in Table 9 and effectively show the migration timing and time to peak abundance for both juvenile chum and chinook salmon outmigrants. Results of the juvenile outmigration timing observed for this study indicate that chum salmon migrate along the Elliott Bay shoreline before chinook salmon and that their relative numbers are much higher that those of chinook salmon in Elliott Bay during the 1996 outmigration (Figure 9). Migration patterns indicate that while chum salmon are reaching their peak migration abundance through May the chinook outmigrants are just beginning their migration. Results of our qualitative surveys indicate that chinook salmon reach their peak outmigration abundance along the Elliott Bay shoreline in late June. This migration pattern holds true whether fish are summed together during snorkel events or are segregated by snorkel events at low or high tide stages (Figures 10 & 11).

Chum salmon were the most actively migrating fish observed. They frequently swam past the snorkel observer at a very quick pace of approximately 25 feet in 10 seconds. The chum salmon observed were always found in schools between 25 and 300-500 individuals each, they were never seen swimming alone. Chum salmon ranged in size from 50 - 80mm during this snorkel study. However, on occasion a larger individual would be observed in the range of 90 - 100mm. The chum salmon schools were always found oriented at the water surface down to 10-feet in depth and were almost always oriented close (between 2 to 15 feet) to the shoreline or other moorage facility structure.

Conversely, individual chinook and coho salmon were frequently seen swimming alone, although they too generally formed schools. Chinook schools were usually between 10 and 50 fish each and individual fish ranged in size from 150mm to 250mm in total length. Unlike the chum salmon observed, the chinooks tended to show a slower migration rate, and frequently showed no net migration at all. Individual chinooks were frequently found following large schools of chum salmon. Chinooks were usually found at a depth of between 5 to 20 feet, they usually did not stay near the water surface for extended periods of time.

While non-salmonids were qualitatively and inconsistently noted, Pacific herring (*Clupea harengus pallasi*), various perch (Embiotocidae), and Pacific sandlance (*Ammodytes hexapterus*) were among the other most commonly seen fish. The herring especially formed some of the largest schools of non-salmonid fishes, numbering a few thousand in a couple of cases. These fish were approximately the same size as the most of the salmonids, and were then probably not food prey at the time of observation.

Avian Predator Observations

Predatory bird observation results indicate that there has been no observations of unusual concentrations of avian predators in the vicinity of the Pier 64/65 moorage facility. Furthermore, there is no indication that avian predators that were observed in the vicinity are feeding at a greater rate within or around the newly constructed Pier 64/65 facility. No predatory avian species were observed near the fish opening during our surveys. The bird species which were encountered are ones that are typically or commonly observed along the entire Elliott Bay shoreline.

Avian predators observed during our surveys include: Western grebes (*Aechmophorus occidentalis*), Belted kingfishers (*Megaceryle alcyon*), gulls (*Larus* sp.), and Common or Red-Breasted Mergansers (*Mergus merganser* or *M. serrator*). A total of 16 western grebes, 6 mergansers, 2 belted kingfishers and numerous gulls were encountered during the study period. See Figures 2a and b through 8a and b for location of birds observed within the Pier 64/65 moorage facility. Bird activity is indicated on these figures showing whether the birds were actively diving/feeding or merely floating in the area.

Predatory birds were most frequently observed during the beginning and end of our study period. Ironically, predatory birds were not observed during the height of the salmon outmigration in May and early June. Avian predators such as mergansers and western grebes were observed diving and catching fish within the moorage facility during our April surveys. These birds were frequently found along the shoreline and within the floating moorage docks (see Figure 2a and 2b). However, after the April survey these species were not observed again until the late June and early July surveys. Common seagulls were frequently seen within the moorage facility, however, their presence was not recorded on Figures 2a and 2b through 8a and 8b. Gulls were never observed feeding on

fish. They were, however, seen eating starfish and crabs along the shoreline and on the floating moorage structures.

Belted kingfishers were the most prevalent predatory bird species observed in June and July within the Pier 64/65 moorage facility. Two kingfishers were frequently observed flying back and forth between the Marina Harbormaster's office flooring and the Elliott Bay seawall. These belted kingfishers were never seen catching or eating fish during our surveys. They were, however, apparently building nests or roosting, as they were found at these same locations during June and July.

DISCUSSION

Fish passage through the POS Pier 64/65 short-stay moorage facility appeared to be successfully accomplished by all species of salmon observed. Although no chum salmon were physically observed passing through the waveboard's fish opening they were usually observed on both sides of the waveboard in the vicinity of the fish opening. Chinook and coho salmon juveniles were seen actively passing through the opening. In fact, chinook juveniles were usually found in the vicinity of the fish opening, displaying both feeding and holding behavior. The chinook individuals would frequently pass back and forth through the fish opening several times within a few minutes, usually showing no net migration north or south.

The fish schools observed did show an active migration pattern typical for Green/Duwamish River outmigrating fish, from south to north along the Elliott Bay shoreline. While some schools were seen travelling north to south in a few rare instances, it is unclear whether this was due to diver disturbance, natural alternating directional movements by the fish, or an affect of the facility.

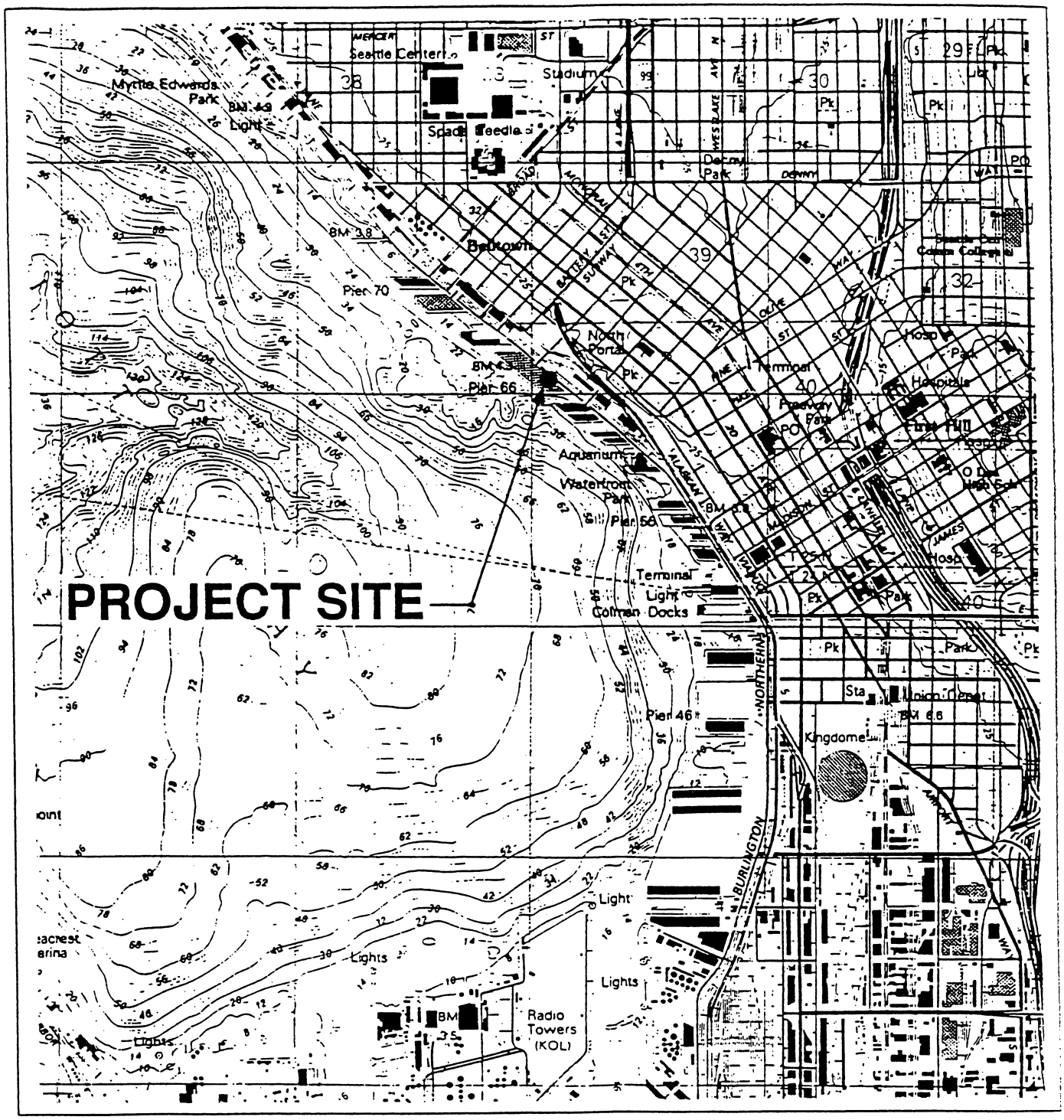
The results obtained for this qualitative fish observation study are meant to be used as a subjective means of determining fish passage success through the Pier 64/65 short-stay moorage facility and avian predator presence within and around the facility only. The results are by no means quantitative, as no statistically relavant tests were designed or attempted to quantify the data obtained during these surveys.

The numerical results of chum and chinook salmon abundance presented in Table 9 and Figures 9-11 are based on the highest estimate for each fish school encountered and observed. For example, when a fish school was encountered and the snorkel observer estimated approximate fish abundance a range was often recorded (e.g. 200-300 fish). The high estimate was always used for numerical calculations. This was done to overcome the bias of not observing fish schools that were present during the survey but were not encountered. Frequently, the dock-side observer would see fish schools swimming around the in-water snorkel observer out of his visibility range. Undoubtedly, this occurred on a regular basis throughout the study period. By using the high estimate of fish schools that were observed, we believe a better numerical estimate was achieved.

A particular problem with fish observations during this qualitative fish observation study was the avoidance behavior of the juvenile salmon outmigrants. Frequently, the dock-side observer noted that the fish schools would swim around and out of the snorkel observers visual range, avoiding detection altogether. On some occasions the fish school would encounter the snorkel observer and quickly swim into open water out of visual range. During these instances the snorkel observer would attempt to identify the species and school abundance, but was sometimes unsuccessful. On these attempts, the fish were recorded as unknown. In light of this avoidance behavior, the reader should be aware that some identified fish schools may have in fact been misidentified as to salmonid species, but more likely, as to total fish abundance.

A further problem with snorkel observations of fish schools within and around the Pier 64/65 moorage facility was the poor water clarity in Elliott Bay. The water clarity during the snorkel observations effected the visibility range in which the snorkel observer could detect fish. Water clarity was especially poor during the April and May snorkel events. However, visibility tended to improve during the June and July snorkel events as the summer progressed. Visibility ranges were typically between 10-feet in April and May to approximately 20 to 25-feet in July. Water clarity was usually worse along the seaward side of the outer waveboard, but usually improved inside the moorage facility. Water clarity and visibility tended to be poor during our snorkel observations because snorkeling occurred at both high and low tide periods, periods which occasionally offer poor water clarity due to the accumulation and concentration of floating materials along the Elliott Bay shoreline.

FIGURES



BASE SOURCE: USGS MAP, SEATTLE SOUTH WASHINGTON, 1983

0 1/4 1/2 1

APPROXIMATE SCALE IN MILES

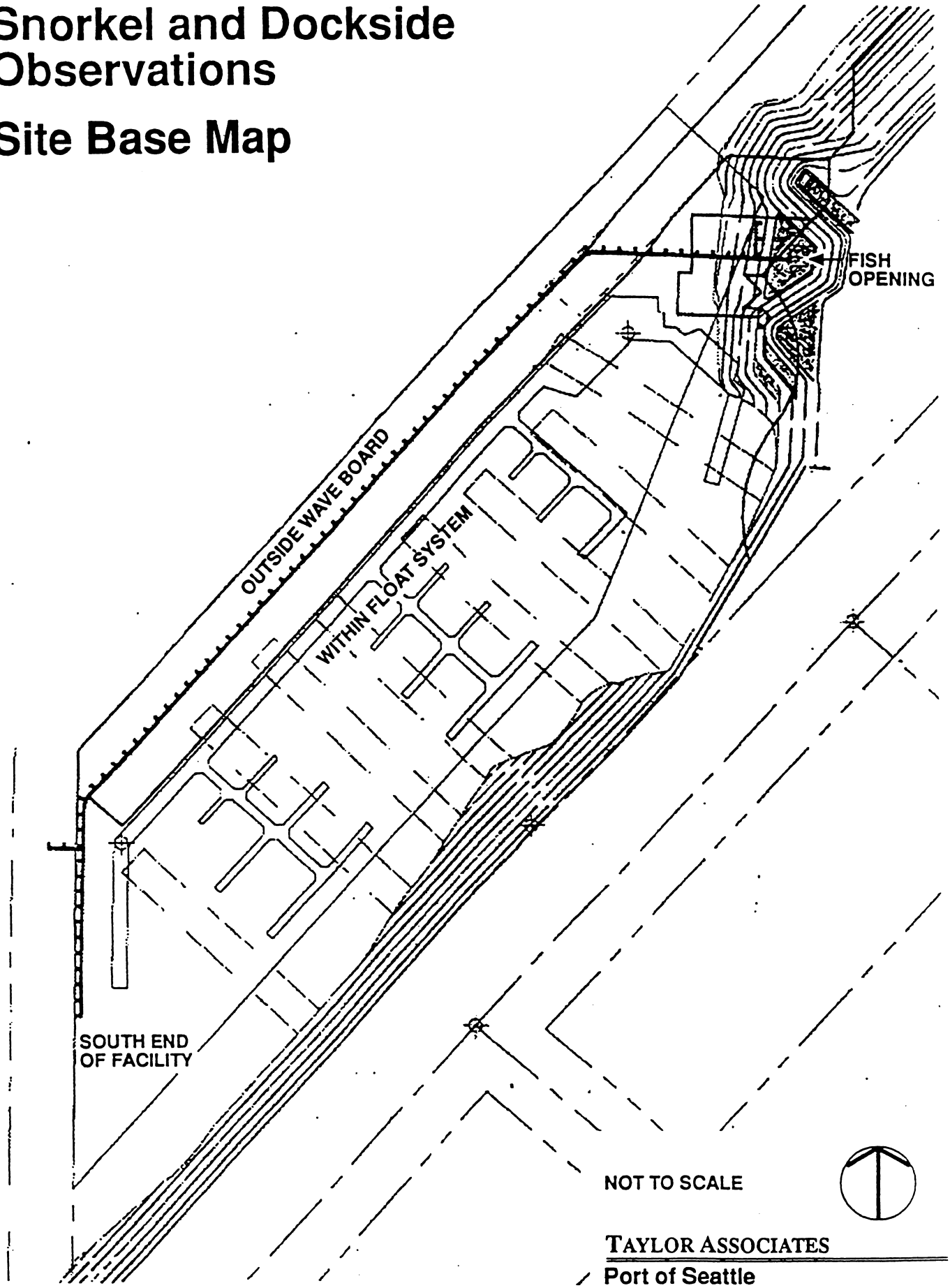
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Short Stay Morage
Site Location

Figure 1 June 2000

Snorkel and Dockside Observations

Site Base Map



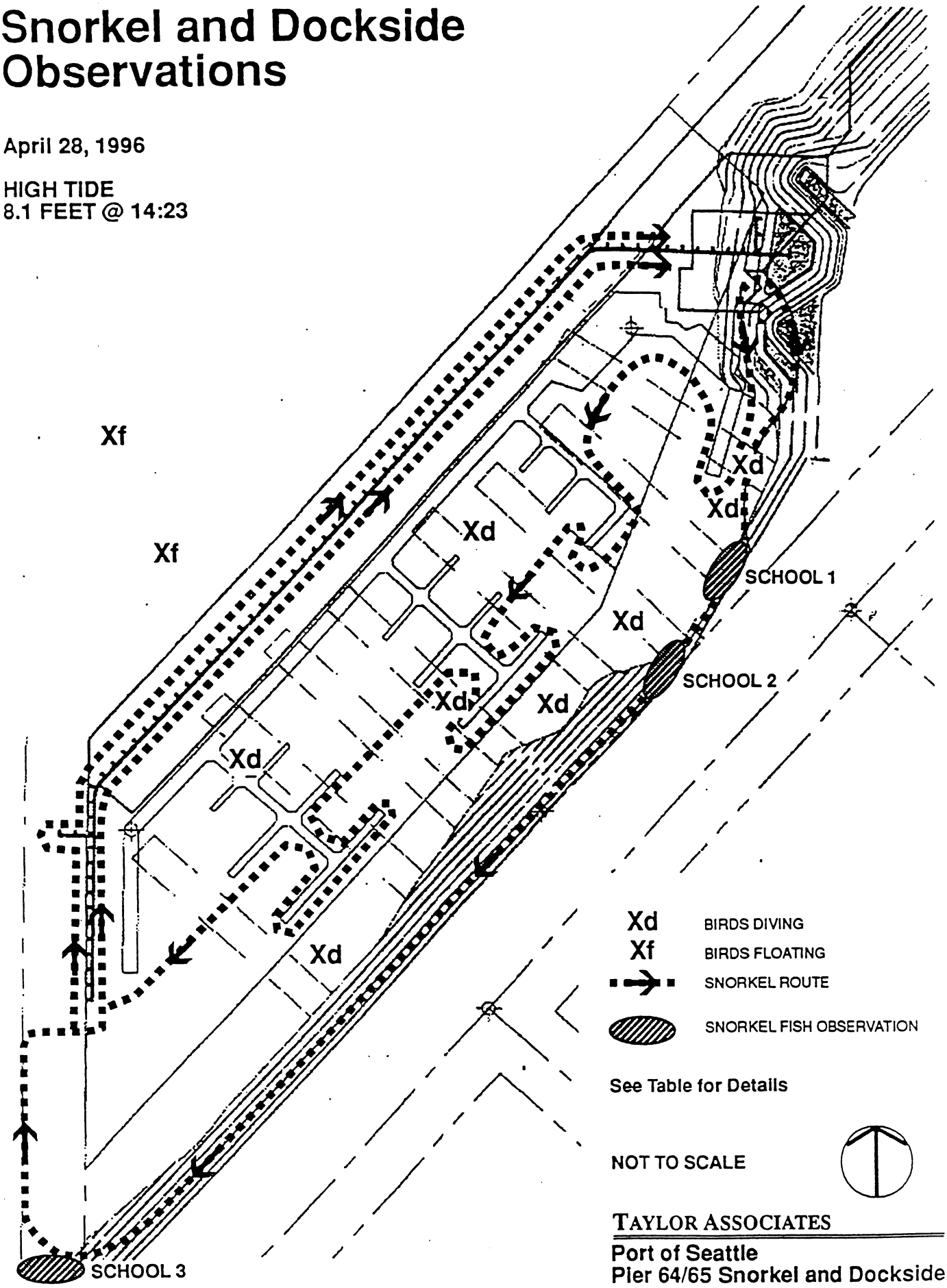
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 2 June 2000

Snorkel and Dockside Observations

April 28, 1996

HIGH TIDE
8.1 FEET @ 14:23



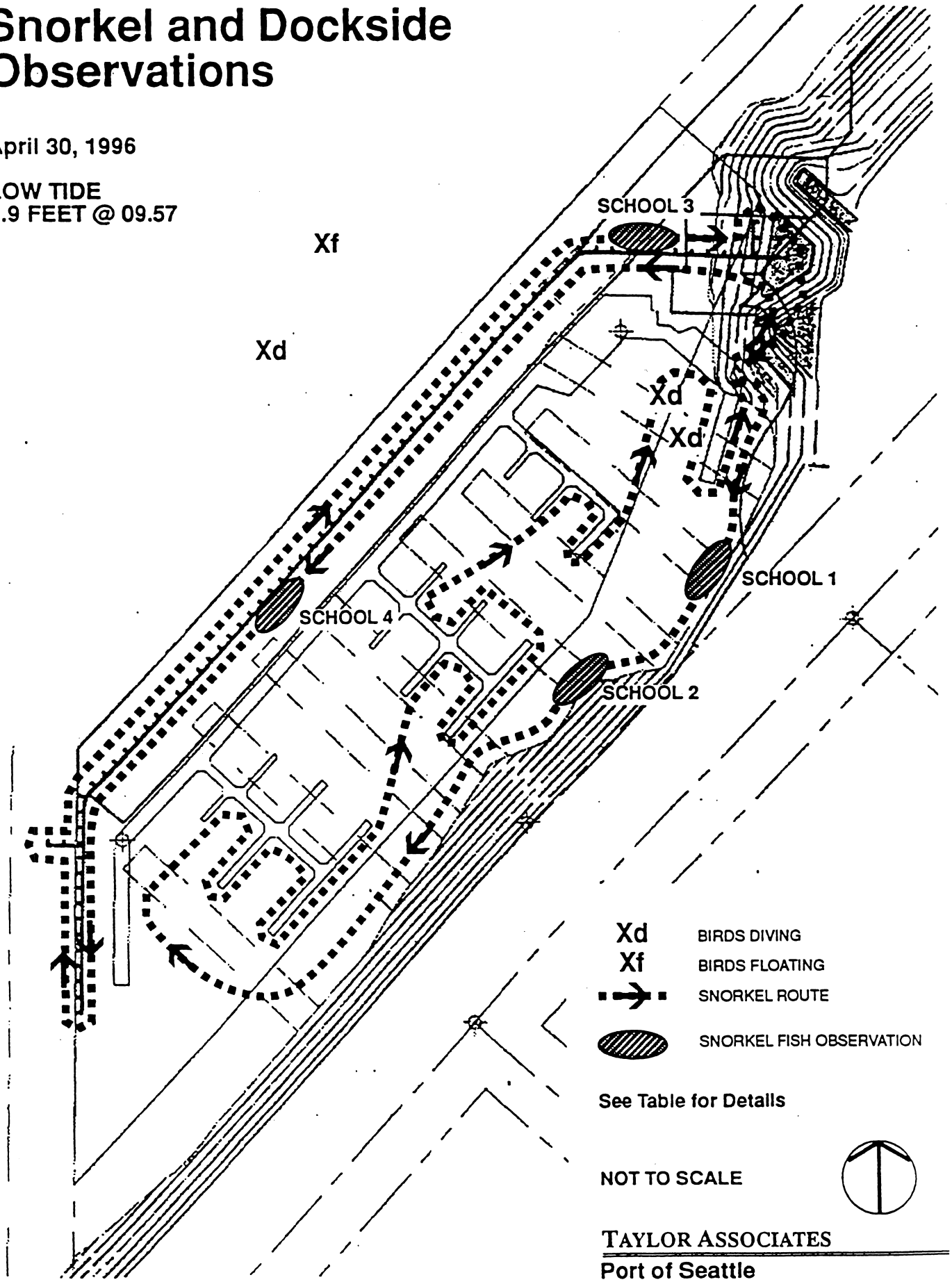
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 2a June 2000

Snorkel and Dockside Observations

April 30, 1996

LOW TIDE
1.9 FEET @ 09.57



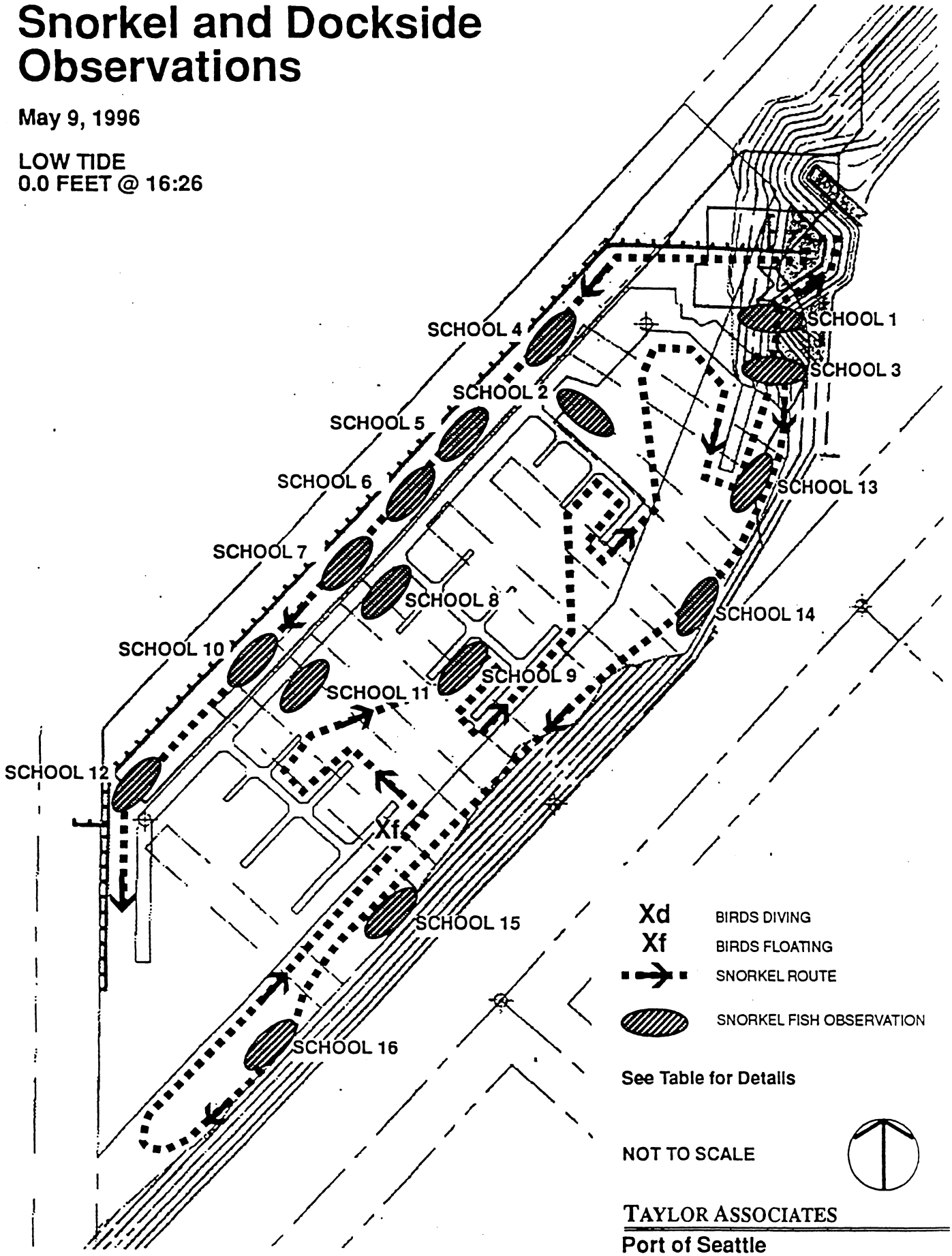
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 2b June 2000

Snorkel and Dockside Observations

May 9, 1996

LOW TIDE
0.0 FEET @ 16:26



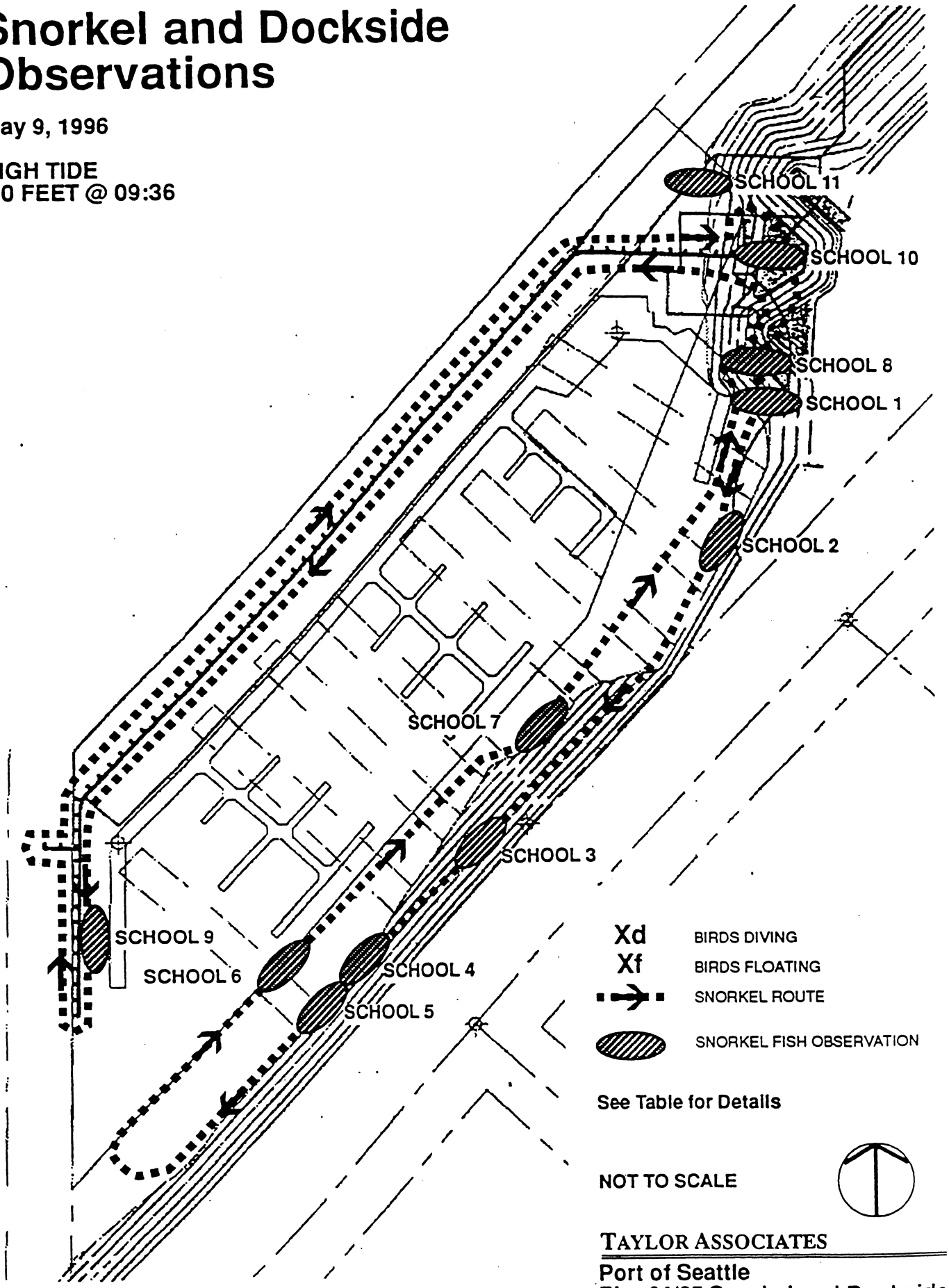
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 3a June 2000

Snorkel and Dockside Observations

May 9, 1996

HIGH TIDE
9.0 FEET @ 09:36



See Table for Details

NOT TO SCALE

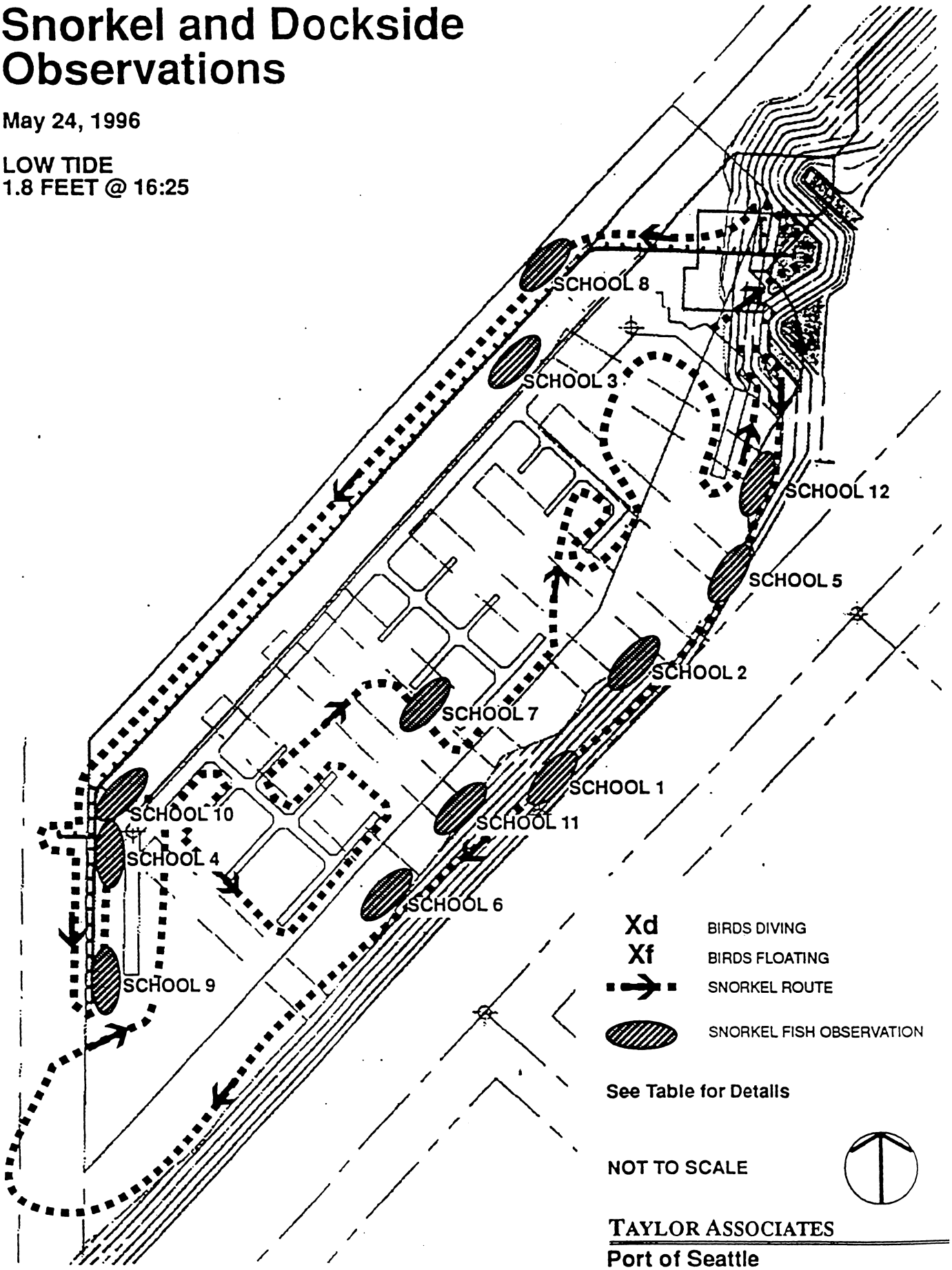
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 3b June 2000

Snorkel and Dockside Observations

May 24, 1996

LOW TIDE
1.8 FEET @ 16:25



See Table for Details

NOT TO SCALE

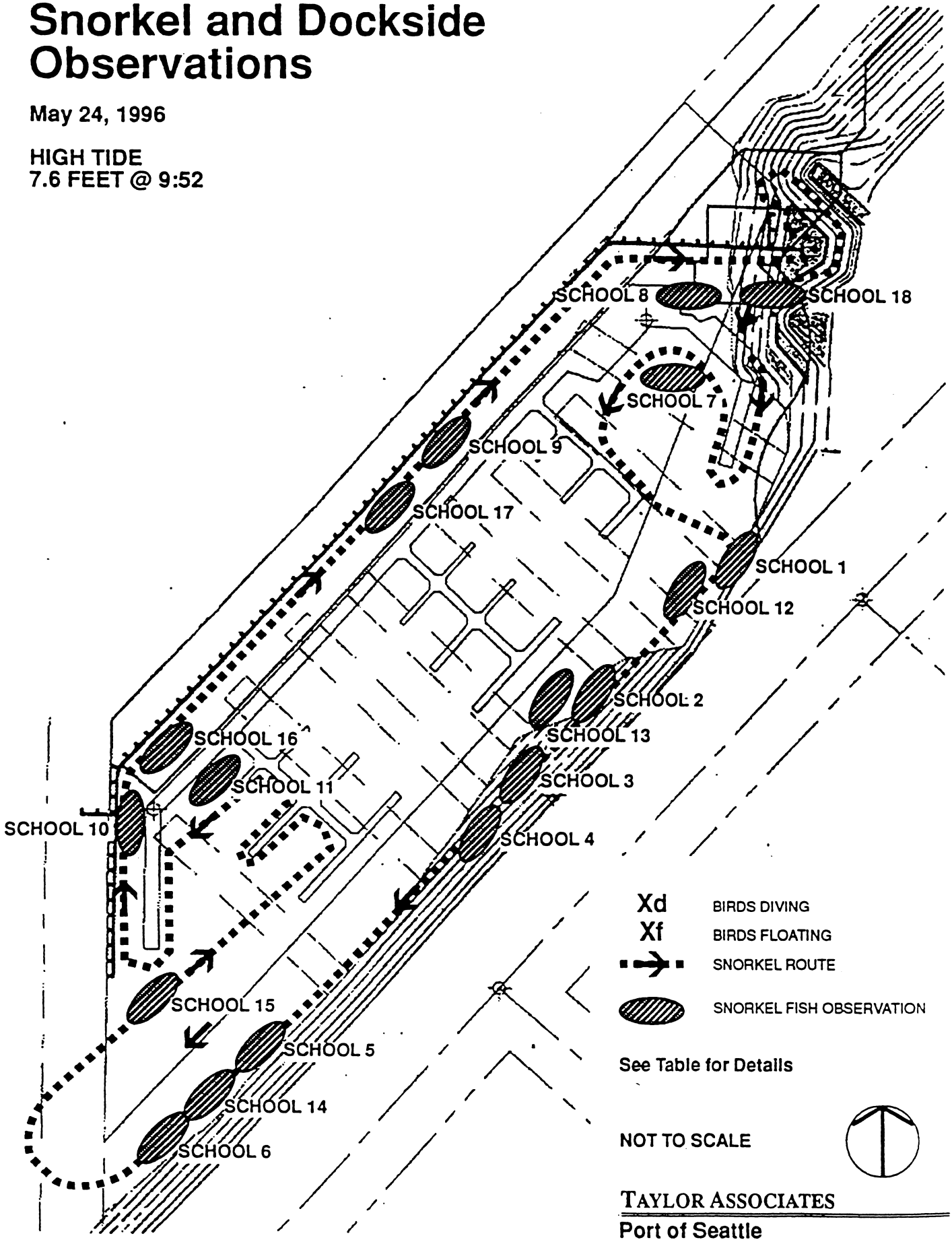
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 4a June 2000

Snorkel and Dockside Observations

May 24, 1996

HIGH TIDE
7.6 FEET @ 9:52



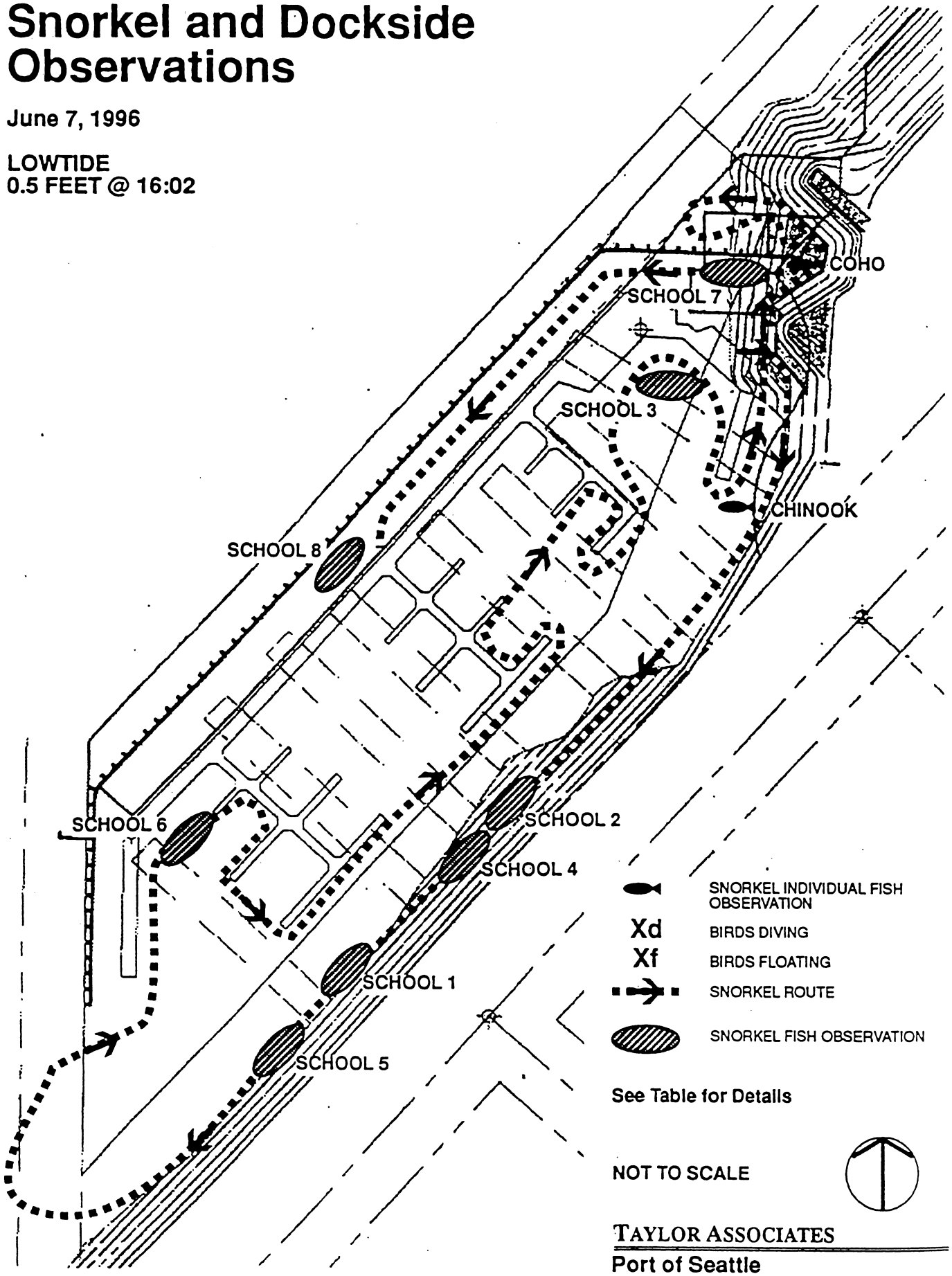
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 4b June 2000

Snorkel and Dockside Observations

June 7, 1996

LOWTIDE
0.5 FEET @ 16:02



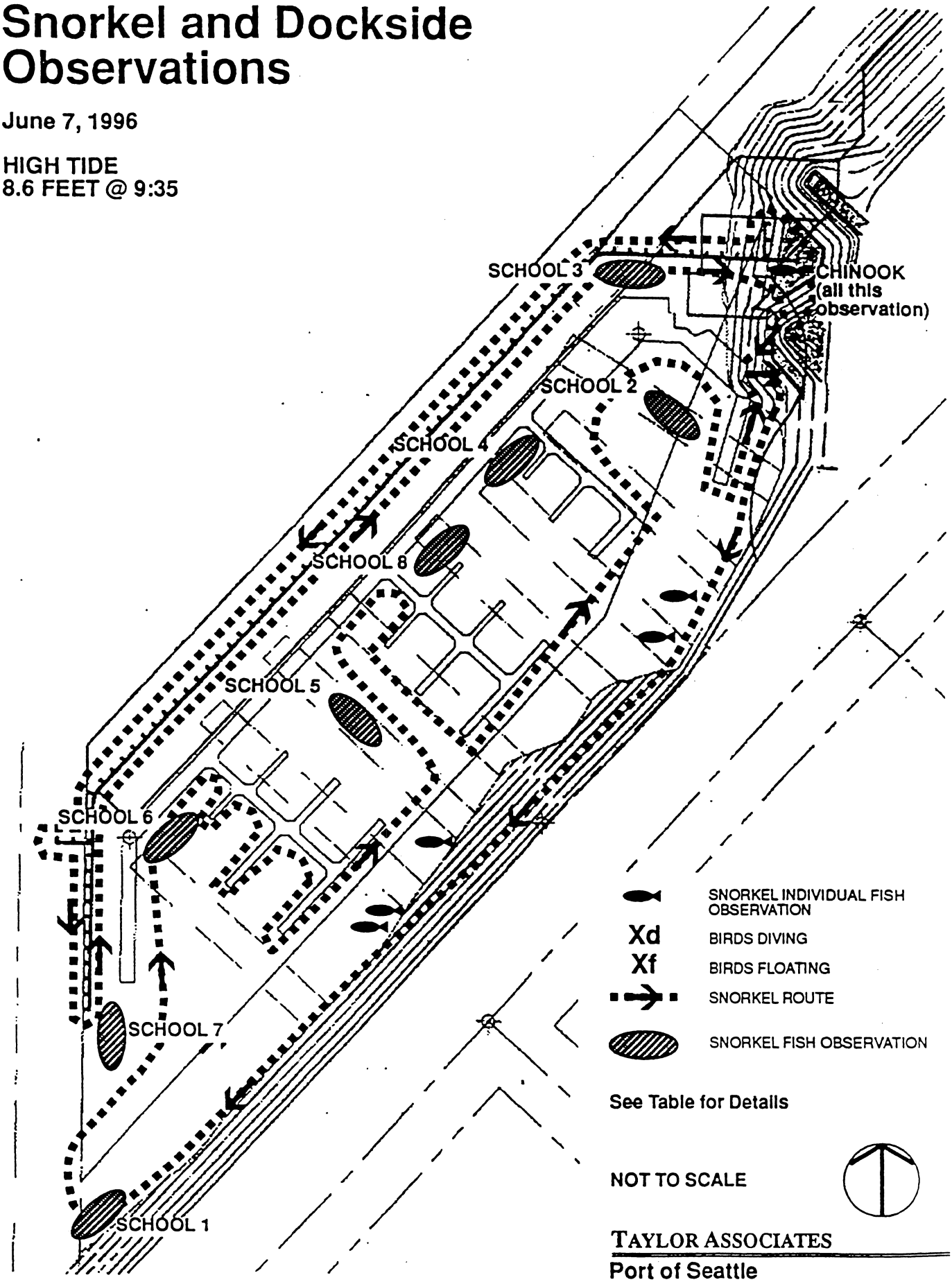
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 5a June 2000

Snorkel and Dockside Observations

June 7, 1996

HIGH TIDE
8.6 FEET @ 9:35



See Table for Details

NOT TO SCALE

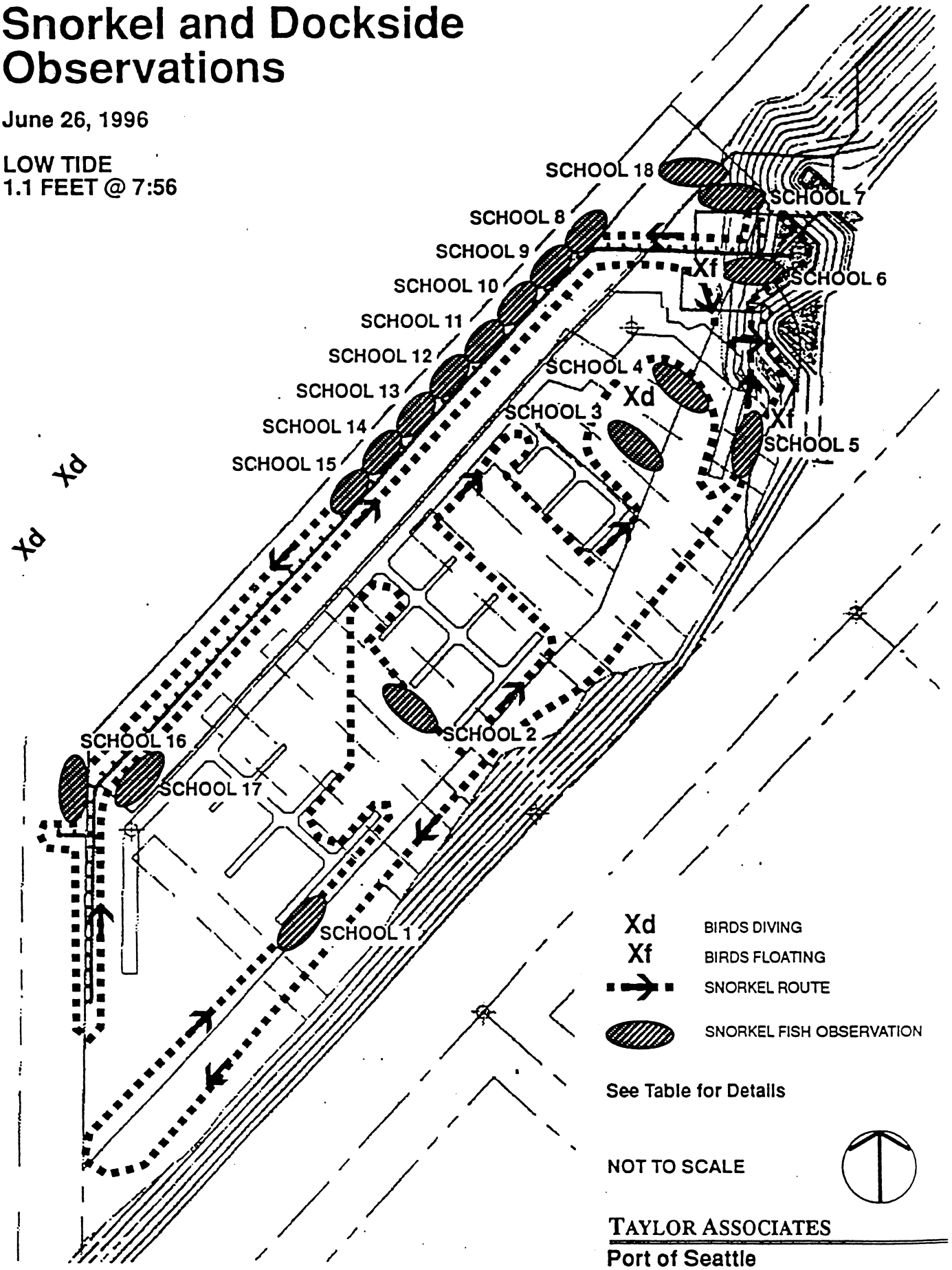
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 5b June 2000

Snorkel and Dockside Observations

June 26, 1996

LOW TIDE
1.1 FEET @ 7:56



See Table for Details

NOT TO SCALE

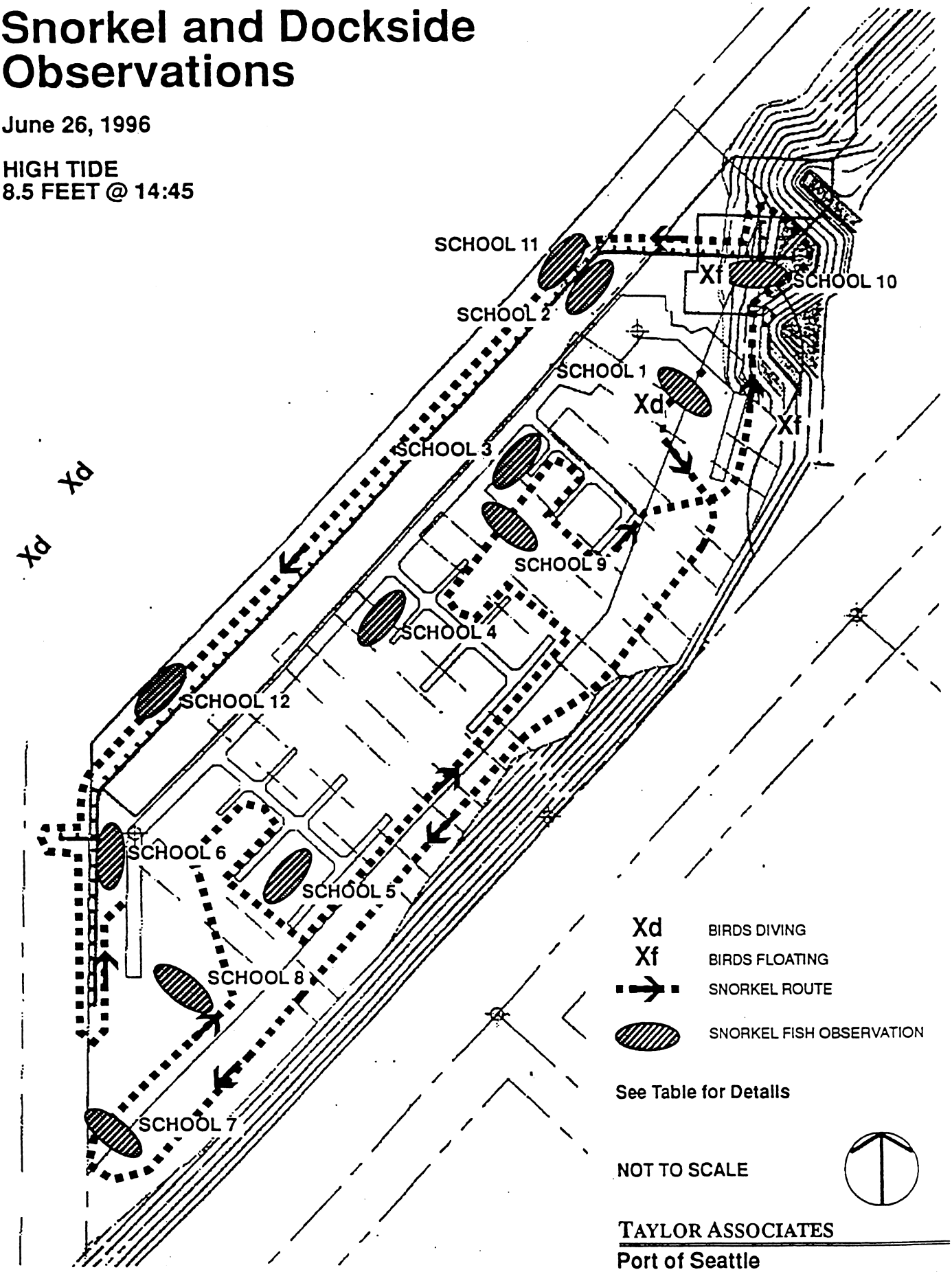
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 6a June 2000

Snorkel and Dockside Observations

June 26, 1996

HIGH TIDE
8.5 FEET @ 14:45



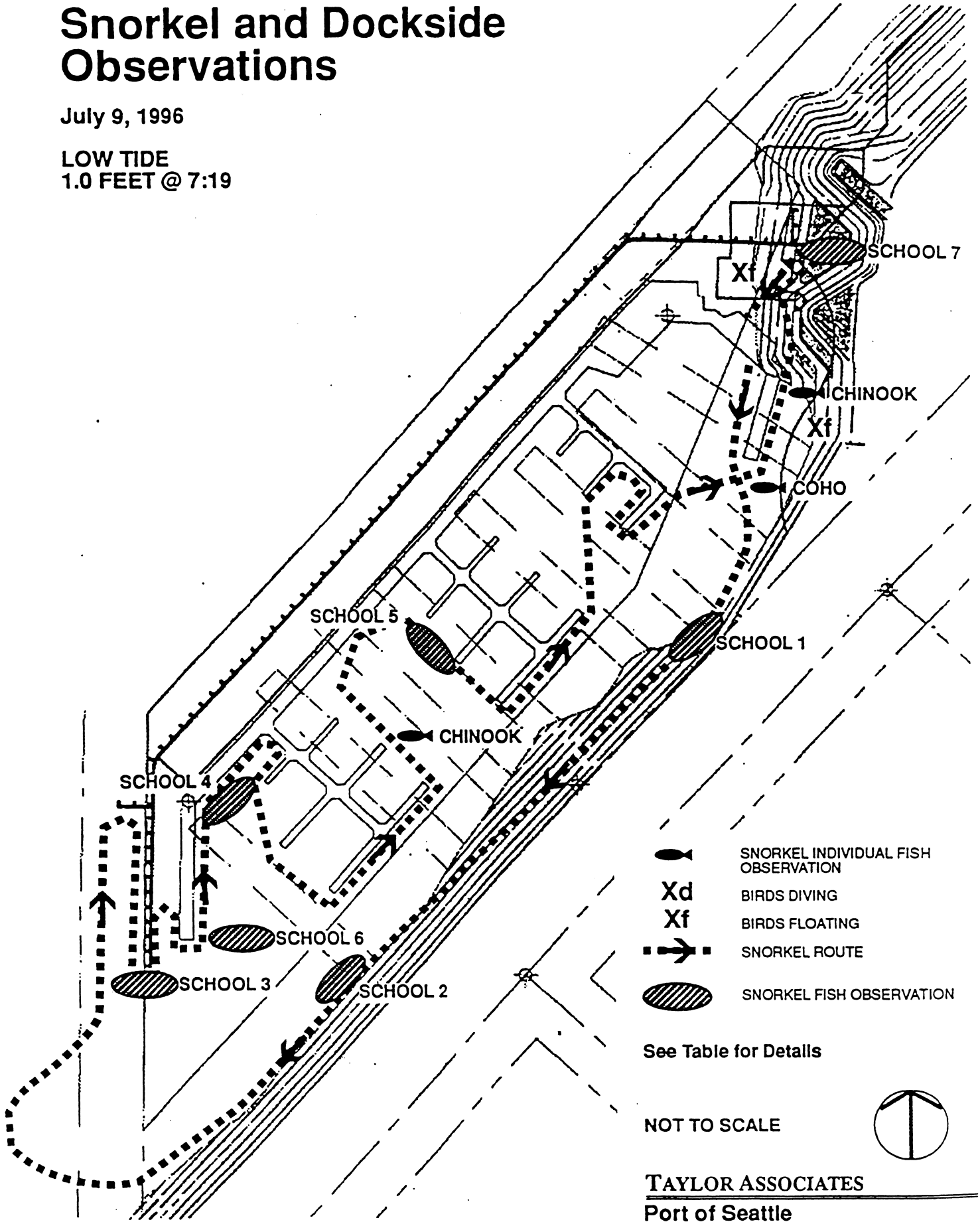
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 6b June 2000

Snorkel and Dockside Observations

July 9, 1996

LOW TIDE
1.0 FEET @ 7:19



See Table for Details

NOT TO SCALE

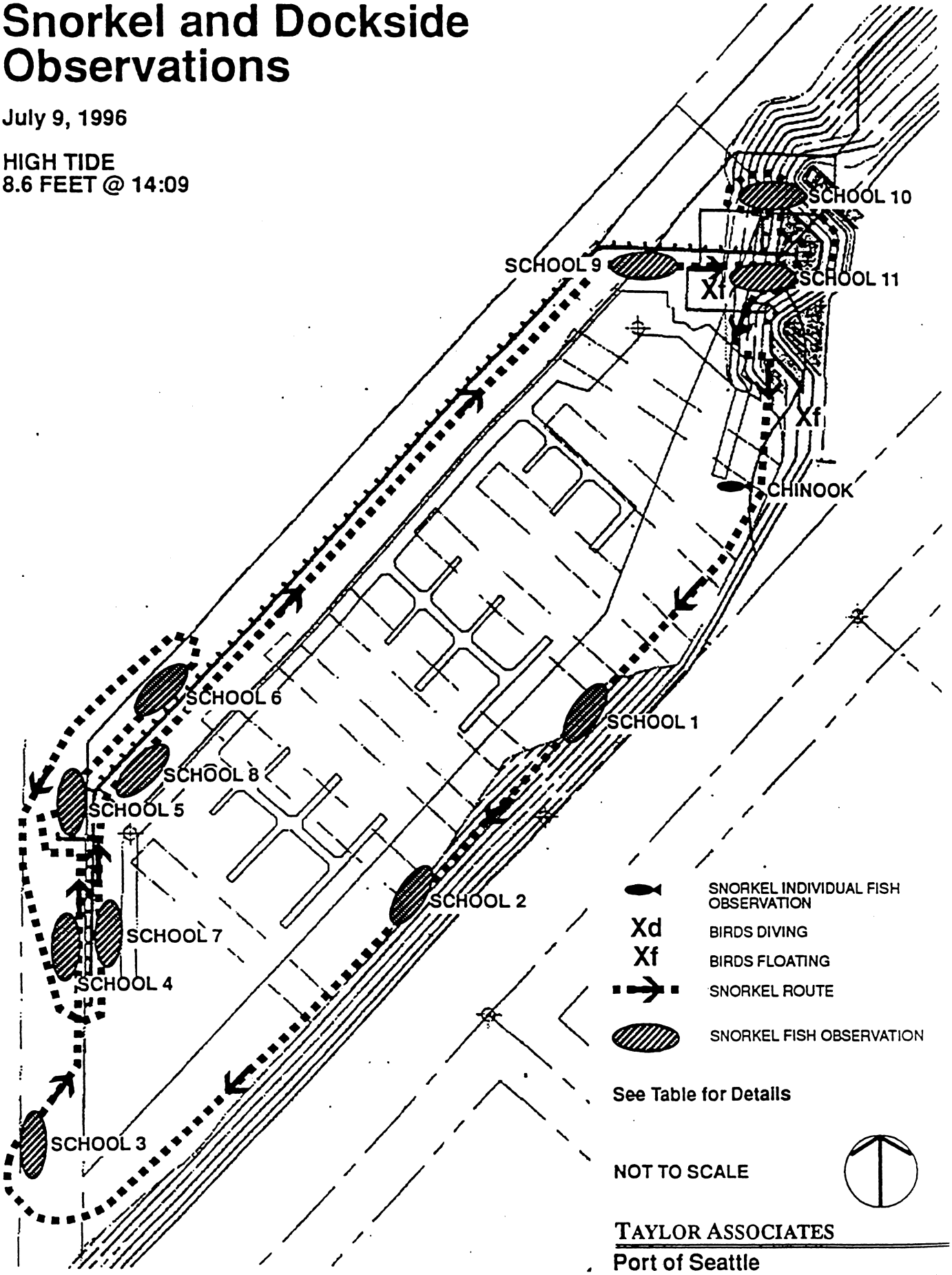
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 7a June 2000

Snorkel and Dockside Observations

July 9, 1996

HIGH TIDE
8.6 FEET @ 14:09



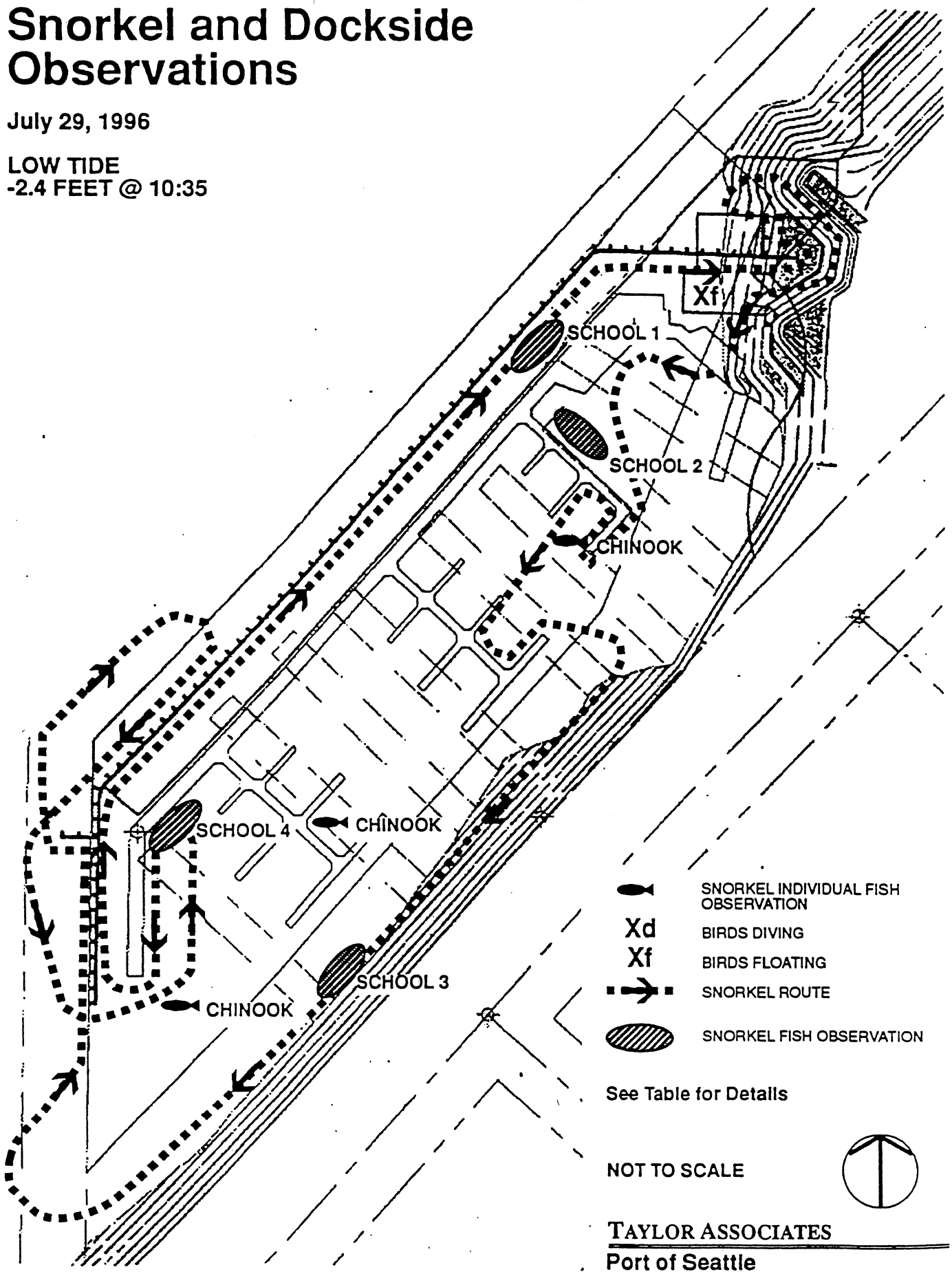
TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 7b June 2000

Snorkel and Dockside Observations

July 29, 1996

LOW TIDE
-2.4 FEET @ 10:35



TAYLOR ASSOCIATES

Port of Seattle
Pier 64/65 Snorkel and Dockside Fish and Bird Observations
Figure 8a June 2000

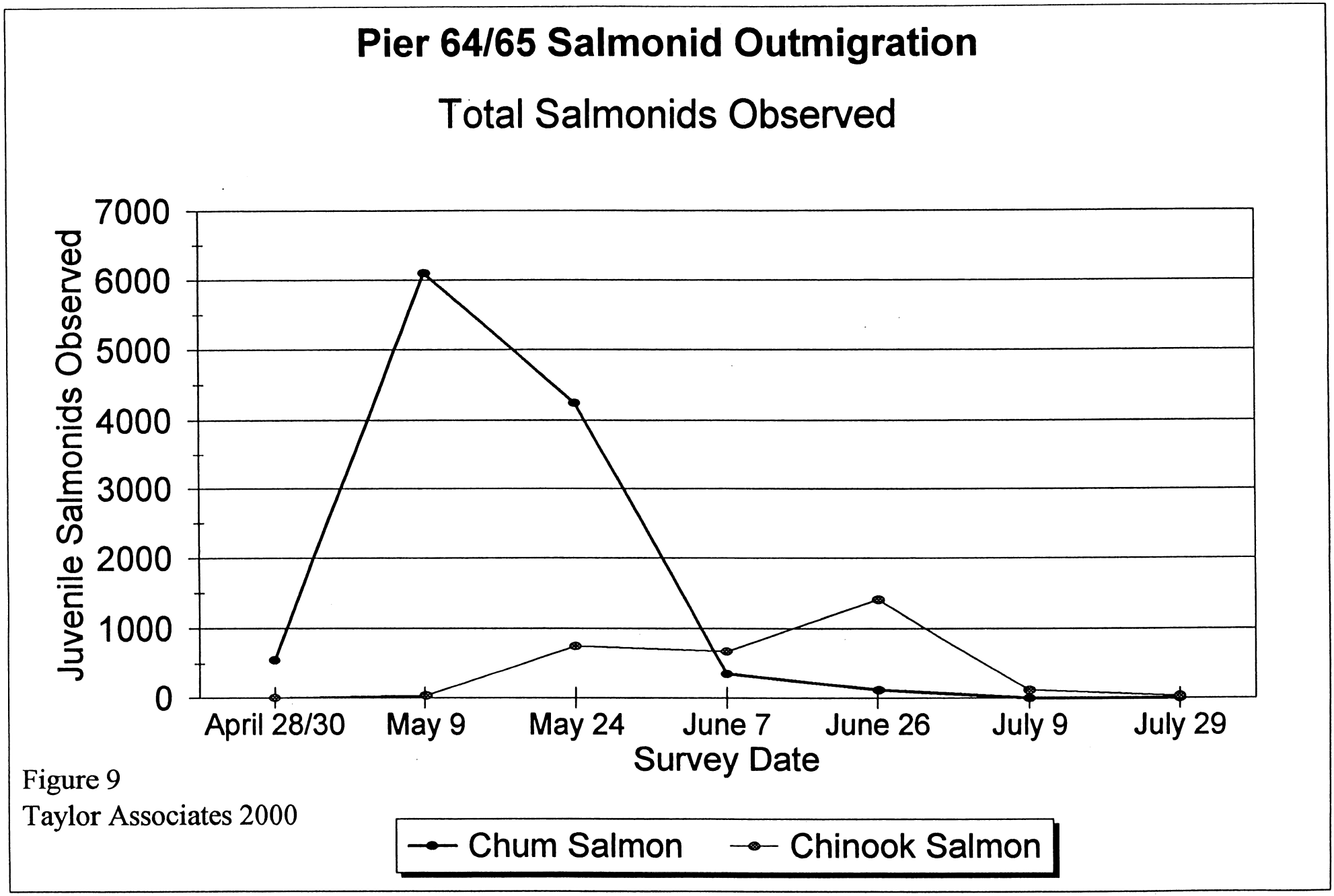


Figure 9
Taylor Associates 2000

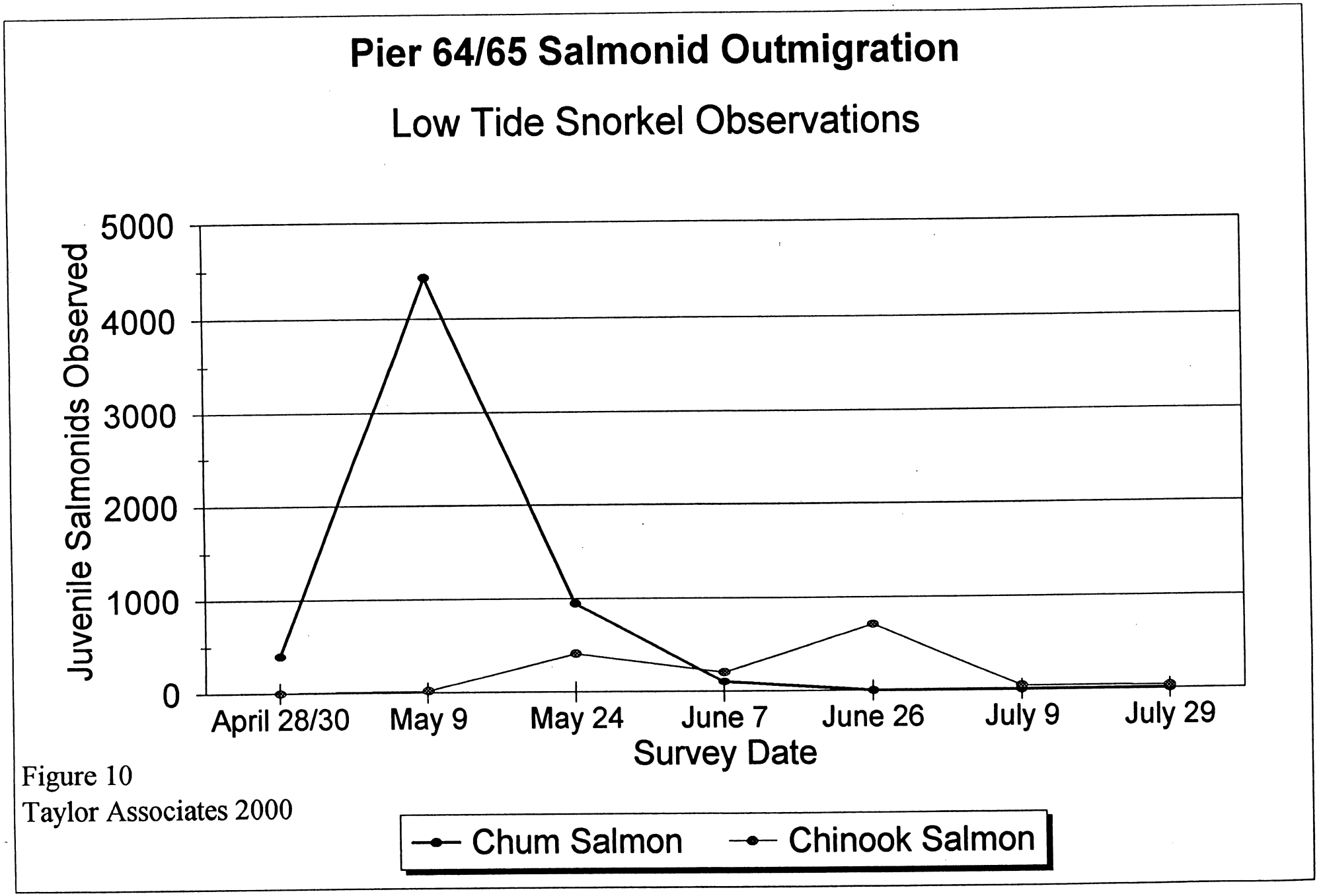


Figure 10
Taylor Associates 2000

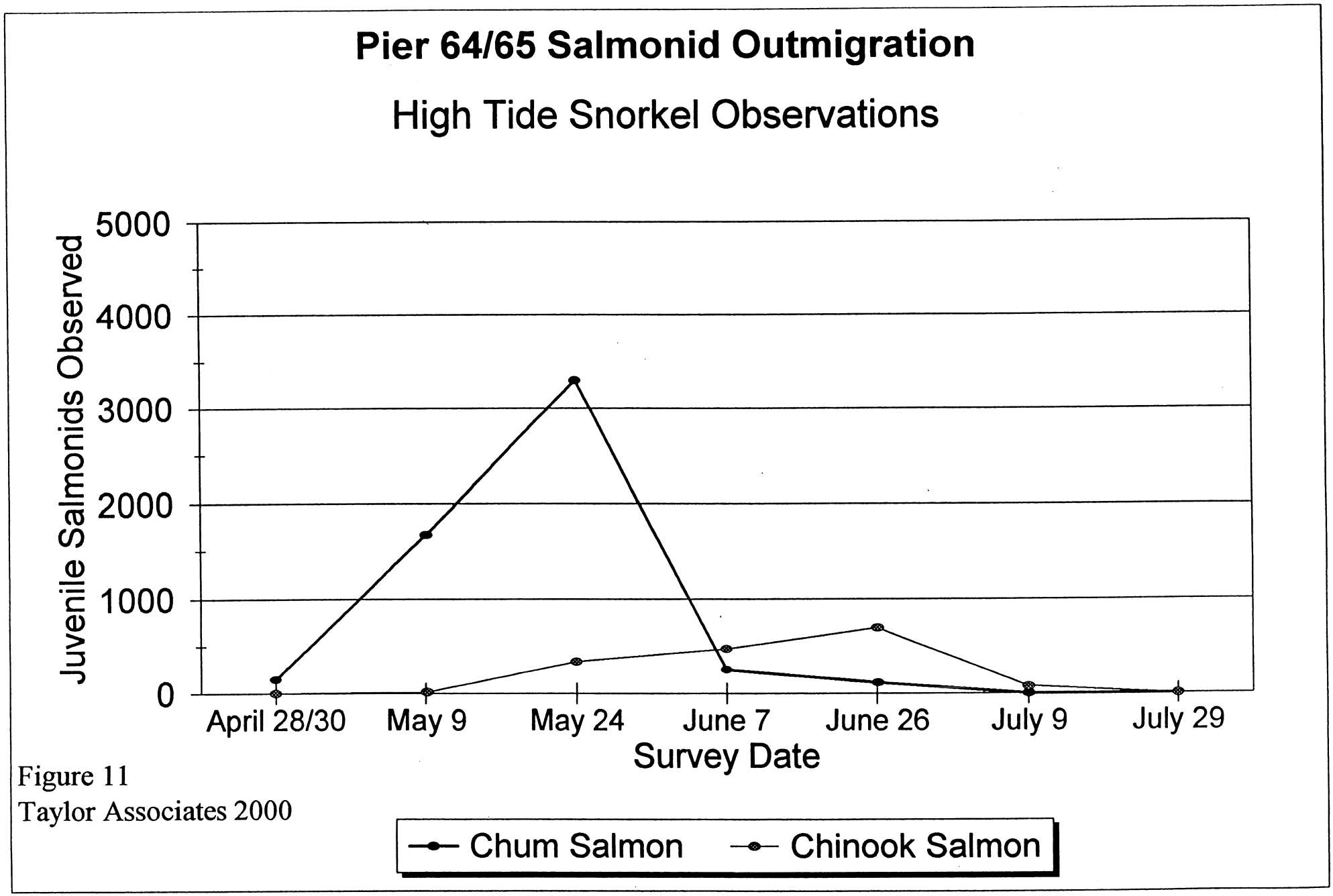


Figure 11
Taylor Associates 2000

TABLES

Table 1. Summary of snorkeling observations dates, times, and tidal conditions at Pier 64/65 the qualitative salmonid observations.

Snorkel No.	Preliminary Snorkel	Snorkel 2		Snorkel 3		Snorkel 4		Snorkel 5	
Date Conducted	April 8, 1996	April 28/30, 1996		May 9, 1996		May 24, 1996		June 7, 1996	
Tide Condition	Low Tide	High Tide	Low Tide	High Tide	Low Tide	High Tide	Low Tide	High Tide	Low Tide
Tide Height	-0.8 ft	8.1 ft	1.9 ft	9.0 ft	0.0 ft	7.6 ft	1.8 ft	8.6 ft	0.5 ft
Time at Peak Tid	14:57	14:23	09:57	09:36	16:26	09:52	16:25	09:35	16:02
Observation Time	14:00-16:30	14:00-16:30	09:00-11:30	08:30-10:30	15:45-18:00	09:00-11:00	16:00-18:30	09:00-11:30	15:15-17:30

Snorkel No.		Snorkel 6		Snorkel 7		Snorkel 8	
Date Conducted		June 26, 1996		July 9, 1996		July 29, 1996	
Tide Condition		Low Tide	High Tide	Low Tide	High Tide	Low Tide	High Tide
Tide Height		1.1 ft	8.5 ft	1.0 ft	8.6 ft	-2.4 ft	11.8 ft
Time at Peak Tid		07:56	14:45	07:19	14:09	10:35	17:50
Observation Time		07:00-09:00	13:30-16:00	06:30-08:30	13:00-15:30	10:00-12:00	16:30-19:00

Table 2. Fish observations recorded for snorkel number 2 at high and low tides, April 28th and April 30, 1996 (See Figures 2a and 2b for location of observed fish schools).

	Snorkel 2					
	April 30			April 28		
Tide Height	Low Tide			High Tide		
Time to Peak Tide	1.9 feet			8.1 feet		
Observation Time	09:57			14:23		
Weather	09:00 - 11:30			14:00 - 16:30		
Visibility	Sunny and Warm			Overcast & 60 degrees		
	~20 feet inside/>10 feet outside			<10 feet inside/ <5 feet outside		
School #	Species	#	Behavior Code	Species	#	Behavior Code
1	Chum	100	1	Chum	100	2
2	Chum	300	1	Chum	50	2
3	Unid. salm.	40	2 + 4	Unid. salm.	100	4
4	Unid. salm.	50	1 + 4			
5						
6						
7						
8						
9						
10						
11						
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14						
15						
16						
17						
18						

Behavior Codes

1= Schooling/Migrating
2= Schooling/Feeding
3= Holding/No Net Migration
4= Avoidance Behavior

Table 3. Fish observations recorded for snorkel number 3 at high and low tides, May 9, 1996 (See Figures 3a and 3b for location of observed fish schools).

	Snorkel 3					
	May 9					
	Low Tide			High Tide		
Tide Height	0.0 feet			9.0 feet		
Time to Peak Tide	16:26			09:36		
Observation Time	15:45 - 18:00			08:30 - 10:30		
Weather	Hazy and Partly Cloudy			Sunny, Partly Cloudy		
Visibility	20 feet			20 feet		
School #	Species	#	Behavior Code	Species	#	Behavior Code
1	Chinook	20	3	Chum	100	1
2	Chum	100 - 200	2	Chum	50 - 100	2
3	Chum	50 - 100	2	Chum	100	1
4	Chum	200 - 300	2	Chum	50 - 100	1
5	Chum	20 - 30	2 + 3	Chum	50 - 100	1
6	Chum	100	2 + 3	Chum	50 - 70	2
7	Chum	200	1 + 3	Chum	300 - 500	1 + 4
8	Chum	500	2	Chinook	6	1
9	Chum	100 - 200	3	Chum	300 - 500	2
10	?	?	1	Chinook	8	2 + 3
11	Chum	300 - 400	2	Chum	100	2 + 4
12	Chum	1000 - 2000	2			
13	Chum	50 - 100	2			
14	Chum	50 - 100	?			
15	Chum	50 - 100	1 + 2			
16	Chum	50 -100	1 + 2			
17						
18						

Behavior Codes

1= Schooling/Migrating
2= Schooling/Feeding
3= Holding/No Net Migration
4= Avoidance Behavior

Table 4. Fish observations recorded for snorkel number 4 at high and low tides, May 24, 1996 (See Figures 4a and 4b for location of observed fish schools).

	Snorkel 4					
	May 24					
	Low Tide			High Tide		
Tide Height	1.8 feet			7.6 feet		
Time to Peak Tide	16:25			09:52		
Observation Time	16:00 - 18:30			09:00 - 11:00		
Weather	Sunny and Warm			Sunny and Warm		
Visibility	25 feet			20 to 25 feet		
School #	Species	#	Behavior Code	Species	#	Behavior Code
1	Chum	50 - 100		Chum	50 - 100	3
2	Chum	100 - 150		Chum	300 - 400	3
3	Chinook	8 - 10		Chum	500	3
4	Chum	200 - 300		Chum	50 - 100	3
5	Chum	100 - 150		Chum	700 - 800	1
6	Ch & Ck	100		Chum ?	200	1
7	Chum	50 - 100		Chinook	30 - 50	3
8	Chum	100		Perch	> 1000	–
9	Chinook	100 - 150		Chum	150 - 200	1
10	Chinook	> 200		Chum	100 - 150	2
11	Chinook	2		Chum	200 - 250	3
12	Chinook	1		Chum	100	3
13				Chum	300	3
14				Chinook	100	2
15				Chum	200	2
16				Chinook	100	2
17				Chinook	50 - 75	2
18				Chinook	15	1

Behavior Codes

1= Schooling/Migrating
2= Schooling/Feeding
3= Holding/No Net Migration
4= Avoidance Behavior

Table 5. Fish observations recorded for snorkel number 5 at high and low tides, June 7, 1996 (See Figures 5a and 5b for location of observed fish schools).

	Snorkel 5					
	June 7					
	Low Tide			High Tide		
Tide Height	0.5 feet			8.6 feet		
Time to Peak Tide	16:02			09:35		
Observation Time	15:15 - 17:30			09:00 - 11:30		
Weather	Sunny with low Clouds			Sunny with low Clouds		
Visibility	25+ feet			25+ feet		
School #	Species	#	Behavior Code	Species	#	Behavior Code
1	Chinook	10 - 20	2	Chinook	6 - 8	3
2	Chinook	20 - 30	2	Chinook	?	2
3	Chinook	?	3	Chinook	8 - 10	2 + 3
4	Ch & Ck	> 100	1 + 2	Chum	100 - 200	2
5	Chum	50	2	Chinook	100	2
6	Chinook	50 - 100	2 + 3	Chinook	100	2
7	Chinook	4	3	Ch & Ck	>100	2 + 3
8	Coho	2	2	Chinook	100 - 200	2 + 3
9	Chinook	1	3	Chinook	2	3
10	Coho	1	4	Chinook	1	3
11				Coho	2	3
12				Chinook	2	2 + 3
13				Coho	2	3
14						
15						
16						
17						
18						

Behavior Codes

1= Schooling/Migrating
2= Schooling/Feeding
3= Holding/No Net Migration
4= Avoidance Behavior

Table 6. Fish observations recorded for snorkel number 6 at high and low tides, June 26, 1996 (See Figure 6a and 6b for location of observed fish schools).

	Snorkel 6					
	June 26					
	Low Tide			High Tide		
Tide Height	1.1 feet			8.5 feet		
Time to Peak Tide	07:56			14:45		
Observation Time	07:00 - 09:00			13:30 - 16:00		
Weather	Sunny with low Clouds			Sunny and warm		
Visibility	20+ feet			25+ feet		
School #	Species	#	Behavior Code	Species	#	Behavior Code
1	Chinook	10	2	Chinook	300-400	1
2	Chinook	50	2	Chinook	20-30	
3	Chinook	50	2	Chinook	5-10	
4	Chinook	50	1 + 2	Chinook	50-100	
5	Chinook	50	1	Chum	50-100	
6	Chinook	2	2	Chinook	30-40	
7	Chinook	25	2	Chinook	50	2
8	Chinook	25-50	1 + 2	Ch & Ck	25	2
9	Chinook	25-50	1 + 2	Chinook	25	
10	Chinook	25-50	1 + 2	Chinook	2	
11	Chinook	25-50	1 + 2	Chinook	10	
12	Chinook	25-50	1 + 2	Chinook	20	
13	Chinook	25-50	1 + 2			
14	Chinook	25-50	1 + 2			
15	Chinook	25-50	1 + 2			
16	Chinook	25	2			
17	Chinook	50	1			
18	Herring	1000-2000				

Behavior Codes

1= Schooling/Migrating
2= Schooling/Feeding
3= Holding/No Net Migration
4= Avoidance Behavior

Table 7. Fish observations recorded for snorkel number 7 at high and low tides, July 9, 1996 (See Figure 7a and 7b for location of observed fish schools).

	Snorkel 7					
	July 9					
	Low Tide			High Tide		
Tide Height	1.0 feet			8.6 feet		
Time to Peak Tide	07:19			14:09		
Observation Time	06:30 - 08:30			13:00 - 15:30		
Weather	Clear and cool			Sunny and warm		
Visibility	20 feet			25+feet		
School #	Species	#	Behavior Code	Species	#	Behavior Code
1	Herring	200 - 300	1 + 2	Chinook	5	2
2	Herring	200 - 300	1 + 2	Herring	300 - 500	2
3	Chinook	25	2 + 3	Herring	200 - 300	2 + 4
4	Chinook	10	2 + 4	Coho	15	4
5	Herring	500	2 + 3	Chinook	15	2 + 3
6	Coho	5	2 + 4	Chinook	25	2 + 3
7	Coho	2	2 + 3	Chinook	5	
8	Chinook	2	3	Herring	>1000	2 + 3
9	Chinook	2	4	Herring	500	2 + 3
10	Coho	1	4	Chinook	20	2
11				Chinook	5	2
12				Chinook	1	3
13						
14						
15						
16						
17						
18						

Behavior Codes

1= Schooling/Migrating
2= Schooling/Feeding
3= Holding/No Net Migration
4= Avoidance Behavior

Table 8. Fish observations recorded for snorkel number 8 at high and low tides, July 29, 1996 (See Figure 8a for location of observed fish schools).

	Snorkel 8					
	July 29					
	Low Tide			High Tide		
Tide Height	-2.4 feet			11.8 feet		
Time to Peak Tide	10:35			17:50		
Observation Time	10:00 - 12:00			16:30 - 19:00		
Weather	Sunny and warm			Sunny with high clouds		
Visibility	20+ feet			15+ feet		
School #	Species	#	Behavior Code	Species	#	Behavior Code
1	Chinook	3	3			
2	Chinook	20	3			
3	Herring	250-300	2			
4	Chinook	5	2			
5	Chinook	1	3			
6	Chinook	1	3			
7	Chinook	1	3			
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						

Behavior Codes

1= Schooling/Migrating
2= Schooling/Feeding
3= Holding/No Net Migration
4= Avoidance Behavior

Table 9. Number of salmonids observed for each snorkel event conducted at the Pier 64/65 moorage facil during spring and summer, 1996.

	Snorkel 2 April 28/30	Snorkel 3 May 9	Snorkel 4 May 24	Snorkel 5 June 7	Snorkel 6 June 26	Snorkel 7 July 9	Snorkel 8 July 29
Species	Total For All Snorkel Surveys						
Chum Salmon	550	6100	4250	350	112	0	0
Chinook Salmon	0	34	753	680	1412	115	31
Unident. Salmonids/ coho	190	0	0	*7*	0	*15*	0
Total Salmonids	740	6134	5003	1037	1524	130	31

Species	Low Tide						
Chum Salmon	400	4430	950	100	0	0	0
Chinook Salmon	0	20	413	205	712	39	31
Unident. Salmonids/ coho	90	0	0	*3*	0	0	0
Total Salmonids	490	4450	1363	308	712	39	31

Species	High Tide						
Chum Salmon	150	1670	3300	250	112	0	0
Chinook Salmon	0	14	340	475	700	76	0
Unident. Salmonids/ coho	100	0	0	*4*	0	*15*	0
Total Salmonids	250	1684	3640	729	812	91	0

italics = coho

Taylor Associates. 2000.