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BAIR ISLAND RESTORATION AND MANAGEMENT PLAN: EXISTING HYDROLOGIC CONDITIONS ASSESSMENT

Prepared for

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Prepared by

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1. INTRODUCTION

The San Francisco Bay Wildlife Society is developing a Restoration and Management Plan for 3,200 acres of Federal and State lands on Bair Island, Redwood City, California (Figure 1). The plan includes restoration of 1,400 acres of inactive, leveed salt production ponds ("salt ponds") to tidal wetlands. This report provides background information on existing hydrologic conditions at Bair Island. This study was conducted by Philip Williams & Associates (PWA) for H.T. Harvey & Associates as part of planning and permitting assistance being provided to the San Francisco Bay Wildlife Society (Society) in support the Bair Island Restoration and Management Plan.

Bair Island is a former tidal marsh that currently consists of inactive salt ponds, former salt ponds restored to tidal marsh, supra-tidal dredged material disposal areas, and remnant historic marsh (Figure 2). Bair Island is composed of three islands – Inner, Middle, and Outer Bair Islands – separated by tidal sloughs. The project study area includes the entire Restoration and Management Plan area (Figure 1), with particular emphasis on the 1,400 acres proposed for restoration.

This study and the assessment of existing biological conditions being prepared concurrently by H.T. Harvey are the first of several in support of the Bair Island Restoration and Management Plan. Subsequent studies will include:

- development of management objectives;
- opportunities and constraints analysis,
- development and evaluation of restoration alternatives;
- preparation of Bair Island Restoration and Management Plan; and
- preparation of Bair Island Restoration and Management Plan Environmental Impact Study (EIS)/Environmental Impact Report (EIR).

Hydrodynamic modeling and additional hydrologic and geomorphic analyses will be conducted to assist in the above studies.

2. HISTORIC SITE CONDITIONS

Bair Island is a former tidal salt marsh that has undergone considerable natural and human-induced changes in its evolution. Although existing hydrologic conditions at the site have been substantially modified from historical conditions, some of the existing characteristics are remnants of historic processes and changes, and are best understood within an historic context.

The description of historic conditions at the site is based on a review of existing information, including historic United States Coast and Geodetic Survey (USCGS) maps, United States Geological Survey (USGS) topographic maps, historical aerial photographs, and secondary studies. These studies include: Bair Island Environmental Study (SLC 1977) and Bair Island Ecological Reserve Operations and Maintenance Plan (RTC 1991).

2.1 THE NATURAL LANDSCAPE

Bair Island was once part of a continuous band of tidal salt marsh wetland fringing the southwest shoreline of southern San Francisco Bay. San Francisco Bay was formed over the past 10,000 years by sea level transgression (Atwater *et al*. 1979). Rising sea levels submerged previously upland valley areas. From the time of initial submergence until large-scale reclamation began approximately 150 years ago, the aerial extent of the Bay's tidal marshes was determined by the interaction of sea level rise, estuarine sedimentation and wind wave erosion.

Initially, the Bay was rapidly submerged by sea levels rising at approximately 10 times the current rate of 1-2 mm/yr. From ~10,000 to 6,000 years before present, the Bay supported only a thin, discontinuous fringe of salt marsh along the expanding perimeter (Atwater *et al.* 1979). Salt marsh sedimentation and organic accumulation were presumably not able to keep pace with the rise in sea level. Approximately 6,000 years ago sea level rise slowed to its current rate. In the Bay, this allowed marsh accretion to keep pace with submergence. Evidence from Bay marsh cores indicates that during the past 6,000 years a continuous marsh fringe formed around the Bay and expanded landward, as sea level continued to rise.

2.2 HUMAN INTERVENTION

A review of historic and recent topographic maps of the area illustrates the changes that have occurred from the 1850s through the present. In 1857, only the bayward two of the three islands that now comprise Bair Island existed as islands; the area that is now Inner Bair was part of the mainland (Figure 3). There were no structures or levees and the entire Bair Island was tidal salt marsh. There were no significant changes between 1857 and 1897, except for a 10-acre area at the confluence of Corkscrew Slough and Redwood Creek, which was diked for use as a fishing village in 1869 (SLC 1977). The 1897 map shows what appears to be Cordilleras Creek discharging to Smith Slough through a small tidal channel on what is now Inner Bair Island. Around the turn of the century, Bair Island was included in several attempts to reclaim marshplain land for agricultural use. A levee around the outer edge of Outer Bair Island, possibly constructed around 1910 (SLC 1977), is shown in the 1931 map (Figure 4). The descriptive report accompanying this map states, "the area between Steinberger and Redwood Sloughs, some of which was at one time reclaimed land, has again reverted to marsh due to the breaking and overflowing of the confining levees. These marshes lie about one foot below extreme high tide. The area is traversed by numerous small sloughs."

Between 1948 and 1952 most of Middle and Outer Bair Island were leveed by Leslie Salt Company for use as salt evaporation ponds (SLC 1977). Salt production on Bair Island was discontinued in 1965, when the ponds were drained and abandoned. Table 1 summarizes the recent history of leveeing and diking for which information is readily available. Pond names and other area locations referenced in Table 1 are shown on Figure 5. Although the date of leveeing for Inner Bair Island is not provided in the existing literature (SLC 1977; RTC 1991), we assume that it was leveed at the same time as Middle and Outer Bair Islands (1948-1952). This is consistent with the 1959 USGS topographic map which shows the Inner Bair leveed. The 1959 map also shows Smith Slough and the borrow ditches south and southwest of Inner Bair in their current locations. It appears that when Inner Bair Island was leveed, a large meander bend in Smith Slough was cut off and leveed within the island, adding acreage to Inner Bair Island which was formerly part of Middle Bair. The borrow ditches were probably created during construction of the Inner Bair levee.

In 1973, Mobil Oil Estates purchased Bair Island and the Redwood Peninsula, where the Redwood Shores development now stands (Figure 5), from Leslie Salt Company. Much of Outer Bair Island was transferred to the California State Lands Commission (SLC) as part of the transaction or as mitigation for marsh loss during the development of Redwood Shores. Tidal action was restored to a large part of Outer Bair Island in the late 1970's and early 1980's through a series of planned and unplanned levee breaches (Table 1).

The locations of the major sloughs have remained essentially unchanged between 1857 and the present, based on a comparison of the historic maps with the recent USGS topographic map (USGS 1973). Flow patterns in the sloughs, however, appear to have changed over time. Leveeing decreased tidal exchange through the sloughs. In addition, Redwood Creek dredging, which began in 1955 and continues to the present, made Redwood Creek a more efficient tidal conveyance channel. Together, these changes would have had the effect of shifting Corkscrew and Smith Slough tidal flows towards Redwood Creek and making Steinberger Slough shallower from lack of tidal scouring. These end results are supported by observations from recent aerial photographs (February 18, 2000). The photographs show that a reach of Steinberger Slough between Smith and Corkscrew Slough is dry at low tides, meaning that Smith Slough and the lower part of Steinberger Slough drain toward Redwood Creek. Also, the existing tidal drainage divide for Corkscrew Slough is in the western part of the channel near Steinberger Slough, meaning that most of Corkscrew Slough drains to Redwood Creek.

As recently as 1975, Steinberger Slough did not drain directly to the Bay at low tide. The USGS topographic map (1959, revised in 1968 and 1973) and old bathymetric maps (NOS 1975) show

Steinberger Slough draining at low tide to Bay Slough and from there to Belmont Slough before discharging to the Bay. More recent bathymetric maps (NOS 1989 and NOS 1995) and low-tide aerial photographs (February 2000) show Steinberger Slough discharging directly to the Bay rather than Bay Slough. The former drainage pattern through Bay Slough was probably a remnant feature of the historical marsh. Steinberger and Bay Slough appear to have been one continuous internal marsh channel which has now become directly connected to the Bay by hundreds of years of sea level rise and shoreline erosion.

The bayward shoreline of Bair Island has experienced both aggradation and erosion, first aggrading from 250 to 1000 feet during the hydraulic mining era (as reflected on the 1857 and 1897 maps), then eroding between 1897 and 1931 and between 1931 and 1959. Relative to its position in 1857, the current shoreline has receded as much as 700 feet in some locations, but has aggraded approximately 200 feet in others.

In addition to lateral movement of the marsh edge, the marshplain elevations of areas that were leveed on Inner, Middle, and Outer Bair Islands have subsided. Subsidence is discussed in Section 3.

TABLE 1. Site History by Sub-Area, 1948 to present

Location	Sub-Area	Date Leveed	Date Breached	Comments
Inner Bair	Pond A-12	1948-1952	NA (not breached)	Inner Bair restoration area. 297 acres.
Middle Bair	Ponds A-9, A-10, and A-11	1948-1952	NA (not breached)	Middle Bair restoration area. Total 779 acres.
	Deepwater Slough and land bounded by it	1965	date unknown	Purchased by Port of Redwood City in 1963 and 1964. The ends of Deepwater Slough (at Redwood Creek) were diked in 1965. Used for dredged material disposal until 1970.
	North of Deepwater Slough	unknown (1965?)	date unknown	May have received dredged material overflow from the area bounded by Deepwater Slough. Appears relatively undisturbed, except for leveeing. No evidence that this area was used for salt production.
	West and South of Deepwater Slough	unknown	date unknown	It appears that dredged material was placed on 5 to 10 acres of this parcel. No levee visible in aerial photographs on the southeast side of the parcel; may never have been leveed. Shows ponding and evidence of disturbed/poor drainage.
Outer Bair	Pond B-1	1948-1952	1976 (unplanned)	Ownership transferred from Mobil Corporation to SLC in 1973. Interior levee between Ponds B-1 and B-2 was breached sometime after 1979, and again in 1983 to allow greater tidal action in Pond B-2. Approximately 310 acres.
	Pond B-2	1948-1952	1979-1983	Mitigation for development on Redwood Peninsula. Interior levee between Ponds B-1 and B-2 was breached sometime after 1979, and again in 1983 to allow greater tidal action in Pond B-2. Approximately 182 acres.
	Pond B-3	1948-1952	NA (not breached)	Outer Bair restoration area. 419 acres.
	Pond VI	1948-1952	1983	Ownership transferred from Mobil Corporation to SLC in 1973. Unplanned breach began in 1983. Interior levee constructed in 1983 to protect least tern nesting sites from tidal inundation. The western levee of Pond VI was repaired and raised in 1986. Approximately 128 acres.
	Eastern Outer Bair	1948-1952	appears not to be breached	Part of this area referred to as Pond VII was used for salt production. The exact location of Pond VII within eastern Outer Bair is unknown. Ownership for part of eastern Outer Bair transferred from Mobil Corporation to SLC in 1973.

Sources: SLC 1977, RTC 1991, and D. Jewell, pers. comm.

NA = not applicable

Note: All of Outer Bair Island except Pond B-3 was leveed and breached between 1897 and 1931.

3. EXISTING SITE CONFIGURATION AND GRADES

Inner, Middle, and Outer Bair Islands are separated by natural and constructed tidal sloughs (Figure 5). Steinberger Slough and the tidal portion of Redwood Creek are located to the west and east of Bair Island, respectively. Corkscrew Slough separates Outer and Middle Bair; Smith Slough separates Middle and Inner Bair. Two borrow ditches separate Inner Bair Island from the mainland.

3.1 LAND USE AND INFRASTRUCTURE

The site consists of leveed inactive salt ponds, restored tidal marsh, supra-tidal dredged material disposal areas, and remnant historical marsh (Figures 2 and 6 and Table 2). Part of Inner Bair (Pond A-12) is owned by the San Carlos Airport and maintained as a safety area for emergency landings (Figure 7).

TABLE 2. Existing Habitat Type by Sub-Area

Loca-tion	Sub-Area	Existing Habitat Type	Notes
Inner Bair	Pond A-12	inactive salt pond	Inner Bair restoration area. 297 acres.
Middle Bair	Ponds A-9, A-10, and A-11	inactive salt ponds	Middle Bair restoration area. Total 779 acres.
	Deepwater Slough and land bounded by it	supra-tidal dredged material and poorly-drained high marsh	
	North of Deepwater Slough	tidal marsh (elevation unknown; appears to be high marsh)	
	West and South of Deepwater Slough	tidal marsh (elevation of marsh unknown) and supra-tidal dredged material	
Outer Bair	Pond B-1	young low/mid-elevation tidal marsh	Approximately 310 acres.
	Pond B-2	young low/mid-elevation tidal marsh	Approximately 182 acres.
	Pond B-3	inactive salt pond	Outer Bair restoration area. 419 acres.
	Pond VI	northern part is young low/mid-elevation tidal marsh; southern part is leveed	Approximately 128 acres.
	Eastern Outer Bair	leveed; portions are supra-tidal	relatively little information available

Sources: aerial photographs (February 2000), SLC 1977, RTC 1991, and D. Jewell, pers. comm.

Infrastructure within the area proposed for restoration includes the South Bay System Authority (SBSA) sewer line, a PG&E transmission tower, and a slide-gated culvert, all of which are located on Inner Bair (Figure 7). The SBSA line runs northwest underneath the Inner Bair Island levee from the Whipple Avenue interchange, across/under the western Inner Bair borrow ditch, and along the San Carlos Airport property. The PG&E transmission tower is located just inside of the Inner Bair levee, near the eastern tip of the island. Infrastructure also includes existing levees (many abandoned), which are discussed in the next sub-section.

3.2 TOPOGRAPHY

Existing topographic information for the site consists of 1981 topographic maps of Inner and Middle Bair Islands (BKFA 1981), 1993 surveys of levee crest elevations on Inner Bair (Bohley Maley Associates, 1993), and field surveys conducted for this study. PWA surveyed elevations of marshplain transects and levee/borrow ditch cross-sections in the inactive salt pond areas of Inner, Middle, and Outer Bair Islands in February through April, 2000 (locations shown in Figure 8).

3.2.1 Marshplains

Representative elevations for natural marshplains surveyed at Bair Island outboard of the leveed islands average 3.4 feet NGVD[1], or approximately the local MHW elevation (tides are discussed further in Section 5). Natural pickleweed marshplain elevations range between 2.1 and 4.8 feet NGVD (Table 3).

In contrast, subsidence has caused marshplains within the leveed salt ponds to lower by several feet below natural marshplain elevations (Table 3). Subsidence is caused by decomposition of the organic material that comprises much of marsh soils and by soil consolidation, which is accelerated by de-watering. The degree of subsidence depends on how long a site has been leveed and drained, and how aggressively the site has been drained (i.e., how low water levels were kept). Total subsidence and subsidence since 1981 are shown in Table 3. Total subsidence depths were calculated as the difference between the average natural marshplain elevation and average pond interior elevations from 2000 field surveys (this study). The 1981 to 2000 subsidence depths were calculated as the difference between the 2000 field survey elevations (this study) and those on the 1981 map (BKFA 1981).

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[1] National Geodetic Vertical Datum, a fixed vertical datum at the mean sea level of 1929.

TABLE 3. Bair Island Marshplain Elevations

Location	Feature	Average Elevation (feet NGVD)	Minimum Elevation (feet NGVD)	Maximum Elevation (feet NGVD)	Subsidence between 1981 and 2000 (feet)	Total Subsidence (feet)
Inner Bair	Transect T-5	0.1	-0.8	1.0	0.8	3.3
	Safety Zone Transect	0.0	-0.8	0.7	0.8	3.4
Middle Bair	Transect T-4	1.2	0.4	1.9	1.5	2.2
	Transect T-6	0.8	0.1	1.3	2.1	2.6
Outer Bair	Transect T-1	1.1	0.1	2.2	NA	2.3
	Transect T-2	0.0	-0.8	1.4	NA	3.4
Outside of levees	Natural marshplain	3.4	2.2	4.8	---	---

Source: PWA field surveys (2000) and BKFA (1981).
Note: Marshplain elevations exclude channel and levee portions of transects.

3.2.2 Levees

Levees on Inner, Middle, and Outer Bair were originally constructed to contain salt ponds and not necessarily to prevent flooding during large flood events (such as the 100-year flood). The majority of the Middle and Outer Bair levees have not been maintained since the ponds were abandoned in 1965. The Inner Bair levee has been repaired and raised since 1965, primarily to protect the SBSA force main that runs underneath most of the southern part of the levee and to protect the San Carlos Airport safety area. Survey information from Bohley Maley Associates (1993) indicates that the Inner Bair Island perimeter levee elevation was likely raised at least once prior to 1993, by creating a narrower levee on top of the original levee. The survey was performed to aid in the design of a second maintenance project, which would raise the levee to a design elevation of 8.0 feet NGVD by adding another narrow band of material on top of the section that was raised previously (Bohley Maley Associates, 1993). Spot checks of the levee elevation from 2000 PWA surveys indicate that the current levee crest elevation is approximately 8 feet NGVD on Inner Bair Island, excluding the portion of the levee above the force main. PWA's April 2000 surveys of the levee above the force main indicate that the crest elevations are approximately 10 feet NGVD for this portion of the levee.

TABLE 4. Levee Crest Elevations

Location	Data Source	Average Elevation (feet NGVD)	Minimum Elevation (feet NGVD)	Maximum Elevation (feet NGVD)
Inner Bair	1981 survey (BKFA 1981)	~6	5.2	7.8
	1993 survey (Bohley Maley Associates)	~7	5.9	7.9
	2000 survey (this study) excluding the portion of the levee above the force main	7.9	7.6	8.2
	2000 survey (this study) portion of levee above the force main only	9.9	9.4	10.7
Middle Bair	1981 survey (BKFA 1981)	~7	6.1	9.1
	2000 survey (this study)	7.0	6.6	7.8
Outer Bair	2000 survey (this study)	7.6	6.3	8.7

3.3 HYDROGRAPHY

Existing hydrographic information for the site consists of NOS bathymetric maps (NOS 1995) and field surveys conducted for this study. PWA surveyed channel and borrow ditch cross-sections in the inactive salt pond areas of Inner, Middle, and Outer Bair Islands in February and March, 2000 (locations shown in Figure 8). Towill surveyed 30 cross-sections of the major slough channels (Redwood Creek, Steinberger Slough, Smith Slough, and Corkscrew Slough) in February 2000, for the current study.

Redwood Creek, Steinberger Slough, Corkscrew Slough, and Smith Slough are the major tidal channels adjacent to Inner, Middle, and Outer Bair Islands. Outer Bair Island is bordered by an approximately 3000-foot wide outboard mudflat that is exposed at low tide. Shallow water continues offshore to the deepwater shipping channel through South San Francisco Bay, approximately 6,000 feet offshore of Outer Bair.

Redwood Creek is dredged for use as a shipping channel to service the Port of Redwood City (discussed further in Section 8) and is the largest and deepest of the Bair Island sloughs (Table 5). Most of the tidal exchange for the Bair Island slough system is through Redwood Creek. Drainage divides are located in Steinberger Slough just south of its confluence with Corkscrew Slough and in Corkscrew Slough, approximately 3000 feet east of its confluence with Steinberger Slough (Figure 9). The drainage divide areas are dry at low tide.

In light of the drainage divide locations, Smith Slough and most of Corkscrew Slough drain to Redwood Creek. The southern part of Steinberger Slough, between Smith and Corkscrew Sloughs, drains through Smith Slough to Redwood Creek. The remainder of Steinberger Slough drains directly to the Bay. The western 3000 feet of Corkscrew Slough drains to Steinberger Slough and from there to the Bay.

Two borrow ditches adjacent to Inner Bair Island (Figure 7) are minor tidal channels. Cordilleras and Pulgas Creeks empty into the western borrow ditch and from there to Smith Slough. A pump station draining approximately 140 acres empties into the eastern borrow ditch (Linsley Kraeger, 1985). Although it carries less upland runoff, the eastern borrow ditch is deeper and wider than the western borrow ditch.

TABLE 5. Channel Bathymetry

Location		Channel Bottom Elevation (feet NGVD)	Depth at MHHW [H] (feet)	Top Width at MHHW (feet)	Comments
Redwood Creek	at mouth, near Redwood Point	-34.8	38.9	NA*	
	Port of Redwood City	-39.0	43.1	509	Design dredge depth is -33.9 ft NGVD
	south end, near Highway 101	-8.9	12.9	984	
Steinberger Slough	at mouth	-9.2	13.2	656	
	south end, near Smith Slough	-7.62	11.7	390	
Smith Slough	west end	-6.1	10.2	377	
	east end	-13.1	17.2	328	
Corkscrew Slough	west end	-2.6	6.7	308	
	east end	-12.8	16.9	433	
Inner Bair borrow ditches	western	-3.3	7.3	45	
	eastern	-5.9	10.0	141	

H MHHW = Mean Higher High Water
* Channel top of bank is not defined on the west bank.
Source: Towill field surveys (February 2000; this study).

4. WIND CLIMATE

Wind data for Bair Island were collected by USGS for approximately one-year (J. Dingler, pers. comm.). According to these measurements, the primary wind direction is from the west-northwest, with an average wind speed of 6.2 mph. The Bair Island data show seasonal and diurnal patterns typical of San Francisco Bay, where on-shore sea breezes create strong summer afternoon winds and winter storms bring high velocity, shorter duration winds from the south-southeast.

In addition to the USGS data, continuous wind data are available from the NOAA meteorological station located on Wharf 5 at the Port of Redwood City. The period of record extends from August 22, 1997 to the present and consists of hourly recordings of wind speed, wind direction, and wind gust. No summarized information exists for this data set.

5. TIDAL CHARACTERISTICS

5.1 AVERAGE AND EXTREME TIDE ELEVATIONS

Tidal characteristics at the Redwood Creek tide gauge are shown in Table 6. Mean tide conditions are from the National Ocean Service (NOS, 1987). The 10- and 100-year estimated high tides are from the U.S. Army Corps of Engineers (USACE, 1984).

The published tide data presented in Table 6 were checked for consistency with elevations from the 2000 field surveys using a tidal datum analysis. Vertical datum control is important in areas that are subsiding rapidly. Benchmark subsidence and inaccurate vertical control are common difficulties in the tidal marsh environment. Based on preliminary results from this analysis, the published data were found to be consistent with elevations from the current surveys and no vertical correction was necessary. The results of the tidal datum analysis are preliminary and finalized in a subsequent study.

TABLE 6. Tide Characteristics at Redwood Creek, Channel Marker No. 8, San Francisco Bay

	Elevation	
	MLLW (feet)	**NGVD (feet)**
Estimated 100-Year High Tide	11.2	7.3*
Estimated 10-Year High Tide	10.5	6.6
Mean Higher High Water (MHHW)	7.96	4.05
Mean High Water (MHW)	7.35	3.44
Mean Tide Level (MTL)	4.27	0.36
National Geodetic Vertical Datum , 1929 (NGVD)	3.91	0.00
Mean Low Water (MLW)	1.19	-2.72
Mean Lower Low Water (MLLW)	0.00	-3.91

Sources: NOS (1987), USACE (1984), PWA analysis.
Note: Elevations are for the 1960 to 1978 tidal epoch.
*Adopted elevation: adopted by the USACE from the smoothed profile of calculated 100-year tides.

6. EXISTING DRAINAGE

Existing local and regional drainage are important elements of restoration design.[2] Until specific restoration alternatives are developed and evaluated, however, it is not possible to know which details of the existing drainage will be most relevant to the design. Therefore, in preparation of this section of the study, we assume certain project changes associated with the restoration and use these changes to focus the scope of our existing conditions assessment. Existing drainage and potential project impacts will be analyzed in more detail in subsequent phases of the project, once specific restoration alternatives have been developed.

We assume that restoration will re-introduce full tidal action to most, if not all, of the available restoration area. The project will directly affect drainage in the restoration areas and has the potential to affect the elevation-duration characteristics of typical tide cycles in adjacent sloughs.[3] Changes in water levels are expected to be short-term and limited to "typical tides," within approximately the mean diurnal tidal range. During the initial period of site development, typical tides may be muted within the restoration area and adjacent channels. Water levels in the local slough channels may not fall as quickly or drain as low during the ebb tide as under existing conditions. In the long-term, as the local slough channels enlarge and the restored areas fill with sediment, typical tide levels are expected to return to close to existing conditions.

Changes to typical tides could affect drainage in adjacent areas that rely upon low tides for storm discharge. The potential for impact, however, depends upon the type of drainage for each area, described below in Section 6.2.2.

6.1 ON-SITE

Drainage within the Restoration and Management Plan area, in terms of which sub-areas are tidal versus non-tidal, is discussed above in Section 3. This section focuses on detailed drainage for the areas of Bair Island proposed for tidal restoration.

Water levels in the inactive salt ponds on Middle and Outer Bair Islands are controlled by ponding of direct rainfall, evaporation, and levee seepage. Seepage between the ponds and adjacent channels occurs in both directions (into and out of the pond), depending on relative water levels. A slide-gated culvert on Inner Bair appears to offer some level of drainage connection between the pond interior and Smith Slough. We assume that the culvert is functioning to some extent, since water levels in Inner Bair were observed to be lower than in Middle and Outer Bair during recent PWA field surveys. Middle and Outer

[2] Drainage refers to surface runoff during typical (non-extreme) rainfall events or tidal flow during typical diurnal tides. Flooding refers to surface runoff and tide conditions during extreme events. Flooding is discussed separately in Section 7.
[3] Potential project impacts to flooding are discussed separately in Section 7.

Bair ponded water levels remained high following several recent storm events. The slide gate and culvert appear to be at least a decade old and have been observed by San Mateo County Mosquito Abatement District staff to be filled with debris (D. Jewell, pers. comm.). During PWA field surveys conducted during March 2000, observed water levels were approximately –0.5 feet NGVD at Inner Bair, 0.1 to 1.3 feet NGVD at Middle Bair (varied by pond and date of survey), and 1.1 feet NGVD at Outer Bair.

Until recently, water in the Middle and Outer Bair salt ponds was siphoned periodically during the rainy season to keep ponding, and associated mosquito production, to a minimum. According to Dennis Jewell, Supervisor with the San Mateo County Mosquito Abatement District, temporary siphons were used to drain Middle and Outer Bair beginning in the late 1970s or early 1980s (D. Jewell, pers. comm.). Mobil Oil installed and operated the siphons originally, then operations were continued by the Mosquito Abatement District. The Mosquito Abatement District siphoned during the rainy season; by June, the ponds would usually be dry. The Mosquito Abatement District discontinued siphon operations at Bair Island this year due to lack of funds and staffing. The siphons are constructed of white PVC pipe and are still visible at the site today (PWA site reconnaissance, March 2000).

It appears that Inner Bair Island has never been siphoned. Siphoning for mosquito control was not used at Inner Bair because the area is easily accessible for other types of mosquito abatement treatment (D. Jewell, pers. comm.). In addition, there are potential vandalism problems associated with storage of siphons at Inner Bair.

6.2 OFF-SITE

6.2.1 Prior Studies

Existing information reviewed for the off-site drainage section includes FEMA Flood Insurance Studies for the Cities of San Carlos and Redwood City (FIA 1977 and FEMA 1981) and the following reports: *Update of Master Plan for Storm Drainage, Water, and Sanitary Sewer Systems, City of Redwood City* (KJC, 1986); and *Addressing the Problems of Flooding and Drainage Along Cordilleras Creek, Draft Preliminary Report* (CFCCNA, 1999). Additional information was obtained through conversations with engineers from the City of Redwood City Engineering Department (J. Lynch, S. Vorametsanti, and C. Chang, pers.comm.).

6.2.2 Drainage Mechanisms

Drainage of storm water runoff in coastal areas can be categorized according to the following drainage mechanisms: (1) gravity drainage of supra-tidal areas, (2) gravity drainage of diked inter-tidal areas, and (3) pumped drainage of diked inter-tidal areas. Restoration-related changes in typical tide elevations are not expected to significantly affect drainage for adjacent areas relying upon the first and third drainage mechanisms. They could, however, affect gravity drainage of inter-tidal areas (the second mechanism) by reducing the frequency and duration of very low tides, when stored storm water can drain through passive drainage structures to adjacent sloughs.

6.2.3 Regional Drainage Overview

Three major creeks—Redwood, Cordilleras, and Pulgas Creeks—convey surface runoff from the hillsides southwest of Bair Island to San Francisco Bay (Figure 10). Redwood Creek continues all the way to the Bay, while Cordilleras and Pulgas Creeks flow into the western Inner Bair borrow ditch and from there to Smith Slough and Steinberger Slough. Smith Slough drains to Redwood Creek and from there to the Bay. The part of Steinberger Slough near Smith Slough drains directly to the Bay only during higher water levels. The storm drain systems of Redwood City and San Carlos discharge storm runoff into Redwood Creek and Pulgas Creek, respectively, through a combination of gravity drainage and pumping. Additionally, there are several areas that discharge directly to the tidal sloughs or to the Bay itself, either via pump stations or gravity drainage.

Table 7 provides a summary of the drainage mechanisms and flood protection infrastructure for areas adjacent to Bair Island (see Figure 10 for locations). A discussion of this information follows in Sections 6.2.4 through 6.2.7.

6.2.4 Redwood Creek

Redwood Creek drains an area of 9.3 square miles, almost entirely within the city limits of Redwood City. The watershed is largely developed, ranging from medium-density residential areas in the hills to high-density residential, commercial, and industrial areas near the Bay. The Highway 101 bridge over Redwood Creek is built on piers at an elevation well above the 100-year tide (Caltrans, 1999), allowing unrestricted passage of high flows as they drain to the Bay. Redwood City began a major storm drain improvement and channelization project on Redwood Creek in 1967, which extended and enlarged the storm drain system, added pump stations, and lined portions of the creek channel with concrete.

Most of the flows from low-lying areas of the Redwood Creek watershed near the Bay are collected by 9 pump stations, 8 of which discharge directly to Redwood Creek and one of which discharges through flap-gated culverts to a leveed storage basin known as Basin 1 between Highway 101 and Inner Bair Island (Figure 7) (KJC, 1986, J. Lynch, pers. comm., and Fong, 1979). Basin 1 drains through a culvert to the eastern Inner Bair borrow ditch.

Figure 10 indicates the locations of areas adjacent to Bair Island that are discussed below. The area west of Highway 101 within the regional drainage and flooding focus area (Figure 10) drains to pump stations (KJC, 1986). East of 101, the areas that drain to pumps include: the Bair Island Road area from the Whipple Avenue interchange to Docktown Marina and Pete's Harbor, the area bounded by Maple Street, the area between 101 and Bloomquist Street, and the Seaport Center (C. Chang, pers. comm.). A pump station for the Pacific Shores office complex at the northern end of the Port of Redwood City will be installed upon completion of the development (J. Lynch, pers. comm.). The areas that drain to Redwood Creek via gravity drainage include: the area northwest of Maple Street which houses the San Mateo County Women's Correctional Center and Work Furlough Facility, the area north of Bloomquist Street, and the Port of Redwood City (C. Chang, pers. comm.). Information currently available is not sufficiently detailed to indicate the elevations of the gravity-drained areas or culvert characteristics relative to the tides, although we assume most of these areas are intertidal.

TABLE 7. Drainage Mechanisms and Flood Protection Infrastructure Near Bair Island

Watershed	Drainage Area	Drainage Type	Flood Protection Infrastructure	Historical Flooding
Redwood Creek	Port of Redwood City	Inter-tidal gravity drainage	Unknown	None documented
	Pacific Shores Development (future)	Pump (future)	Levee (future)	NA
	Seaport Center	Pump	Levee	None documented
	North of Bloomquist Street	Inter-tidal gravity drainage	Unknown	None documented
	South of Bloomquist Street	Pump	Unknown (borders area north of Bloomquist St.)	None documented
	Maple Street area	Pump	Levee / high ground	1973, 1982, 1983. Caused by levee failure and overtopping.
	Northwest of Maple Street	Inter-tidal and supra-tidal gravity drainage	Levee	1973, 1982, 1983. Caused by levee failure and overtopping.
	Bair Island Road area (from Whipple Ave interchange to Docktown Marina and Pete's Harbor)	Pump	Levee	1982, 1983. Caused by levee failure and overtopping.
	Redwood City east of the Southern Pacific Railroad and west of 101	Pumps	Some areas leveed	1958, 1967, 1973, 1982. Caused by high creek flows, back-ups at Middlefield Rd. culvert.
Cordilleras Creek	West of 101	Inter-tidal gravity drainage	None documented	1958, 1973, 1982, 1983. Caused by high tides and heavy rainfall.
Pulgas Creek	West of 101	Inter-tidal gravity drainage, one pump	None documented	1958, 1973, 1982, 1983, 1986. Caused by high tides and heavy rainfall.
Steinberger Slough and San Francisco Bay	San Carlos Airport	Pumps	Levee	1973. Caused by high tides.
	Northern San Carlos and Belmont	Pumped from Phelps Slough holding pond	Levee (some areas may be supra-tidal)	Not available in sufficient detail to document
	Redwood Shores	Mostly pumps, some inter-tidal gravity drainage	Levee	None documented

Sources: KJC 1986, FIA 1977, FEMA 1981, USACE 1989, C. Chang, J. Lynch and S. Vorametsanti, pers. comm.
Notes:
NA = not applicable
Inter-tidal elevations are for typical tides (range from –3.9 to +4.1 feet NGVD)
See Table 8 for levee elevations.

6.2.5 Cordilleras Creek

Cordilleras Creek drains a 3.6-square mile watershed and forms much of the border between Redwood City and San Carlos. Most of the channel remains in its natural state without significant human alterations. The creek passes through three 12' x 6' concrete box culverts under Highway 101 before discharging into the western Inner Bair borrow ditch. Tidal influence extends 1000 feet up the creek from the Bay to Redwood High School, where the creek makes a 90-degree turn. All of the land bordering the creek is privately owned, and there are no public easements for creek access and maintenance. Cordilleras Creek is not connected to the main storm drain systems of either Redwood City or San Carlos (CFCCNA, 1999).

6.2.6 Pulgas Creek

Pulgas Creek collects surface runoff from a 3.6-square mile area in central San Carlos and a small part of Belmont (FIA, 1977). In its lower watershed, it has been confined to culverts under Arroyo Avenue near Walnut Street, continuing below El Camino Real, the Southern Pacific Railroad embankment, and ending east of Old County Road. It passes through a 12 ft x 6 ft concrete box culvert under Highway 101, approximately 700 feet upstream of its entrance to Steinberger Slough. The creek has been channelized east of Old County Road, and lined with levees east of Highway 101 to protect adjacent areas (primarily the San Carlos Airport) against tidal flooding (FIA, 1977).

There is little information available about the storm drainage network and pump stations in San Carlos. The San Carlos Flood Insurance Study (FIA, 1977) indicates that there is a pump station at Industrial Road that pumps floodwaters from nearby street conduits into the creek. The remainder of the Pulgas Creek drainage area appears to be gravity-drained.

6.2.7 Steinberger Slough and San Francisco Bay

There are three main drainage areas northwest of Bair Island that discharge to Steinberger Slough or directly to San Francisco Bay. Storm water runoff from the San Carlos Airport is accommodated by several on-site pump stations (FIA, 1977) which likely drain to Steinberger Slough. Runoff from northern San Carlos and Belmont that drains to a holding pond in Phelps Slough is pumped into Steinberger Slough (KJC, 1986). Runoff from Redwood Shores is routed to a controlled interior lagoon. Some of the flows are collected at pump stations (C. Chang, pers. comm.) and some are stored until they can be released via gravity drainage at low tide to Steinberger Slough or to the Bay (KJC, 1986).

7. FLOODING

Flooding on and around Bair Island usually occurs in winter or early spring, and is most severe when a large frontal storm coincides with an extreme high tide (FEMA, 1981). A compilation of FEMA Flood Insurance Rate Maps showing the extents of the 100-year floodplain on Bair Island and in the surrounding areas of Redwood City and San Carlos is provided in Figure 10.

As in Section 6, we assume certain project changes associated with the restoration and use these changes to focus the scope of our existing conditions flood assessment. Existing flooding and potential project impacts will be analyzed in more detail in subsequent phases of the project.

The proposed restoration plan has the potential to create short-term changes in typical tide elevations around Bair Island (as discussed in Section 6). These changes would not affect flooding from extreme high tides and would be unlikely to affect high creek flows. They could potentially affect flooding caused by the combination of high tides and high creek flows by increasing the duration of higher tides that impede creek drainage. In the long-term, the capacities of Steinberger and Smith Sloughs may be increased by greater tidal exchange with the restored marsh areas, which could help alleviate flooding in the downstream reaches of Cordilleras and Pulgas Creeks. Flood mechanisms and potential project impacts are discussed in greater detail below.

7.1 ON-SITE

Current FEMA flood mapping shows Bair Island completely within the 100-year floodplain in a region dominated by tidal flooding (Figure 10). It appears, however, that levee improvements made since the date of FEMA mapping now protect Inner Bair from 100-year flooding. The levee around Inner Bair, which protects the San Carlos Airport safety area from tidal inundation, has a design elevation of 8.0 feet NGVD (Bohley Maley Associates, 1993). Spot elevations from recent PWA surveys confirm that current levee crest elevations are at or above approximately 8.0 feet NGVD. This elevation provides protection against approximately the 100-year flood with only a small allowance (0.7 feet) for wave run-up and freeboard. It should be noted that for most of the levee only a 2- to 3-feet portion of the levee width has been raised to this elevation, and the majority of the width of the levee is up to several feet lower (Bohley Maley Associates, 1993). Table 8 provides levee elevations for Inner, Middle, and Outer Bair Islands.

TABLE 8. On-site and Off-site Levee Elevations

Feature	Minimum Elevation (feet NGVD)	Maximum Elevation (feet NGVD)	Comments
Inner Bair Island levees excluding the force main levee	7.6	8.2	Around most of Pond A-12 (PWA, 2000)
Inner Bair force main levee	9.4	10.7	Force main levee survey (PWA, 2000)
Middle Bair Island levees	6.6	7.8	Around Ponds A-9, A-10, and A-11 (PWA 2000)
Outer Bair Island levees	6.3	8.7	Around Pond B-3 (PWA, 2000)
Seaport Center levee	~8.0 (design elevation)	~8.0 (design elevation)	Design elevation = 8.0 feet NGVD (S. Vorametsanti, pers. comm.).
Maple Street area levee / high ground	~6.0	~7.5	Elevations of high ground around the west and north sides of Maple Street (CRCCDD, 1989). Survey performed prior to construction of the Police Department offices in this location. Current elevations may differ.
Pete's Harbor levee	*	*	
PG&E levee	6.2	7.2	Elevations from BKFA (1981). Fong (1979) indicates minimum elevation of 5.6 feet NGVD.
Basin 1 levee	6.7	7.9	Elevations from BKFA (1981). Fong (1979) indicates approximate elevation of 7.0 feet NGVD. Levee elevations may have changed with redesign of Whipple Avenue interchange in 1982 (Caltrans, 1982).
San Carlos Airport levees	7.8	9.2	Elevations known for approximately 1000-foot length where roadway rebuilt out of total 4500-foot levee length (SMC, 1993). Elevations for remainder of levee not readily available from San Carlos Airport or San Mateo County.
Redwood Shores levees	~9.5 (design elevation)	~9.5 (design elevation)	Design elevation = 9.5 feet NGVD, Redwood City in the process of levee maintenance. Most areas raised already, some still need to be raised (S. Vorametsanti, pers. comm.).

*Accounts of historical flooding along Redwood Creek indicate the existence of levees in this area (USACE, 1989). However, after conversations with the City of Redwood City and San Mateo County Public Works Departments, we are unable to locate any information about these levees (S. Vorametsanti, J. Lynch and K. Wick, pers. comm.).

7.2 OFF-SITE

7.2.1 Prior Studies

Existing information reviewed for the off-site flooding section includes the *San Mateo and Northern Alameda Counties Interim San Francisco Bay Shoreline Study* (USACE, 1989), in addition to sources cited previously in Section 6.2.1.

7.2.2 Flooding Mechanisms

Flooding in coastal areas can be categorized according to the following mechanisms: flooding from high tides, flooding from rainfall runoff, and flooding from the combination of high tides and rainfall runoff. For the purposes of this study, tidal flooding is defined as direct flooding from high tides overtopping shoreline levees or high ground. Rainfall runoff flooding is defined as flooding caused by high creek flows exceeding channel or culvert capacity. Flooding caused by the combination of high tides and high rainfall runoff is defined as creek flooding (typically in the downstream reaches) that occurs when high tide levels at the creek mouth create a backwater effect that limits the creek's drainage.

Based on expected project-related changes in tide elevations, the project's zone of influence on regional flooding is limited to areas where creek drainage could experience tidal backwater effects. Therefore, the regional flooding discussion was focused on the area within and a small distance outside of the 100-year tidal flooding zone (elevation 7.3 feet NGVD). In general, this study includes areas below approximately 15 feet NGVD and encompasses the area from Bair Island to approximately the Southern Pacific Railroad in San Carlos and El Camino Real in Redwood City (Figure 10).

7.2.3 Flood Protection Infrastructure

Table 8 provides elevations of the levees on and adjacent to Bair Island. All of the levees for which elevations are readily available protect the areas they surround against the 100-year tide (7.3 feet NGVD, from Table 6), except the remnant salt pond levees on Middle and Outer Bair Island, the levees/high ground around the Maple Street area east of Highway 101, and the Bair Island Road area levee parallel to the eastern Inner Bair borrow ditch. The part of this levee east of the Whipple Avenue interchange is on PG&E property and will be referred to as the PG&E levee; the part west of Whipple Avenue surrounds Basin 1 (Section 6.2.4) and will be referred to as the Basin 1 levee (Figure 7). FEMA maps confirm that the areas with lower levees are within the 100-year floodplain (Figure 10). Jon Lynch, the City Engineer for Redwood City, also identified the Maple Street area as a location that has experienced significant flooding (J. Lynch, pers. comm.). Current FEMA flood mapping shows the Seaport Center completely within the 100-year floodplain (Figure 10). However, levee improvements with a design elevation of 8.0 feet NGVD made since the date of FEMA mapping now protect this area from 100-year flooding (S. Vorametsanti, pers. comm.).

There are no levees along Highway 101 where it parallels the western Inner Bair borrow ditch. The elevation of the highway in this region ranges from 8.6 to 10.9 feet NGVD (Caltrans, 1999), which is higher than the 100-year tide level.

7.2.4 Tidal Flooding

Tidal flooding has been documented in portions of Redwood City and San Carlos near Bair Island in 1973, 1982, 1983, and 1986 (USACE, 1989). Areas east of Highway 101 have experienced the most severe flooding. The storms of January 1973, which involved the combination of high rainfall and tides that were reported to be 100-year elevations in some locations, caused a levee failure at the south end of the San Carlos Airport, flooding an automobile wrecking yard and the southern part of the airport. Levee overtopping and failure caused flooding at Pete's Harbor parking lot, the Docktown Marina offices, and on Bair Island Road in the winter of 1982-1983. Maple Street east of 101 (including the old Redwood City Sewage Treatment Plant, the San Mateo County Work Furlough Facility and Women's Correctional Center, and the Society for the Prevention of Cruelty to Animals facilities) and the area by the old Circle Star Theater (just west of 101) have been flooded by high tides multiple times since records have been kept.

7.2.5 Flooding on Regional Creeks

The adjacent watersheds of Redwood, Cordilleras, and Pulgas Creeks experience approximately the same rainfall and tides. Because of these similarities, creek flooding typically occurs during the same storm events. Major surface runoff flooding events on these creeks occurred in 1940, 1955, 1958, 1973, 1982, and 1983 (USACE, 1989).

7.2.5.1 Redwood Creek

The flood events prior to the 1967 storm drain project seem to be caused largely by high creek flows and the overtopping of channel banks, while later flood events appear to be caused by backed-up storm drain systems and limited culvert capacity (USACE, 1989). According to the Redwood City FIS published in 1981 (FEMA, 1981), the critical overflow point is at Middlefield Road where Redwood Creek enters an underground culvert. The downtown area of Redwood City (including Middlefield Road, Broadway, and Veteran's Blvd) was flooded by storm water backed-up at the Middlefield Road culvert entrance during the January 1973 floods. The ground elevation at this culvert entrance appears to be approximately equal to the 100-year tide level (KJC, 1986), and high tides may contribute to flooding problems by retarding creek drainage.

Estimated flows for various design floods on Redwood Creek are listed in Table 9. A USGS stream gauge was operated from 1959 to 1997 in the upper watershed of Redwood Creek.

TABLE 9. Estimated Creek Flows

Location		Drainage Area (sq. mi.)	Q_{10} (cfs)	Q_{30} (cfs)	Q_{50} (cfs)	Q_{100} (cfs)	Source
Redwood Creek	USGS Gauge	1.82	--	720	--	--	KJC (1986)
	Broadway	8.8	1800	--	3200	3800	FEMA (1981)
	Highway 101[1]	9.3	1900	--	3300	4000	FEMA (1981)
Cordilleras Creek	El Camino Real	3.3	470	--	940	1170	FEMA (1981)
	Highway 101	3.6	525	--	700[2]	850[2]	FEMA (1981)
Pulgas Creek	Highway 101	3.6	1005	--	1460	1820	FIA (1977)[3]

Notes:
[1]KJC (1986) lists a 30-year peak flow of 1800 cfs at Veteran's Blvd just upstream of Highway 101. This flow is approximately equal to the 10-year peak flow FEMA values at Broadway and Highway 101, 1300 and 1700 feet upstream and downstream, respectively. It is likely that this discrepancy results from different methods of analysis used in the two studies.
[2]The flows at El Camino Real are higher than those downstream at Highway 101. This discrepancy is caused by a diversion of high flows from Cordilleras Creek to Pulgas Creek that FEMA factored into its analysis for the 50- and 100-year flows (E. Boscacci, pers. comm.). KJC (1986) lists a 30-year peak flow of 1000 cfs at Highway 101. This flow, which is significantly higher than the FEMA values at Highway 101, indicates that the diversion of high flows was likely not included in the KJC analysis, but the discrepancy may also be the result of different methods of analysis.
[3]The flow values were not listed in the 1977 San Carlos FIS (FIA, 1977), but were obtained from FIS back-up data. The 50- and 100-year flows include diverted flows from Cordilleras Creek (E. Boscacci, pers. comm.).

7.2.5.2 Cordilleras Creek

Flooding on Cordilleras Creek is exacerbated by erosion in the upper watershed, resulting in deposition and blockage downstream in the flat, low-lying areas. The more serious flooding on this creek occurs east of El Camino Real, particularly from the Redwood High School to Industrial Road (CFCCNA, 1999). In more extreme (50- and 100-year) events, flow from Cordilleras Creek backs up at El Camino Real and joins with ponded areas to the northwest created by overflows from Brittan and Pulgas Creeks (Figure 10) (FIA, 1977).

Estimated flows for various design floods on Cordilleras Creek are listed in Table 9. The flows at El Camino Real are higher than those downstream at Highway 101, indicating that the overflow diversion mentioned above was factored into flow calculations for the 50- and 100-year flows.

7.2.5.3 Pulgas Creek

Overflow from Pulgas Creek causes flooding in the industrial area between Highway 101 and El Camino Real. The pump station at Industrial Road is not large enough to relieve flooding from extreme events in this area (FIA 1977). Flooding in the industrial area is most severe when drainage is limited by high tides. Estimated flows for various design floods on Pulgas Creek are listed in Table 9. The 50- and 100-year flows include diverted flows from Cordilleras Creek as discussed in the preceding section (E. Boscacci, pers. comm.).

Due to persistent minor flooding in the industrial area, the city plans to install two new culverts under city streets upstream of Highway 101 as part of a long-term flood management initiative (D. Gilbert, pers. comm.). Caltrans also plans to enlarge the culvert under Highway 101 to accommodate the increased capacity upstream (S. Goodson, pers. comm.).

8. SEDIMENTATION

This section presents regional suspended sediment concentrations and sedimentation estimates for the dredged portion of Redwood Creek. Long-term sedimentation predictions for the project area will be developed during subsequent hydrology and sedimentation analyses.

8.1 REGIONAL SUSPENDED SEDIMENT CONCENTRATIONS

Suspended sediments are predominantly muds carried to the Bay by river flows during large floods. These sediments are deposited and stored in shallow subtidal and intertidal mudflat areas. Wind-wave action and tidal currents re-suspend and redistribute these sediments throughout the year. The mudflats outboard of Bair Island provide a year-round source of sediment inflow to the slough channels surrounding Bair Island. During storm events, the regional creeks are an additional, probably minor, source.

Suspended sediment concentration data for San Francisco Bay are available for a network of USGS monitoring stations. Bair Island is located approximately equidistant between the San Mateo Bridge and Dumbarton Bridge stations. These stations are located in deepwater areas, where suspended sediment concentrations are generally low compared to shallow water areas. Thus, suspended sediment concentrations for these stations (Table 10) provide a lower limit estimate of concentrations expected at Bair Island.

TABLE 10. Suspended Sediment Concentrations for San Mateo and Dumbarton Bridges

	San Mateo Bridge		Dumbarton Bridge	
Year	Mean (mg/l)	Median (mg/l)	Mean (mg/l)	Median (mg/l)
1992-1993	66	53	73	64
1994	63	52	97	86
1995	44	35	98	63
1996	40	25	120	89
1997	58	45	122	106

Note: Data are for mid-depth observations.

Sources: USGS 1995, USGS 1996a, and USGS 1996b.

Local suspended sediment concentration data were collected in Corkscrew Slough by the USGS between 1997 and 1998, but are not available at this time (J. Dingler, pers. comm.). The data are preliminary and are currently undergoing quality control review. According to preliminary review of the data by USGS staff, some or all of the data may be unusable due to damage at the measurement station.

8.2 REDWOOD CREEK DREDGING

Redwood Creek has been dredged approximately every two to four years since 1955. The dredged portion includes a 3.5-mile segment extending from the ship channel in San Francisco Bay to the Redwood City Yacht Harbor (Figure 11). It averages 300 to 400 feet wide with a required dredge depth of -33.9 feet NGVD (–30.0 feet MLLW) (Moffatt & Nichol 1992). There is also a shallow draft channel further upstream from the Yacht Harbor with a dredge depth of -8.9 feet NGVD (-5.0 feet MLLW). It has not been dredged since 1960 due to budgetary constraints. (Larry Graham, USCOE project manager, pers. comm.). Dredged sediments have mostly consisted of silty clay (Moffatt & Nichol 1997).

Past dredge events for the Redwood Creek ship channel are listed on Table 11. Between 1973 and 1999, the channel was dredged eight times. For this entire period, the average annual dredge volume was 200,000 cubic yards/year, which corresponds to a vertical accretion of 10 inches/year, assuming an average dredge area of 3.5 miles by 350 feet. Among the separate dredge episodes, the average annual accretion varied from 3 inches/year (1977) to 20 inches/year (1993).

Moffatt & Nichol (1992) assessed local variation in sedimentation rates between 1984 and 1989 by comparing the 1984 post-dredge and 1989 pre-dredge surveys. Sedimentation varied from 3 inches/year to 20 inches/year of accretion, depending on location (see Figure 11). The highest sedimentation (from 10 to 20 inches/year) occurred in a one-mile segment that includes the junctions of West Point Slough and Corkscrew Slough. This area regularly receives the most sediment accumulation (Larry Graham, USCOE, pers. comm.; Michael J. Giari, Port of Redwood City, pers. comm.). The specific causes of this high sedimentation were not analyzed.

TABLE 11. Dredge Events for the Redwood Creek Ship Channel

Date of dredging	Date of previous dredging	Volume removed (cubic yards)	Average annual volume (CY/yr)	Average annual accumulation (in/yr)[1]
1977	1973	250,000	62,000	0.3
1981	1977	300,000	75,000	0.3
1984[2]	1981	790,000	260,000	1.1
1990	1984	800,000	110,000	0.5
1992[3]	1990	250,000	130,000	1.6
1993	1992	400,000	400,000	1.8
1996	1993	970,000	320,000	1.6
1999	1996	570,000	190,000	1.1
Average:				
1977	1999	4,300,000	200,000	0.8

[1]Accumulation calculated by using a depositional area 3.5-miles long and 350-feet wide.
[2]1984 dredge depth 2 to 8 feet shallower than design dredge depth of –33.9 feet NGVD (Moffatt & Nichol 1992).
[3]In 1992, only a 1-mile segment was dredged, versus 3.5 miles in all other years.
Sources: Moffatt & Nichol 1992, L. Graham, pers. comm.
Note: Design dredge depth is –33.9 feet NGVD (-30.0 feet MLLW).

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Dingler, John, Branch of Pacific Marine Geology, U.S. Geological Survey, January, 1999 and April 2000.

Giari, Michael J., Port of Redwood City.

Gilbert, Don, Civil Engineering Assistant, San Carlos Department of Public Works, March 7, 2000.

Goodson, Stewart, Design Division, Caltrans, March 7, 2000.

Graham, Larry, project manager, US Army Corps of Engineers.

Jewell, Dennis, Supervisor, San Mateo County Mosquito Abatement District, March 23, 2000.

Lynch, Jon, City Engineer, Redwood City Department of Public Works, April 6, 2000.

Vorametsanti, Peter, Senior Civil Engineer, Redwood City Department of Public Works, January 13, 2000 and April 6, 2000.

Wick, Ken, Engineering Assitant, San Mateo County Public Works Department.

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FIGURES

APPENDIX A
FIELD SURVEYS

- Topographic transects T1 through T6 and Safety Zone transect
- Pond interior channel cross sections 1 through 17
- South Bay System Authority (SBSA) levee cross-sections 1 through XS5
- Hydrographic cross-sections in the major slough channels:
  location map and cross-sections 1 through 30
- Tide measurements for 6 stations

f i g u r e *1*

BairIsland

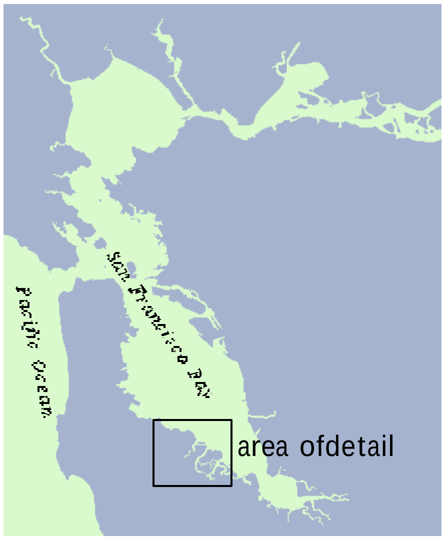
SiteLocation Map

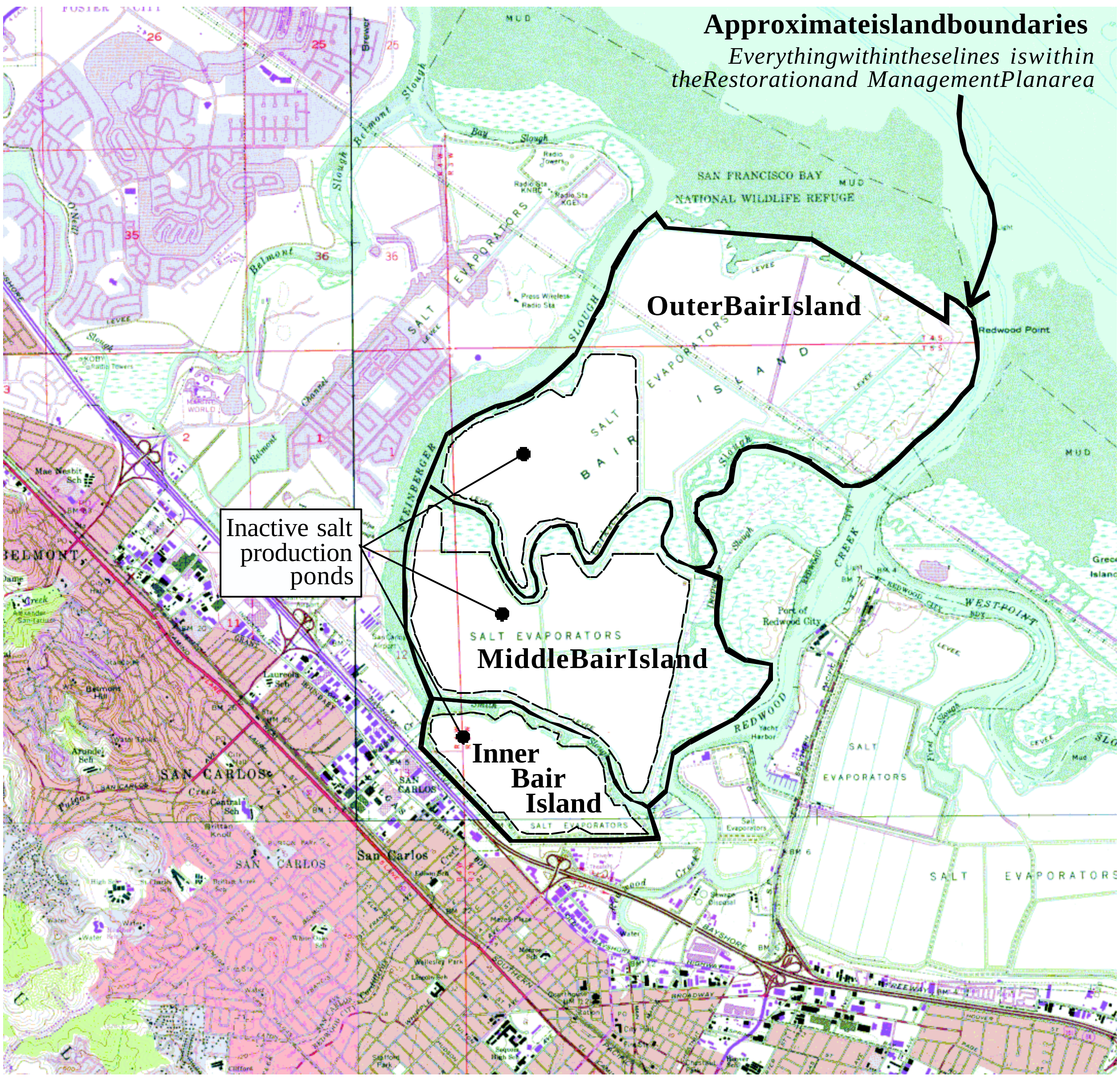
Basemap:USGStopographicmap (1959,revised1968and1973)

N

0 5,000

f e e t





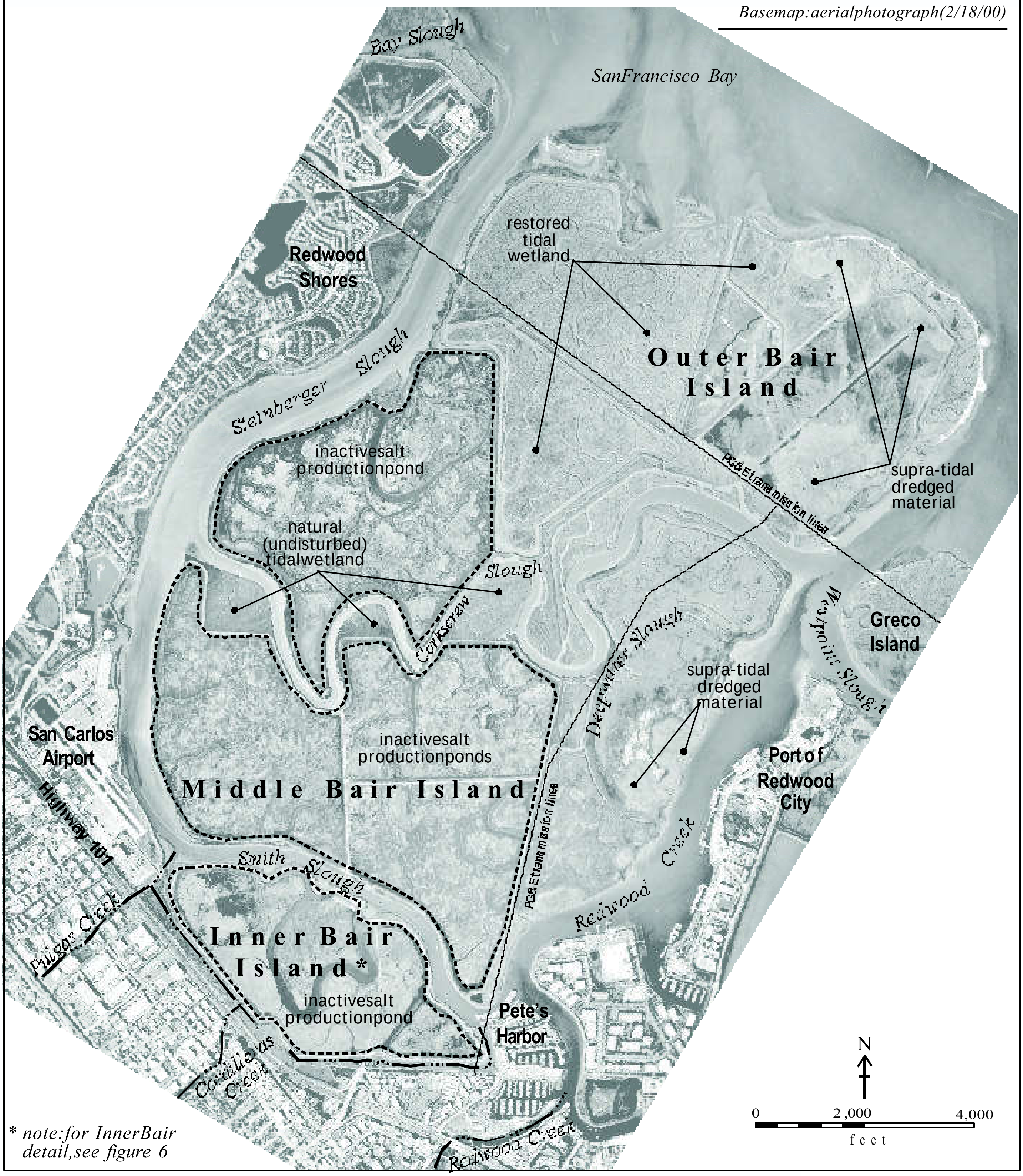
1413 bic map 2.odi

figure 2

Bair Island

Existing Conditions

Basemap: aerial photograph (2/18/00)



* note: for Inner Bair detail, see figure 6

PWA

N

0 2,000 4,000
feet

figure 3

Bair Island
Historic Conditions, 1857

1857map.cdr

PWA

figure 4

BairIsland

Historic Conditions,1897

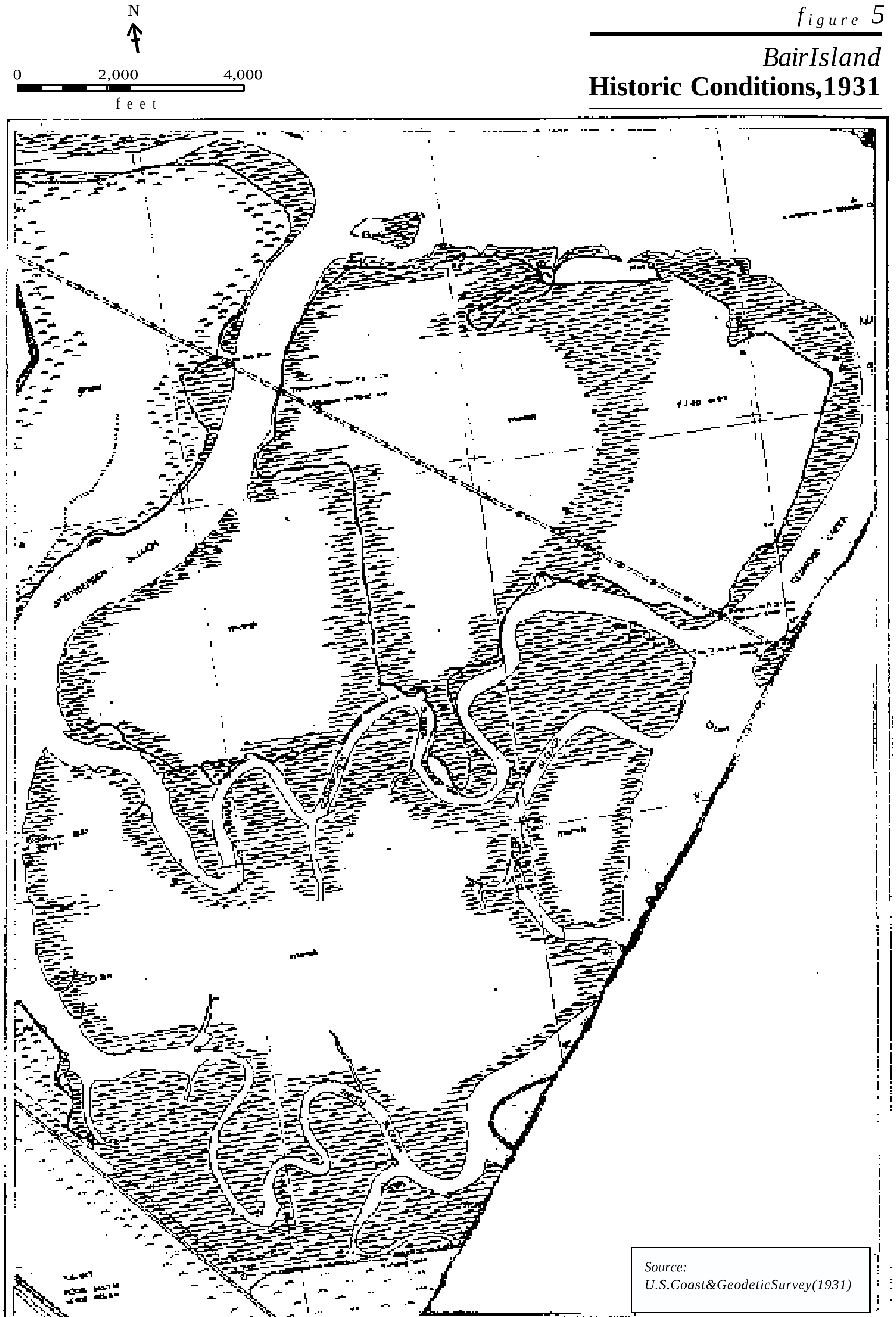
1387map.cdr

PWA

figure 5

Bair Island

Historic Conditions, 1931



Source:
U.S. Coast & Geodetic Survey (1931)

PWA

figure 6

Bair Island

Sub-Area Map

Basemap: USGS topographic map (1959, revised 1968 and 1973)

Note:
Number and letter sub-area names correspond with former salt pond names

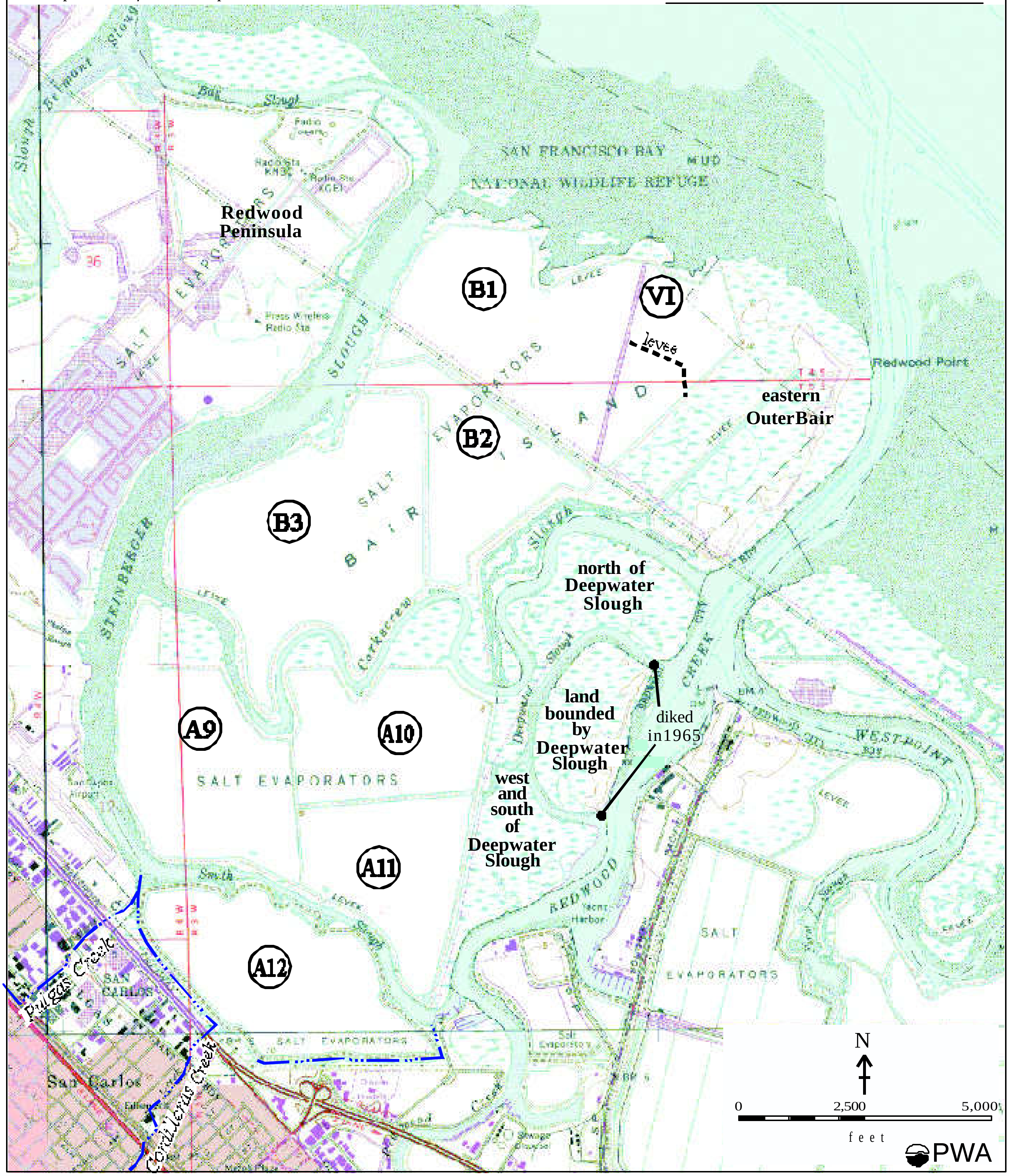


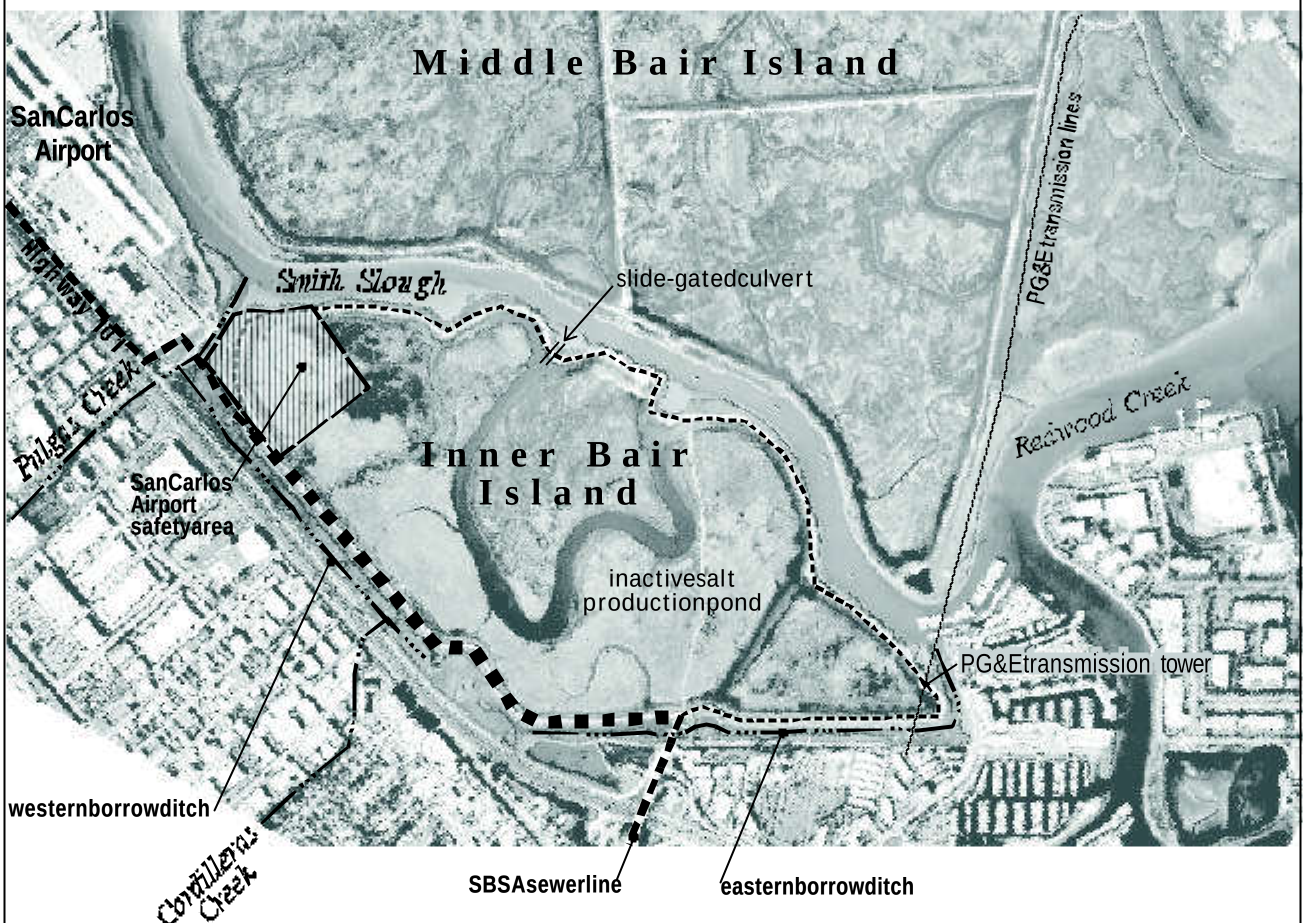
figure 7

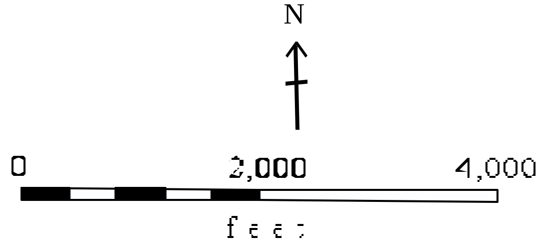
BairIsland

Existing Conditions, Inner Bair Detail

Basemap: aerialphotograph(2/18/00)

channels
levees
SBSAsewerline
SBSAsewerlineunderlevee





Inner Bair.cdr

PWA

figure 8

Bair Island

Field Survey Locations

Basemap: aerial photograph (2/18/00)

PWA

`413 fieldwork ll.cdr

figure 9

Bair Island

Drainage Divides and Flow Directions at Low Tide

Basemap: USGS topographic map (1959, revised 1968 and 1973)

drainage divide at low tide

ebb tide flow direction at low tide

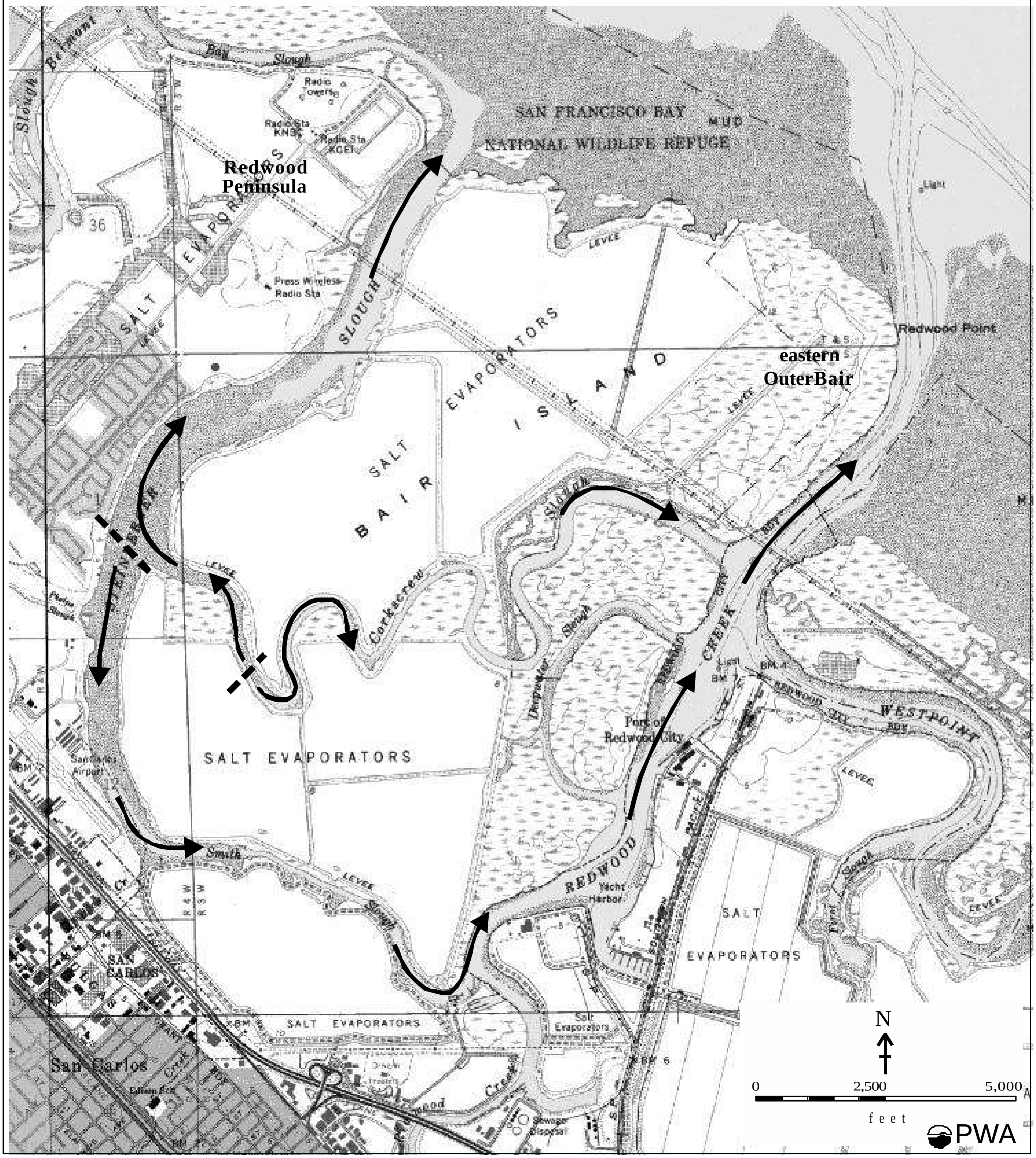


figure 10

BairIsland

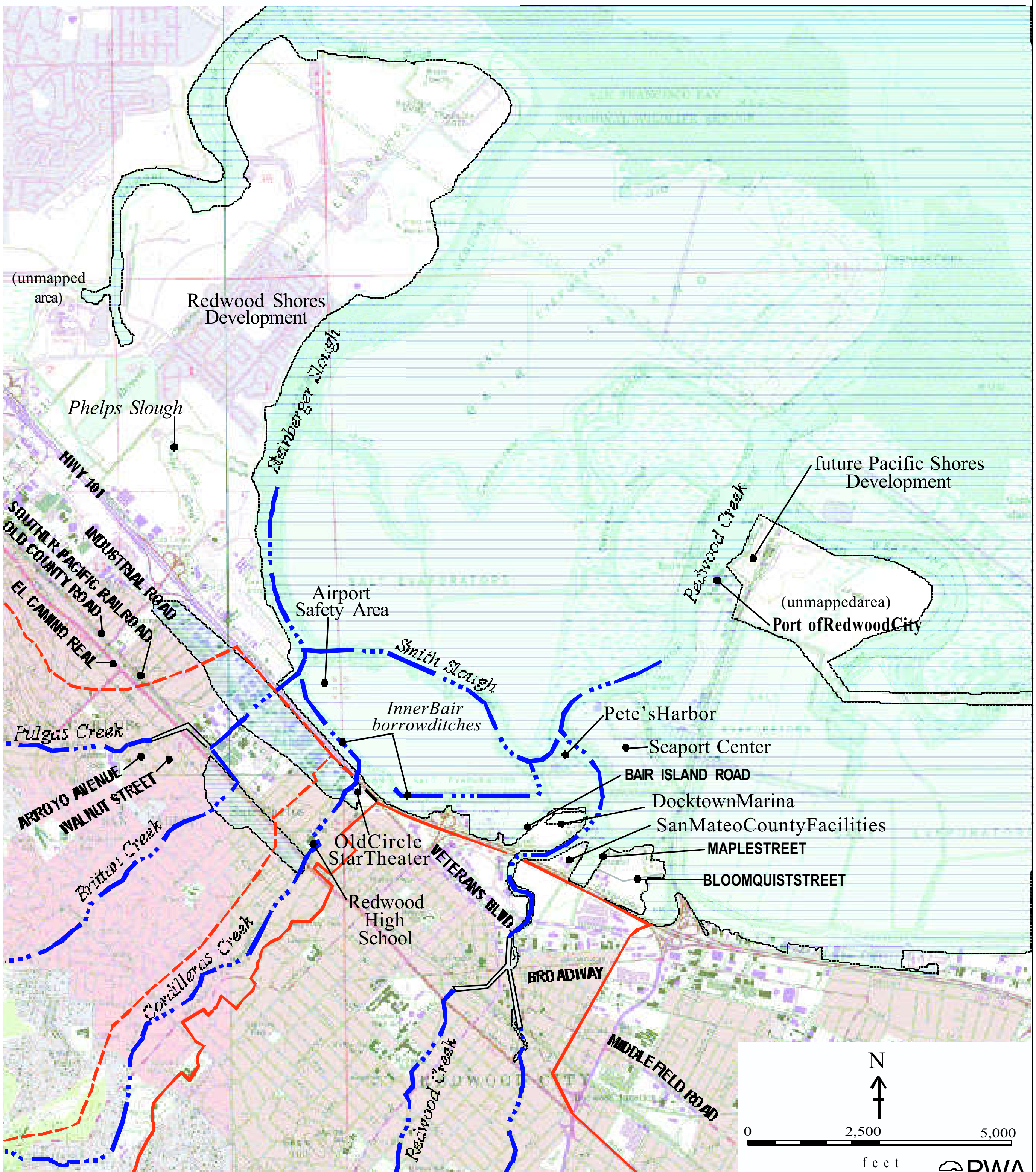
Regional Drainage Map

Source:FEMA,FloodInsuranceRateMap;SanCarlos(1979),RedwoodCity(1982)

Basemap:USGStopographicmap(1959,revised1968and1973)

Note: LeveeimprovementsonInnerBairIsland&theSeaportCenterhaveremovedtheseareas fromthe100-yearfloodplain.Thischangeisnotreflectedincurrent FEMAmapping.

- areainundated by 100 year flood
- watershed divide
- approximatewatersheddivide
- creeks
- culverts



PWA

1413dra nage map.cdr

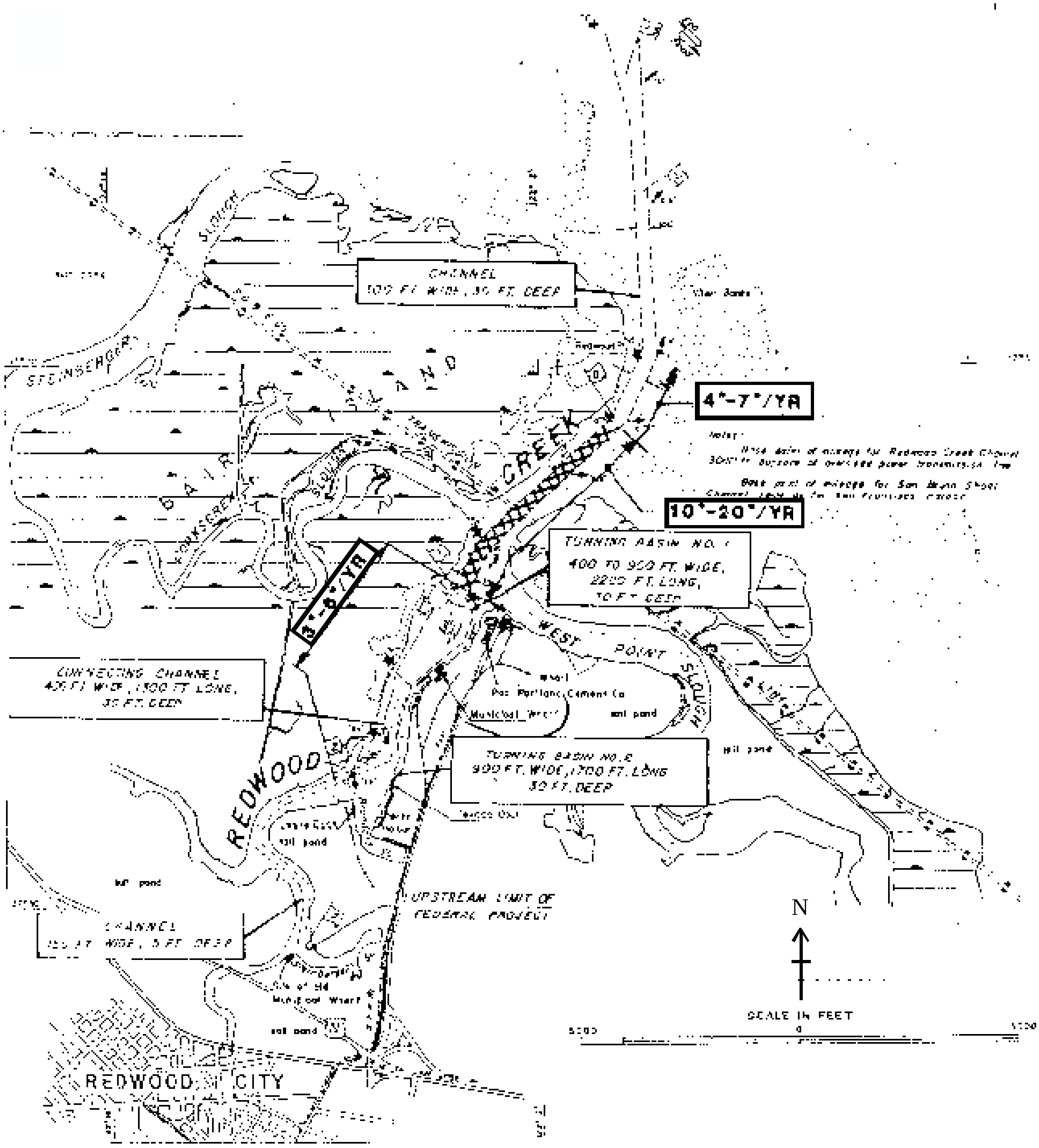
figure 11

Bair Island

Redwood City Harbor Dredging

source: USACE (1972)

=locationwheresignificant shoalingoccurs

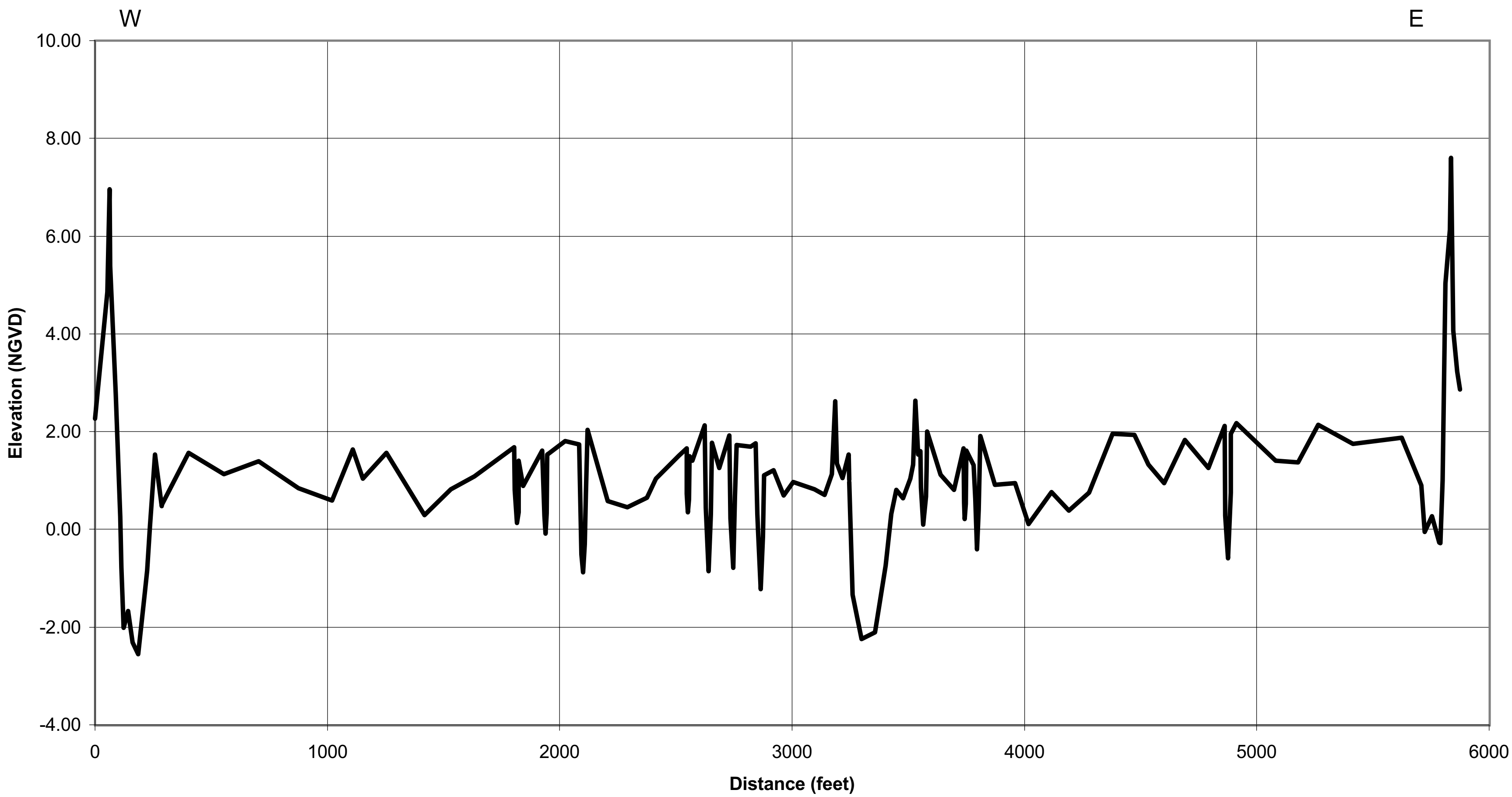


1413dredging.cdr

PWA

APPENDIX A
FIELD SURVEYS

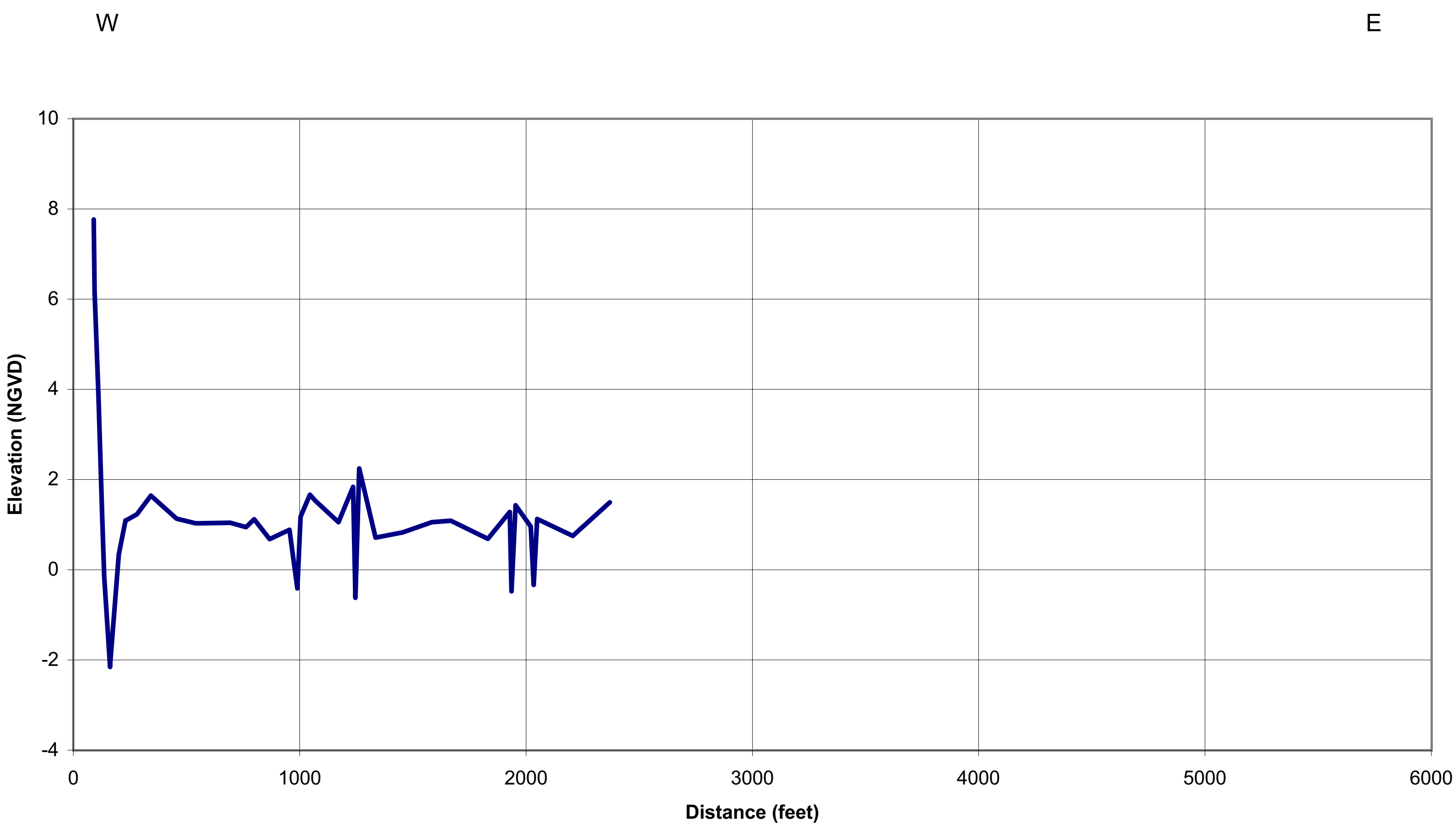
A-1 Topographic transects T1 through T6 and Safety Zone transect



Source: PWA field surveys (March 2000).

BAIR ISLAND
T1

PWA | PWA#: 1413

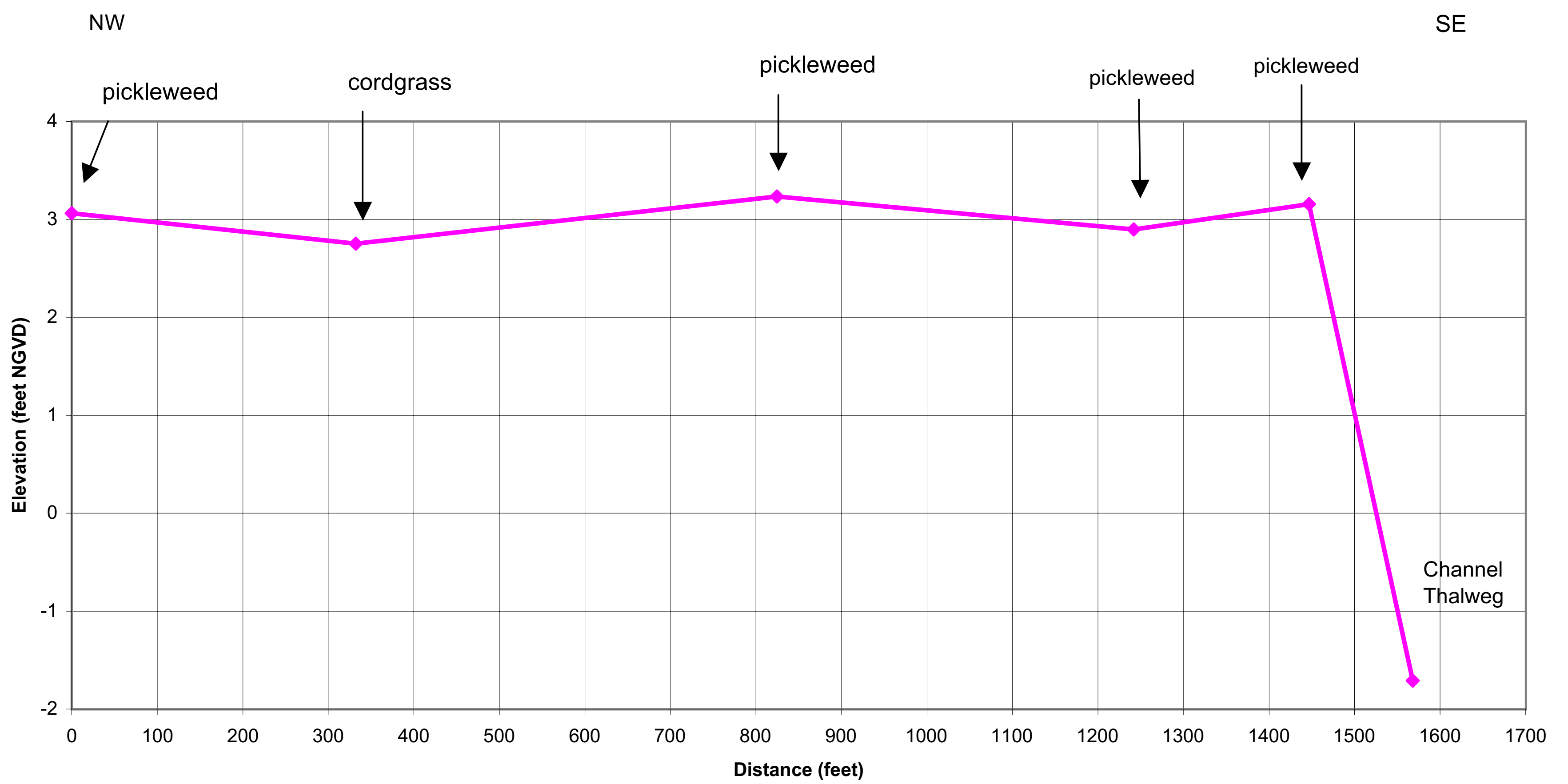


Source: PWA field surveys (July 2000).

BAIR ISLAND
T2

PWA

PWA#: 1413

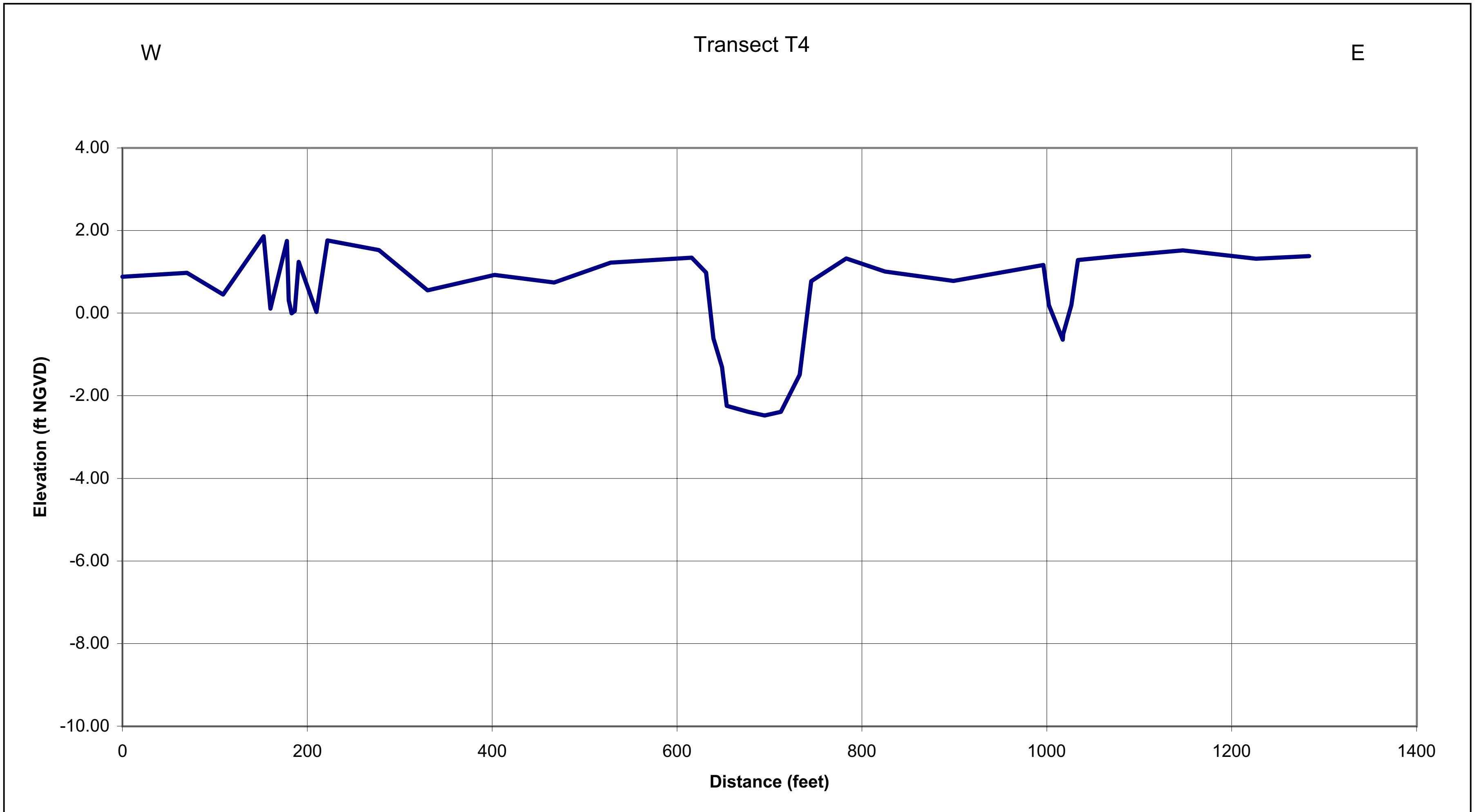


Source: April 19, 2000 PWA survey (this study).
Note: Transect located parallel to and ~10 feet north of power tower boardwalk.

Bair Island
Outer Bair Transect T3 (Pond B-1)

PWA

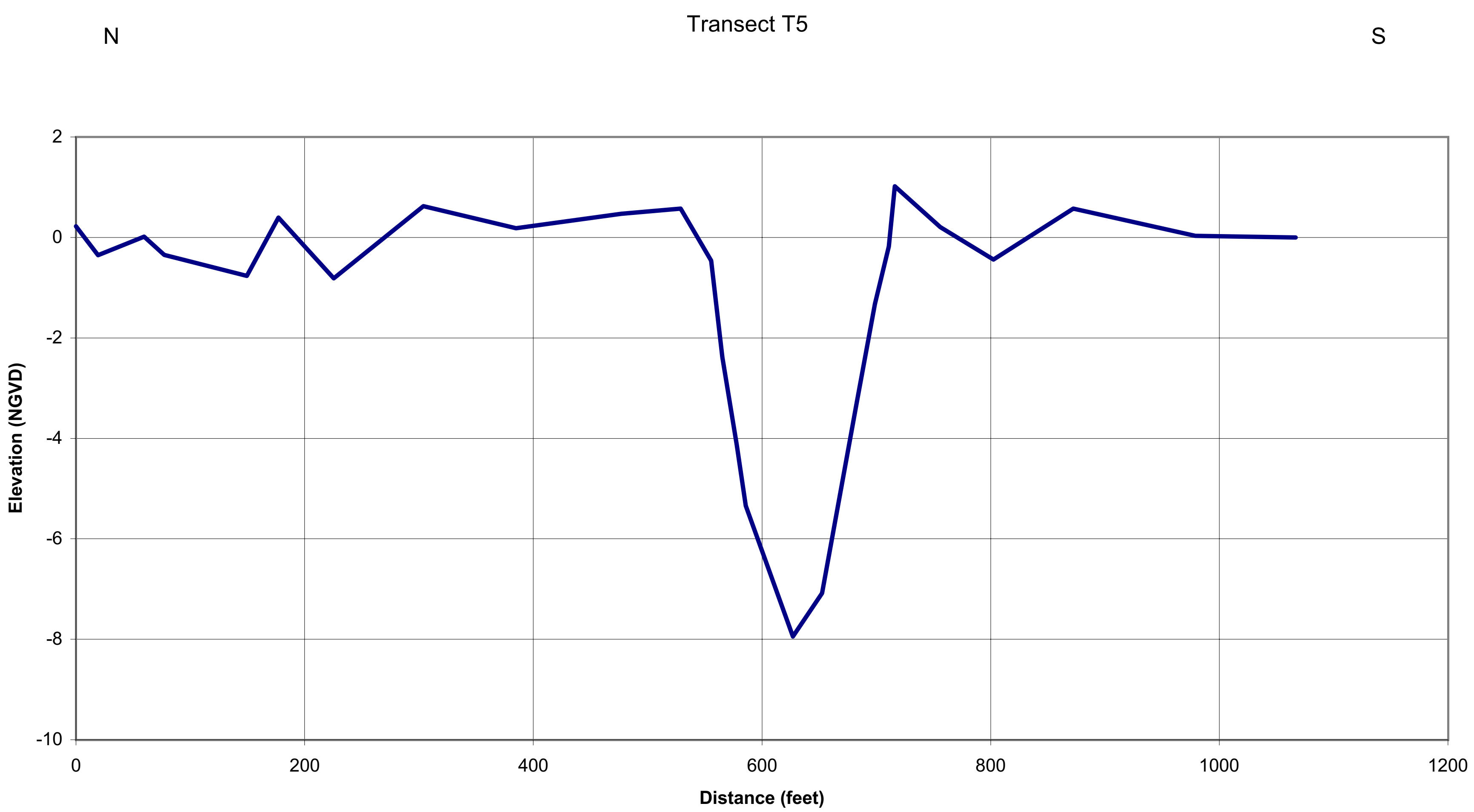
PWA#: 1413



Source: PWA field surveys (March 2000).

BAIR ISLAND
Transect T4

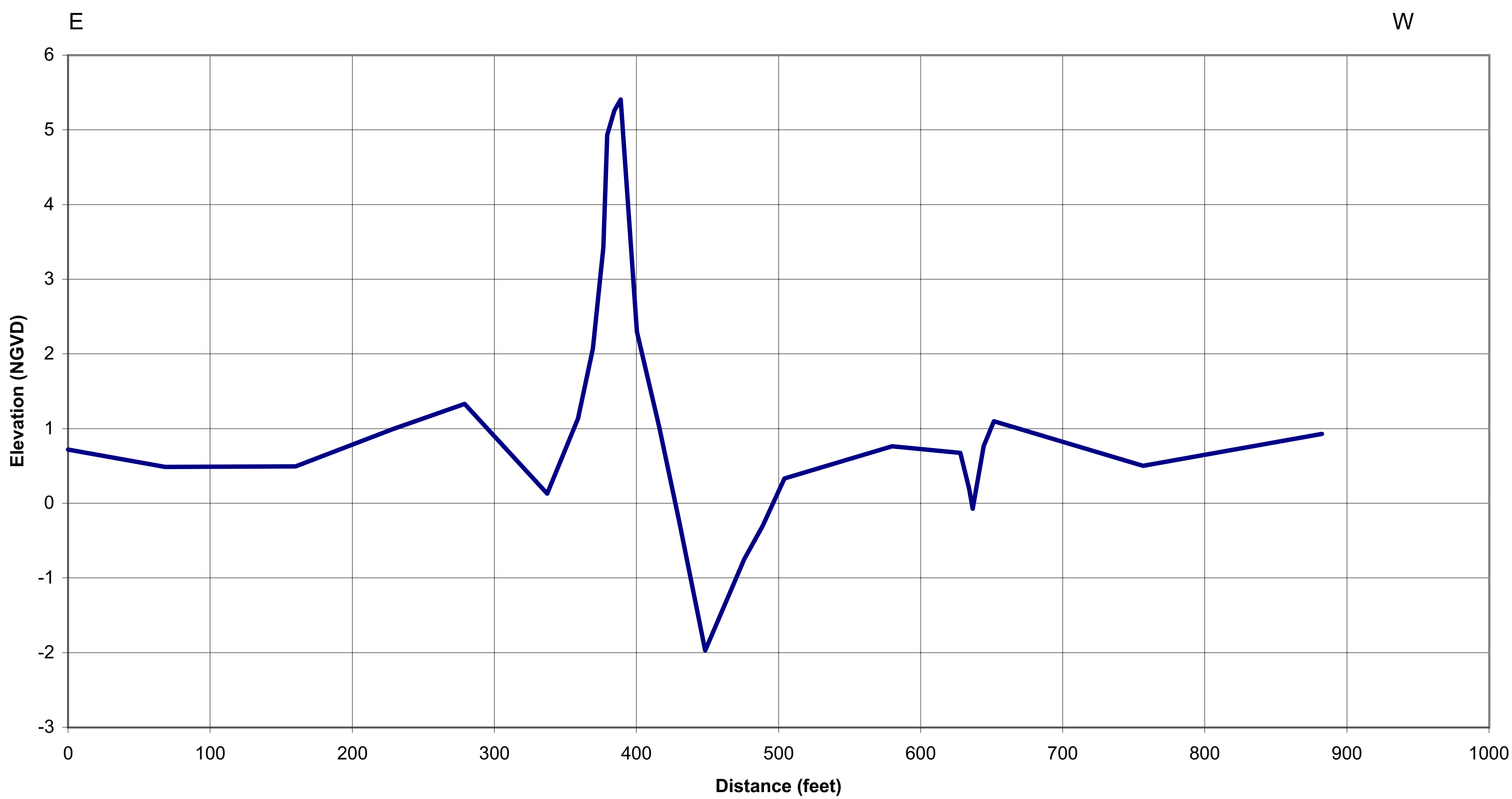
PWA | PWA#: 1413



Source: PWA field surveys (March 2000).

BAIR ISLAND
T5

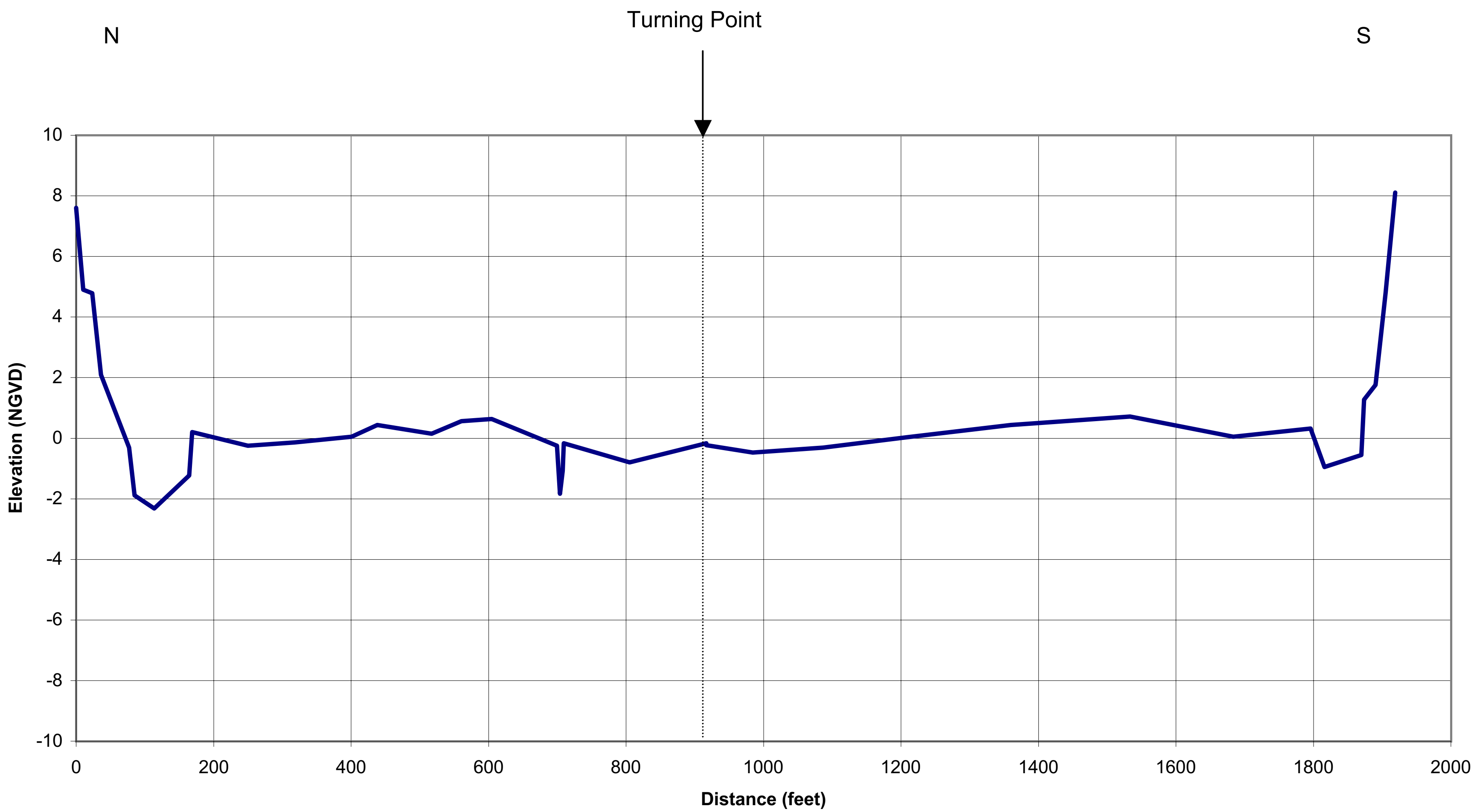
PWA | PWA#: 1413



Source: PWA field surveys (March 2000).

BAIR ISLAND
T6

PWA | PWA#: 1413



Source: PWA field surveys (March 2000).

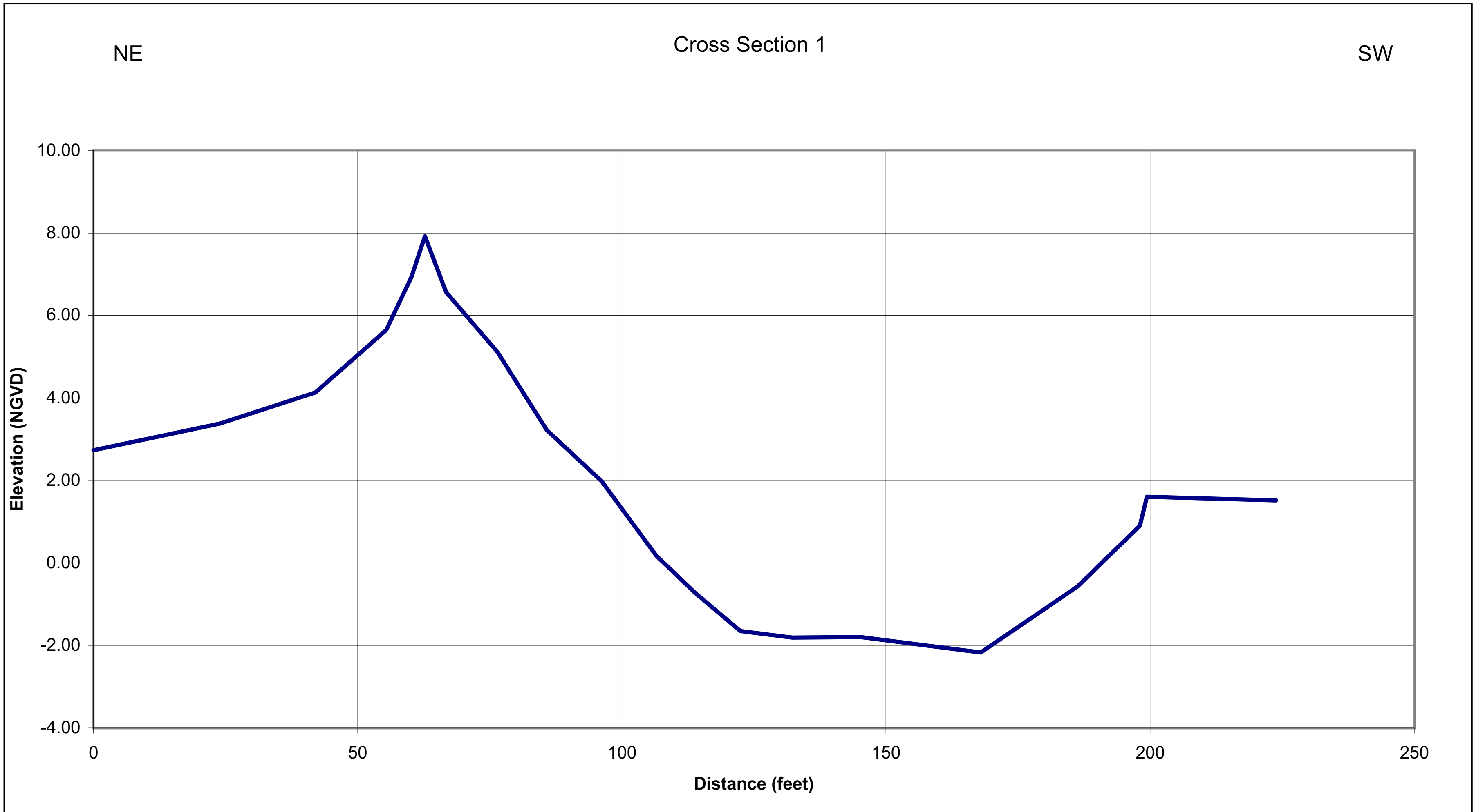
BAIR ISLAND
Transect T SZ (Safety Zone)

PWA

PWA#: 1413

APPENDIX A
FIELD SURVEYS

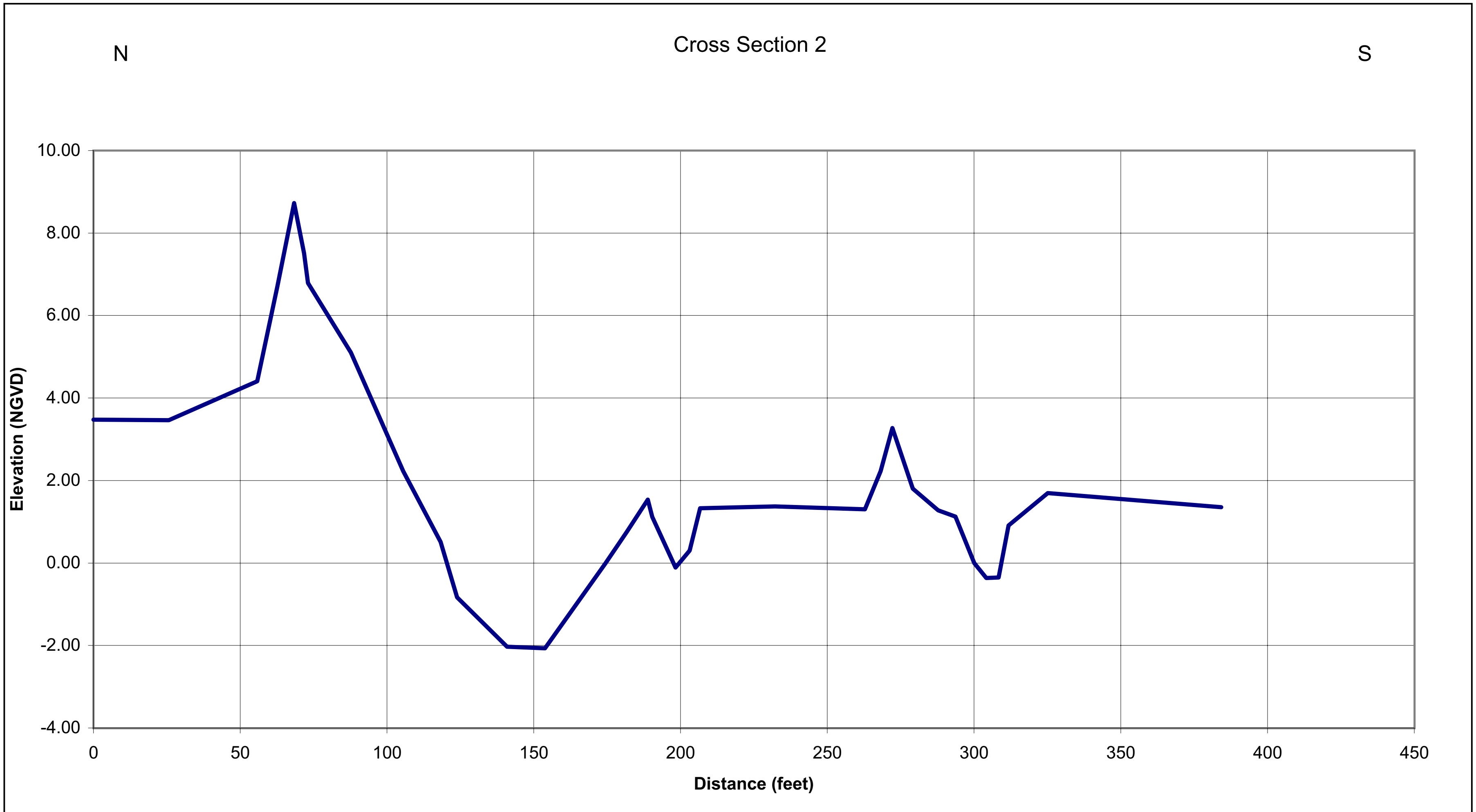
A-2 Pond interior channel cross sections 1 through 17



Source: PWA field surveys (March 2000).

BAIR ISLAND
xs 1

PWA | PWA#: 1413

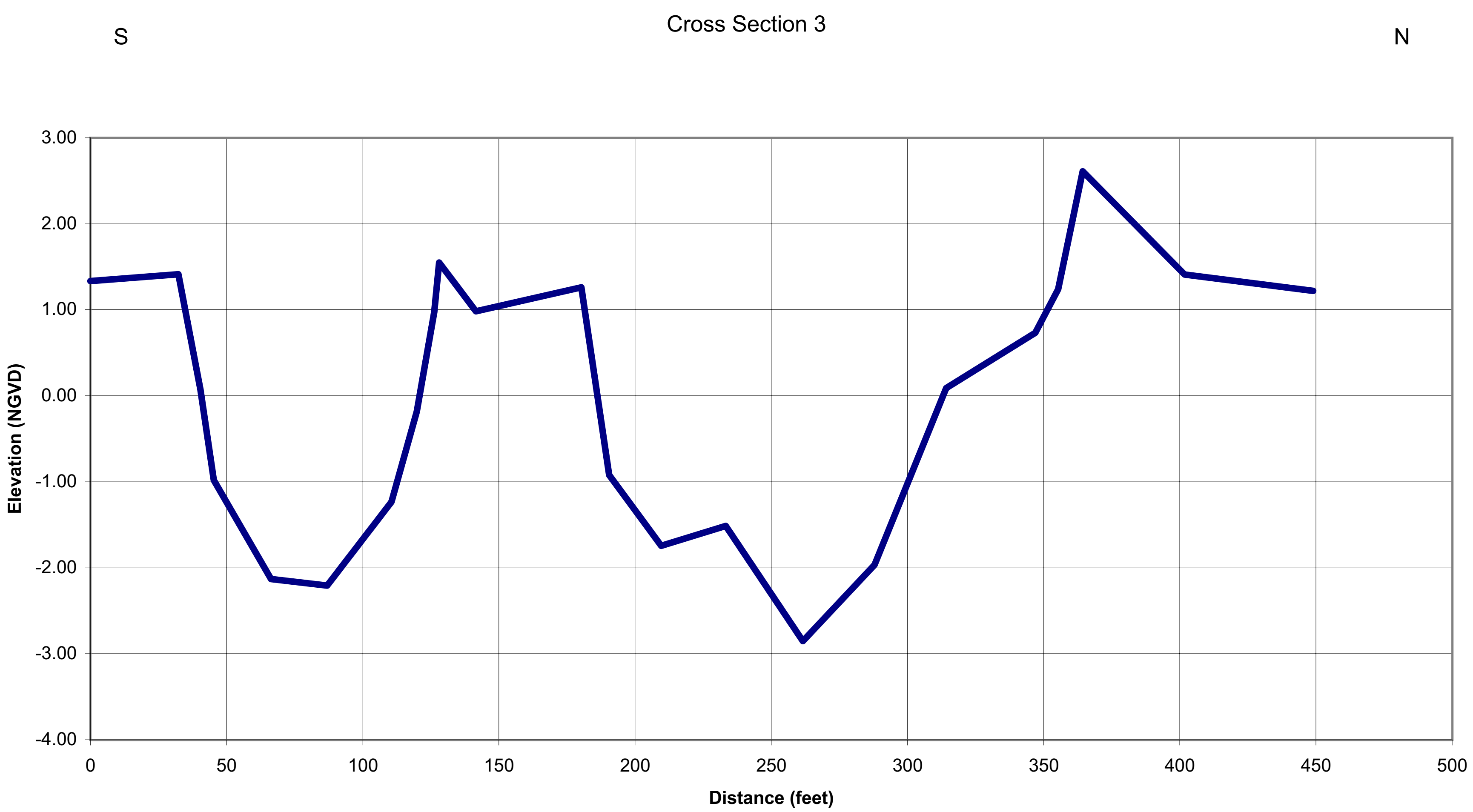


Source: PWA field surveys (March 2000).

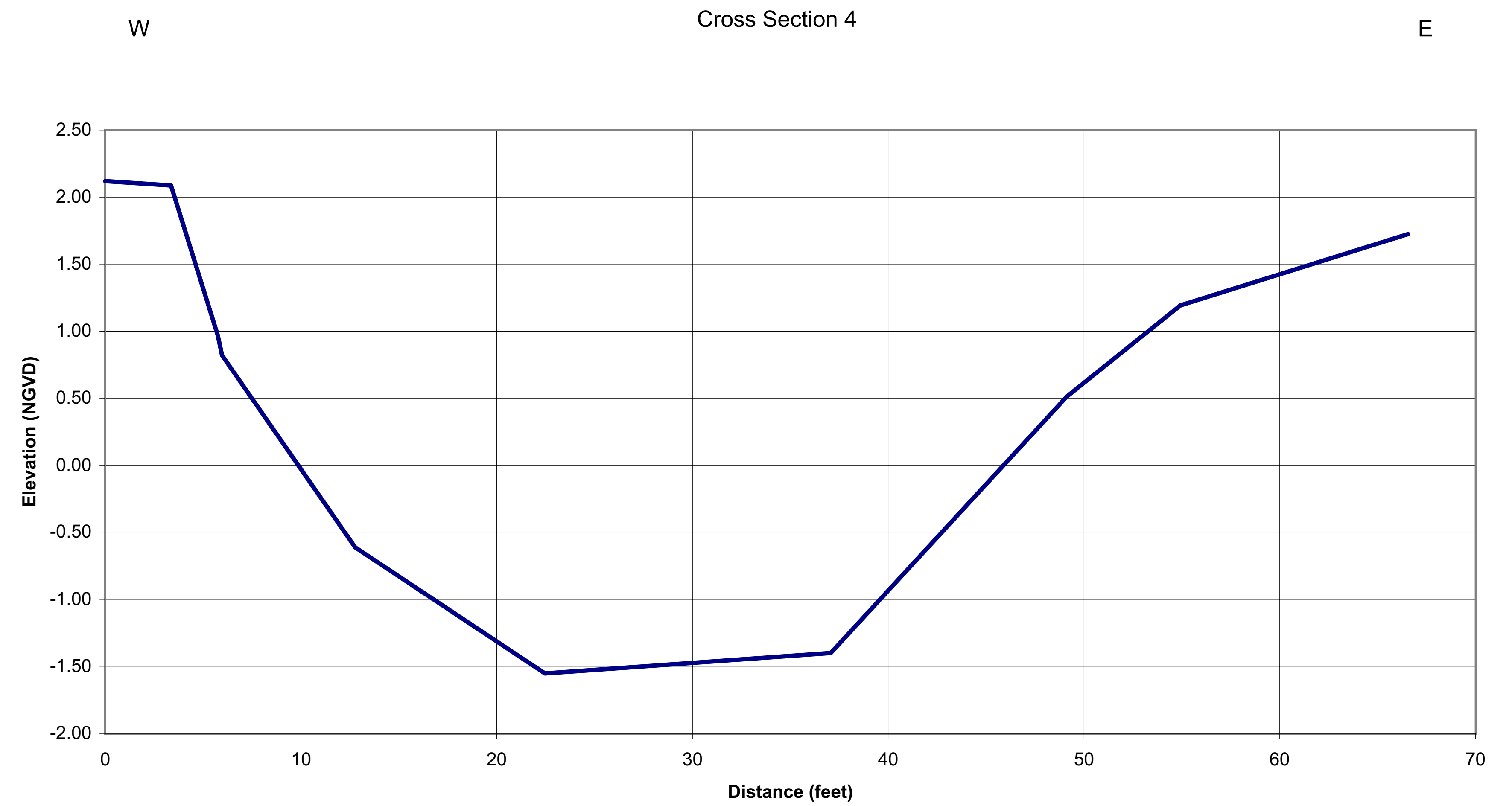
BAIR ISLAND
xs 2

PWA

PWA#: 1413



Source: PWA field surveys (March 2000).	*BAIR ISLAND* ***xs 3***
	PWA — PWA#: 1413

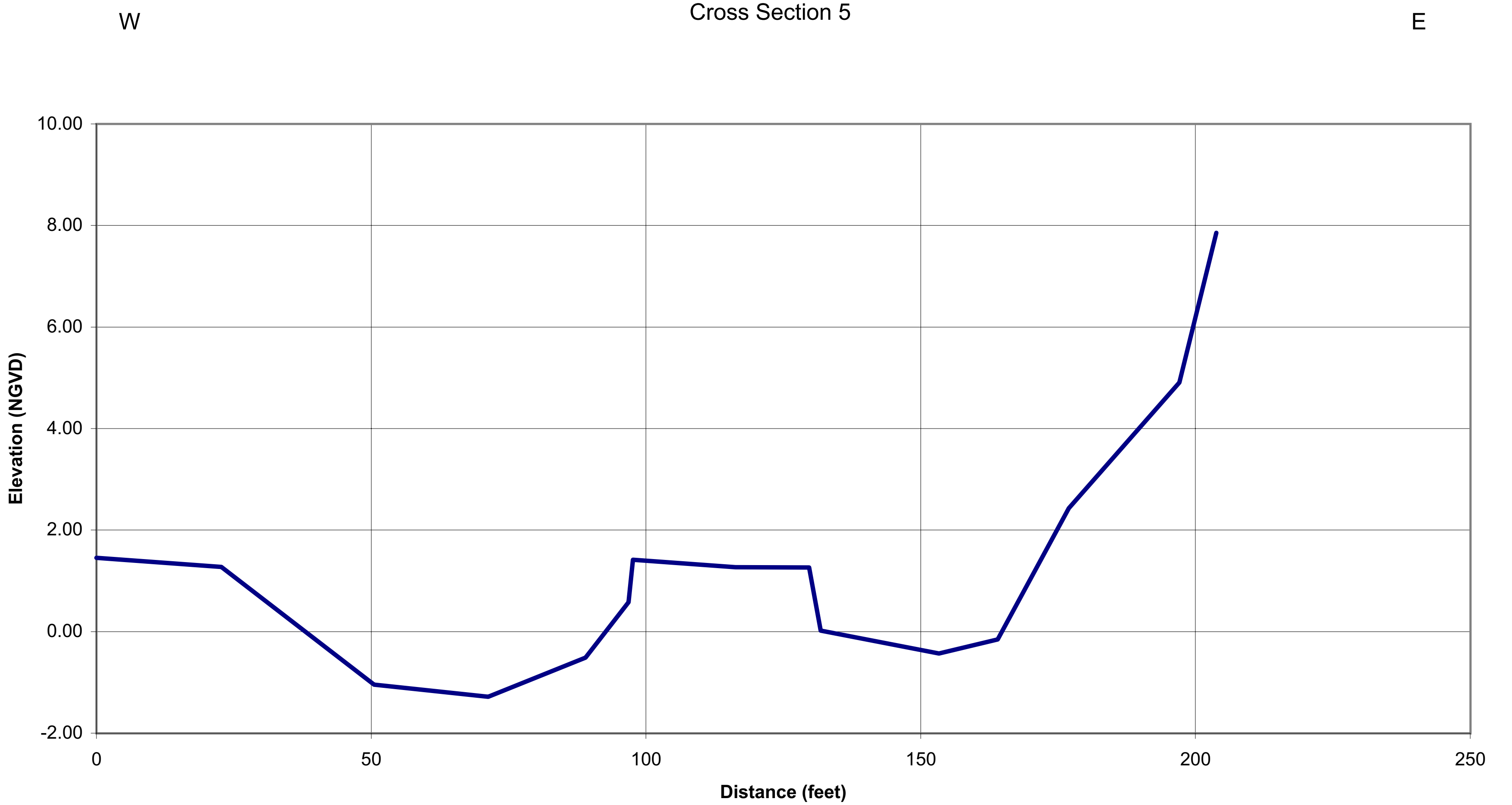


Source: PWA field surveys (March 2000).

BAIR ISLAND
xs 4

PWA

PWA#: 1413

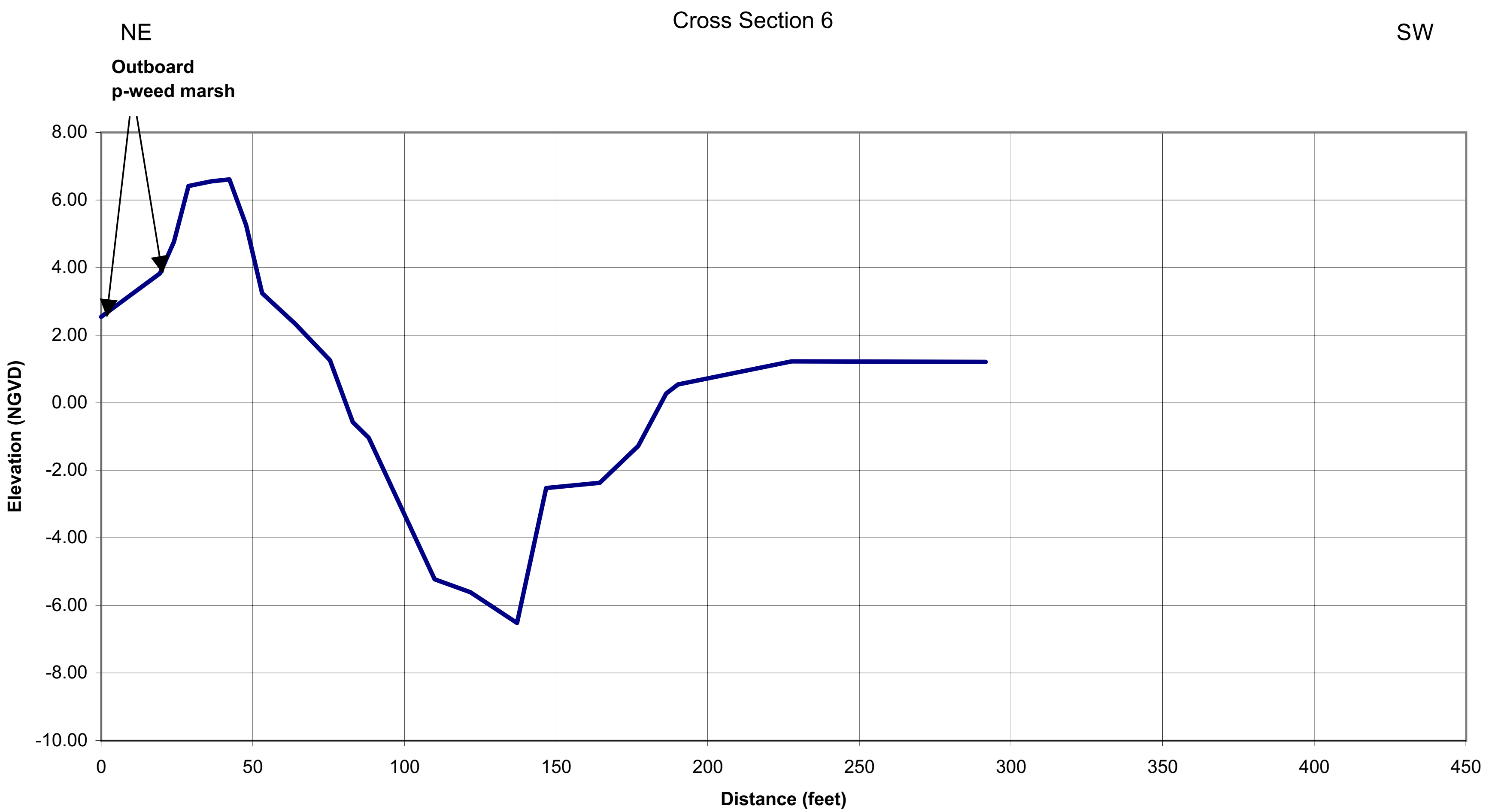


Source: PWA field surveys (March 2000).

BAIR ISLAND
xs 5

PWA

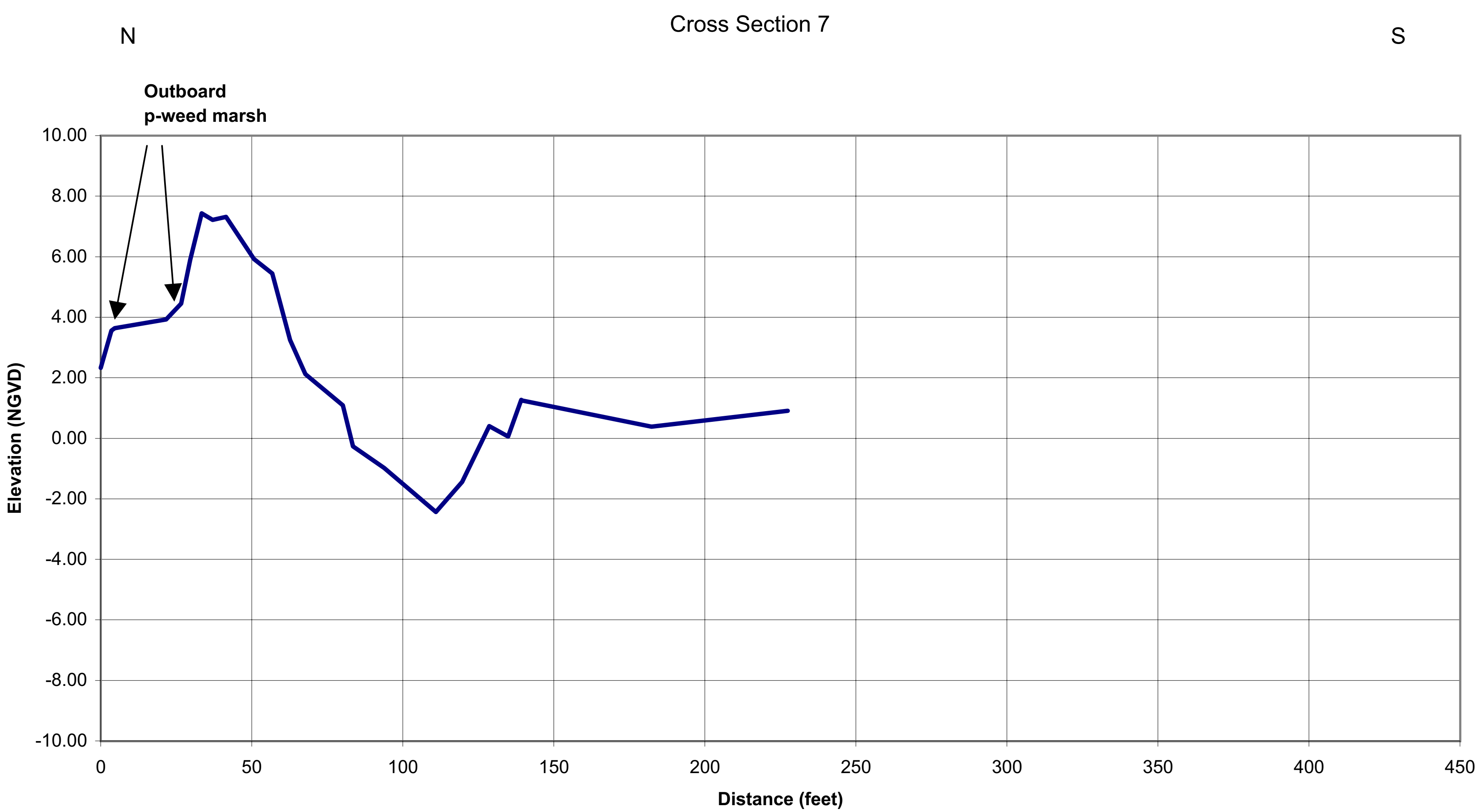
PWA#: 1413



Source: PWA field surveys (March 2000).

BAIR ISLAND
xs 6

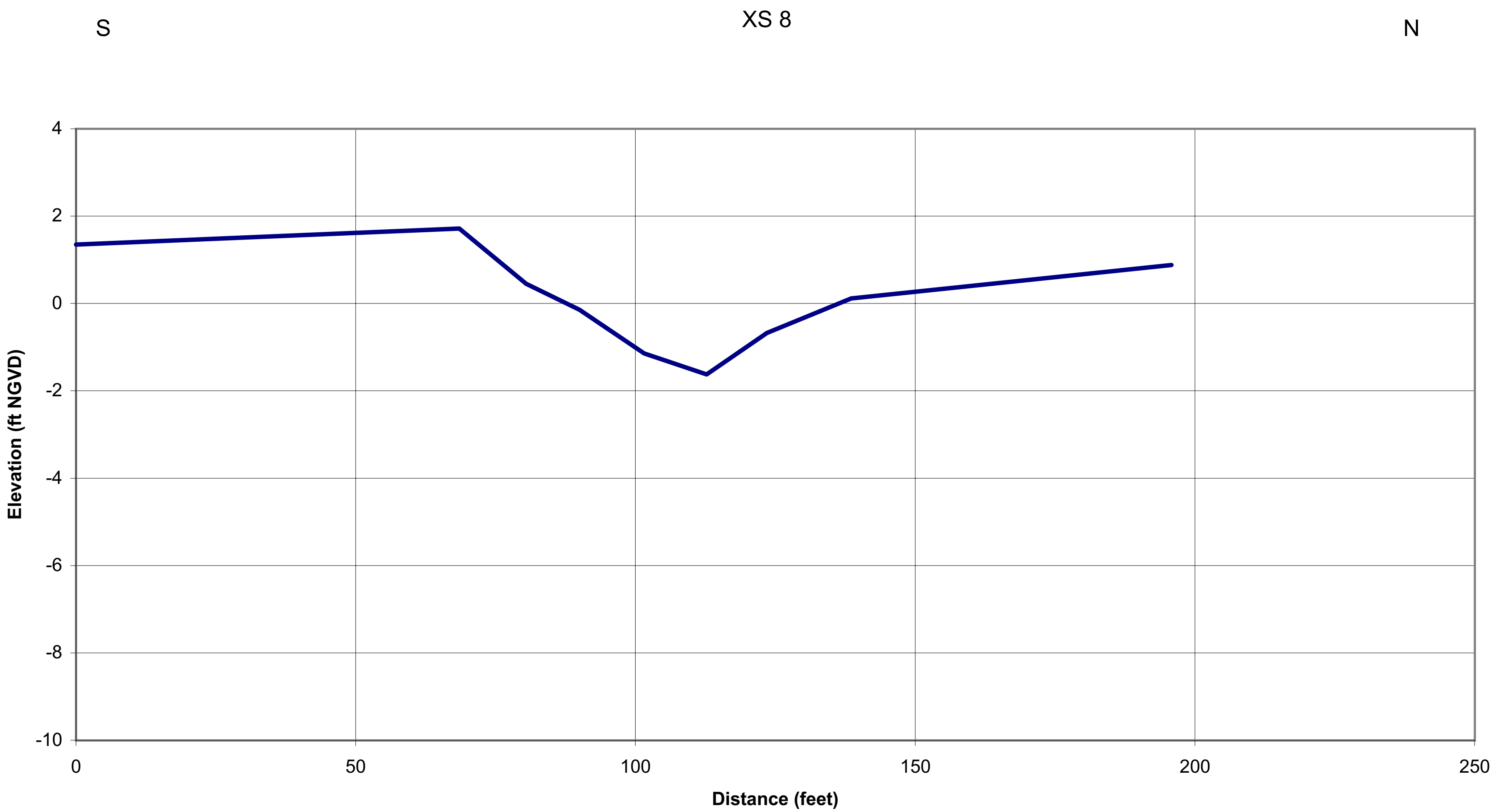
PWA | PWA#: 1413



Source: PWA field surveys (March 2000).

BAIR ISLAND
***xs** 7*

PWA | PWA#: 1413

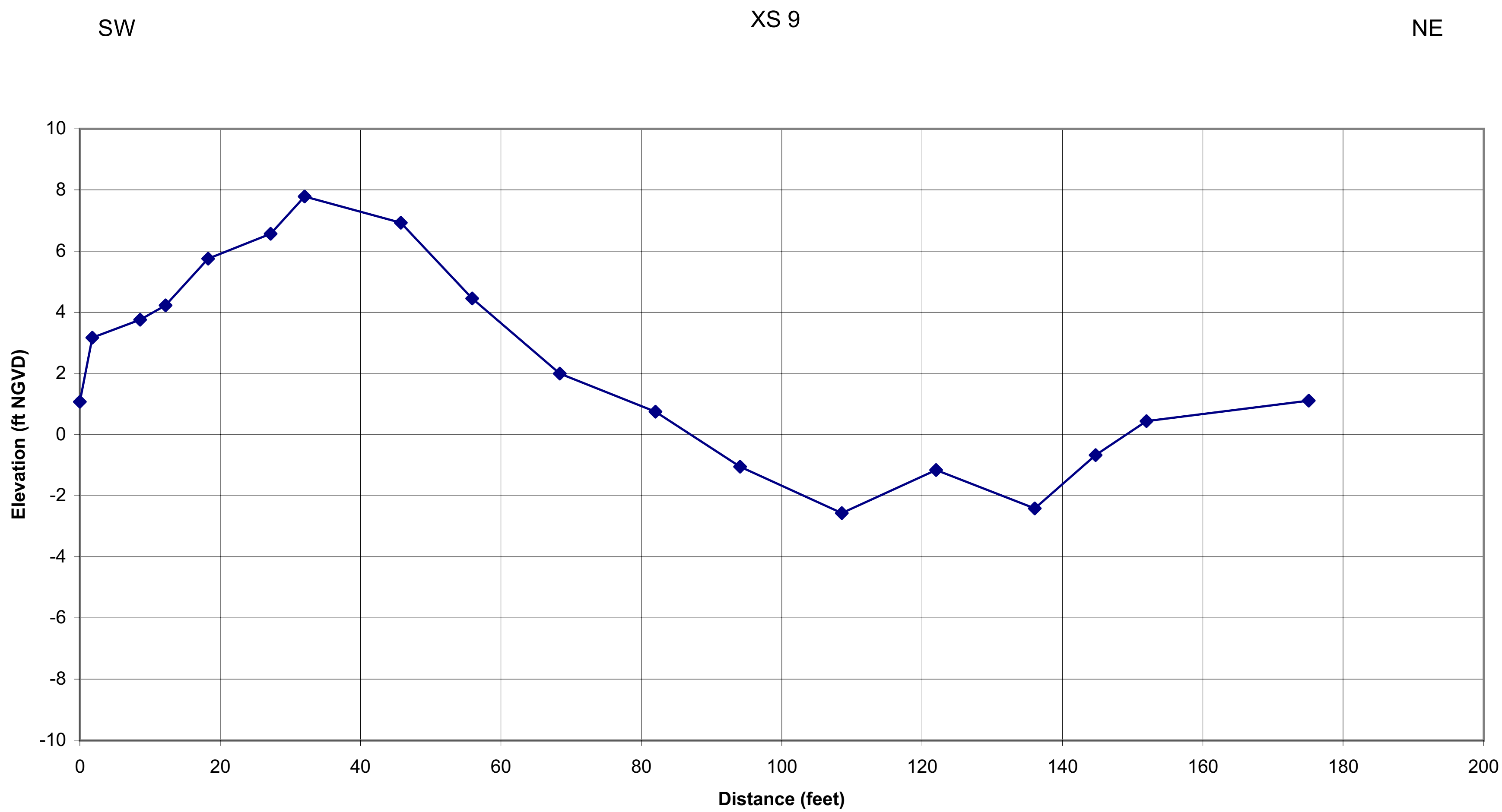


Source: PWA field surveys (March 2000).

BAIR ISLAND
XS 8

PWA

PWA#: 1413

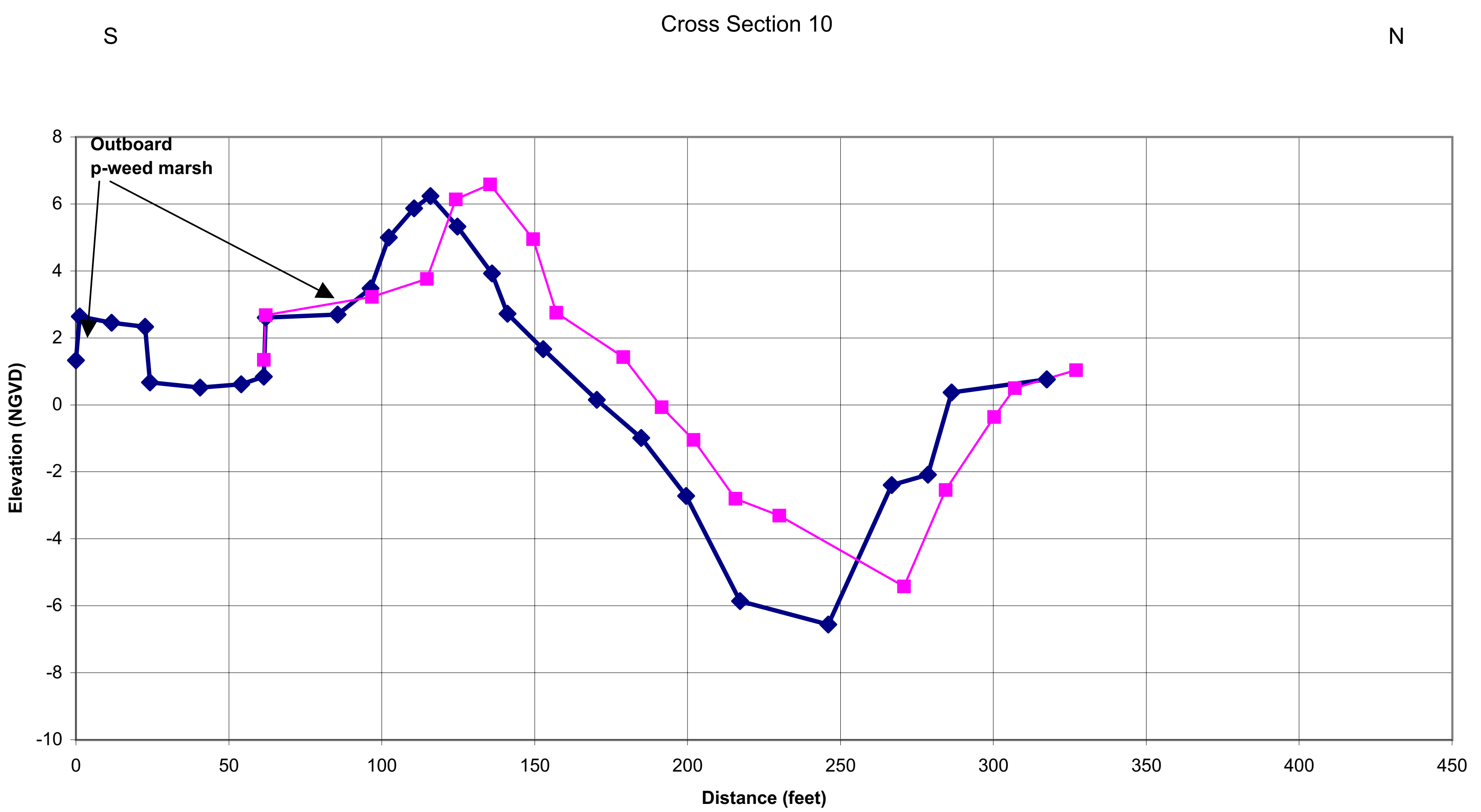


Source: PWA field surveys (March 2000).

BAIR ISLAND
XS 9

PWA

PWA#: 1413

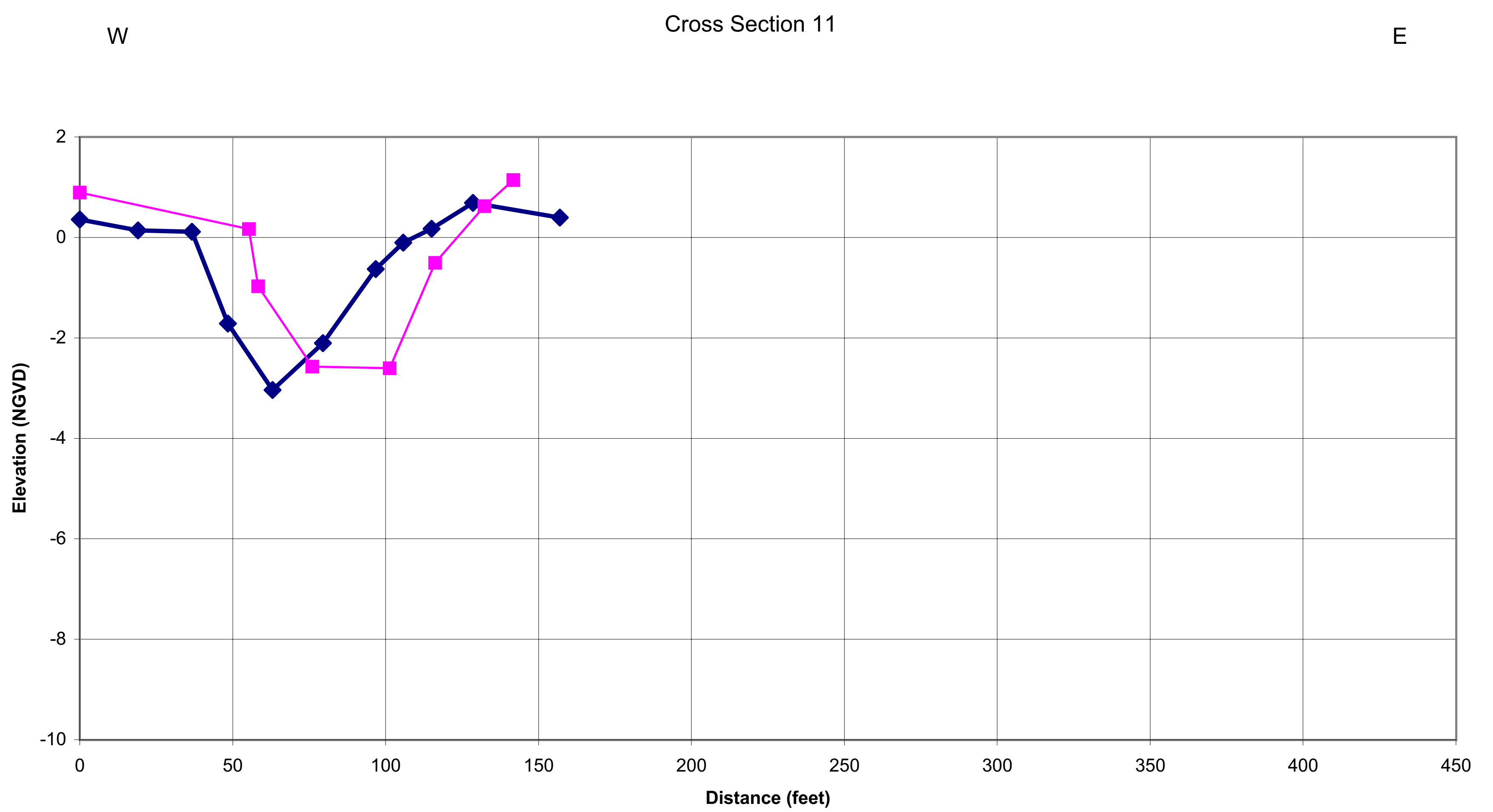


Source: PWA field surveys (March 2000).
Note: Preliminary data; vertical datum confirmation in progress.

BAIR ISLAND
XS 10

PWA

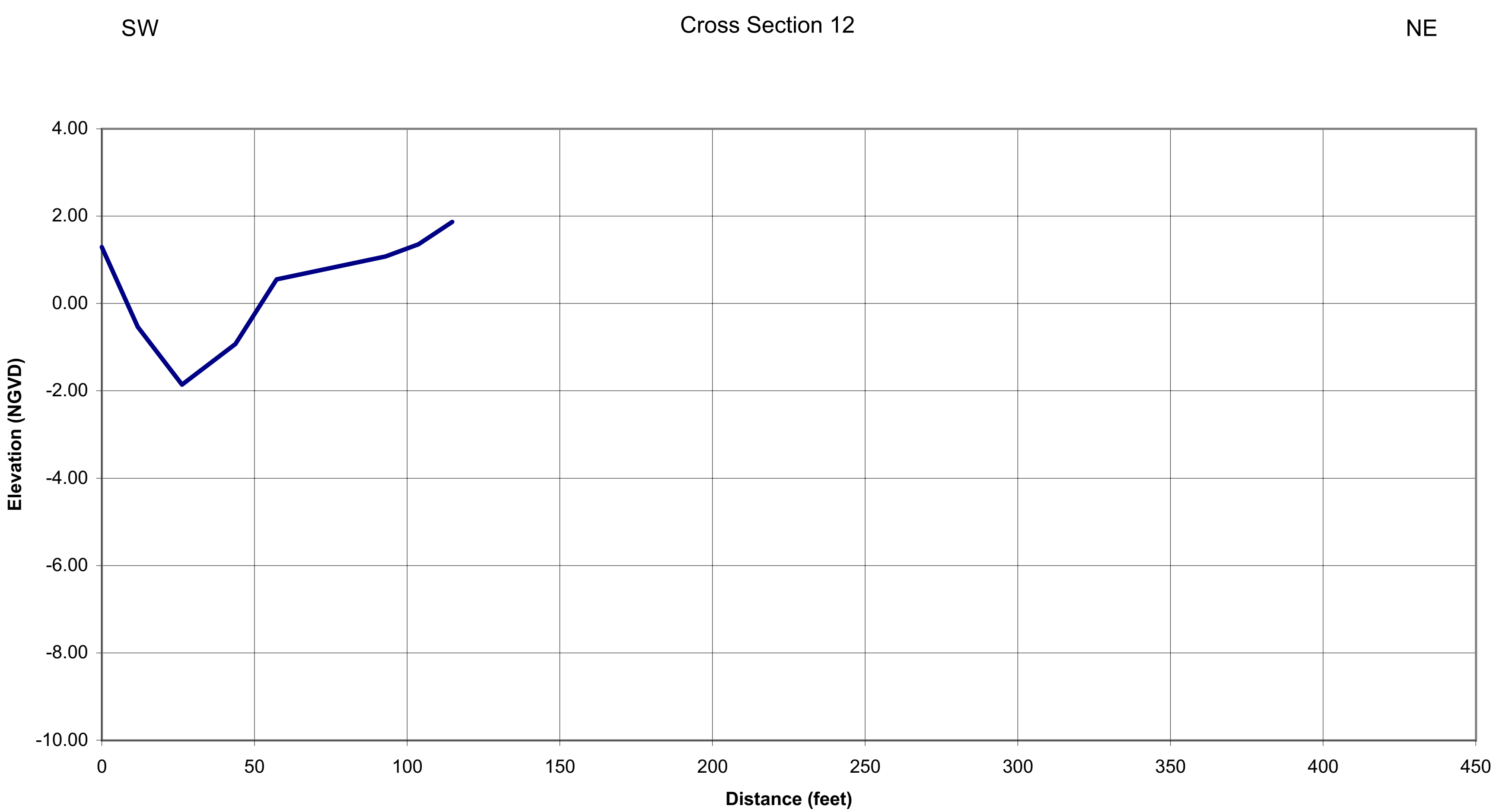
PWA#: 1413



Source: PWA field surveys (March 2000).
Note: Preliminary data; vertical datum confirmation in progress.

BAIR ISLAND
XS 11

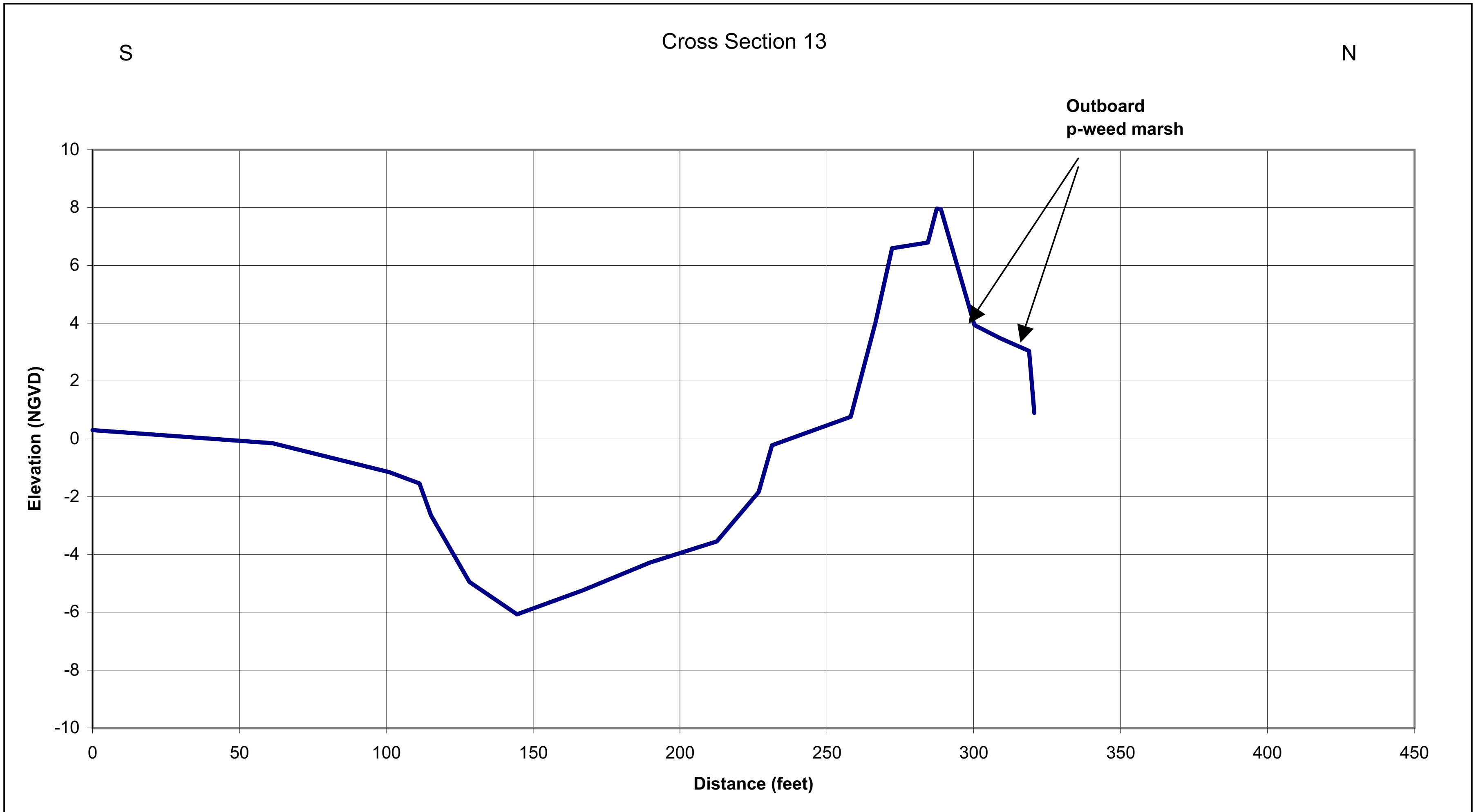
PWA | PWA#: 1413



Source: PWA field surveys (March 2000).

BAIR ISLAND
xs 12

PWA | PWA#: 1413

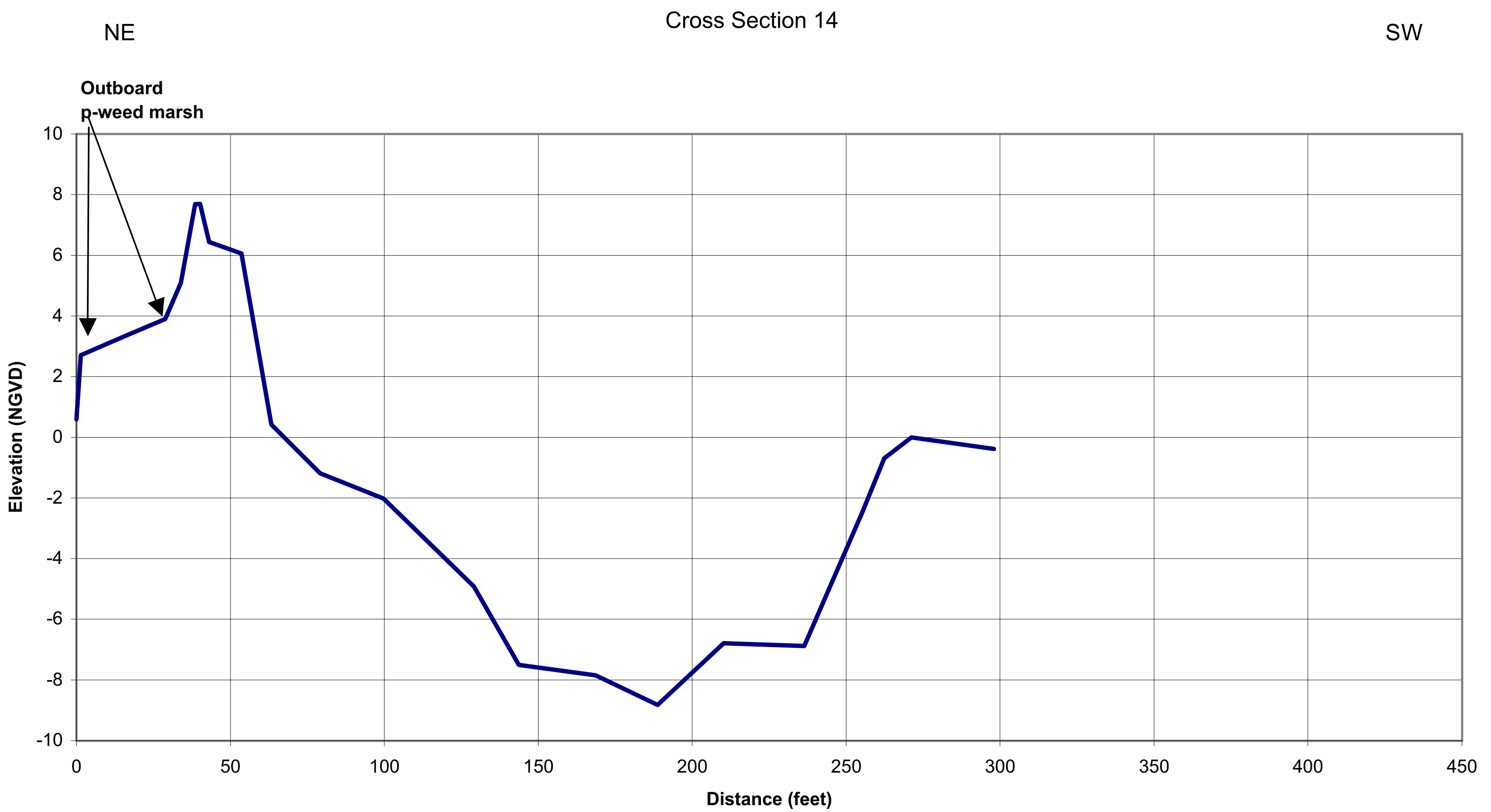


Source: PWA field surveys (March 2000).

BAIR ISLAND
xs 13

PWA

PWA#: 1413

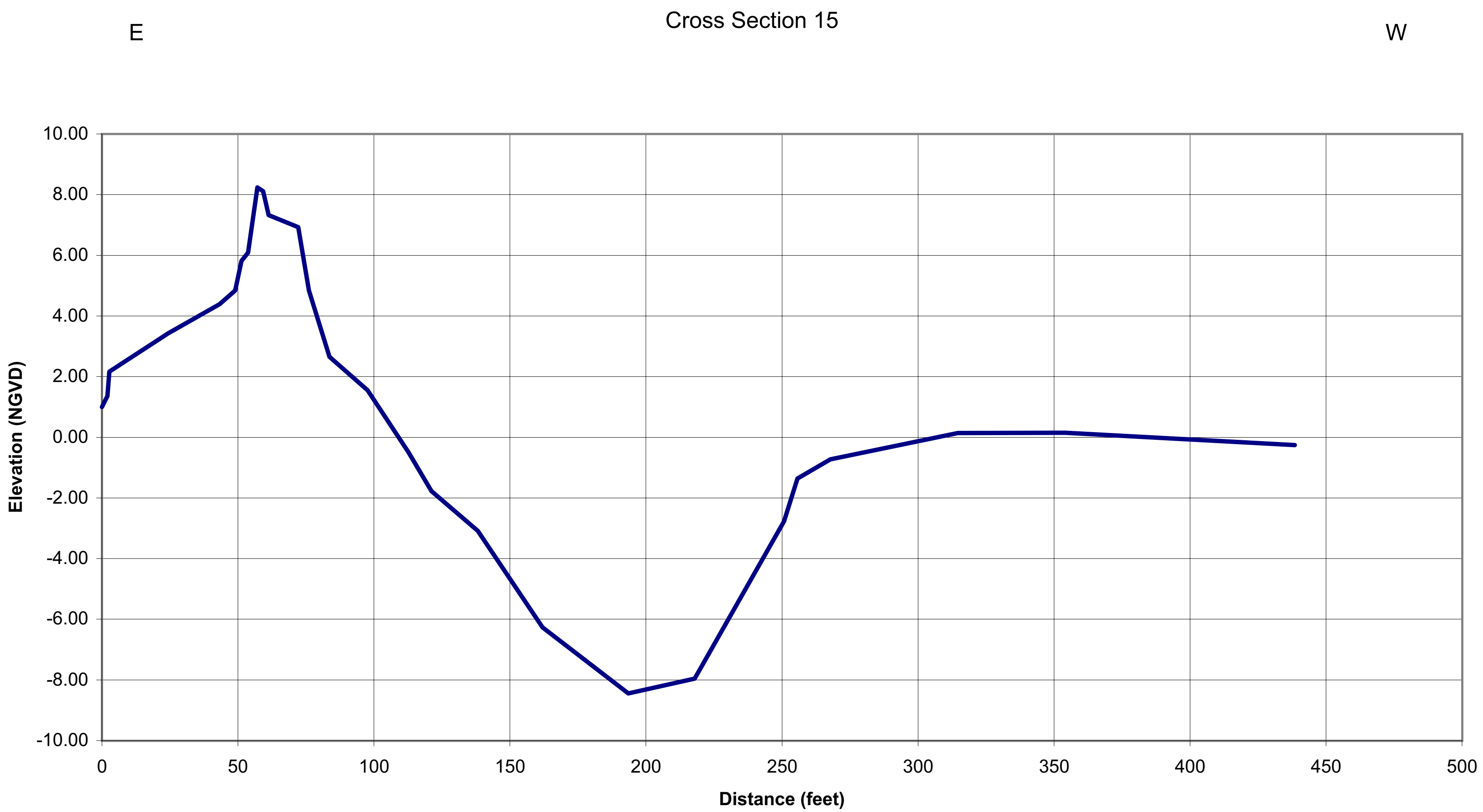


Source: PWA field surveys (March 2000).

BAIR ISLAND
xs 14

PWA

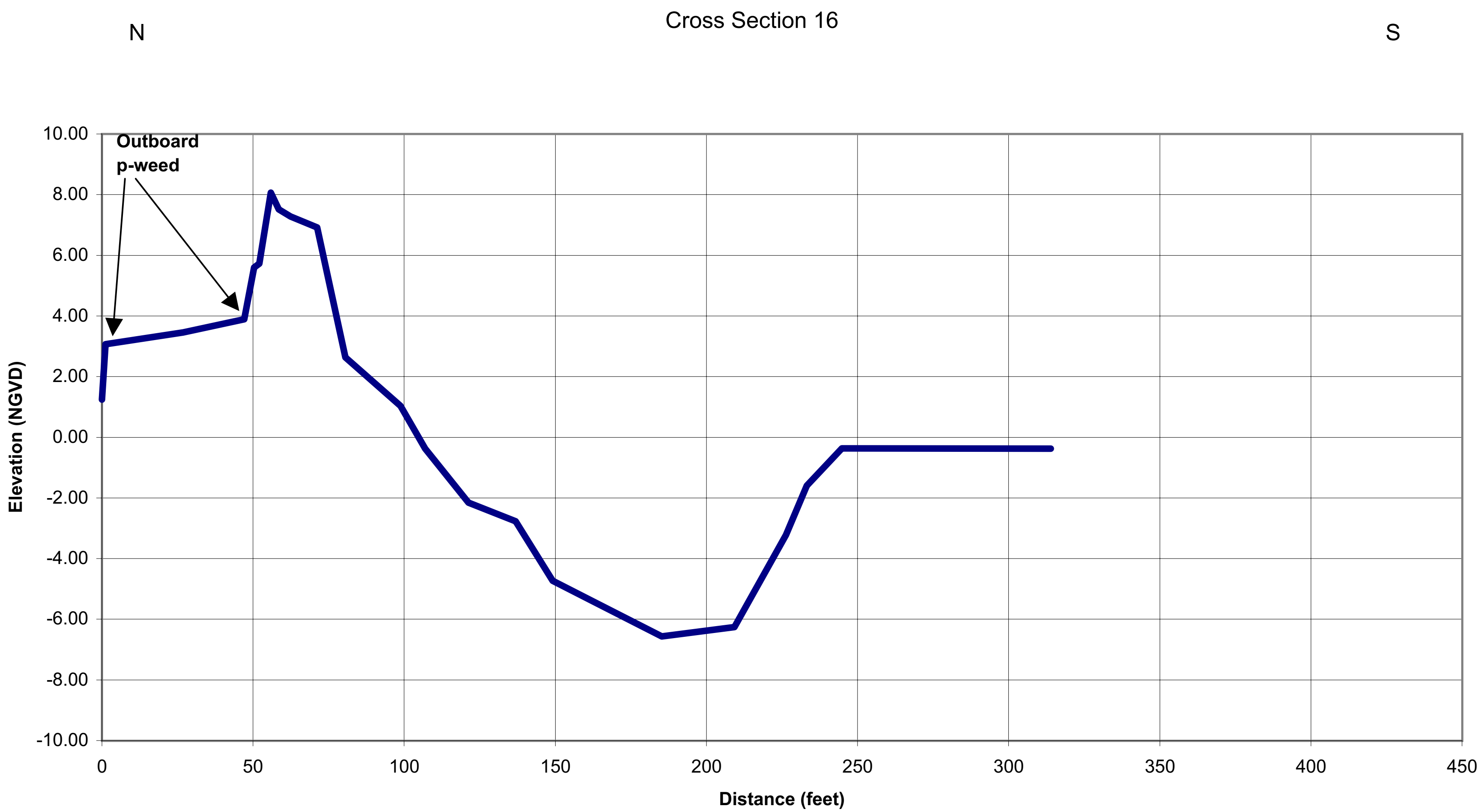
PWA#: 1413



Source: PWA field surveys (March 2000).

BAIR ISLAND
XS ***15***

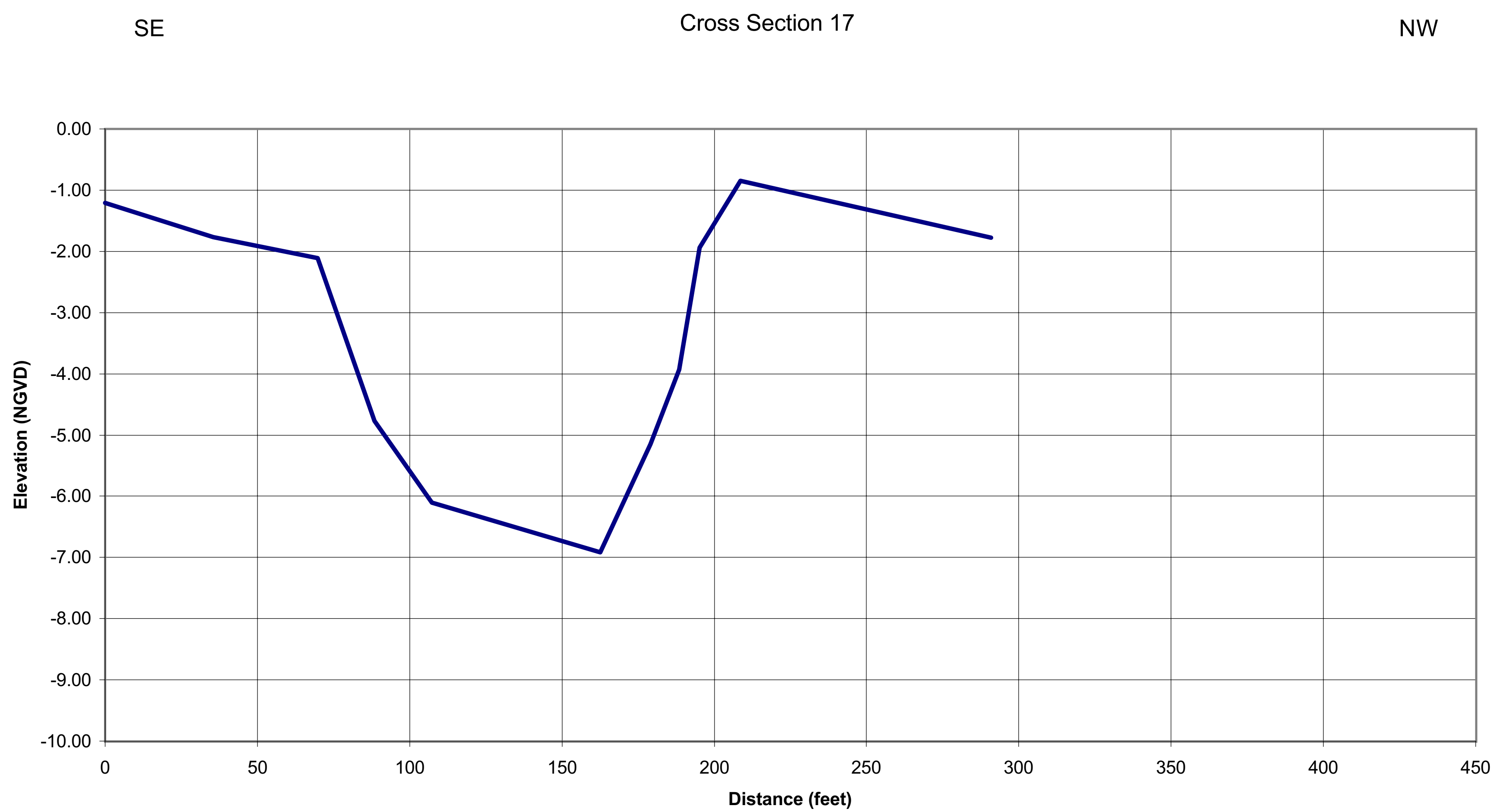
PWA | PWA#: 1413



Source: PWA field surveys (March 2000).

BAIR ISLAND
xs 16

PWA | PWA#: 1413



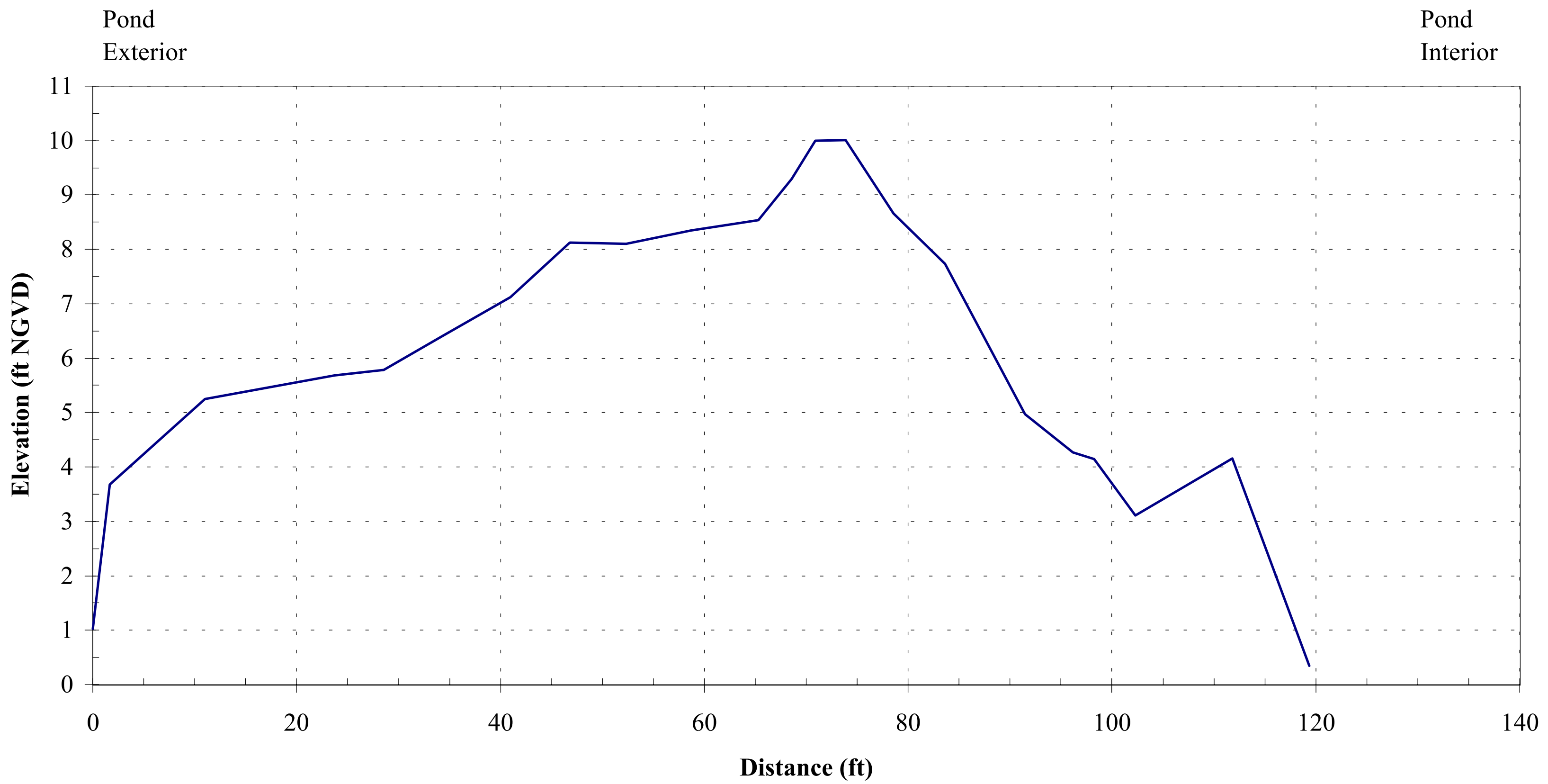
Source: PWA field surveys (March 2000).

BAIR ISLAND
xs 17

PWA | PWA#: 1413

APPENDIX A
FIELD SURVEYS

A-3 South Bay System Authority (SBSA) levee cross-sections 1 through XS5

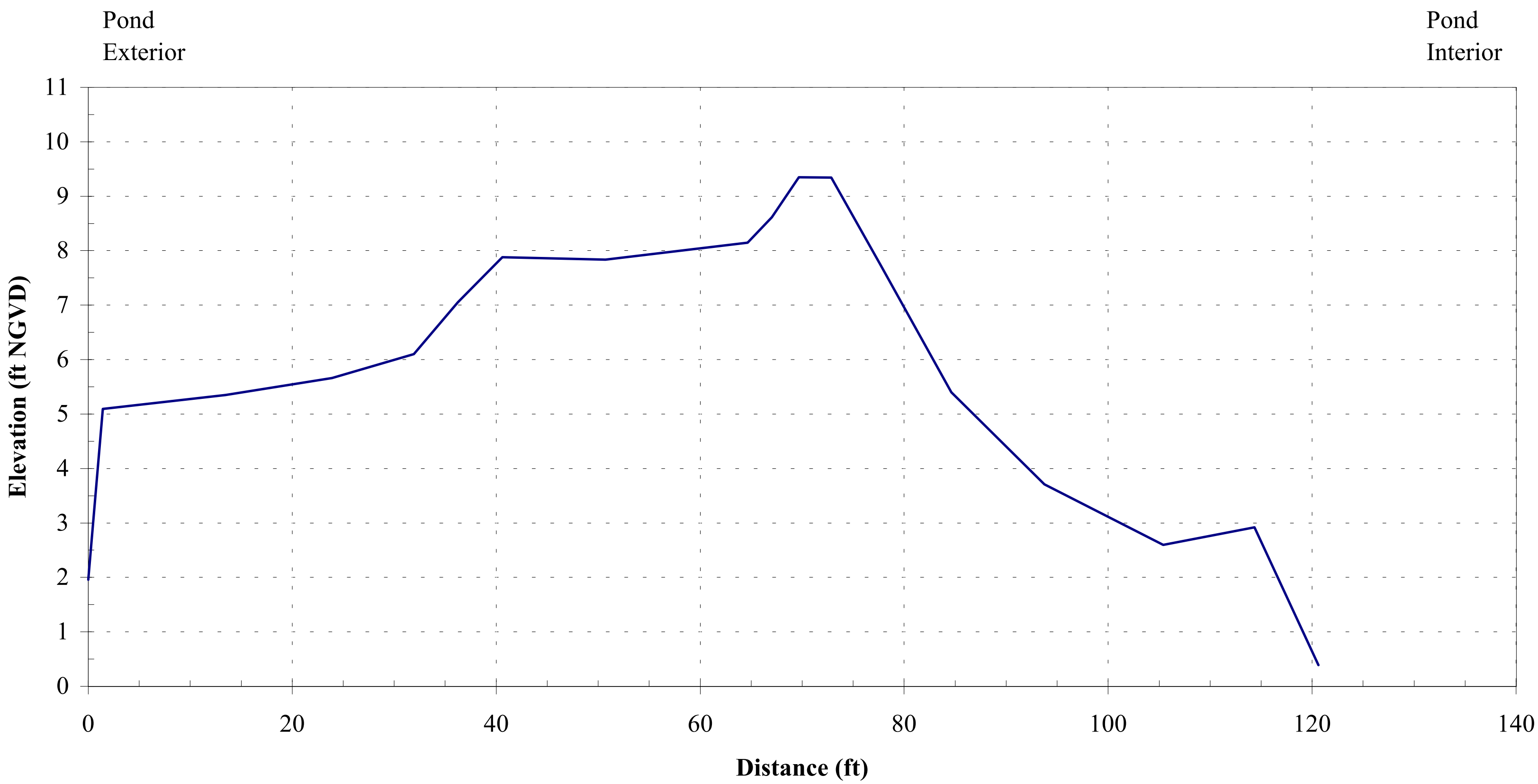


Source: PWA field surveys (04/05/2000)

SBSA Sewer Line
Cross Section 1

PWA

PWA #: 1413

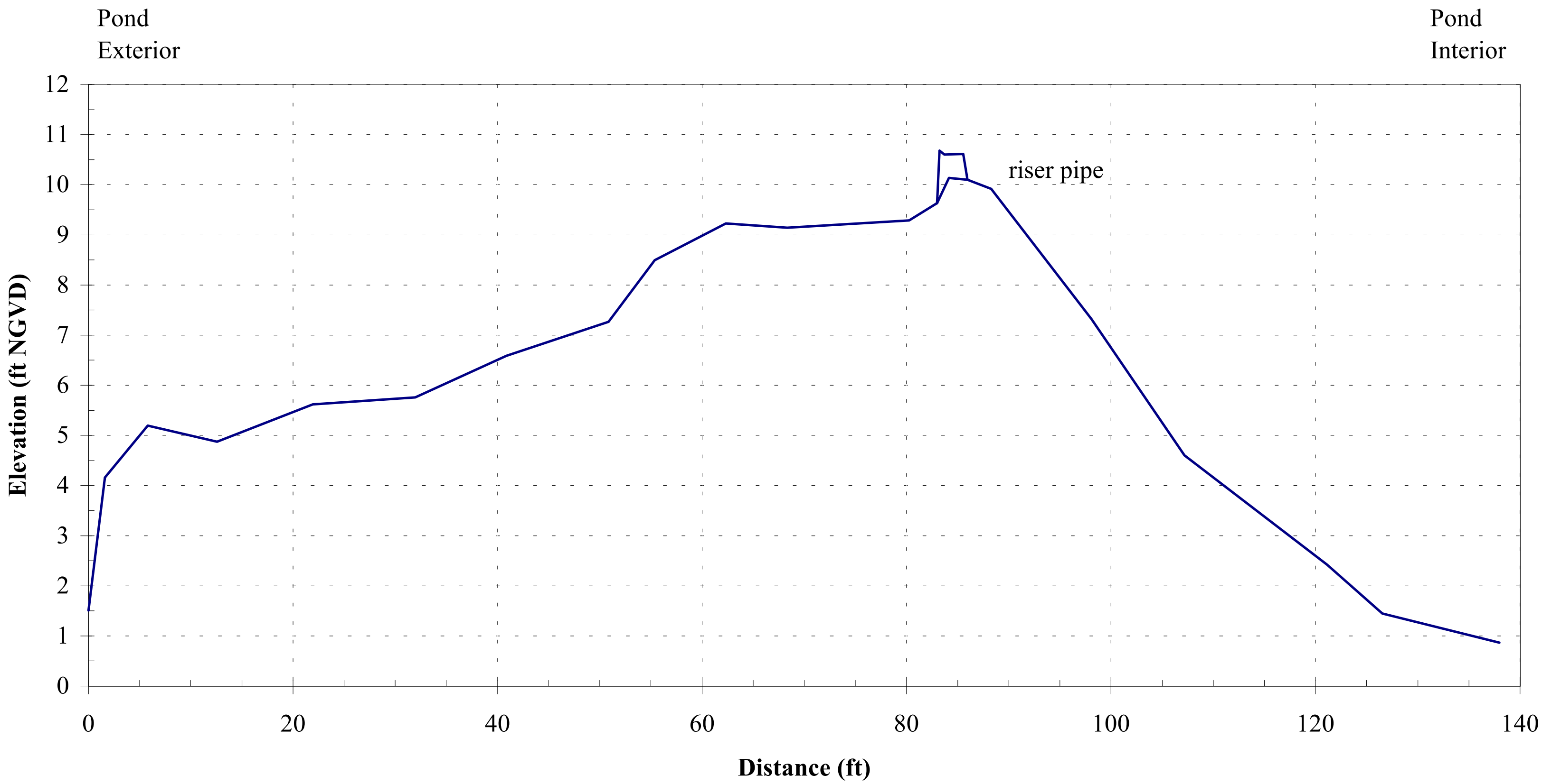


Source: PWA field surveys (04/05/2000)

SBSA Sewer Line
Cross Section 2

PWA

PWA #: 1413

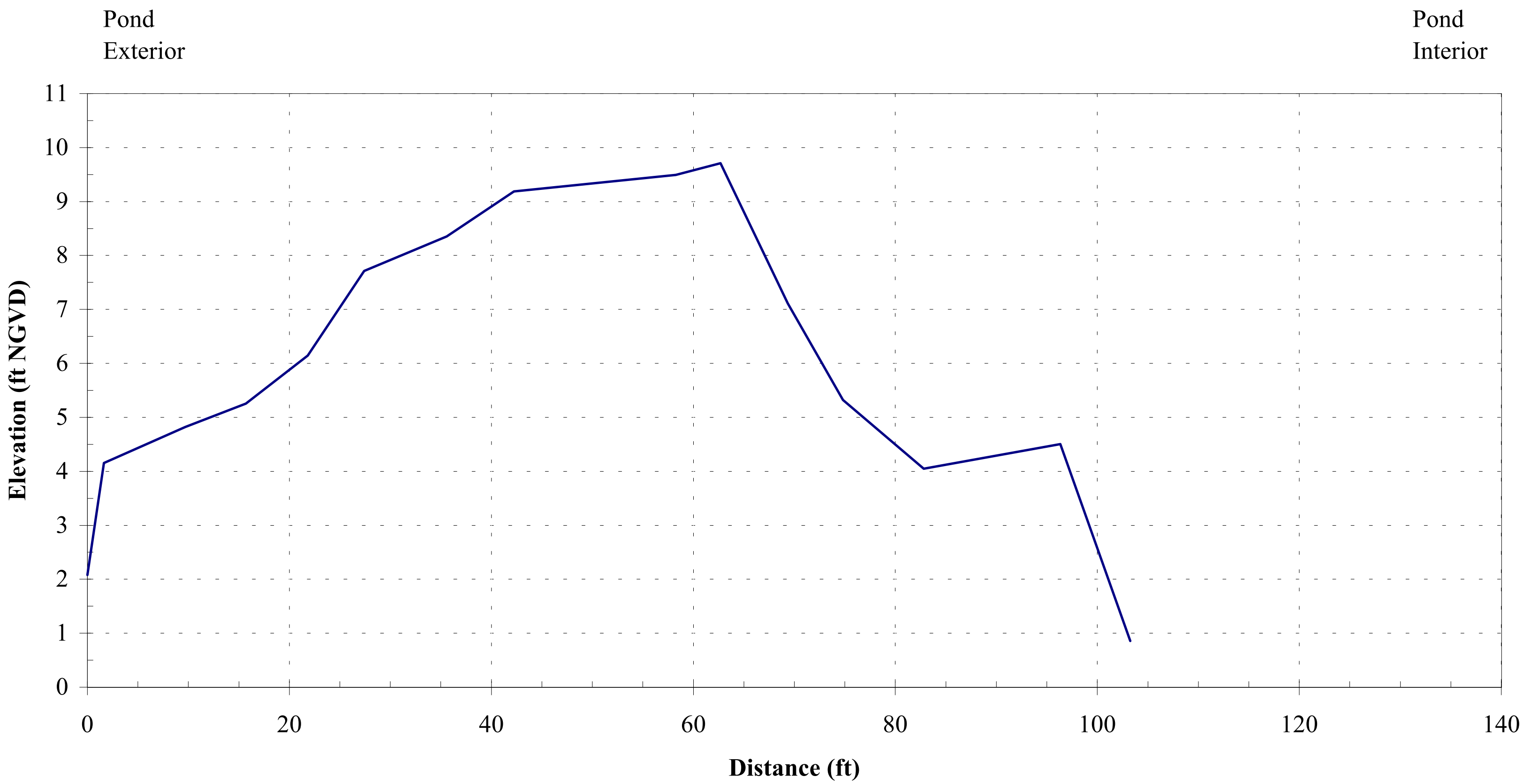


Source: PWA field surveys (04/05/2000)

SBSA Sewer Line
Cross Section 3

PWA

PWA #: 1413

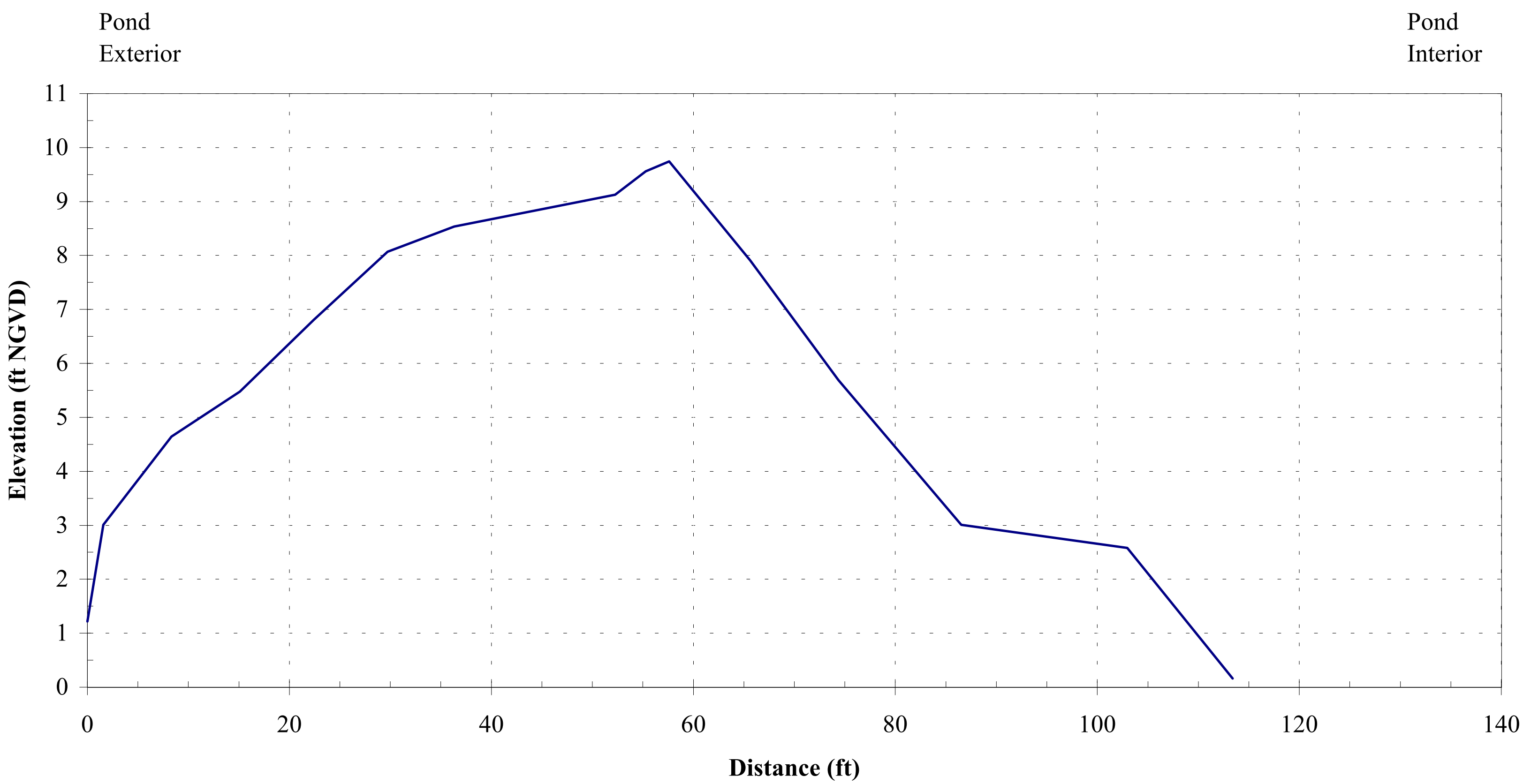


Source: PWA field surveys (04/05/2000)

SBSA Sewer Line
Cross Section 4

PWA

PWA #: 1413



Source: PWA field surveys (04/05/2000)

SBSA Sewer Line
Cross Section 5

PWA

PWA #: 1413

APPENDIX A
FIELD SURVEYS

A-4 Hydrographic cross-sections in the major slough channels: location map and cross-sections 1 through 30

SAN FRANCISCO BAY
NATIONAL WILDLIFE REFUGE
MUD
Belmont Slough
Radio Towers
Radio Sta KNBC
Radio Sta KGEI
Press Wireless Radio Sta
SALT EVAPORATORS
SLOUGH
BAIR ISLAND
Redwood Point
LEVEE
STEINBERGER
Corkscrew
Deepwater Slough
REDWOOD CREEK
Port of Redwood City
WESTPOINT
Smith Slough
Yacht Harbor
SALT EVAPORATORS
Salt Evaporators
Sewage Disposal
BAYSHORE
San Carlos Airport
SAN CARLOS
Light
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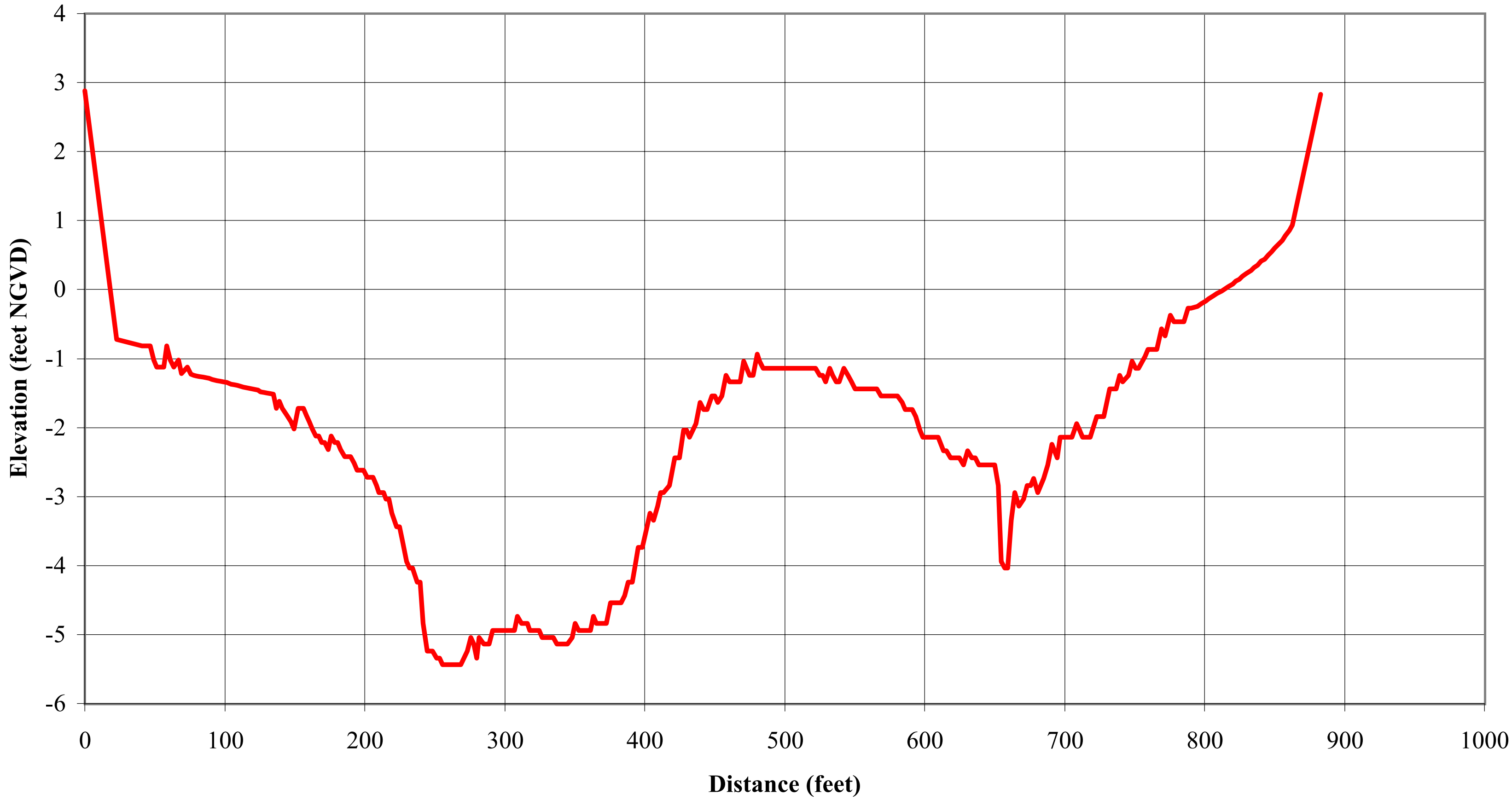


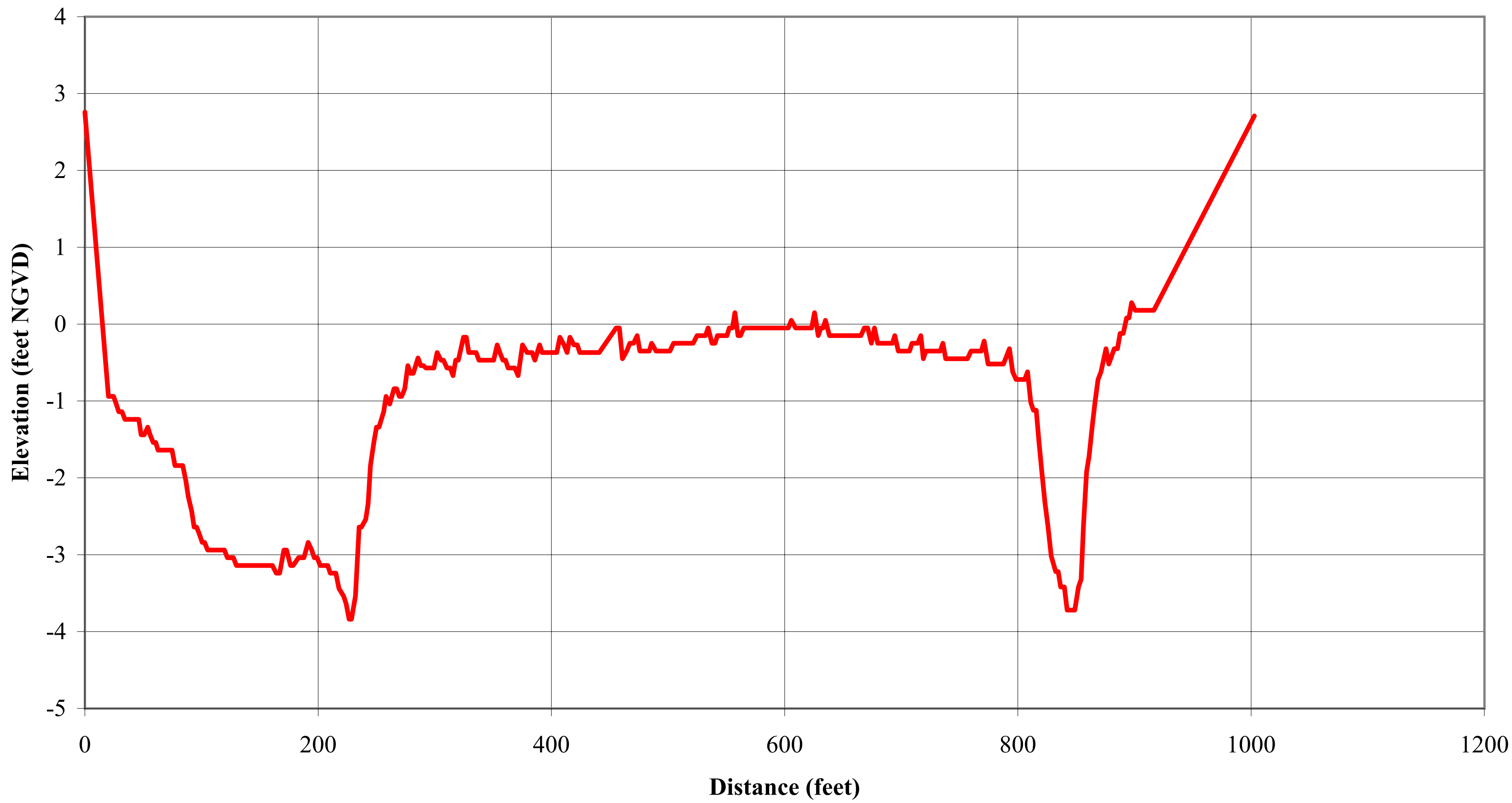
Source: Towill surveys (February 2000).

Bair Island

Cross Section 1

PWA

PWA #:1413



Source: Towill surveys (February 2000).

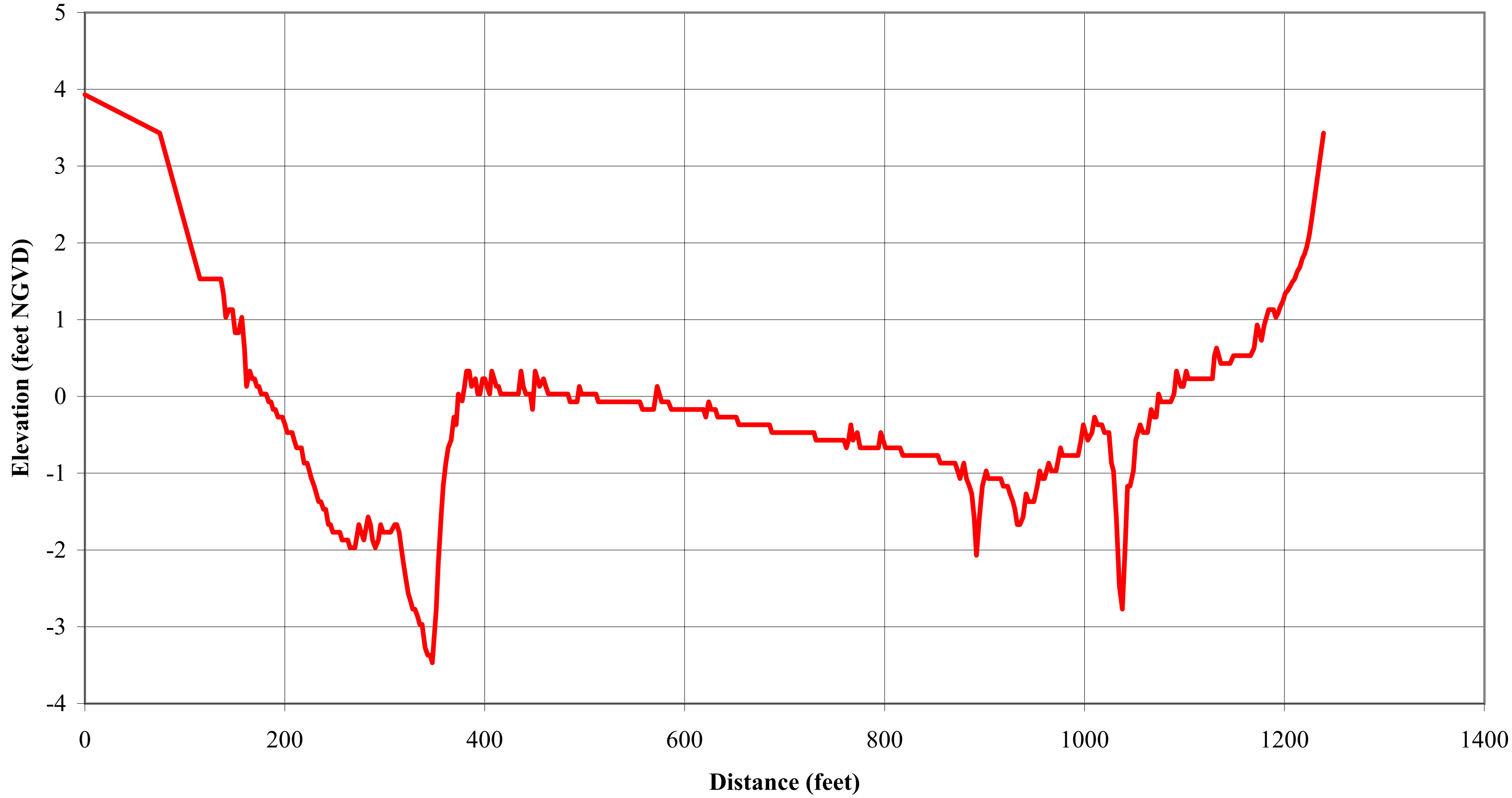
Bair Island

Cross Section 2

PWA

PWA #:1413

towillXS.xls 02 fig 2/6/04



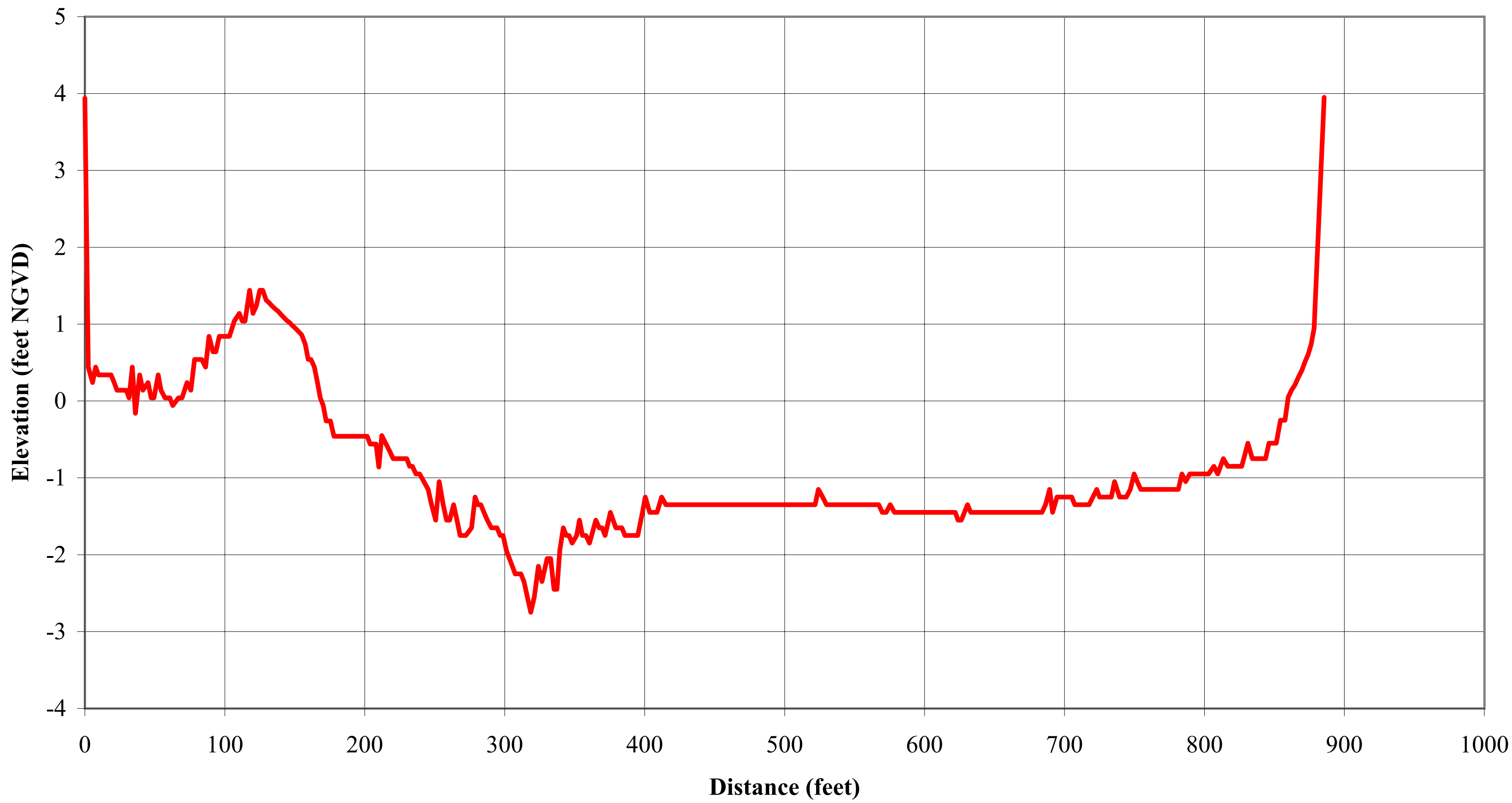
Source: Towill surveys (February 2000).

Bair Island

Cross Section 3

PWA

PWA #:1413



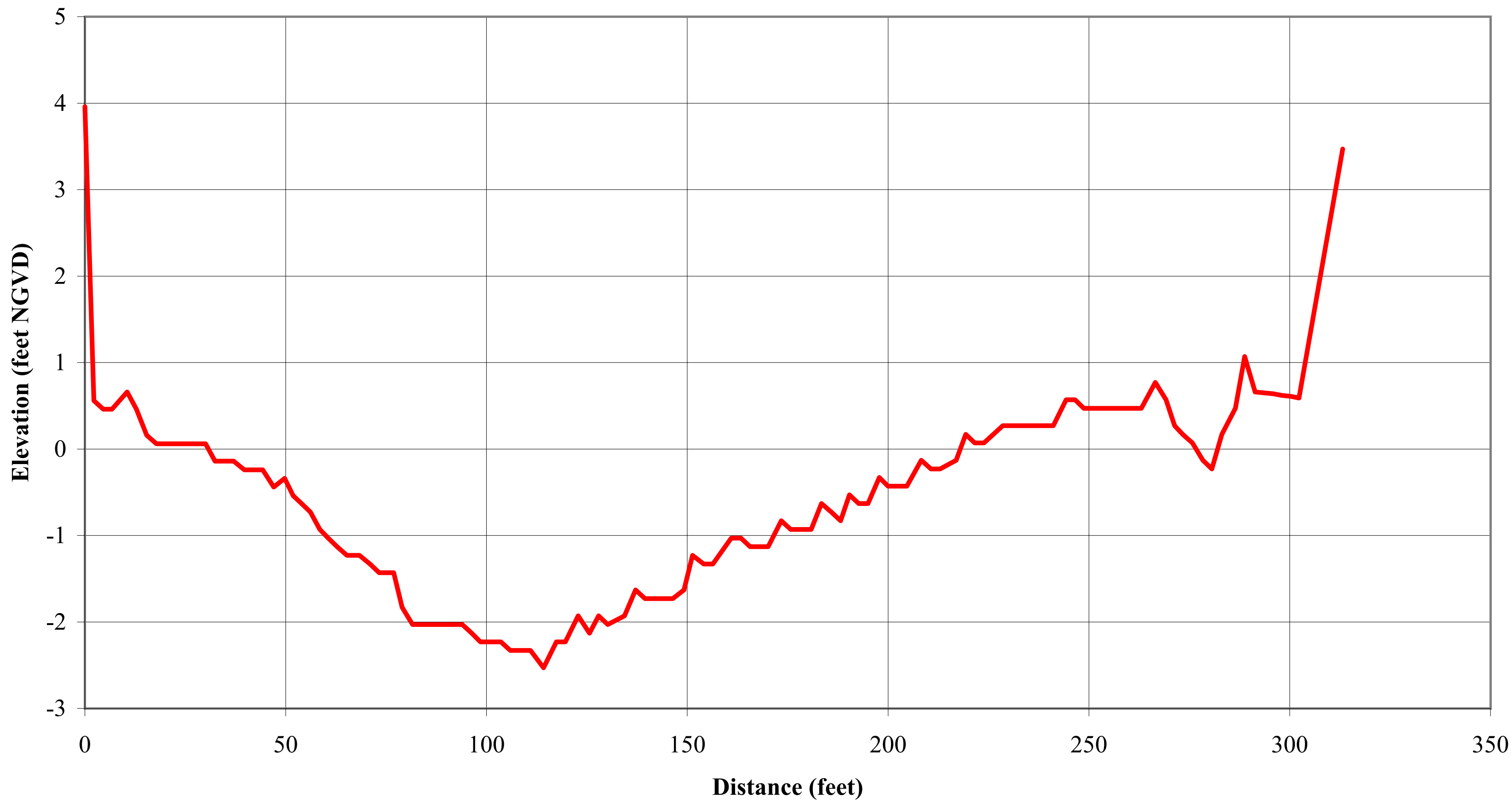
Source: Towill surveys (February 2000).

Bair Island

Cross Section 4

PWA

PWA #:1413



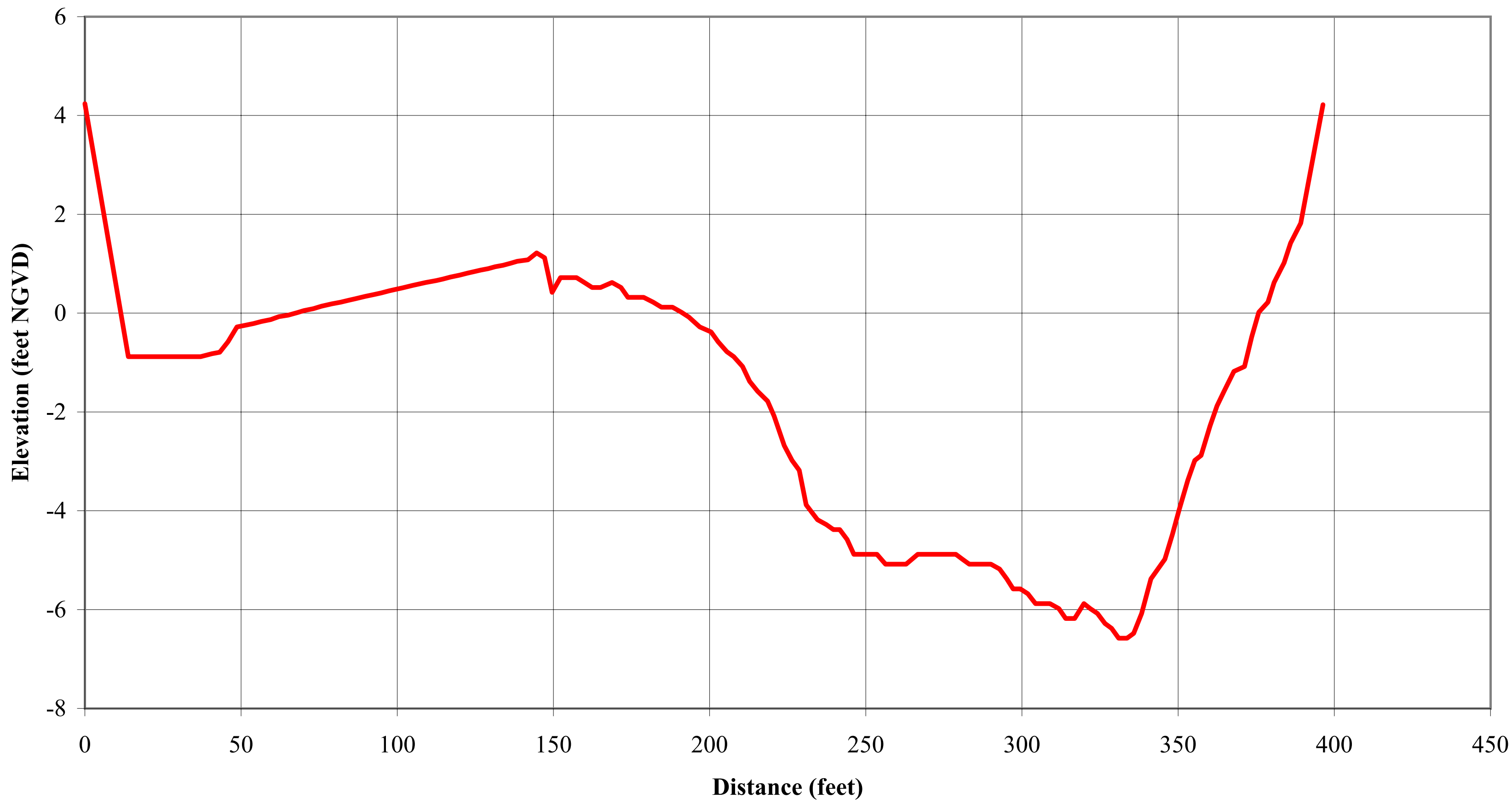
Source: Towill surveys (February 2000).

Bair Island

Cross Section 5

PWA

PWA #:1413



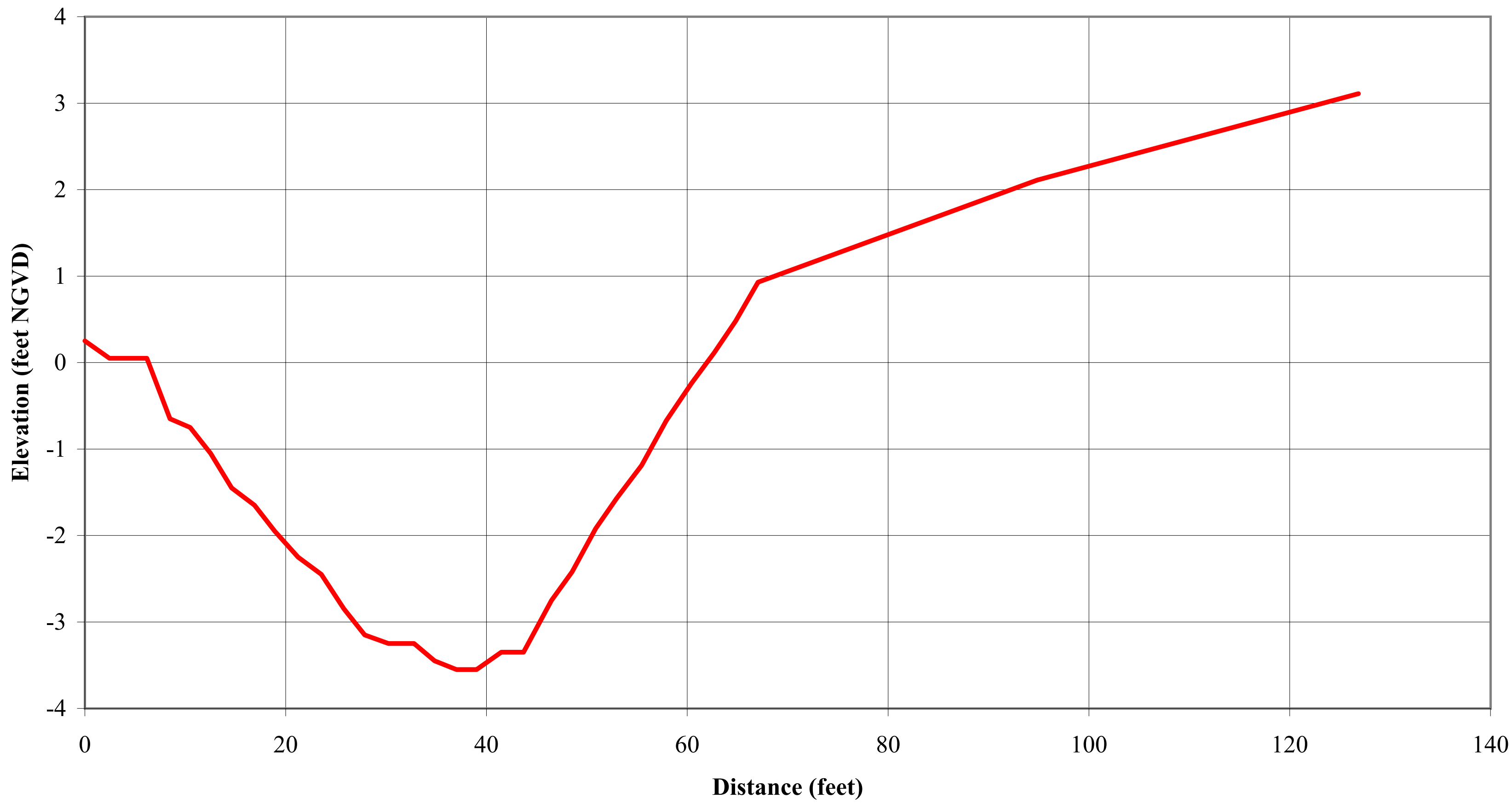
Source: Towill surveys (February 2000).

Bair Island

Cross Section 6

PWA

PWA #:1413



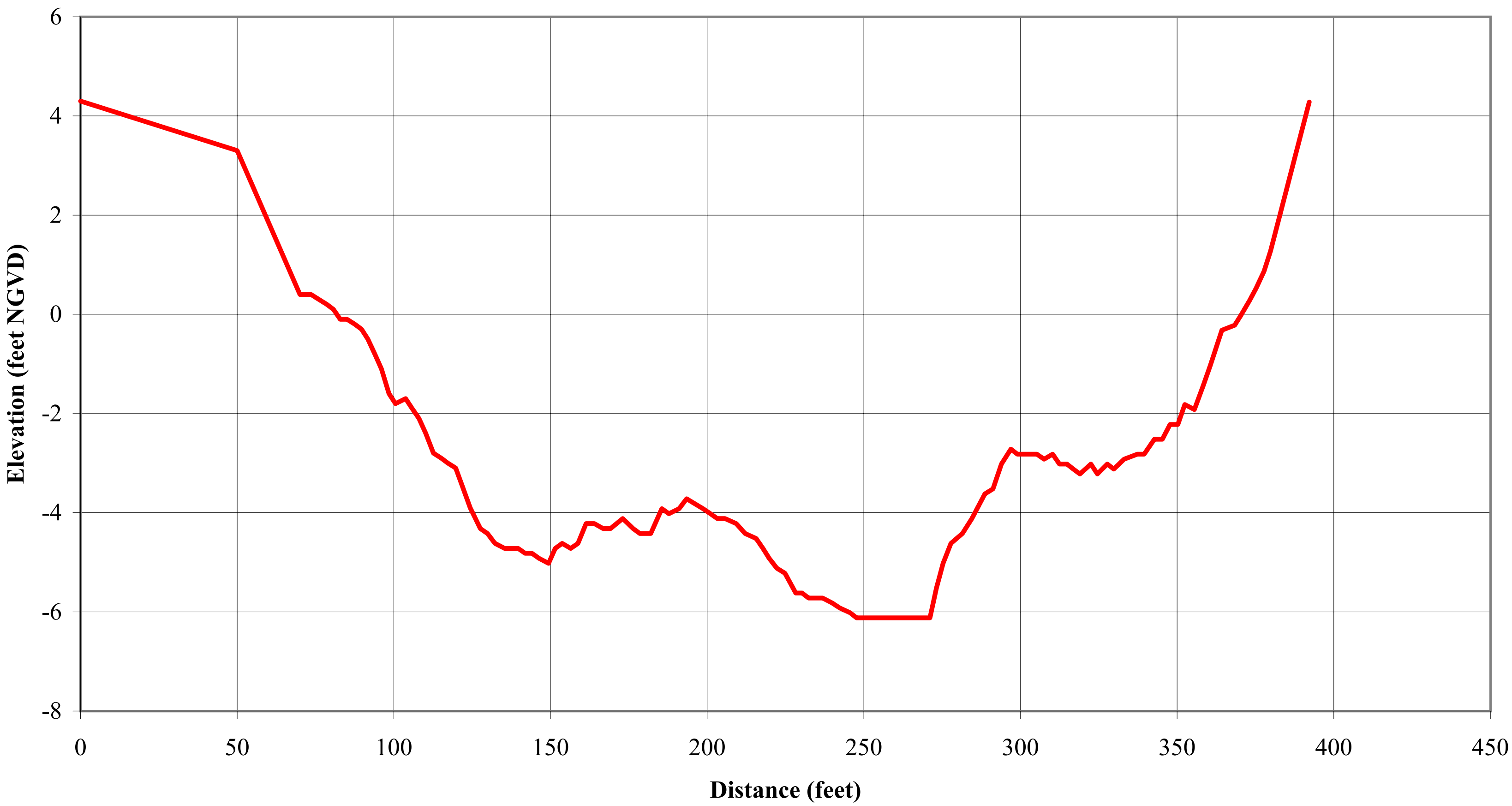
Source: Towill surveys (February 2000).

Bair Island

Cross Section 7

PWA

PWA #:1413



Source: Towill surveys (February 2000).

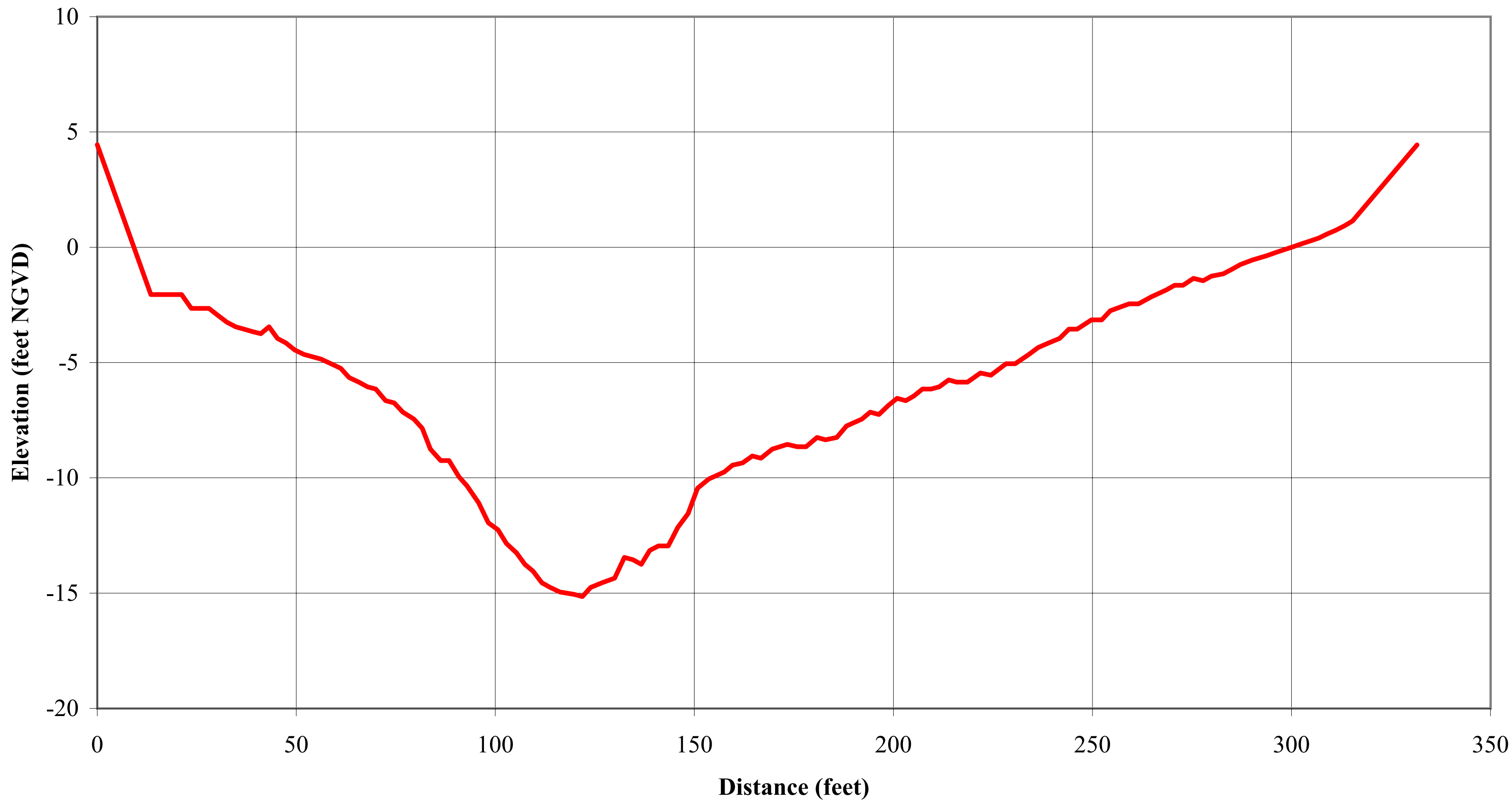
Bair Island

Cross Section 8

PWA

PWA #:1413

towillXS.xls 08 fig 2/6/04



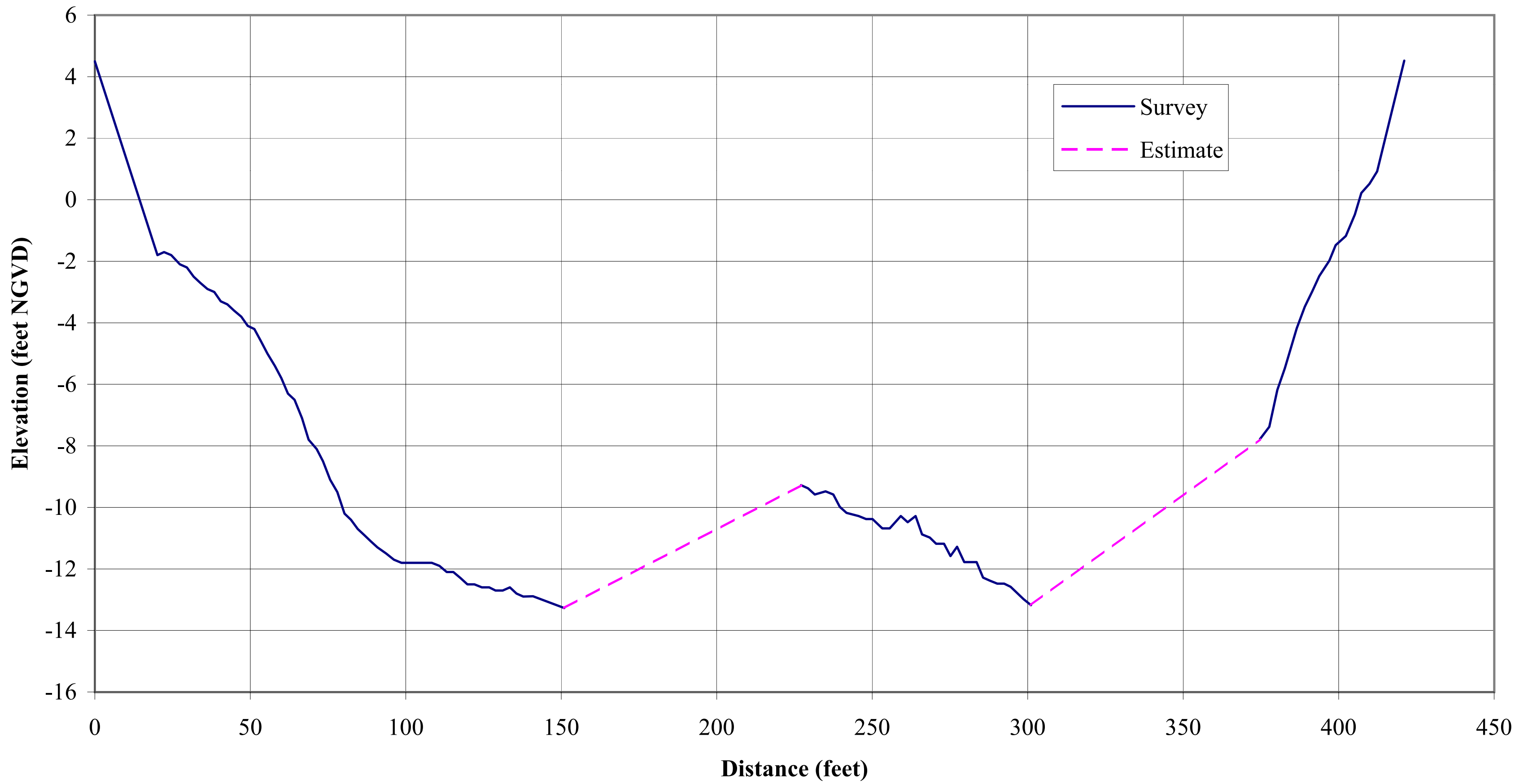
Source: Towill surveys (February 2000).

Bair Island

Cross Section 9

PWA

PWA #:1413



Source: Towill surveys (February 2000).

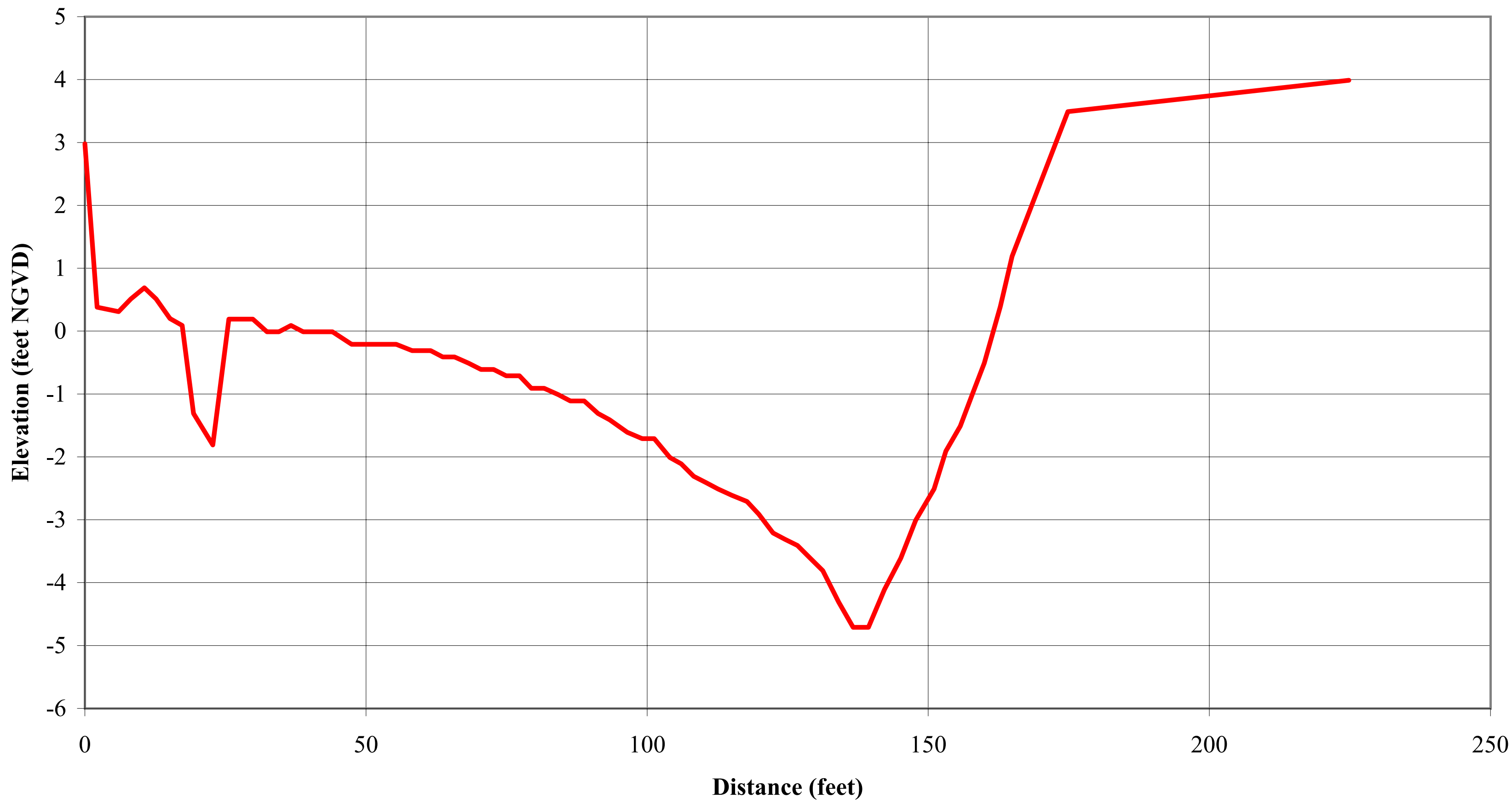
Note: Parts of the cross-section could not be surveyed because of obstructions (anchored boats). These parts of the cross-section are estimted.

Bair Island

Cross Section 10

PWA

PWA #:1413



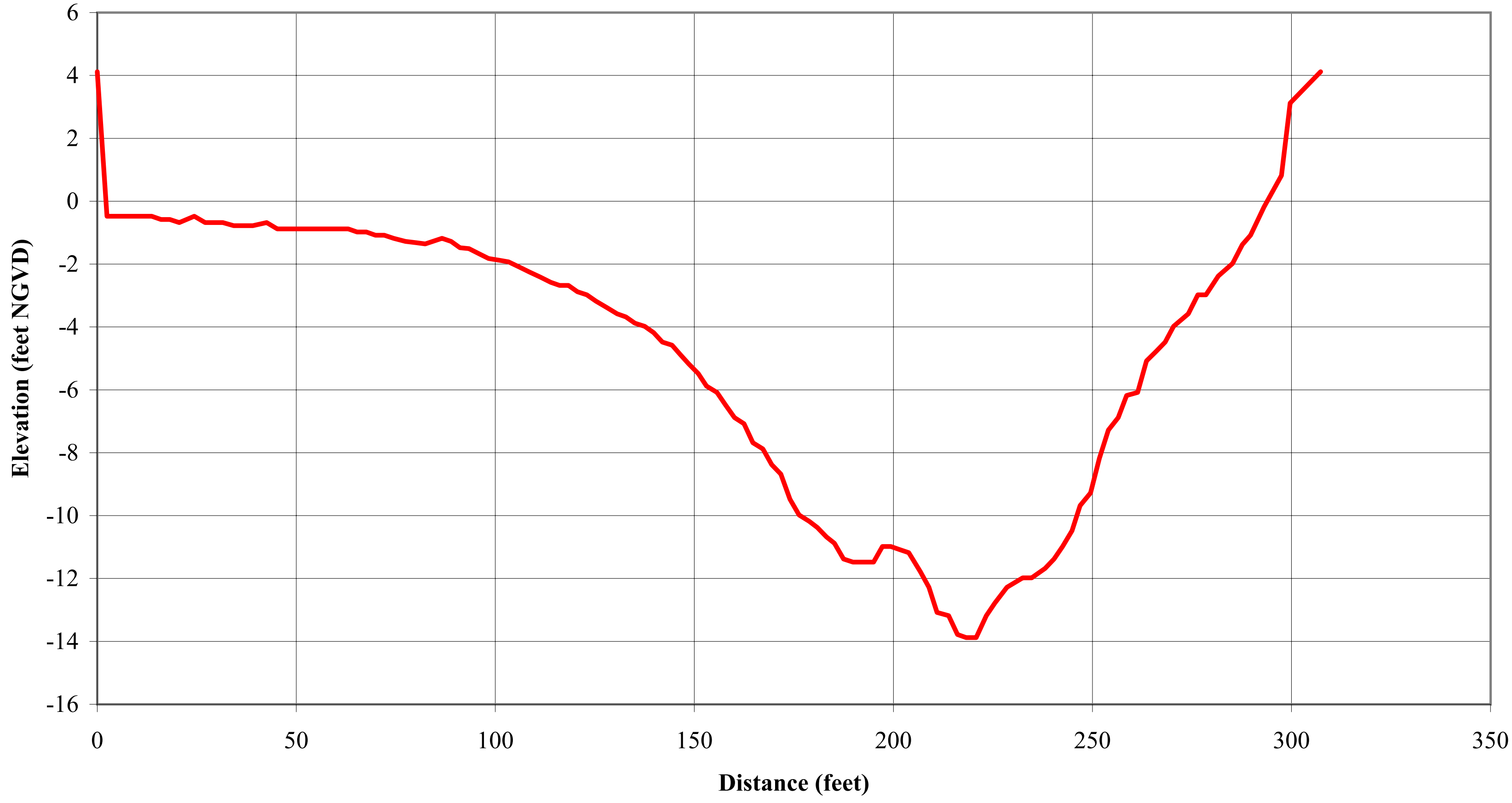
Source: Towill surveys (February 2000).

Bair Island

Cross Section 11

PWA

PWA #:1413



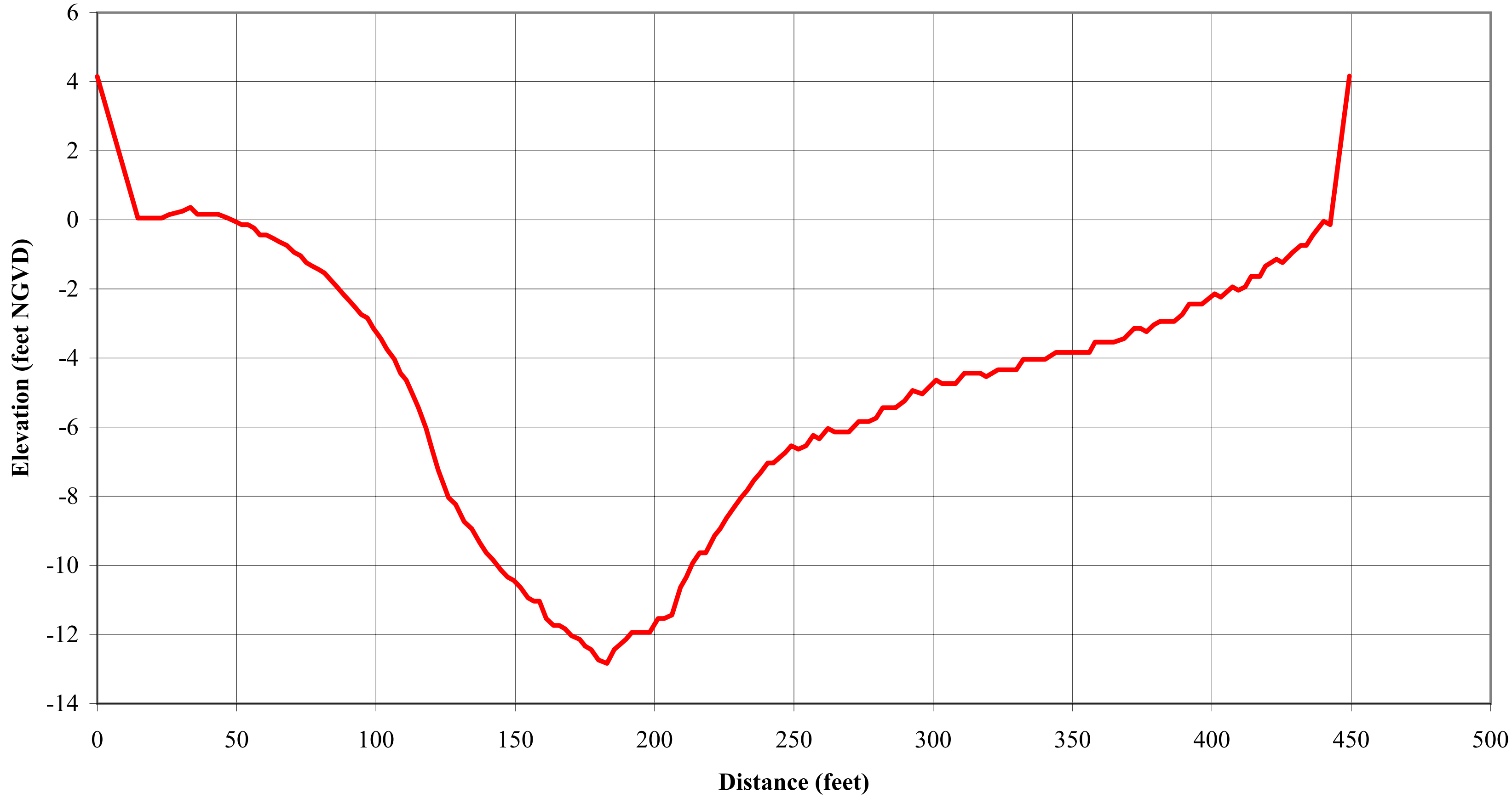
Source: Towill surveys (February 2000).

Bair Island

Cross Section 12

PWA

PWA #:1413



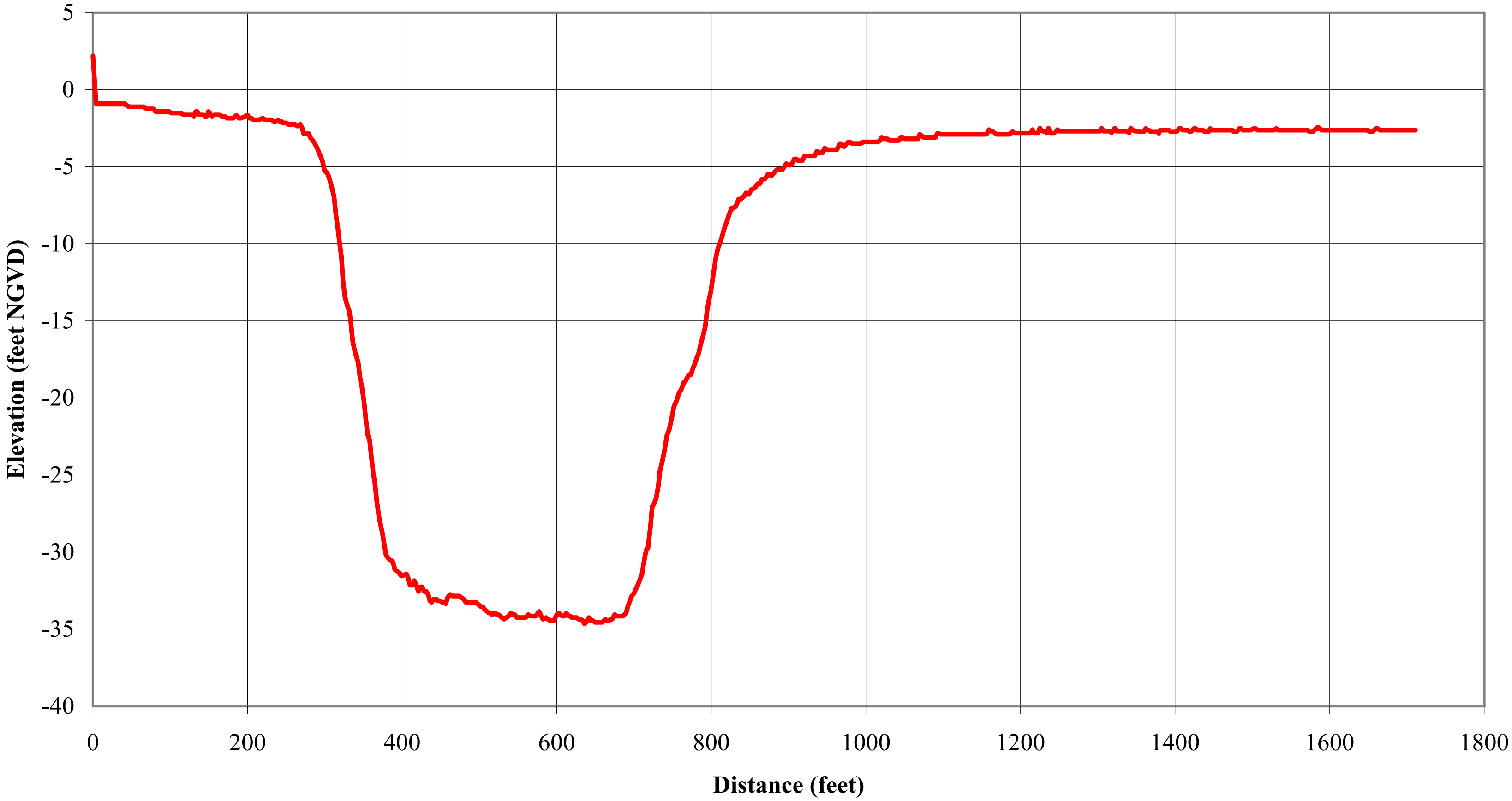
Source: Towill surveys (February 2000).

Bair Island

Cross Section 13

PWA

PWA #:1413



Source: Towill surveys (February 2000).

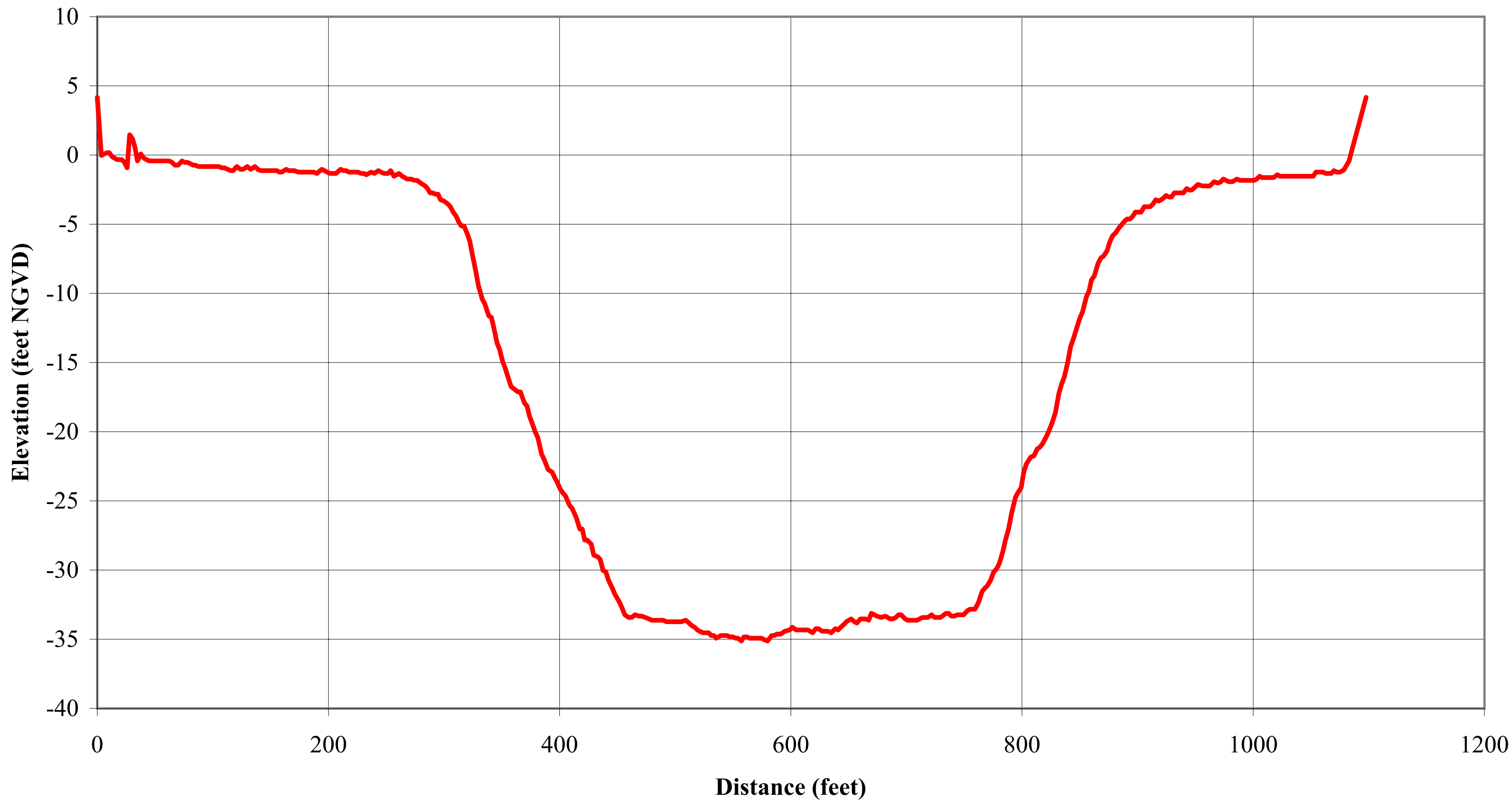
Bair Island

Cross Section 14

PWA

PWA #:1413

towillXS.xls 14 fig 2/6/04



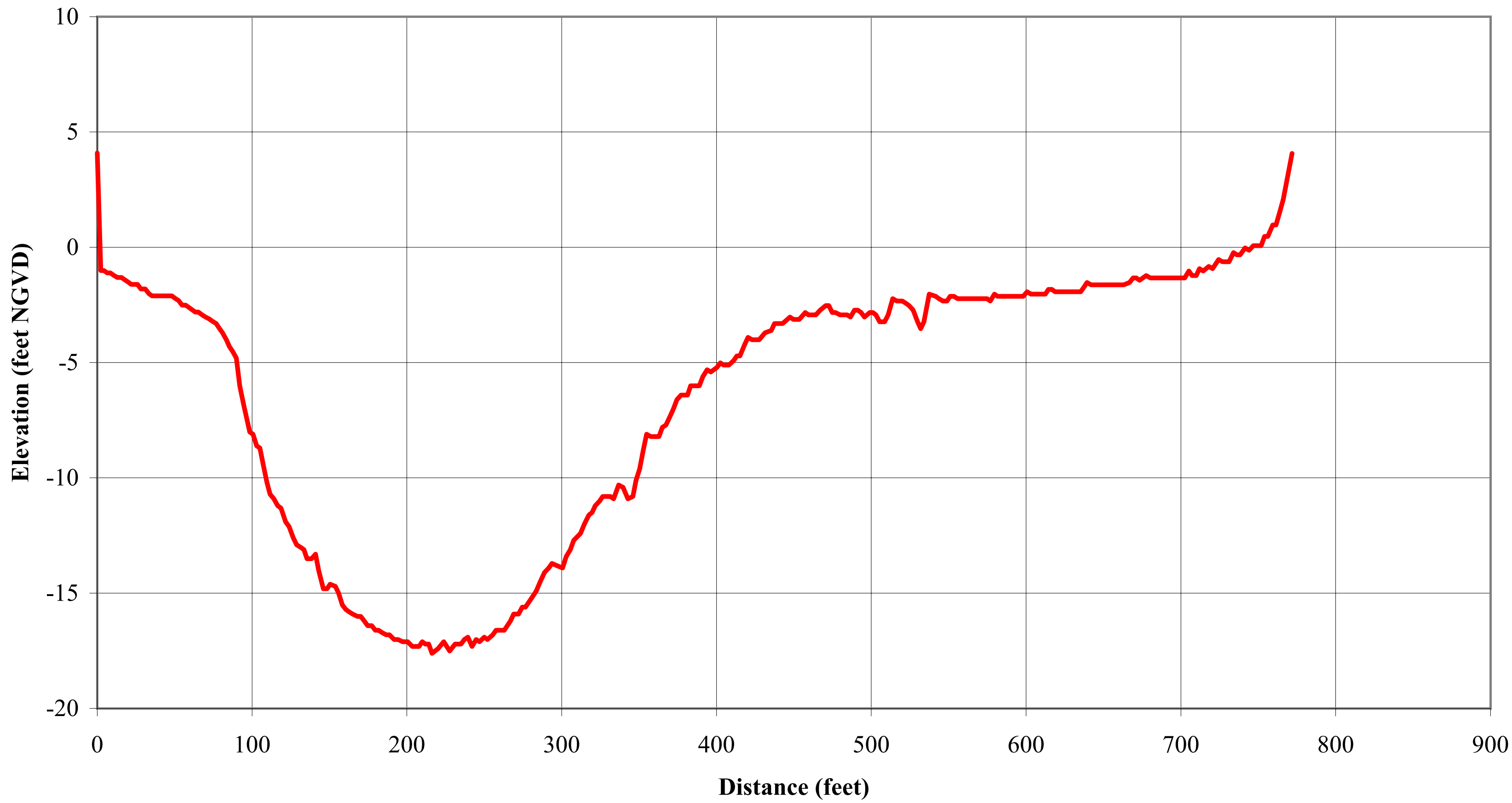
Source: Towill surveys (February 2000).

Bair Island

Cross Section 15

PWA

PWA #:1413



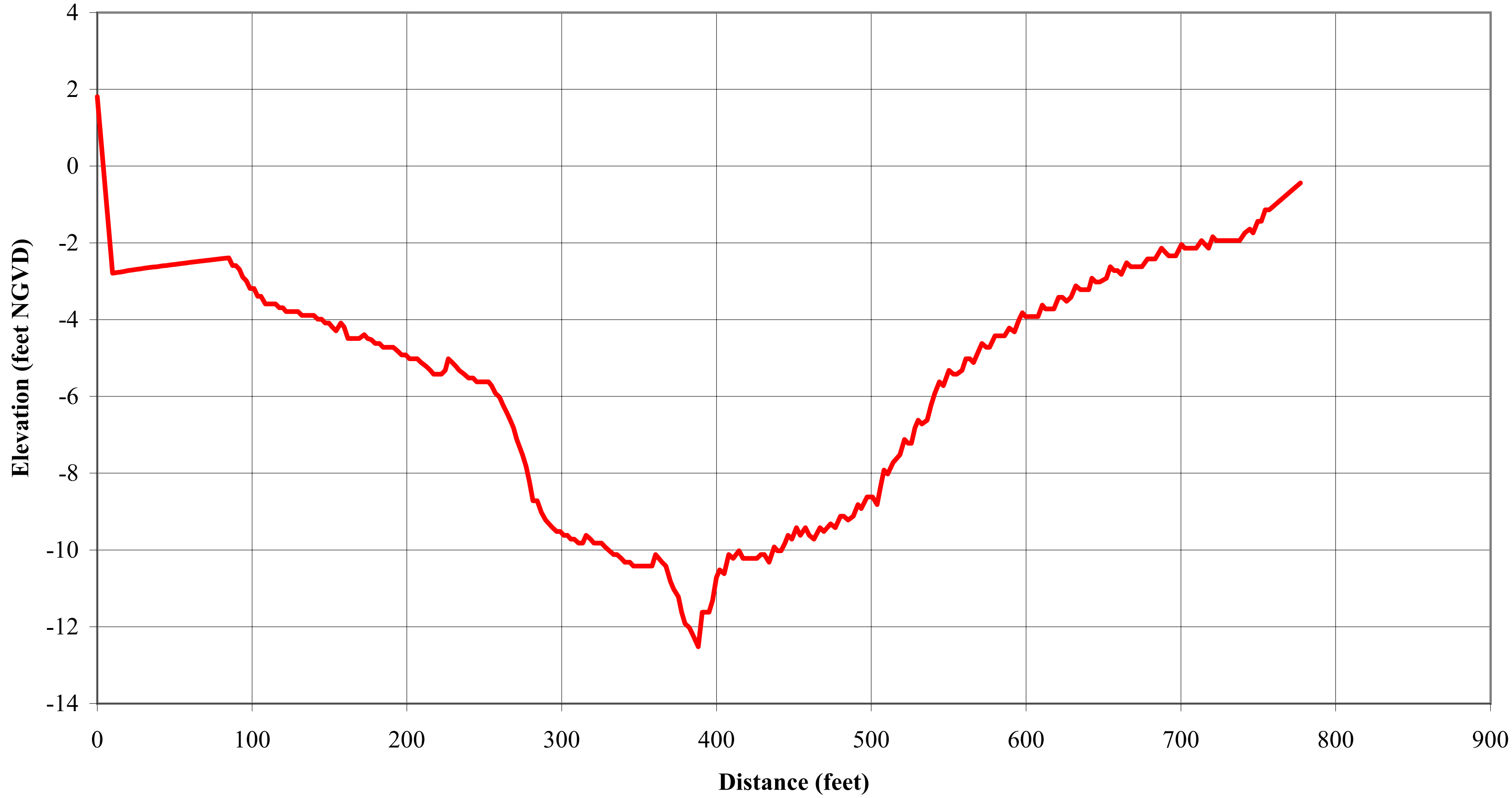
Source: Towill surveys (February 2000).

Bair Island

Cross Section 16

PWA

PWA #:1413



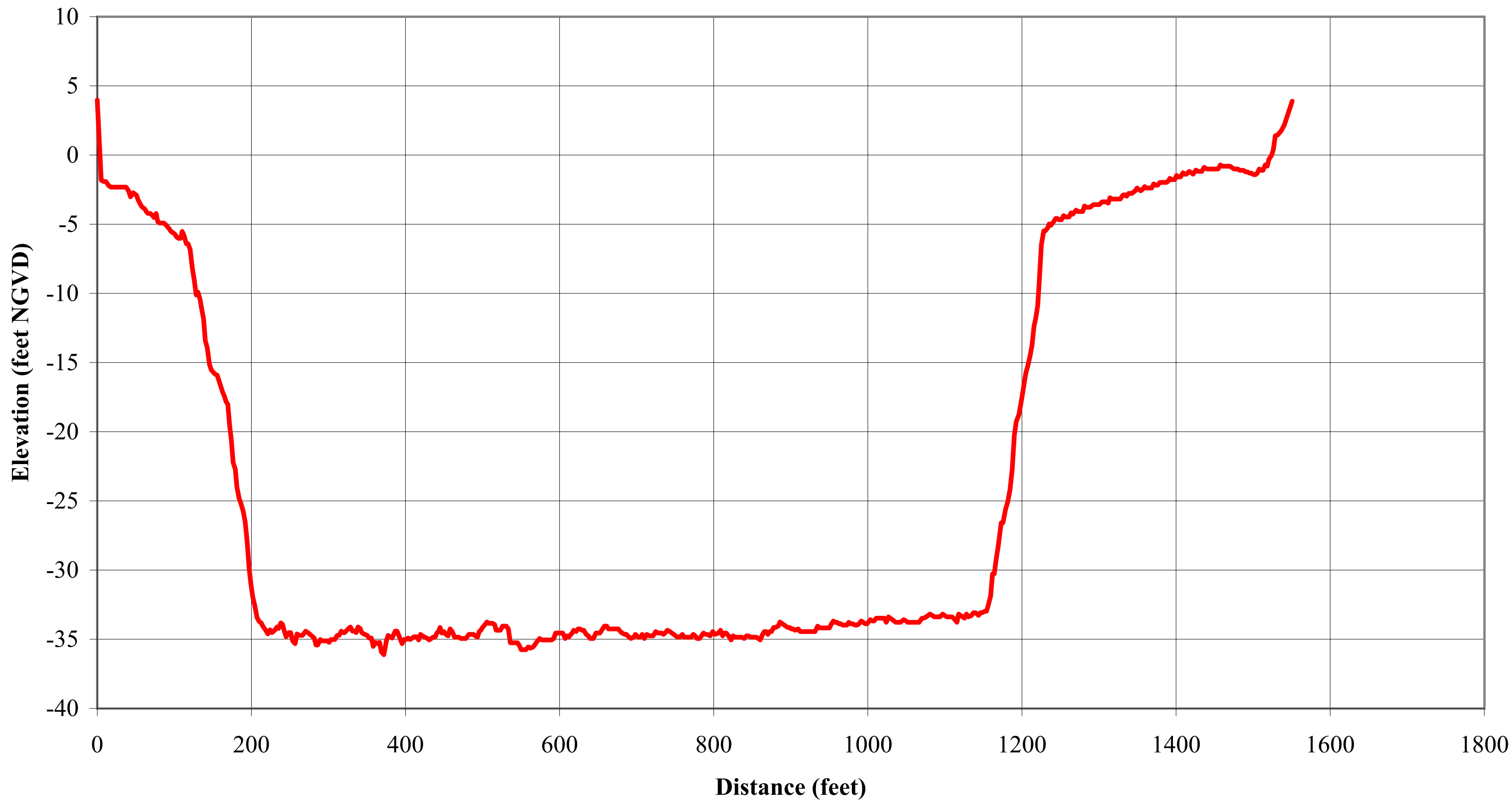
Source: Towill surveys (February 2000).

Bair Island

Cross Section 17

PWA

PWA #:1413



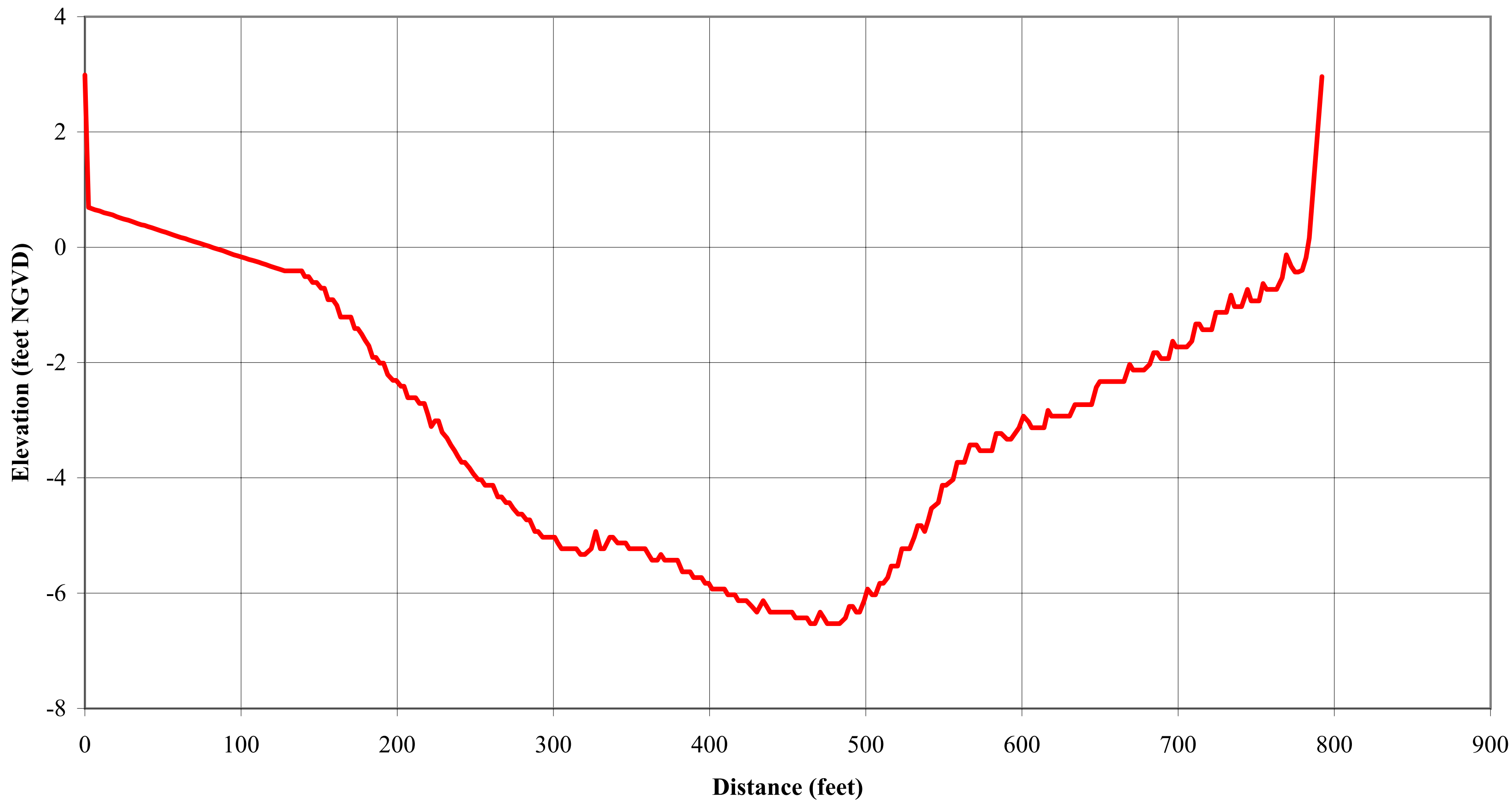
Source: Towill surveys (February 2000).

Bair Island

Cross Section 18

PWA

PWA #:1413



Source: Towill surveys (February 2000).

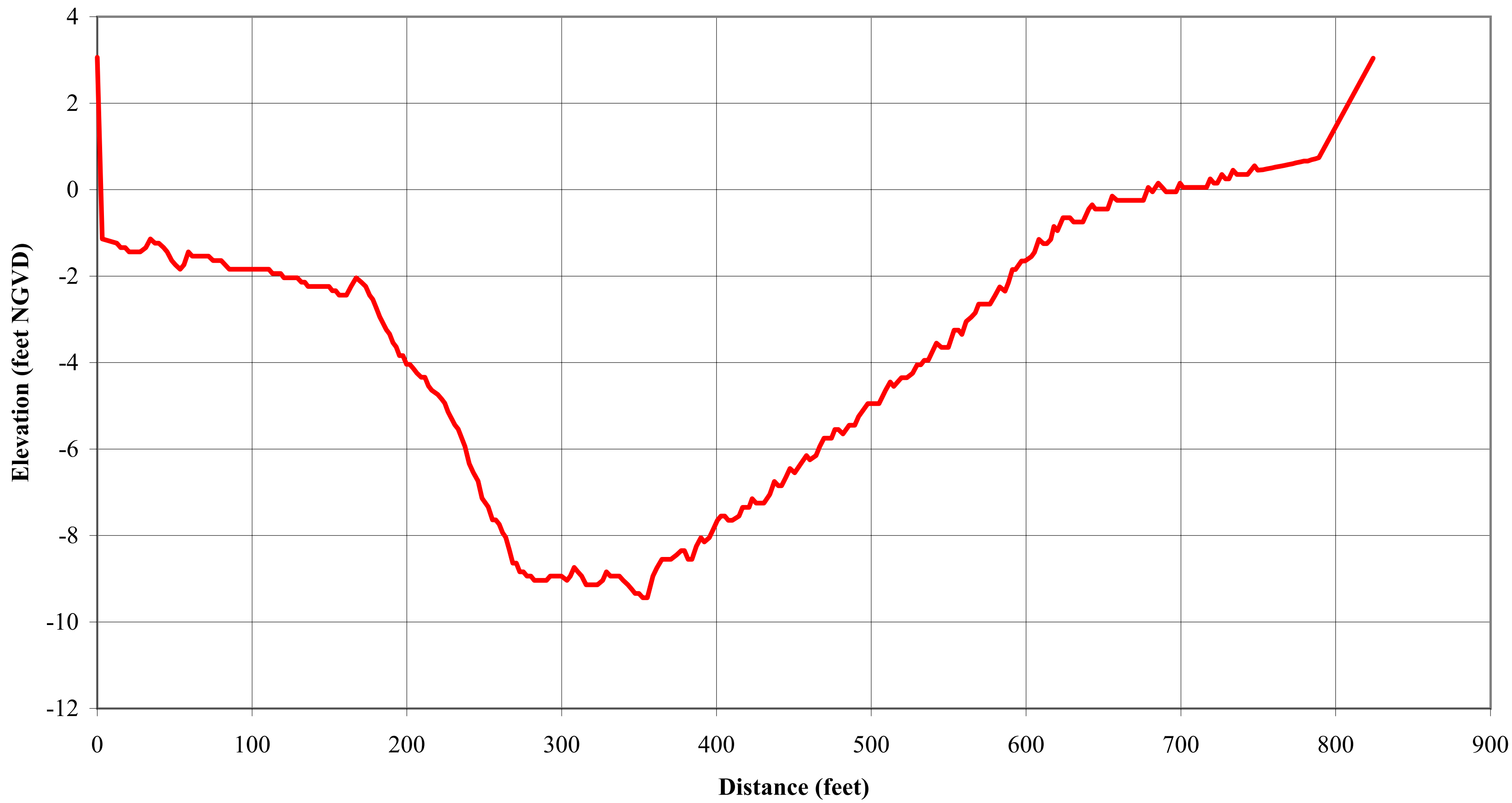
Bair Island

Cross Section 19

PWA

PWA #:1413

towillXS.xls 19 fig 2/6/04



Source: Towill surveys (February 2000).

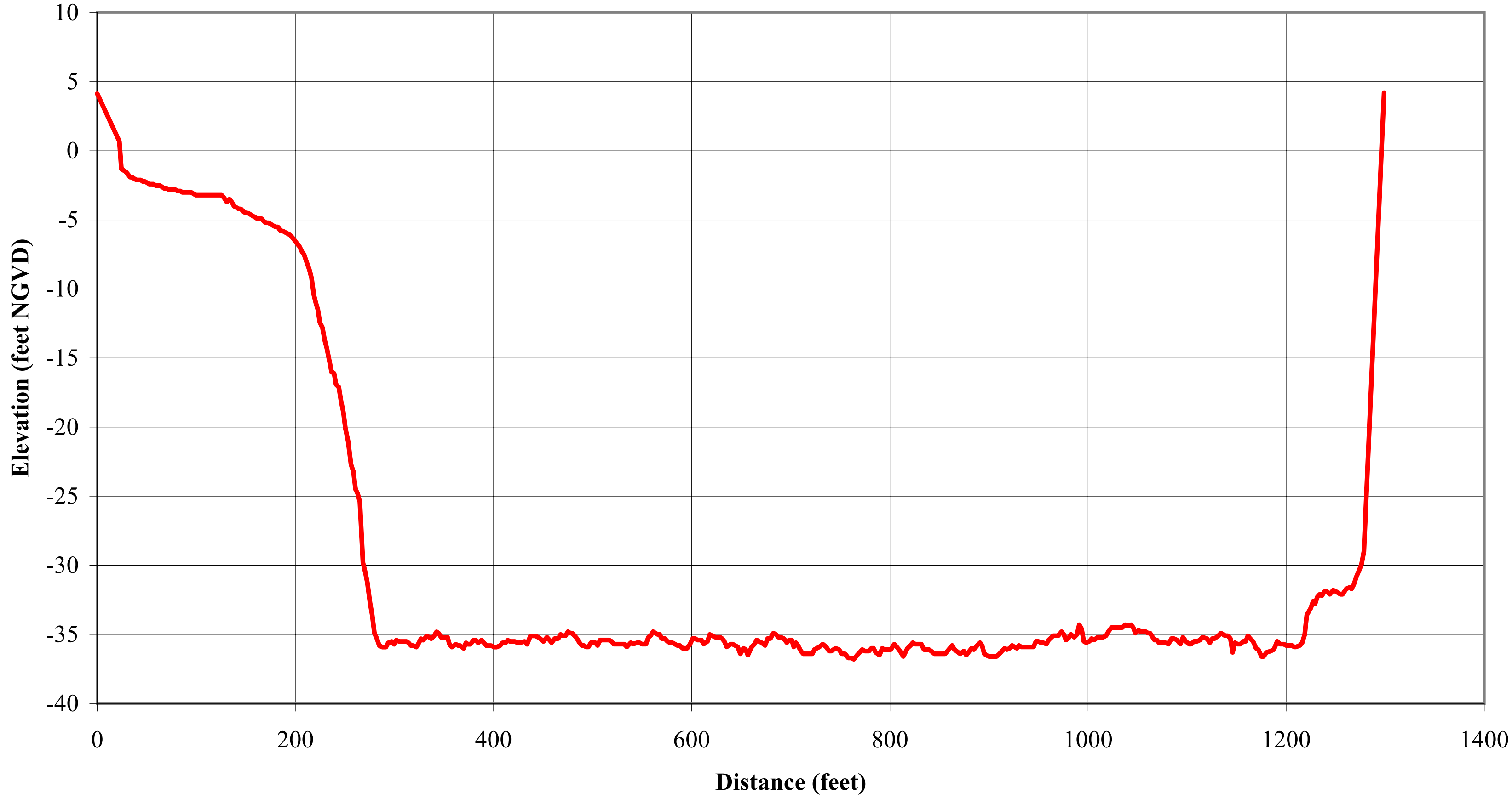
Bair Island

Cross Section 20

PWA

PWA #:1413

towillXS.xls 20 fig 2/6/04



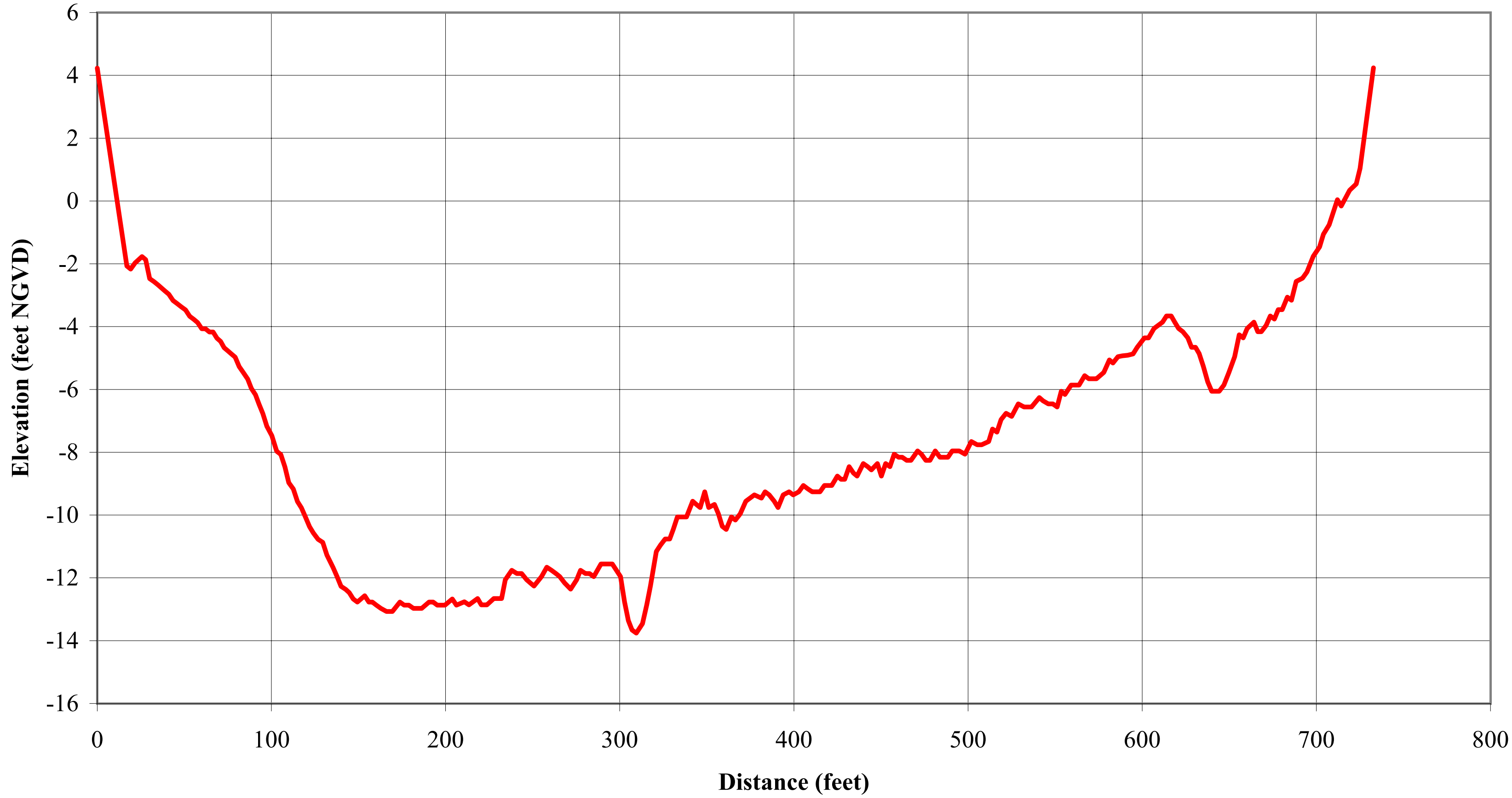
Source: Towill surveys (February 2000).

Bair Island

Cross Section 21

PWA

PWA #:1413



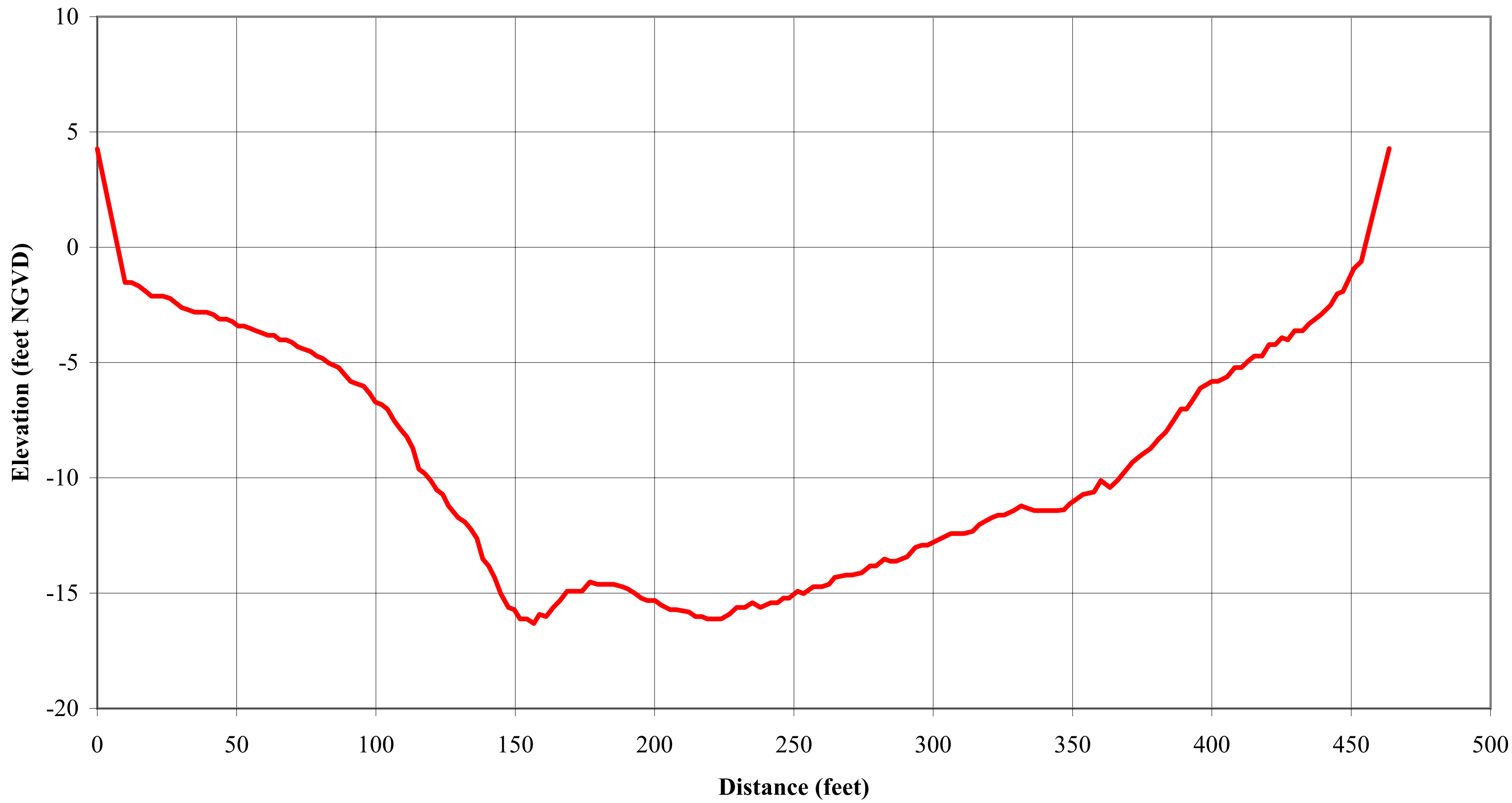
Source: Towill surveys (February 2000).

Bair Island

Cross Section 22

PWA

PWA #:1413



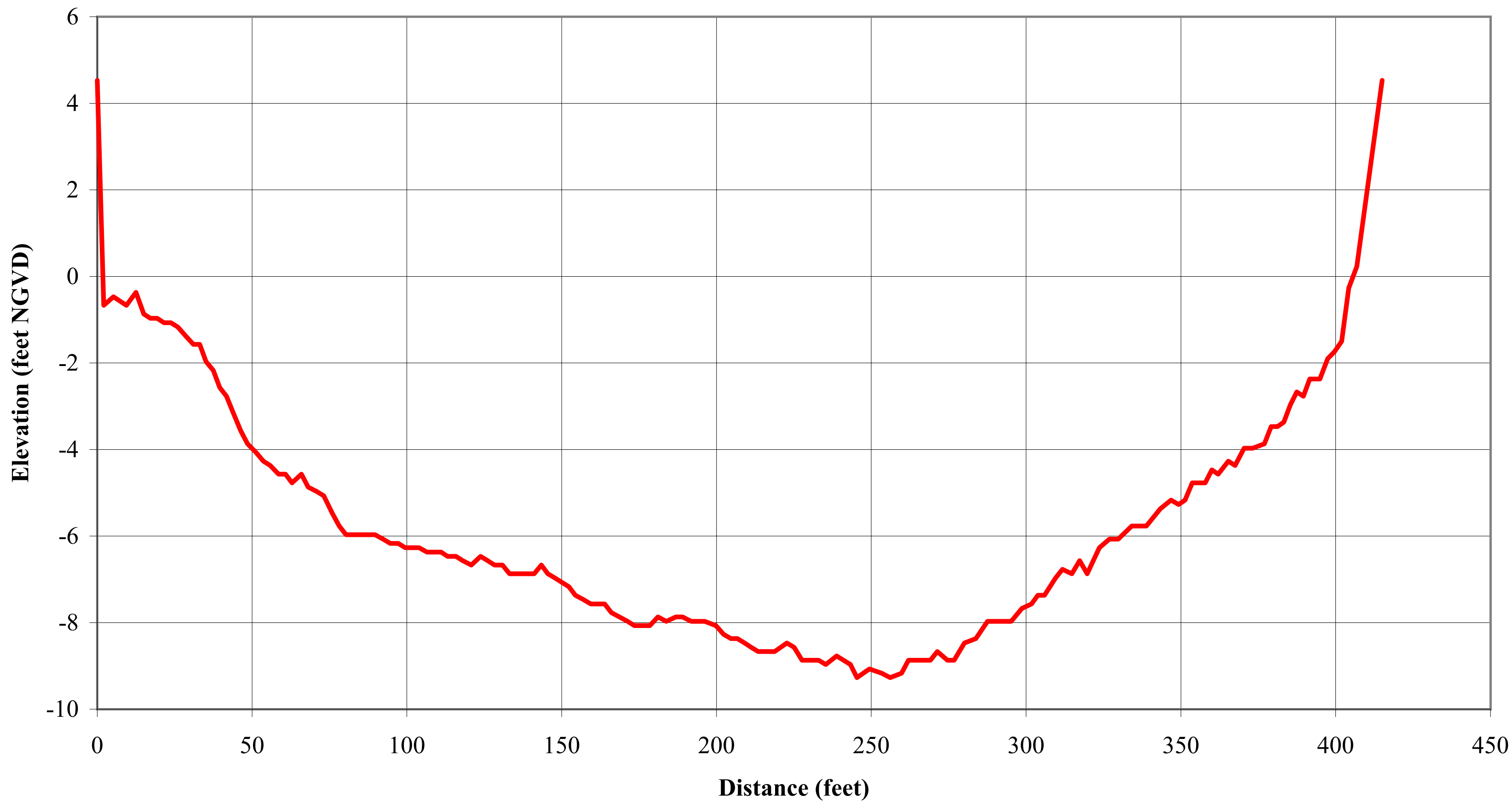
Source: Towill surveys (February 2000).

Bair Island

Cross Section 23

PWA

PWA #:1413



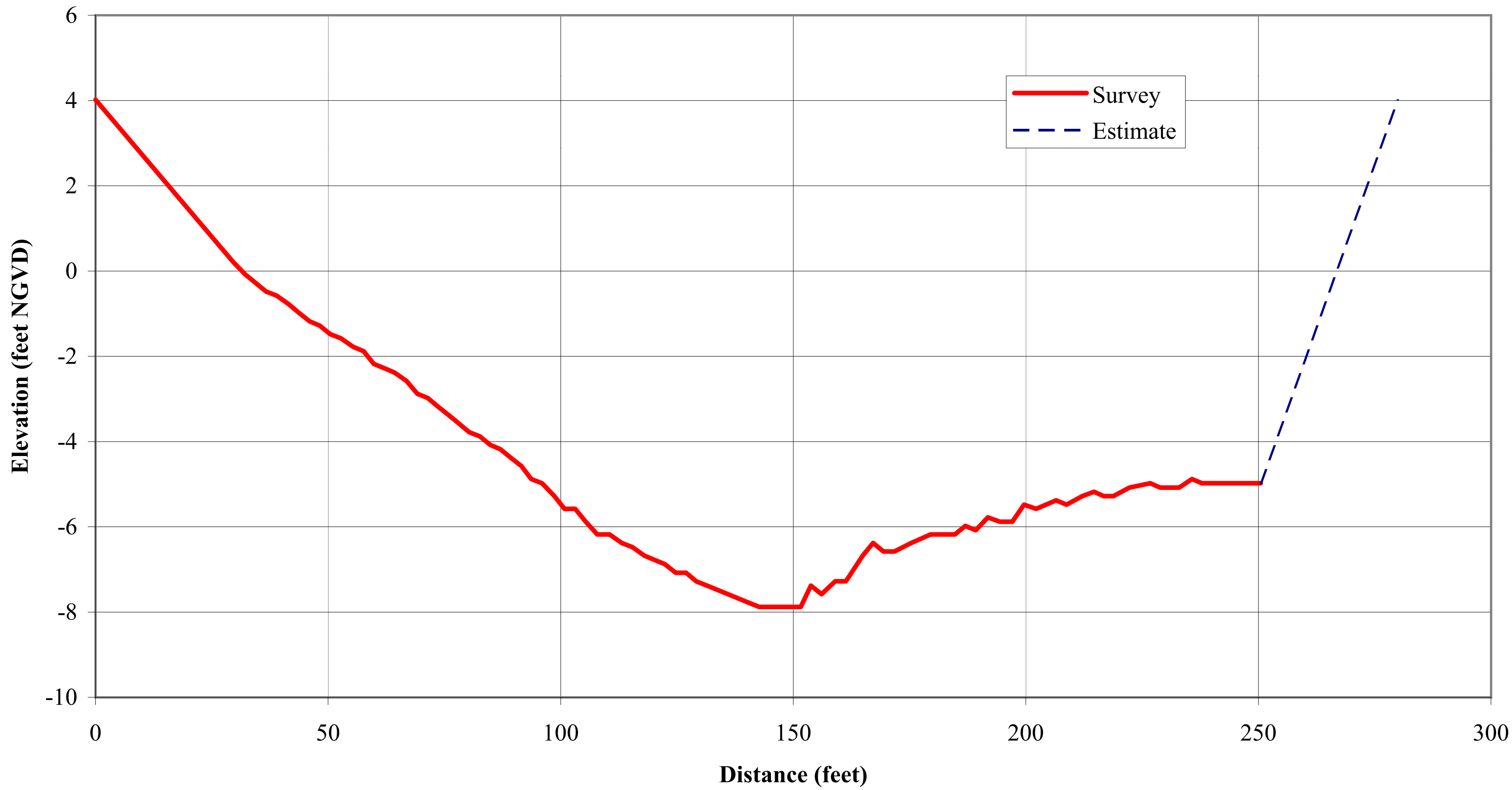
Source: Towill surveys (February 2000).

Bair Island

Cross Section 24

PWA

PWA #:1413



Source: Towill surveys (February 2000).

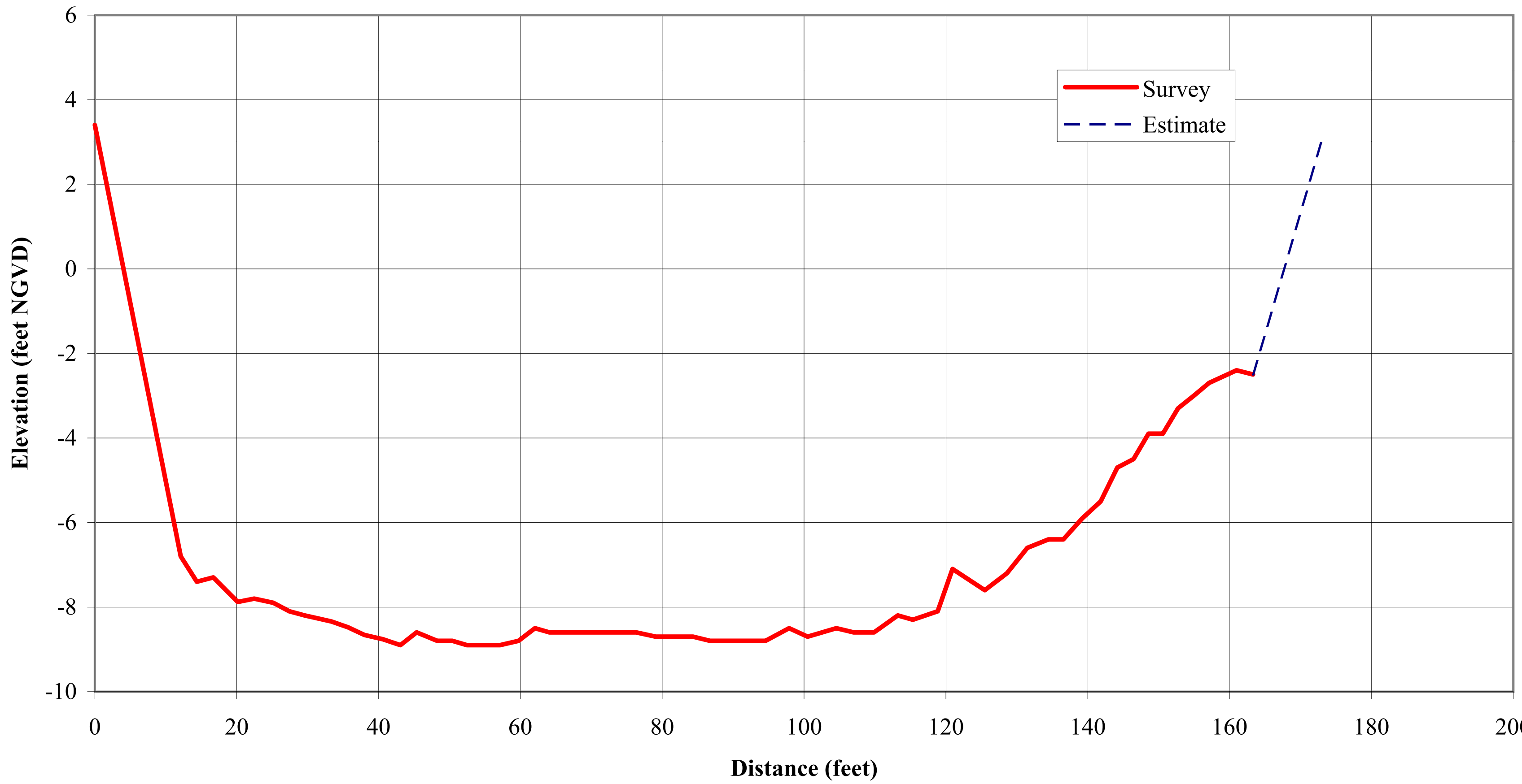
Bair Island

Cross Section 25

PWA

PWA #:1413

towillXS.xls 25 fig 2/6/04



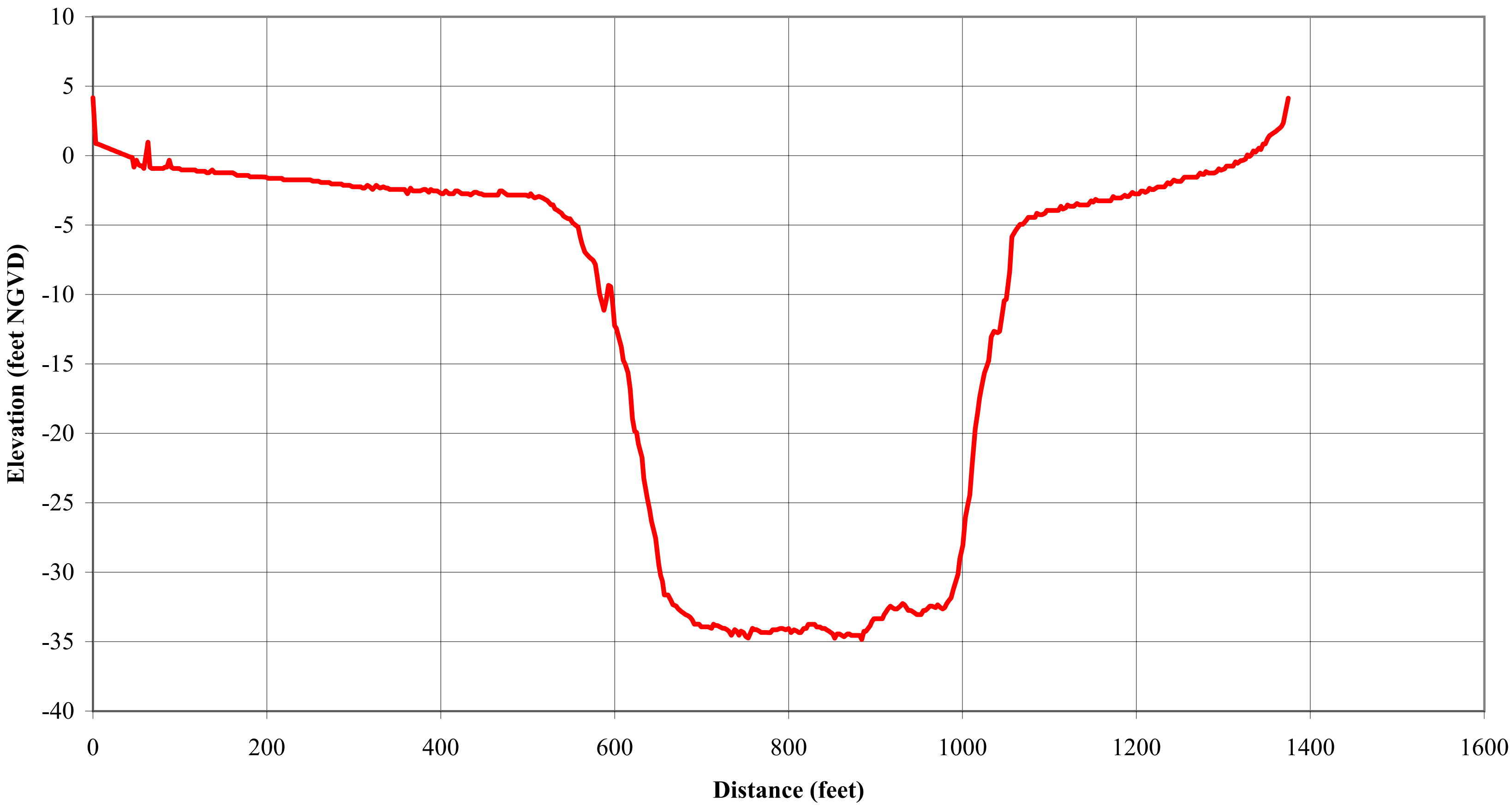
Source: Towill surveys (February 2000).

Bair Island

Cross Section 26

PWA

PWA #:1413



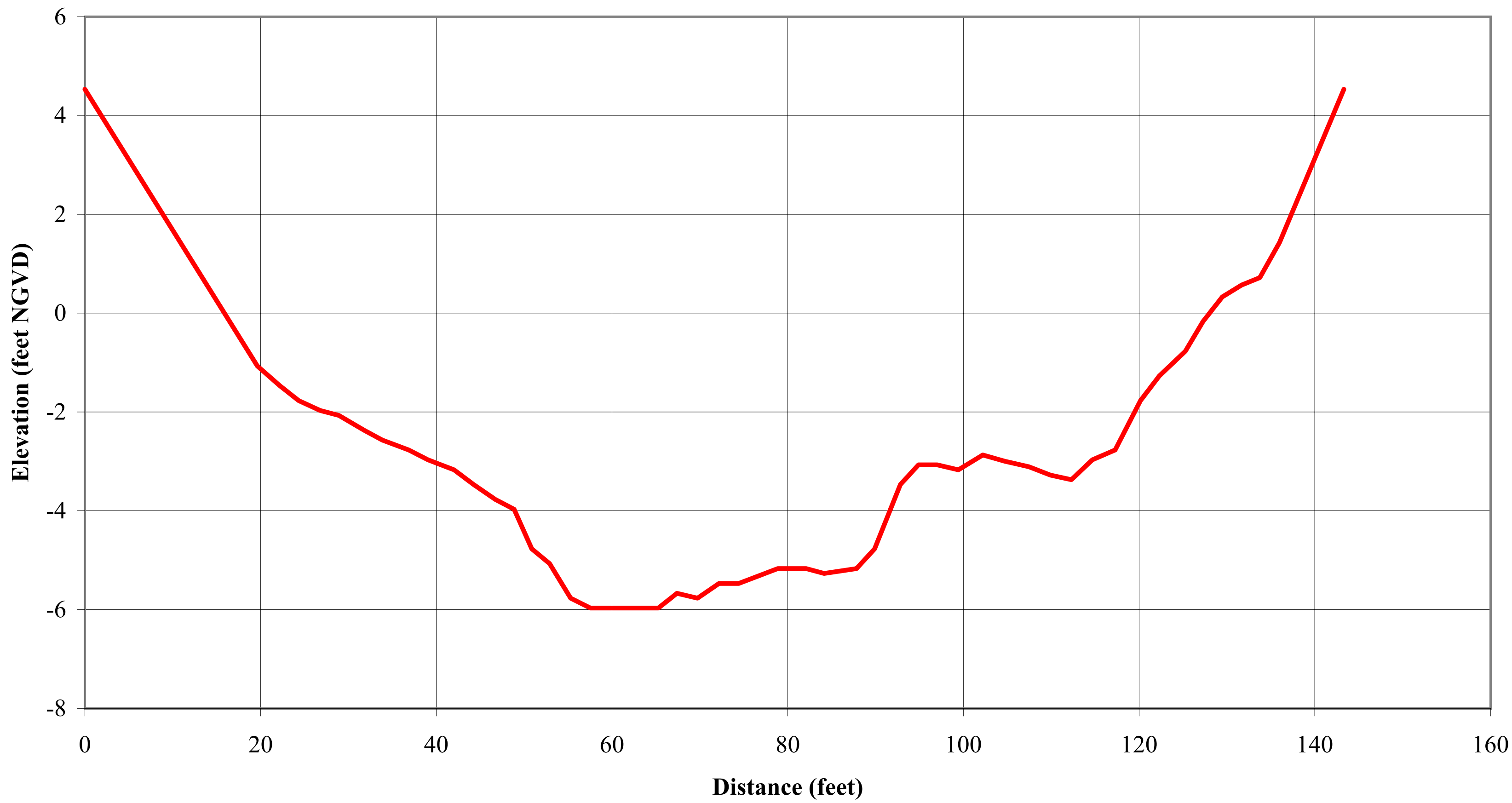
Source: Towill surveys (February 2000).

Bair Island

Cross Section 27

PWA

PWA #:1413



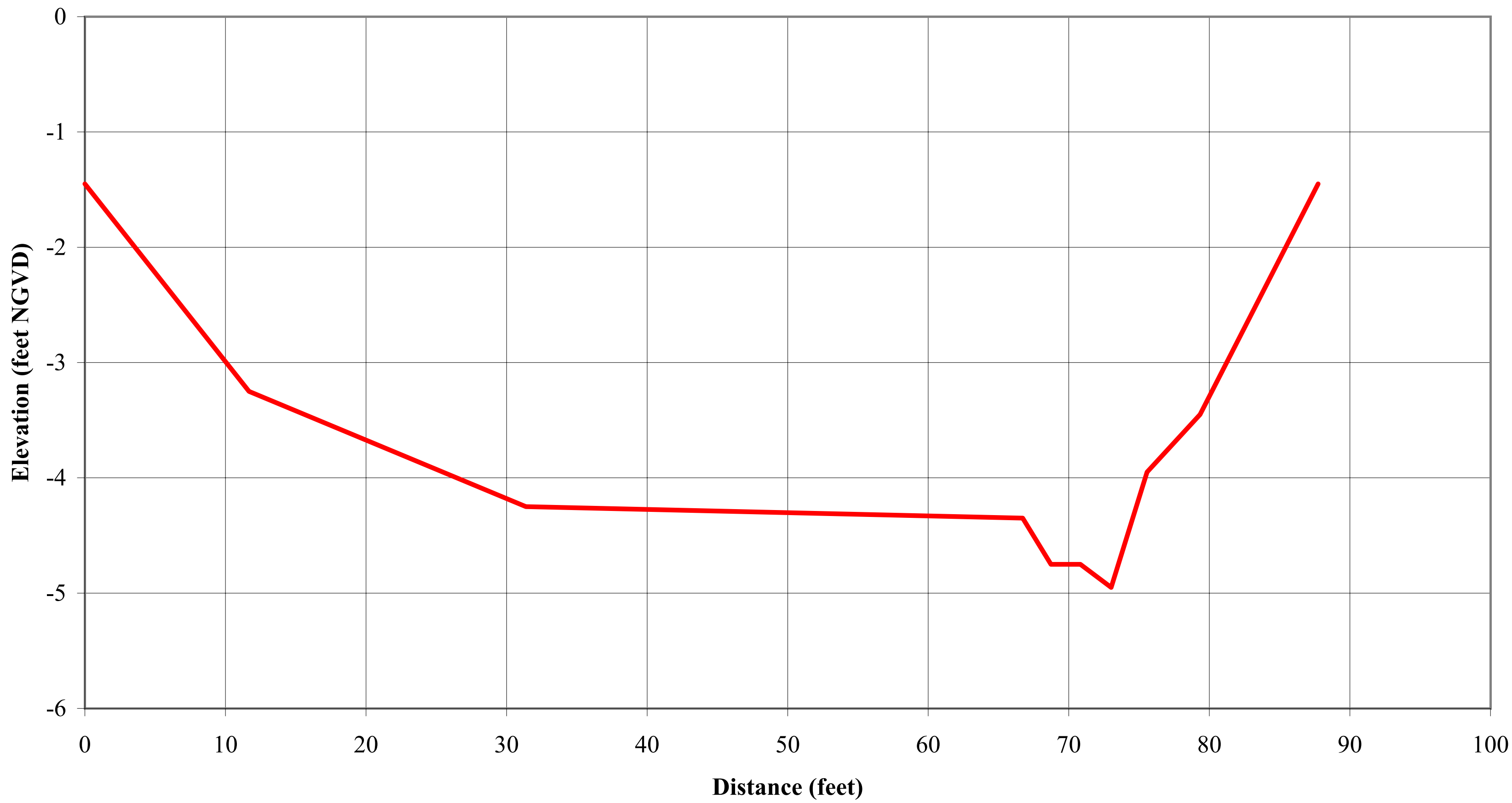
Source: Towill surveys (February 2000).

Bair Island

Cross Section 28

PWA

PWA #:1413



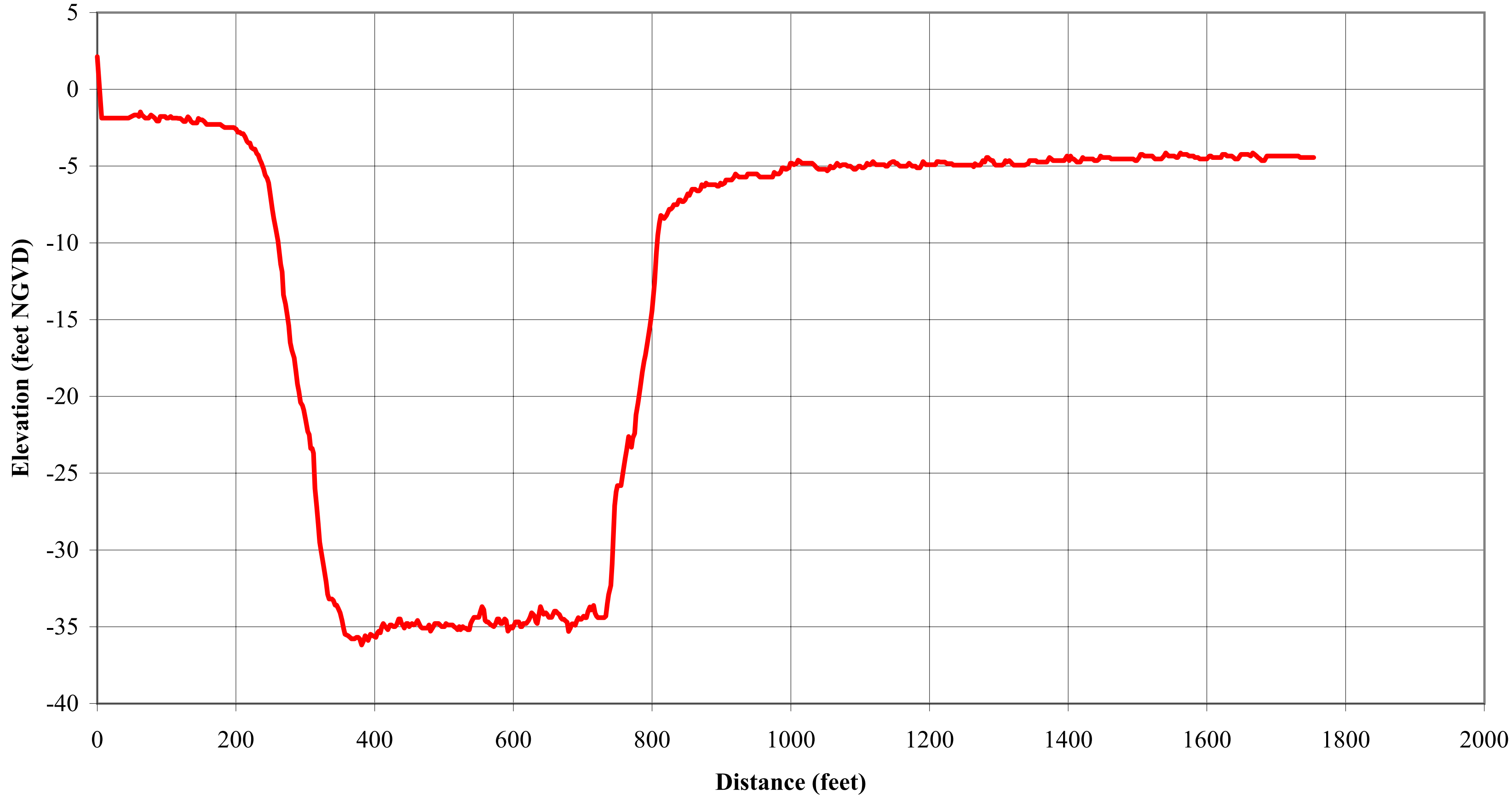
Source: Towill surveys (February 2000).

Bair Island

Cross Section 29

PWA

PWA #:1413



Source: Towill surveys (February 2000).

Bair Island

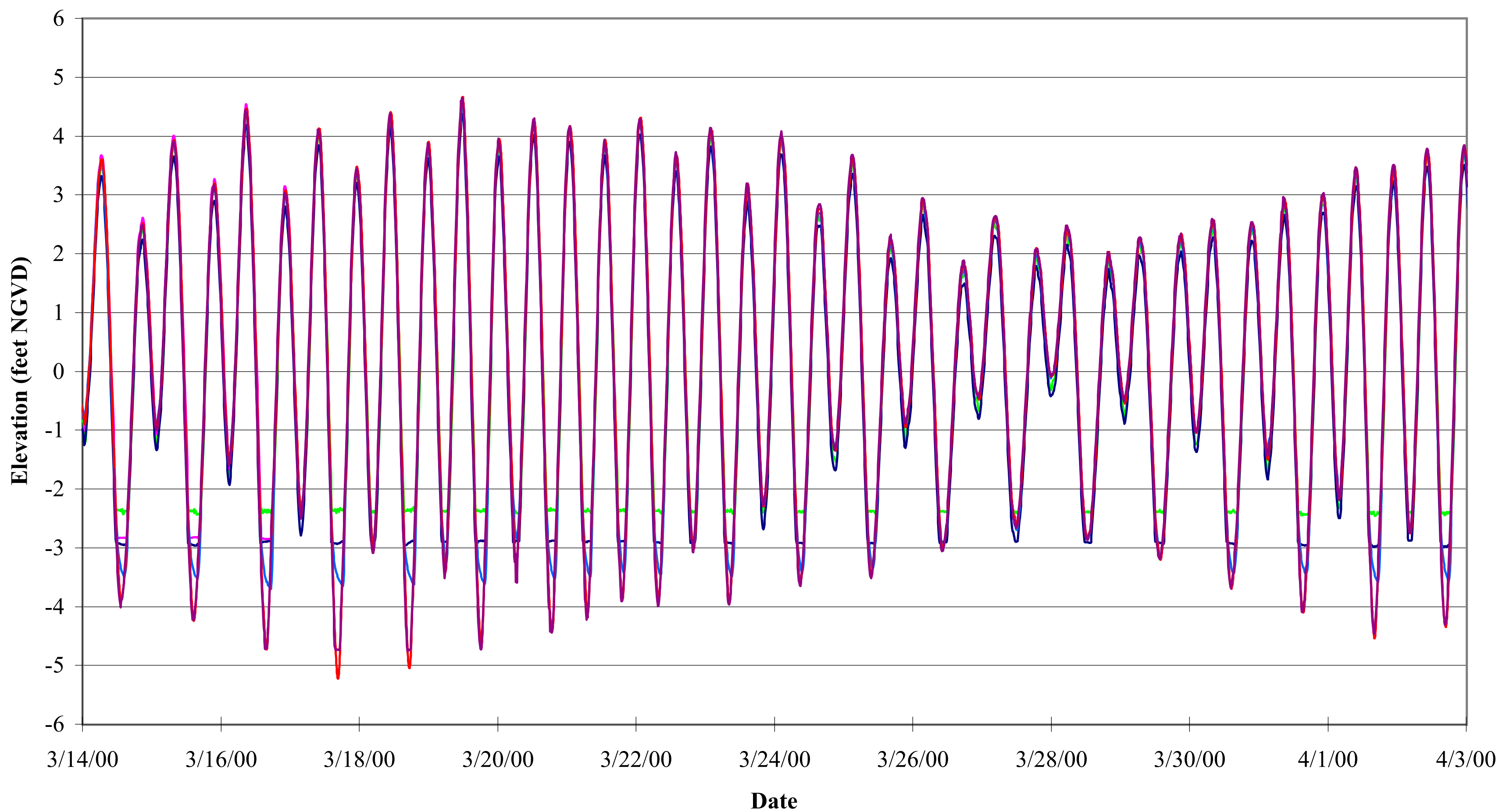
Cross Section 30

PWA

PWA #:1413

APPENDIX A
FIELD SURVEYS

A-5 Tide measurements for 6 stations



Corkscrew Slough
Smith Slough Marina
Redwood Creek Wharf 5
Steinberger Slough Pilings at Airport
Steinberger Slough Power Tower
Redwood Creek Channel Marker 8

Source: PWA field surveys (this study) and NOS (2000)

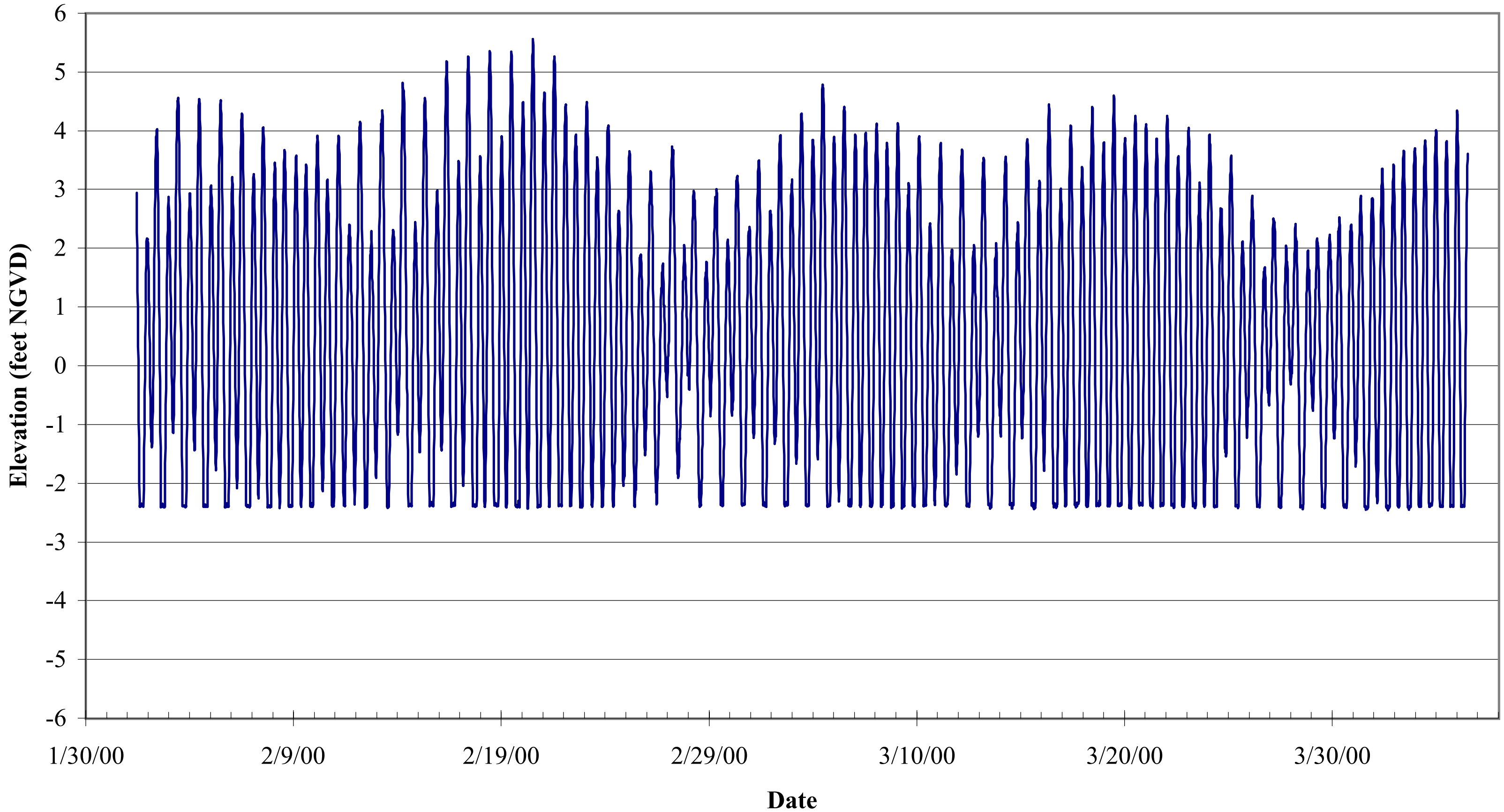
Bair Island

All Tidal Monitoring Stations from March 14 to April 3, 2000

PWA

PWA #: 1413

Projects\1413_Bair_orig\Task2+7_PWA\surveys\tidesall tides june2000.xls all chart 2/6/04



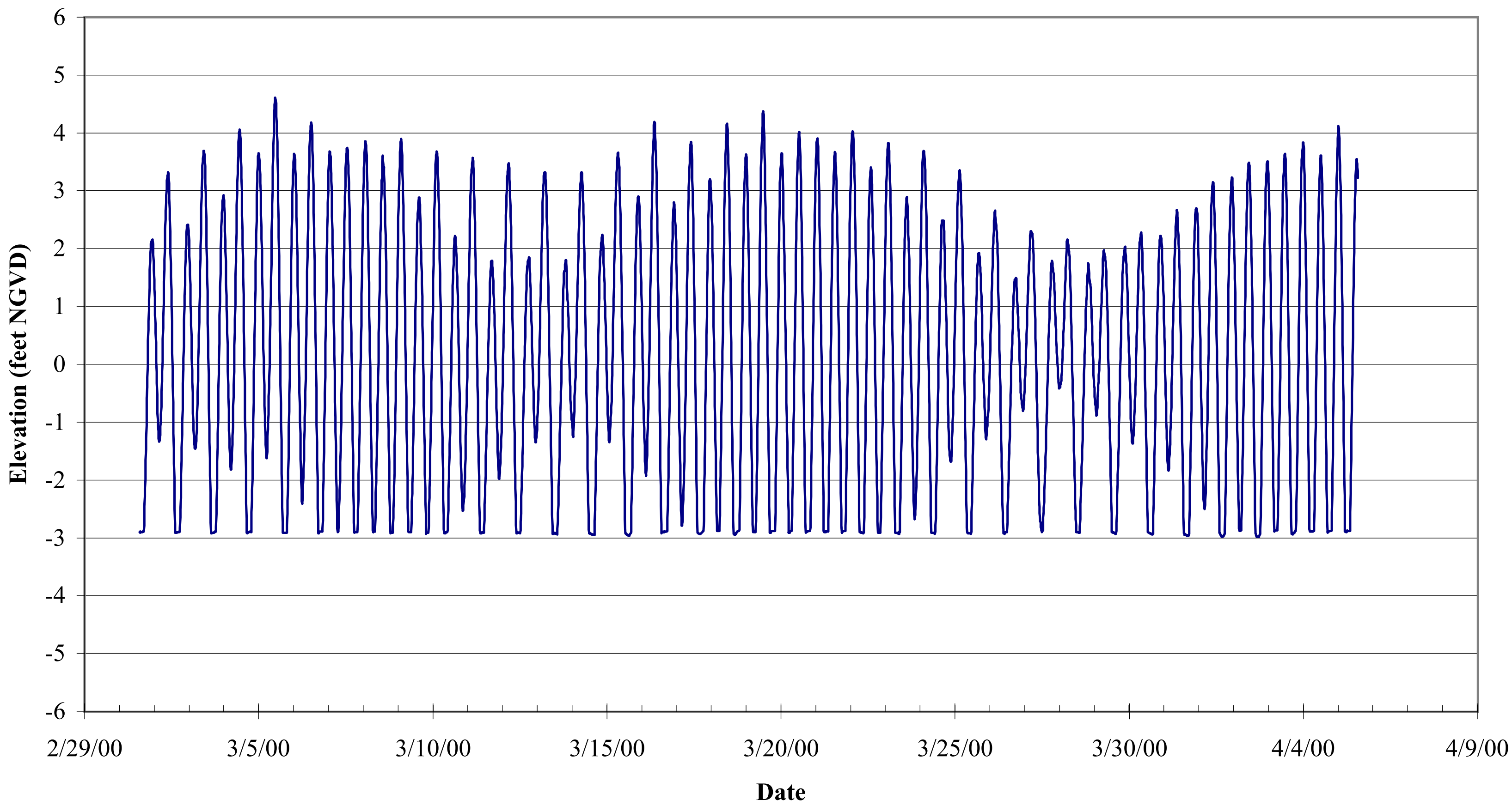
Source: PWA field surveys.

Bair Island

Corkscrew Slough
from February 1 to April 5, 2000

PWA

PWA #: 1413



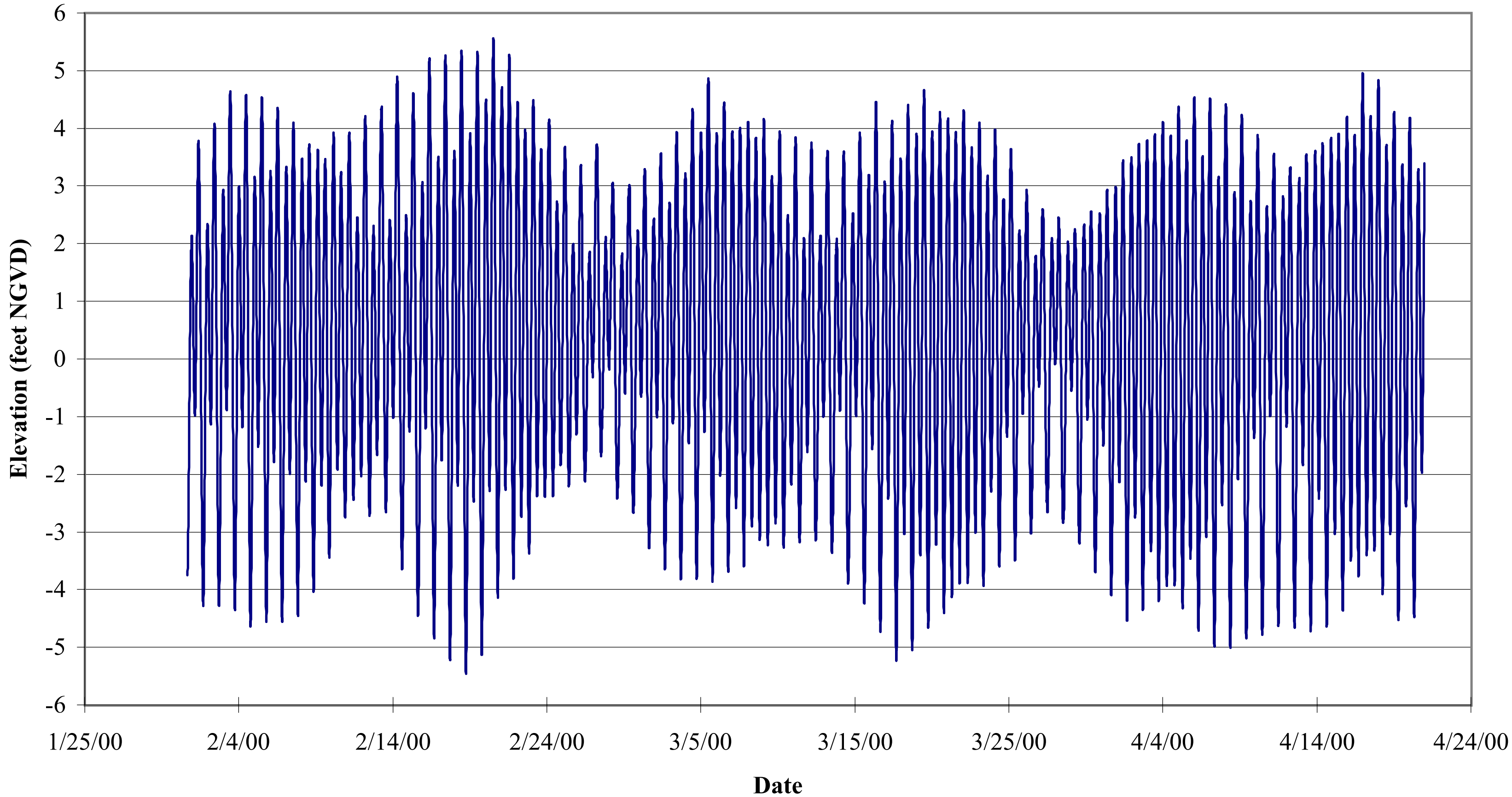
Source: PWA field surveys.

Bair Island

Smith Slough near Pete's Marina from March 1 to April 5, 2000

PWA

PWA #: 1413



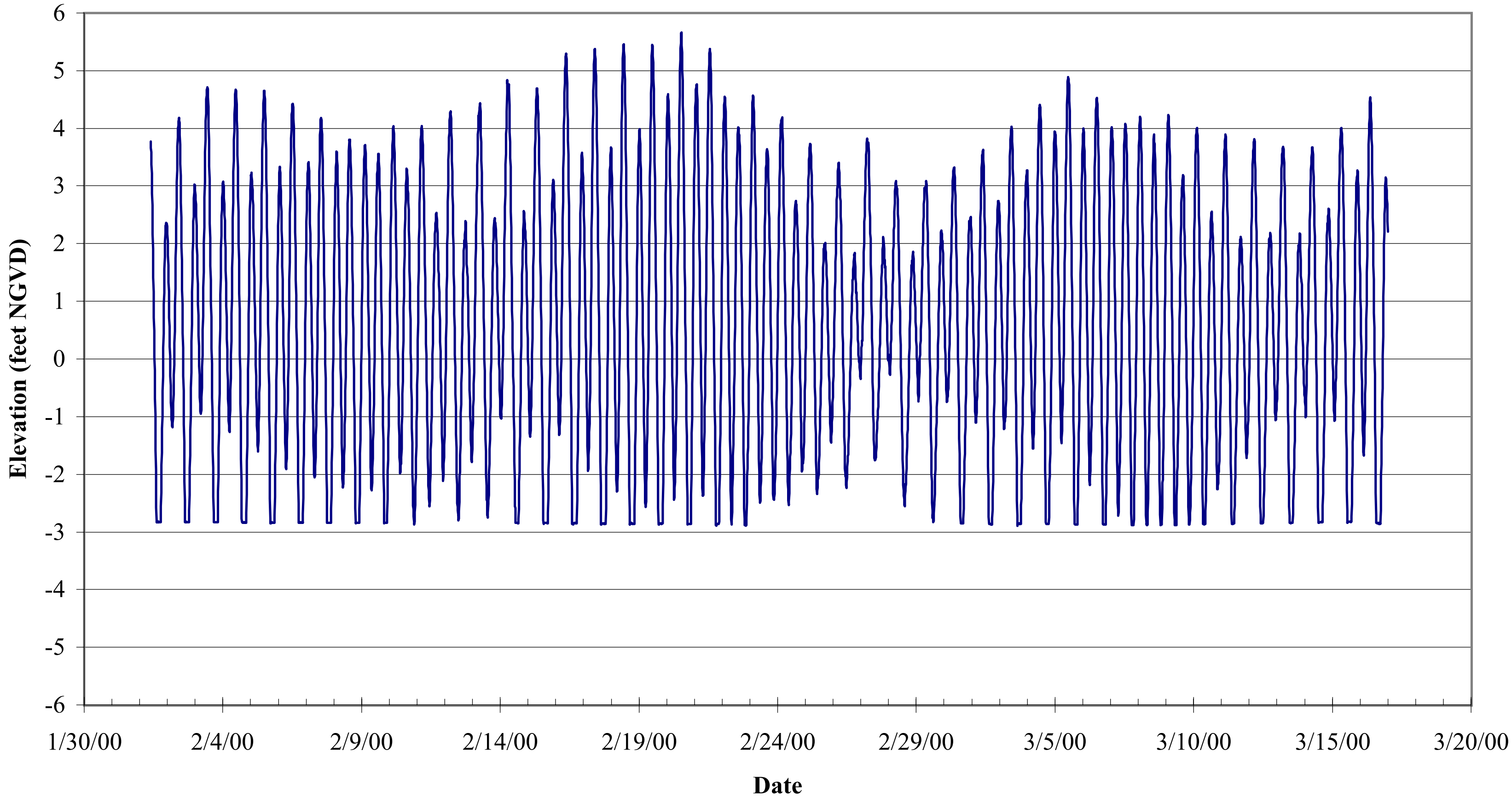
Source: NOS 2000 and PWA survey (this study).
Note: Tide elevations relative to MLLW are from NOS (2000) at Station 9414523 (Redwood City Wharf 5). Tidal datum conversion from MLLW to NGVD (-4.12 feet) is based on PWA field survey . Other methods of estimating the conversion based on previous published conversion values (NOS 1983) and published benchmark elevation data (NGS 2000) yield different conversion estimates.

Bair Island

Wharf 5 on Redwood Creek from February 1 to April 20, 2000

PWA | PWA #: 1413

Projects\1413_Bair_orig\Task2+7_PWAsurveys\tides \ all tides june2000.xls wharf5 chart 2/6/04



Source: PWA field surveys.

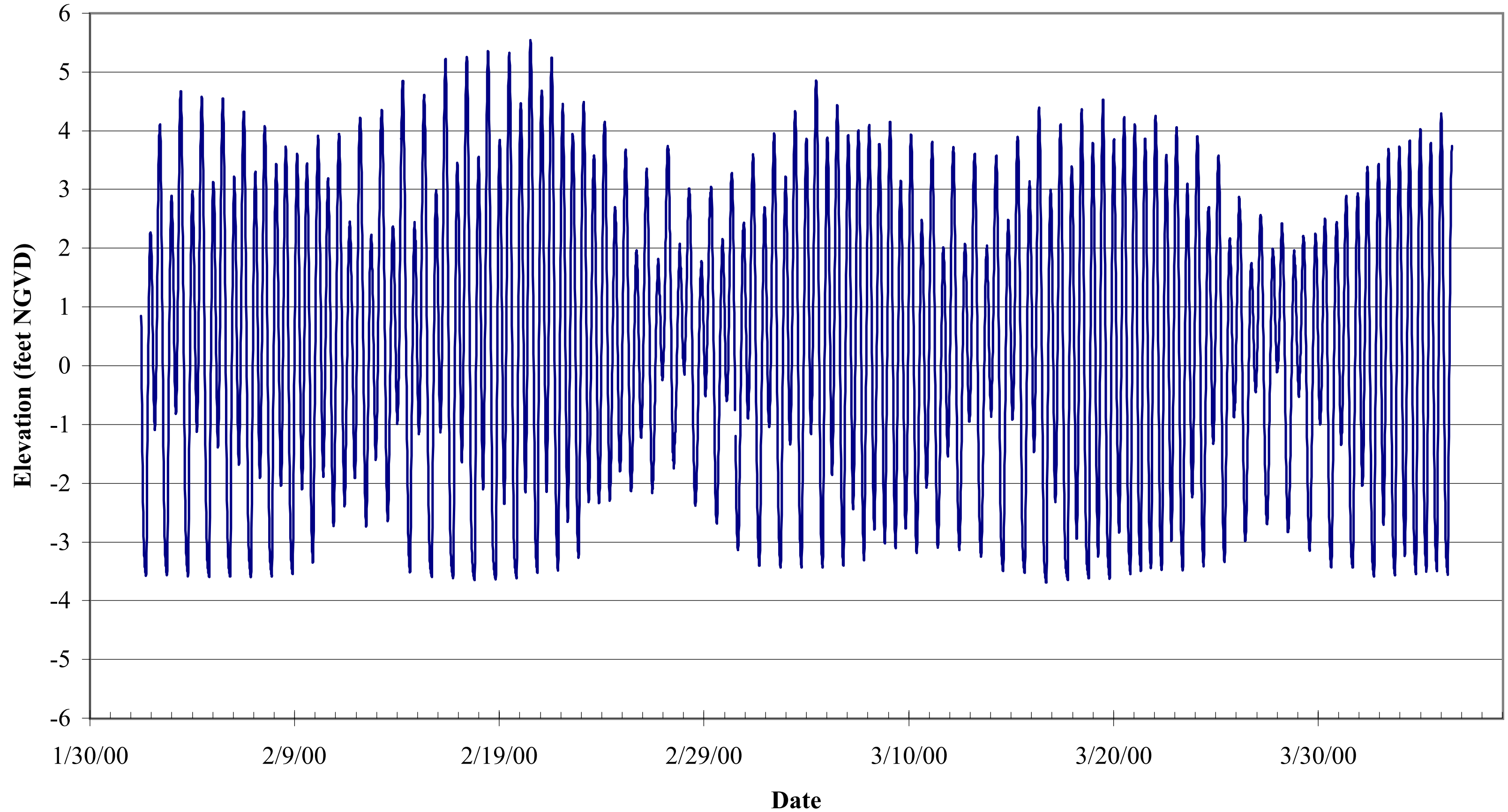
Bair Island

Steinberger Slough Pilings at Airport from February 1 to March 16, 2000

PWA

PWA #: 1413

Projects\1413_Bair_orig\Task2+7_PWAsurveys\tides \ all tides june2000.xls piling chart 2/6/04



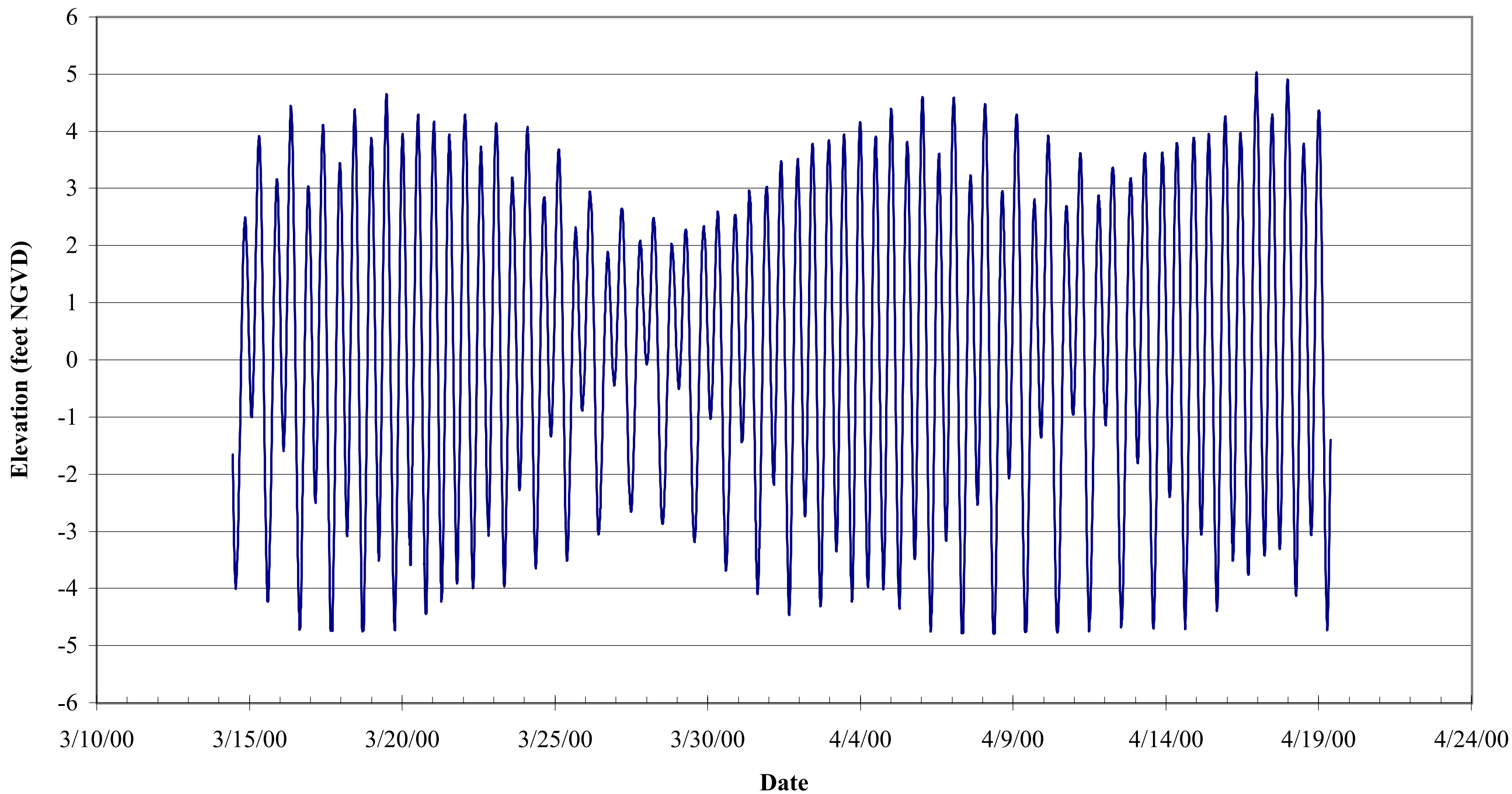
Source: PWA field surveys

Bair Island

Steinberger Slough Power Tower from February 1 to April 5, 2000

PWA

PWA #: 1413



Source: PWA field surveys.

Bair Island

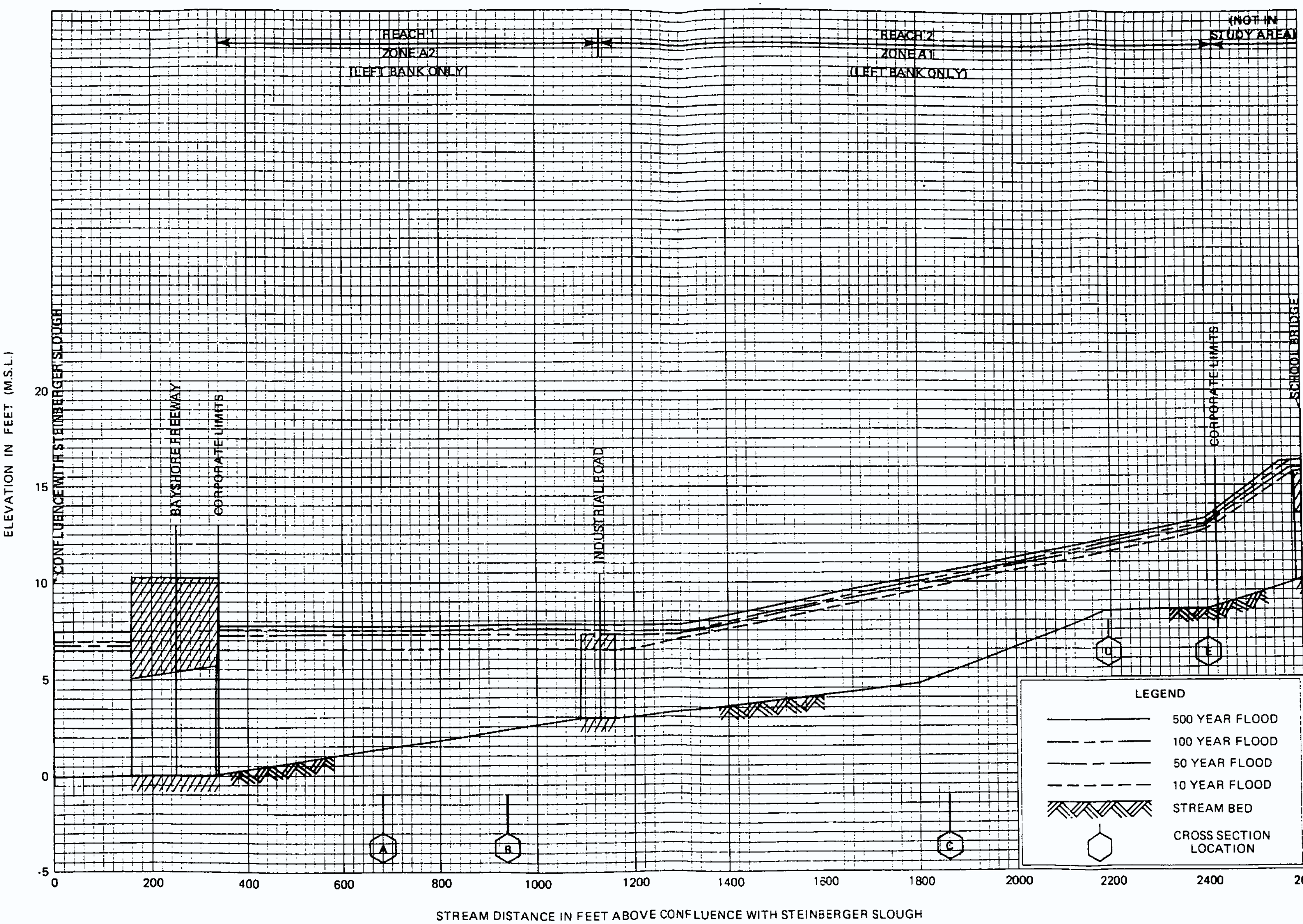
Channel Marker 8 on Redwood Creek from March 13 to April 19, 2000

PWA | PWA #: 1413

Projects\1413_Bair_orig\Task2+7_PWAsurveys\tides \ all tides june2000.xls ch mark8 chart 2/6/04

APPENDIX B
FEMA 100-YEAR WATER SURFACE ELEVATION PROFILES

- Cordilleras Creek
- Pulgas Creek



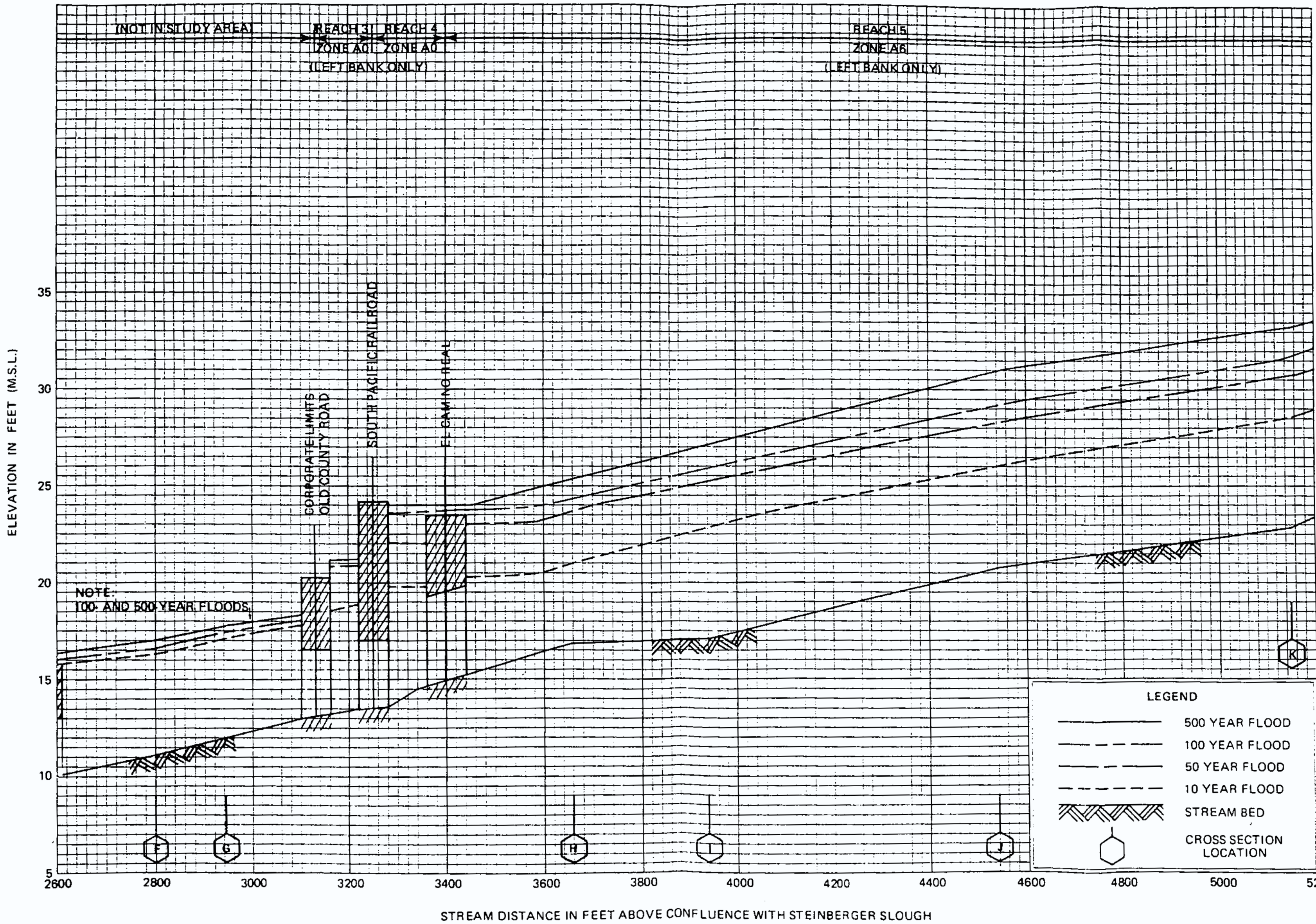
FLOOD PROFILES

CORDILLERAS CREEK

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration

CITY OF SAN CARLOS, CA
SAN MATEO COUNTY

01P



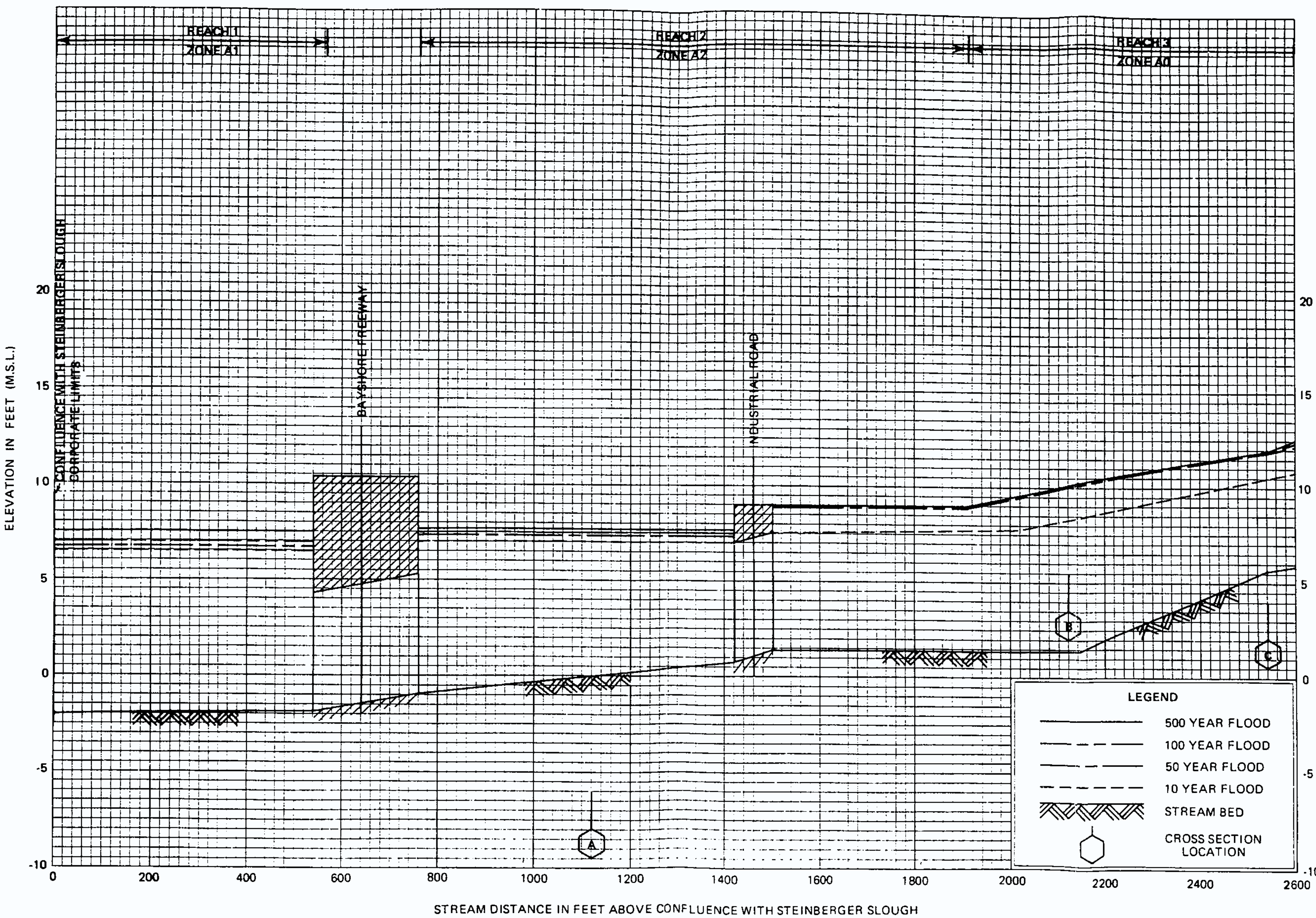
FLOOD PROFILES

CORDILLERAS CREEK

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration

CITY OF SAN CARLOS, CA
SAN MATEO COUNTY

02P



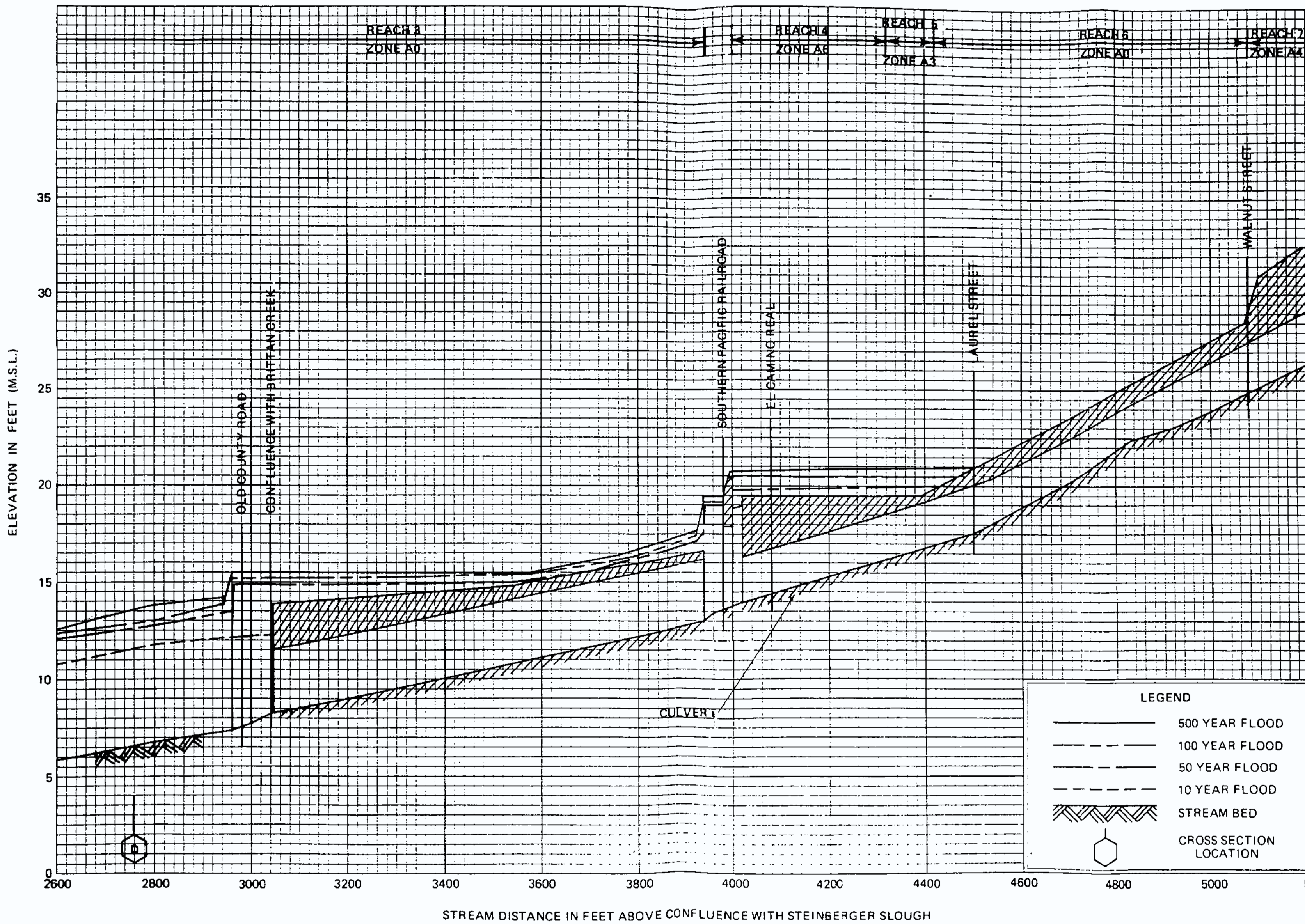
FLOOD PROFILES

PULGAS CREEK

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration

CITY OF SAN CARLOS, CA
SAN MATEO COUNTY

09P



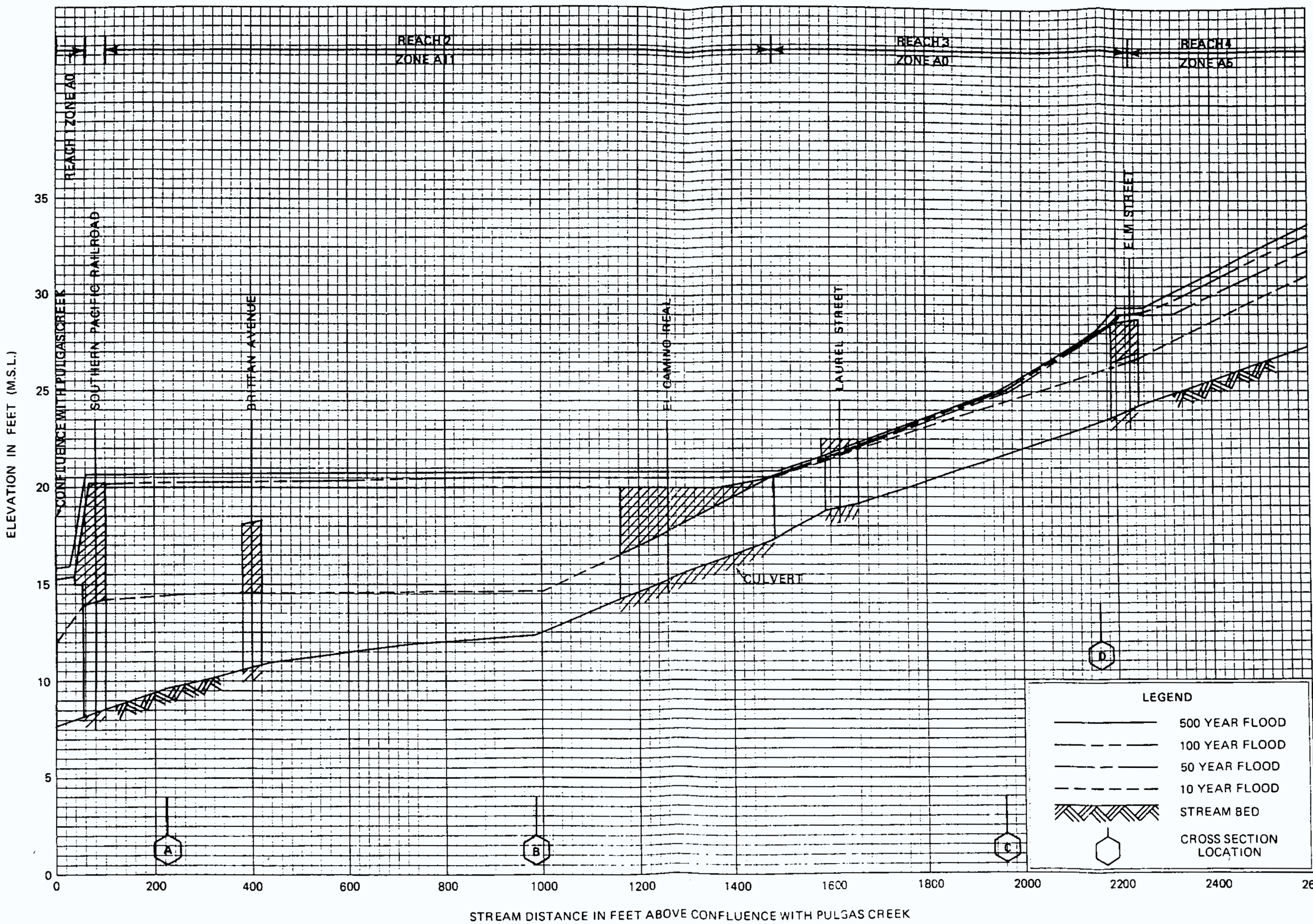
FLOOD PROFILES

PULGAS CREEK

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration

CITY OF SAN CARLOS, CA
SAN MATEO COUNTY

10P



FLOOD PROFILES

BRITTAN CREEK

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration

CITY OF SAN CARLOS, CA
SAN MATEO COUNTY

05P